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**University boundary units and technology transfer in emerging country:
structure and strategies**

Breno Valente Fontes Araújo
Doctor Scientiae

**VIÇOSA - MINAS GERAIS
2026**

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Thesis submitted to the Business Administration Graduate Program of the Universidade Federal de Viçosa in partial fulfillment of the requirements for the degree of *Doctor Scientiae*.

Adviser: Ana Claudia Azevedo

Co-adviser: Adriana Ferreira de Faria

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To my beloved wife and my parents.

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"The important thing is not to stop questioning"
Albert Einstein

ABSTRACT

ARAÚJO, Breno Valente Fontes, D.Sc., Universidade Federal de Viçosa, February, 2026. **University boundary units and technology transfer in emerging country: structure and strategies.** Adviser: Ana Claudia Azevedo. Co-adviser: Adriana Ferreira de Faria.

Universities play an important role in innovation ecosystems as generators and disseminators of knowledge. The effectiveness of this role, however, depends on organizational arrangements and coordination mechanisms that enable interaction between academia, industry, and government. Within this context, university boundary units (BU), including Technology Transfer Offices (TTO), incubators, science parks, and informal boundary-spanning arrangements, emerge as strategic intermediary arrangements in the Technology Transfer (TT) process. While a substantial body of literature has examined these units, existing research remains fragmented, often addressing contextual, organizational, and operational dimensions in isolation and offering limited integration across levels of analysis. In this sense, the general objective of this thesis is to analyze how university BU influence the dynamics and outcomes of TT across different contexts. To achieve this objective, the thesis is structured around three complementary studies. Specifically, it aims to: (i) critically examine how BU operate and adapt across developed and emerging economies, identifying contextual challenges and barriers; (ii) assess how the strategic orientation of TTOs toward internal, external, and mediatory roles affects early- and late-stage TT performance within an emerging economy; and (iii) explore, at a micro level, how BU enact their roles and mobilize social capital in distinct national contexts. Methodologically, the thesis is structured around three interrelated papers. The first paper employs a configurative systematic review to synthesize and compare the roles and challenges of boundary units across heterogeneous contexts. The second paper adopts a quantitative approach, using regression models to evaluate the relationship between TTO strategic orientations and TT outcomes. The third paper draws on qualitative, in situ comparative evidence from interviews and document analysis in Brazil and Italy, applying the social capital framework to examine how BU coordinate internal, mediatory, and external interface roles in practice. The findings show that BU operate as interdependent components of broader technology TT rather than as isolated organizational entities. The review highlights that differences between developed and emerging economies are less about the absence of BU and more about how contextual constraints, coordination challenges, and role complementarities shape

their effectiveness. The quantitative results demonstrate that TTO performance depends on a balanced strategic orientation across roles, with misalignment limiting outcomes at different stages of the transfer process. The comparative qualitative analysis shows that while BU mobilize similar cognitive and relational social capital mechanisms across contexts, differences in organizational embeddedness and ecosystem maturity shape how these mechanisms are stabilized, coordinated, and operationalized, independently of national context. By integrating evidence from three complementary studies, this thesis advances theoretical understanding of BU as adaptive and relational intermediaries in TT. It also offers practical implications for university managers and policymakers by providing evidence to support the design of more coherent organizational strategies and public policies, that recognize complementarities among BU and align TT mechanisms with contextual specificities of innovation ecosystems.

Keywords: technology transfer; boundary units; innovation ecosystems; intermediary organizations; entrepreneurial university

RESUMO

ARAÚJO, Breno Valente Fontes, D.Sc., Universidade Federal de Viçosa, fevereiro de 2026. **Unidades de fronteira universitária e transferência de tecnologia em países emergentes: estrutura e estratégias.** Orientadora: Ana Claudia Azevedo. Coorientadora: Adriana Ferreira de Faria.

Universidades desempenham um papel importante nos ecossistemas de inovação como geradoras e disseminadoras de conhecimento. A efetividade desse papel, contudo, depende de arranjos organizacionais e mecanismos de coordenação que viabilizem a interação entre academia, indústria e governo. Nesse contexto, as unidades de fronteira universitárias (boundary units - BU), incluindo Escritórios de Transferência de Tecnologia (Technology Transfer Offices - TTO), incubadoras, parques tecnológicos e arranjos informais de atuação na fronteira organizacional, emergem como arranjos intermediários estratégicos no processo de Transferência de Tecnologia (TT). Embora um corpo substancial da literatura tenha examinado essas unidades, as pesquisas existentes permanecem fragmentadas, frequentemente abordando dimensões contextuais, organizacionais e operacionais de forma isolada e oferecendo integração limitada entre níveis de análise. Nesse sentido, o objetivo geral desta tese é analisar como as BU universitárias influenciam as dinâmicas e os resultados da TT em diferentes contextos. Para alcançar esse objetivo, a tese está estruturada em torno de três estudos complementares. Especificamente, busca-se: (i) examinar criticamente como as BU operam e se adaptam em economias desenvolvidas e emergentes, identificando desafios e barreiras contextuais; (ii) avaliar como a orientação estratégica dos TTOs para papéis internos, externos e mediadores afeta o desempenho da TT em estágios iniciais e finais em uma economia emergente; e (iii) explorar, em nível micro, como as BU desempenham seus papéis e mobilizam capital social em contextos nacionais distintos. Metodologicamente, a tese está estruturada em três artigos inter-relacionados. O primeiro artigo emprega uma revisão sistemática configurativa para sintetizar e comparar os papéis e desafios das unidades de fronteira em contextos heterogêneos. O segundo artigo adota uma abordagem quantitativa, utilizando modelos de regressão para avaliar a relação entre as orientações estratégicas dos TTOs e os resultados da TT. O terceiro artigo baseia-se em evidências qualitativas comparativas in situ, provenientes de entrevistas e análise documental no Brasil e na Itália, aplicando a abordagem do capital social para examinar como as BU coordenam, na prática, papéis de interface interna, mediadora e externa. Os resultados mostram que as BU operam como componentes

interdependentes de processos mais amplos de TT, e não como entidades organizacionais isoladas. A revisão evidencia que as diferenças entre economias desenvolvidas e emergentes dizem respeito menos à ausência de BU e mais à forma como restrições contextuais, desafios de coordenação e complementaridades entre papéis moldam sua efetividade. Os resultados quantitativos demonstram que o desempenho dos TTOs depende de uma orientação estratégica equilibrada entre papéis, sendo que desalinhamentos limitam os resultados em diferentes estágios do processo de transferência. A análise qualitativa comparativa mostra que, embora as BU mobilizem mecanismos semelhantes de capital social cognitivo e relacional em diferentes contextos, diferenças na inserção organizacional e na maturidade do ecossistema moldam como esses mecanismos são estabilizados, coordenados e operacionalizados, independentemente do contexto nacional. Ao integrar evidências de três estudos complementares, esta tese avança a compreensão teórica das BU como intermediários adaptativos e relacionais na TT. Também oferece implicações práticas para gestores universitários e formuladores de políticas públicas, ao fornecer evidências para apoiar o desenho de estratégias organizacionais e políticas públicas mais coerentes, que reconheçam as complementaridades entre BU e alinhem os mecanismos de TT às especificidades contextuais dos ecossistemas de inovação.

Palavras-chave: transferência de tecnologia; unidades de fronteira; ecossistemas de inovação; organizações intermediárias; universidade empreendedora

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ACRONYMS LIST

AI	Artificial Intelligence
BU	Boundary Unit
CES	Câmara de Educação Superior (Higher Education Chamber)
CNE	Conselho Nacional de Educação (National Education Council)
EMBRAPII	Empresa Brasileira de Pesquisa e Inovação Industrial (Brazilian Company for Industrial Research and Innovation)
IP	Intellectual Property
PI	Principal Investigator
EI	Educational Institution
FORTEC	Fórum Nacional de Gestores de Inovação e Transferência de Tecnologia (National Forum of Innovation and Technology Transfer Managers)
GDP	Gross Domestic Product
GII	Global Innovation Index
IBGE	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistic)
ILO	Industry Liaison Office
KTO	Knowledge Transfer Office
LR	Likelihood-Ratio
NIT	Núcleo de Inovação Tecnológica (Center for Technological Innovation)
NRDI	New R&D Institutes
R&D	Research and Development
SD	Standard Deviation
SEBRAE	Serviço Brasileiro de Apoio às Micro e Pequenas Empresas (Brazilian Service for Support to Micro and Small Businesses)
SLR	Systematic Literature Review
SME	Small and Medium-sized Enterprises
STI	Science, Technology, and Innovation
TT	Technology Transfer
TTO	Technology Transfer Office
USD	United States Dollar

SUMMARY

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GENERAL INTRODUCTION

1.1 Context and justification of the research

Universities have reconfigured their societal role, expanding beyond traditional teaching and research to embrace a third mission focused on knowledge transfer, innovation, and socioeconomic development (Guerrero & Lira, 2023; Audretsch, 2014; Sandström et al., 2018). This transformation has been examined through several theoretical frameworks, particularly the entrepreneurial university model, which analyzes how universities connect with industry and government to facilitate Technology Transfer (TT) and innovation development (Etzkowitz & Leydesdorff, 2000; Schaeffer et al., 2024). From this perspective, universities operate within multi-stakeholder networks in which diverse actors jointly shape knowledge exchange and commercialization dynamics (Wurth, Mackenzie & Howick, 2024; Compagnucci & Spigarelli, 2020).

Despite this expansion in universities' societal role, TT outcomes remain persistently heterogeneous (Chapple et al., 2005; Siegel et al., 2007), particularly where contextual constraints and the fragmentation of intermediary functions constrain inter-organizational coordination (Howells, 2006; Colovic et al., 2025; Osei et al., 2025). This inconsistency reveals a critical governance challenge: boundary-spanning organizations, including Technology Transfer Offices (TTO), innovation hubs, science parks, and regional intermediaries, must bridge disconnected stakeholders and stabilize cross-boundary interactions (Aldrich & Herker, 1977; Huyghe et al., 2014) while orchestrating alignment among actors with overlapping mandates and asymmetric capacities across diverse contexts (Dhanaraj & Parkhe, 2006; Stephens et al., 2024).

The extent to which universities engage in these activities varies across national, regional, and organizational contexts. Differences in regulatory frameworks, economic structures, and resource availability influence how universities implement TT strategies and interact with external stakeholders (Guerrero & Menter, 2024; Thomas et al., 2023). Although these variations are widely acknowledged, less is known about how they translate into the organization, role configuration, and effectiveness of the organizational forms that operationalize TT.

Within this context, boundary units (BU)¹ emerge as essential mediators between universities and external actors, formal or informal boundary-spanning arrangements that broker interactions, resources, and rules between university and external stakeholders, playing a strategic role in the TT process (Chau, Gilman & Serbanica, 2017). These units can assume multiple organizational forms, such as TTO, incubators, science parks, national system innovation agencies, or operate through informal mechanisms, such as direct collaboration networks between researchers and firms (Perkmann et al., 2013; Good et al., 2019). While there is broad recognition that university-external actor interactions are associated with regional development, it's important understand the ways in which such interactions occur, and their intensity, because they are linked to TT outcomes (Meissner et al., 2022). Existing research, however, tends to address this topic through partially disconnected lenses: some studies examine BU as independent intermediaries (Etzkowitz & Leydesdorff, 2000; Chau, Gilman & Serbanica, 2017; Pohle et al., 2022; Brescia et al., 2016), whereas others focus on researchers' roles without theorizing how their actions relate to transfer outcomes across stages of the process (Dolmans et al., 2022; Larsen, 2020; Mangematin, O'Reilly & Cunningham, 2014).

As a result, research often remains fragmented, separately addressing contextual factors, regulatory impacts, and BU performance without explaining how these dimensions interact in the TT process (Good et al., 2019; Guerrero & Menter, 2024). What remains underexplained is how multiple BU coordinate (or fail to coordinate) complementary roles across stages of the TT process. When examined atomistically, overlapping activities among TTO, incubators, technology parks, and informal networks can be interpreted as redundancy; yet they may also reflect coordination challenges or unrealized complementarities that shape performance (Good et al., 2019). Prior work indicates substantial overlap and interdependence among BU components, particularly regarding internal and external networking, support for commercialization, and engagement with industry partners (Good et al., 2019). A more integrated lens is therefore required to explain how BU collectively coordinate roles, mobilize resources, and respond to contextual constraints within heterogeneous innovation ecosystems (Guerrero & Menter, 2024; Chen et al., 2024).

Contextual challenges become particularly salient when comparing developed and emerging economies. While universities' roles in innovation ecosystems are more consolidated in developed countries, their implementation in emerging economies often occurs under

¹ Although the literature employs alternative labels, such as intermediary organizations or hybrid organizations, in this study, we use the term boundary units to refer to organizational structures that are formally within the university that perform boundary units and intermediation functions.

additional constraints (Fai et al., 2018; Cao & Shi, 2021). Replicating models associated with developed contexts can be misaligned with local conditions, with implications for effectiveness (Schaeffer et al., 2024). In these settings, the intermediation process may depend less on adopting “best practices” and more on building coordinated intermediation capacity that compensates for weaker supporting organizations and fragmented ecosystem infrastructures. Among the obstacles discussed in this literature are structural holes and institutional voids, which relate to gaps in the quality and availability of support organizations and specialized intermediaries, respectively (Cao & Shi, 2021). These conditions heighten the relevance of examining how BU are configured and coordinated in emerging-economy environments such as Brazil.

Against this background, this thesis addresses these gaps by adopting an integrated analytical approach across three complementary studies to examine how BU shape TT dynamics under heterogeneous contexts. Accordingly, the thesis is guided by the following research question: **How do university boundary units shape technology transfer dynamics across heterogeneous contexts, with particular attention to an emerging-economy setting and comparative insights from a developed context?** To explore this question, the thesis investigates BU in TT by linking contextual conditions, organizational arrangements, and role enactment. It theorizes mechanisms that may travel across contexts while treating contextual environments as conditions that influence how BU roles are configured and enacted.

1.2 Thesis structure

To answer the research question, this thesis adopts an integrated perspective to investigate the role of university BU in TT across three complementary dimensions. This sequence enables cumulative understanding of the phenomenon and supports both theoretical and practical implications for TT mechanisms:

1. A configurative literature review on BU in different contexts, aiming to understand their role in mediating TT by conducting a critical comparative analysis between developed and emerging countries.
2. A quantitative analysis evaluating how different strategic orientations of TTO affect the early and late-stage performance of the TT process.
3. A qualitative *in situ* comparison contrasting the operation of BU in two different national contexts.

This thesis is structured as a collection of three papers that form a progressive analytical framework. Across them, the thesis develops an integrated explanation of BU

effectiveness under contextual heterogeneity. This format reflects the complexity of the phenomenon and aligns with arguments that research on innovation and TT benefits from multifaceted perspectives that connect contextual considerations with organizational and operational characteristics of BU (Sandström et al., 2018; Good et al., 2019). Structuring the thesis into papers allows each study to be examined with methodological focus while maintaining coherence across the overall narrative. Table 1 presents an overview of the three studies.

Table 1 - Thesis structure

Paper	Title	Research Question	Methodology
1	Context Matters: A Systematic Review of Boundary Units in Developed and Emerging Economies	How do BU operate and adapt across different contexts, and how do their dynamics shape (and are shaped by) the complexities of knowledge transfer and technology commercialization?	Qualitative: Configurative systematic review
2	The Influence of Technology Transfer Offices Role Orientations on Technology Transfer Performance	How do TTO orientations toward internal, external, and mediatory roles, influence the early and late stages of the technology transfer process within an emerging economy?	Quantitative: Negative binomial regression
3	Bridging universities and innovation ecosystems: boundary unit roles and social capital across two different national contexts	How do boundary units operationalize their internal interface, mediatory, and external interface roles throughout the technology transfer process in different country settings?	Qualitative: comparative Gioia methodology

Source: Prepared by the author.

The three papers follow a logical progression that links complementary analytical focuses on BU roles in the TT process. The first paper establishes a broad comparative perspective through a configurative systematic review of BU across national contexts, identifying types, roles, and challenges in TT dynamics and contrasting developed and emerging environments. Building on this role categorization, the second paper advances to a quantitative analysis in which each TTO represents an observation, examining how strategic orientations relate to early- and late-stage outcomes and highlighting the role of internal structures in shaping performance. Finally, the third paper returns to cross-context comparison through a qualitative study grounded in in situ comparison. Drawing on a process-oriented perspective and social capital as an analytical lens, it examines how BU operationalize and coordinate internal interface, mediatory, and external interface roles in practice in Brazil and Italy, focusing on role enactment, interaction patterns, and coordination mechanisms over the TT process. Together, this sequence provides an integrated view of the phenomenon, with each paper contributing complementarily to the overall objective of the thesis.

1.3 Contributions

This thesis contributes to the literature by advancing an integrated perspective on TT that connects contextual, organizational, and operational elements of university BU (Guerrero & Menter, 2024). Rather than treating BU as isolated entities, it conceptualizes them as interdependent components of a transfer ecosystem whose performance depends on how overlapping roles, capabilities, and relational structures are configured and coordinated (Good et al., 2019). This perspective reframes apparent redundancy as a coordination issue or unrealized complementarity, explaining why similar organizational forms may be associated with different outcomes across contexts. In doing so, it addresses calls to deepen discussions on organizational determinants that influence the performance of entrepreneurial universities within the third mission agenda (Schaeffer et al., 2024).

Moreover, treating different types of BU as intermediary arrangements aligns with Compagnucci and Spigarelli (2020), who emphasize the relevance of communication and engagement between internal and external stakeholders, and with Wurth, Mackenzie, and Howick (2024), who highlight the need to reconcile ecosystem-based approaches with resource- and capability-based perspectives at the organizational level. By empirically engaging with an emerging-economy setting, the thesis also responds to calls for studies examining how innovation policies and intermediary arrangements adapt to regional and sectoral conditions (Cunningham et al., 2019; Soares et al., 2020).

Beyond theoretical contributions, the thesis offers insights for university managers, policymakers, and private sector stakeholders regarding the organization and coordination of intermediation in TT. For practitioners and firms, the findings inform how information flows and coordination can be strengthened among key actors, supporting universities' contribution to learning and ecosystem dynamics (Heaton et al., 2019). For policymakers, the thesis provides an evaluation of BU operations across contexts and offers input for regulatory strategies tailored to local realities (Maresova et al., 2019; Guerrero & Menter, 2024). Such strategies may support regulatory designs that balance coordination and autonomy among BU, strengthening system capacity while avoiding compliance burdens that can constrain learning processes in less mature innovation ecosystems (Wurth, Mackenzie & Howick, 2024). In this debate, Forlano et al. (2021, p.1) indicate that universities' contribution to socioeconomic development, especially in developing countries, remains a relevant topic for future research.

Finally, as universities are increasingly assessed by their societal contribution beyond academic outputs, understanding the organizational arrangements that underpin TT becomes

more salient (Forliano et al., 2021; Guerrero et al., 2023). This is particularly relevant in emerging countries, where universities may occupy central positions in innovation ecosystems while facing contextual constraints that affect how the third mission is operationalized (Schaeffer et al., 2024). Overall, the thesis informs how university and BU managers can redesign strategies for operationalizing the third mission by aligning complementary BU roles and reducing fragmentation (Good et al., 2019). By examining BU as an interconnected system rather than isolated entities, the research supports more informed decision-making regarding coordination, adaptation to contextual conditions, and the design of governance and evaluation mechanisms capable of recognizing complementarities among BU, thereby strengthening their legitimacy and collective contribution to TT outcomes (Guerrero & Menter, 2024; Goodrich, 2020).

Paper 1: Context Matters: A Systematic Review of Boundary Units in Developed and Emerging Economies

Context Matters: A Systematic Review of Boundary Units in Developed and Emerging Economies

Abstract

Universities have embraced a “third mission” that extends beyond teaching and research to stimulate innovation and socio-economic development. This shift has amplified the importance of boundary units (BU) in facilitating knowledge exchange and forging connections with external partners. However, the distinct socio-economic contexts in which universities operate profoundly influence how BU function and evolve. Whereas in developed countries established models and frameworks guide the operation of these intermediaries, emerging nations encounter more complex hurdles stemming from limited resources, weak institutional frameworks, and cultural or policy misalignments. This study addresses a critical gap in the literature by investigating how BU roles shape (and are shaped by) context-specific challenges. A configurative systematic literature review was carried out, drawing on 58 scholarly works to integrate perspectives from both mature and developing innovation ecosystems. Based on the findings, a new framework was proposed, comprising four dimensions: types of BU, BU roles, challenges, and institutional and cultural context. These dimensions collectively offer a comprehensive understanding of how BU can effectively foster TT, especially in resource-constrained settings. The study contributes to ongoing debates on entrepreneurial universities by clarifying how regional disparities shape the design and impact of BU, and by providing actionable insights for policymakers, university leaders, and other stakeholders seeking to enhance the efficacy of TT initiatives under diverse institutional and cultural conditions. This also opens avenues for future research on robust, context-specific, and dynamic BU strategies.

Keywords: Entrepreneurial universities, Boundary units, Emerging countries.

1. Introduction

Over the last three decades, universities have become central actors in global innovation systems, bridging the gap between academic research and industrial applications. This transition, driven by the demands of the knowledge economy and global challenges such as climate change and digital transformation, has significantly expanded their responsibilities. Universities are now seen not only as teaching and research institutions but also as key agents of innovation and economic growth, embracing a "third mission" focused on societal and economic contributions (Audretsch, 2014; Guerrero & Lira, 2023; Sandström et al., 2018). Within this context, concepts like “entrepreneurial universities” have gained prominence, emphasizing the need for universities to transfer knowledge beyond academic boundaries to maintain their relevance in society and innovation networks (Etzkowitz & Leydesdorff, 2000; Schaeffer et al., 2024).

These institutions have adapted to dynamic environments by realigning their strategies and objectives to integrate more effectively into innovation ecosystems characterized by synergistic relationships between people, knowledge, and resources (Forliano et al., 2021; Russel et al., 2011). An important element of this transformation is the emergence of Boundary Units (BU), formal entities such as technology transfer offices (TTO) and incubators, as well as informal mechanisms like direct interactions between academics and external actors, which act as intermediaries in the transfer of knowledge and technology (Chau, Gilman & Serbanica, 2017; Perkman et al., 2013; Wurth, Mackenzie & Howick, 2024).

Research on BU in developed countries has highlighted their critical role in enabling technology commercialization, fostering research collaborations, and supporting entrepreneurial initiatives (Nsanzumuhire et al., 2021; Siegel et al., 2004). In regions like North America and Western Europe, mature innovation systems provide BU with well-defined frameworks for intellectual property (IP) management, industry engagement, and policy alignment (Fai et al., 2018). For instance, the Triple Helix model (Etzkowitz & Leydesdorff, 2000) illustrates how universities, governments, and industries coalesce to drive innovation, especially through hybrids organizations. Similarly, maturity models proposed by Secundo et al. (2016) identify distinct stages in the evolution of BU, from nascent "awareness" phases to fully integrated and sustained operations.

Despite these advances, existing research predominantly focuses on resource-rich contexts, where institutional stability, robust IP frameworks, and abundant funding create favorable conditions for BU (Fai et al., 2018; Schaeffer et al., 2024). However, this perspective

overlooks the complexities inherent in transferring successful models to developing economies, where resource constraints, institutional weaknesses, and cultural barriers present significant challenges (Cao & Shi, 2021; Telmer et al., 2021). For example, while TTO in the United States have thrived under policies like the Bayh–Dole Act, which incentivized commercialization (Mowery & Sampat, 2004), such frameworks are often ineffective in regions with weaker legal protections and fragmented innovation systems (Fai et al., 2018).

Additionally, studies in developed economies often emphasize output metrics, such as patents, spin-offs, and licensing revenues, as indicators of BU success (Siegel et al., 2004; Debackere & Veugelers, 2005). This narrow focus neglects the relational dynamics and process-oriented approaches critical to fostering sustainable university-industry linkages, especially in contexts where formal mechanisms are underdeveloped (Kruss & Visser, 2017). In emerging economies, for instance, informal channels like personal networks and ad hoc collaborations often play a significant role in knowledge transfer (Arza, 2010), yet these dynamics remain underexplored in literature. Moreover, while developed economies have increasingly embraced broader concepts of knowledge exchange, encompassing research collaborations, public engagement, and social impact, these practices are often tailored to their unique socio-economic contexts (Edwards et al., 2014). In contrast, many developing countries struggle to align university missions with national innovation strategies, address industries limited absorptive capacity, and develop effective mechanisms for technology transfer (TT) (Fai et al., 2018; Cao & Shi, 2021)

Based on the premise that "boundary" between academia and external stakeholders can be ambiguous and shaped by institutional setting of the nation, region and university (Sandström et al., 2018; Beck et al., 2022; Mars & Rios-Aguilar, 2010), this study addresses the gaps in the literature by investigating the following research question: How do BU operate and adapt across different contexts, and how do their dynamics shape (and are shaped by) the complexities of knowledge transfer and technology commercialization?

To address this question, a systematic literature review (SLR) adopting a configurative approach was undertaken. The choice of an SLR is particularly suitable for this study because it allows for a structured synthesis of diverse perspectives and findings, enabling a critical re-evaluation of assumptions underlying the roles and dynamics of BU. Unlike empirical studies, which are often limited to specific contexts or case-based analyses, an SLR provides a broader analytical framework for integrating insights across multiple contexts, including both developed and emerging economies. This is crucial for contesting the romanticized view of BU

as neutral bridges for knowledge transfer, as it enables the identification of tensions, contradictions, and context-specific factors that shape their operations (Sandström et al., 2018). Configurative reviews emphasize an exploratory framework, allowing for methodological adaptations throughout the research process and thereby fostering a more comprehensive and critical understanding of the phenomenon under investigation (Gough et al., 2017).

Consequently, this approach is especially appropriate for the purpose of this work, that is exploring, mapping, and critically examining the diverse features of BU, while recognizing the growing importance of universities as key actors in the innovation ecosystem (Guerrero & Lira, 2023; Schaeffer et al., 2024). Furthermore, by synthesizing existing knowledge, the review enables the development of a nuanced theoretical lens that captures not only the facilitative role of BU but also their active involvement in mediating, shaping, and occasionally constraining knowledge transfer dynamics (Haas, 2015; Maresova et al., 2019).

This study offers both theoretical and practical contributions. Theoretically, it advances the discussion of challenges encountered by entrepreneurial universities and their BU in varied contexts, especially in emerging economies. Considering that the challenges faced by emerging countries differ from those faced by developed nations, this analysis provides deeper and critical insight into the nuanced ways in which these challenges shape the effectiveness of BU in different country contexts (Cao & Shi, 2021; Maresova et al., 2019). Practically, this investigation furnishes university administrators and public policymakers with a better understanding of the complexities inherent in their contexts, enabling them to formulate strategies that are more effectively tailored to local conditions. Such an informed approach to decision-making has the potential to strengthen the linkages between universities and external actors, thereby reinforcing the role of academic institutions in promoting innovation and socio-economic development (Schmitz et al., 2017).

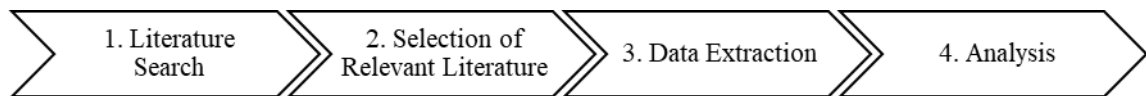
Therefore, this research seeks not only to compile and conceptualize the roles and challenges of BU but also to question the assumptions underlying their performance and impact. By revisiting the literature through a configurative lens, an essential analysis is proposed that goes beyond the idea that BU just connect actors. It argues that these units not only facilitate but also tension and shape the interactions between academia and external actors and can have different perspectives depending on the region and nation contexts.

2. Methodology

In contrast to aggregative reviews, which depend on predefined concepts tested through established methodologies, configurative reviews emphasize an exploratory framework, allowing for methodological adaptations throughout the research process (Gough et al., 2017). Therefore, the selection of a configurative approach is underpinned by two primary considerations. First, this approach enables the mapping of BU' roles without the constraints of prior assessments, thereby capturing the complex interactions between academia and external stakeholders, especially in emerging economies where contextual and institutional factors may hinder the effectiveness of these units. Second, the varied definitions and perspectives surrounding BU necessitate an extensive mapping of the literature, which is essential for drawing informed and critical conclusions about their roles in diverse contexts.

The literature search process was conducted iteratively, guided by the established criteria for the inclusion and exclusion of studies (Levinsson & Prøitz, 2017). The methodological framework for this review was inspired by the work of Sjolund et al. (2023) and comprises four main stages, in a logical sequence, as shown in Figure 1 and detailed below.

Figure 1 - Methodology stages



Source: Prepared by the author.

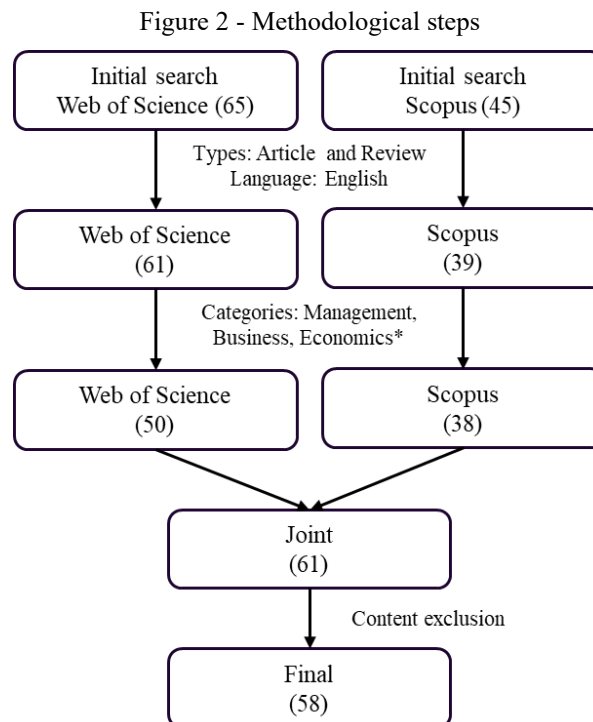
Stage 1 - Literature Search: This stage commenced with an iterative process of defining, clarifying, and refining the research question (Tranfield et al., 2003). A methodology akin to that employed by Fabiano et al. (2020) was subsequently utilized to define the search terms, organizing the investigated aspects into three conceptual axes: 1. Domain refers to the broader field or environment; 2. Phenomenon highlights the central process or situation being studied; and 3. Objective/Extent outlines the precise goal or boundaries of the analysis. Specifically, in this study, those three axes are defined as follows: 1. Domain: University interactions/Innovation; 2. Phenomenon: Technology and knowledge transfer; and 3. Objective/Extent: BU roles. Following iterative consultations with senior academics, further refinements were made, and search queries were subsequently constructed using Boolean operators. Consequently, the search string was formulated as follows: TS = 1. (((universit* OR academ*) NEAR/3 (entrepr*)) AND 2. ((innovat* OR knowledge OR technolog*) NEAR/3 (transfer*)) 3. AND ((boundar* OR intermediar*))).

The databases utilized for this study were the Web of Science (WoS) and Scopus, which are recognized for their rigorous selection of high-quality, peer-reviewed journals in social

sciences (Cobben et al., 2022). Both have advanced search functionalities that enable precise filtering of publications by keywords, time frames, and subject categories, thereby enhancing methodological rigor and replicability.

Stage 2 - Selection of Relevant Literature: During this stage, various types of studies were identified that could contribute to the mapping of the roles of BU within the dynamics of TT, with particular emphasis on the challenges encountered in emerging economies. Furthermore, inclusion and exclusion criteria were established, based on the guidelines provided by Forliano et al. (2021). First, only publications addressing the TT dynamics within universities were considered, ensuring that the context of interest was maintained. Second, studies needed to discuss the roles of BU, a central aspect of this research. Third, only peer-reviewed journals were included, to guarantee the quality of the reviewed documents. Fourth, the search period extended up to July 2024 without any initial date restriction. Fifth, solely English-language literature was included for reasons of operational viability. Finally, the categories of analysis comprised the fields of management, business, and economics.

Figure 2 illustrates the methodological steps undertaken in the systematic literature review, highlighting the application of inclusion and exclusion criteria at each stage. Initially, 65 articles were identified in the Web of Science database and 45 in Scopus. Following the screening and refinement processes, based on types, categories, duplication, and content, 58 articles were analyzed in the final review.



Source: Prepared by the author.

Stage 3 - Data Extraction: In the data extraction phase, the articles included in the final sample were read in their entirety. This process involved extracting information in two different ways (Sjolund et al., 2023): (a) their characteristics and context, such as year of publication, country, national context, methodology, and level of analysis; and (b) descriptions of conceptual categories, in this case: i) Types of Boundary Units; ii) Boundary Units Roles; iii) Challenges; and iv) Institutional and Cultural Context. The organization of this stage utilized a spreadsheet, which facilitated coding and subsequent analysis, enabling the identification and highlighting of specific challenges faced by BU in various contexts.

Stage 4 - Analysis: In the final stage, the extracted information was subjected to analysis through open coding, a common practice in configurative reviews (Gough et al., 2017). Open coding aims to construct a new framework from the reviewed literature, allowing for a more nuanced and dynamic analysis of the interactions between academia and external actors, while considering the tensions and challenges for different contexts. Drawing inspiration from the procedure outlined by Satalkina and Steiner (2020), the initial codes were established based on a preliminary reading of the literature, with flexibility for adjustments as needed.

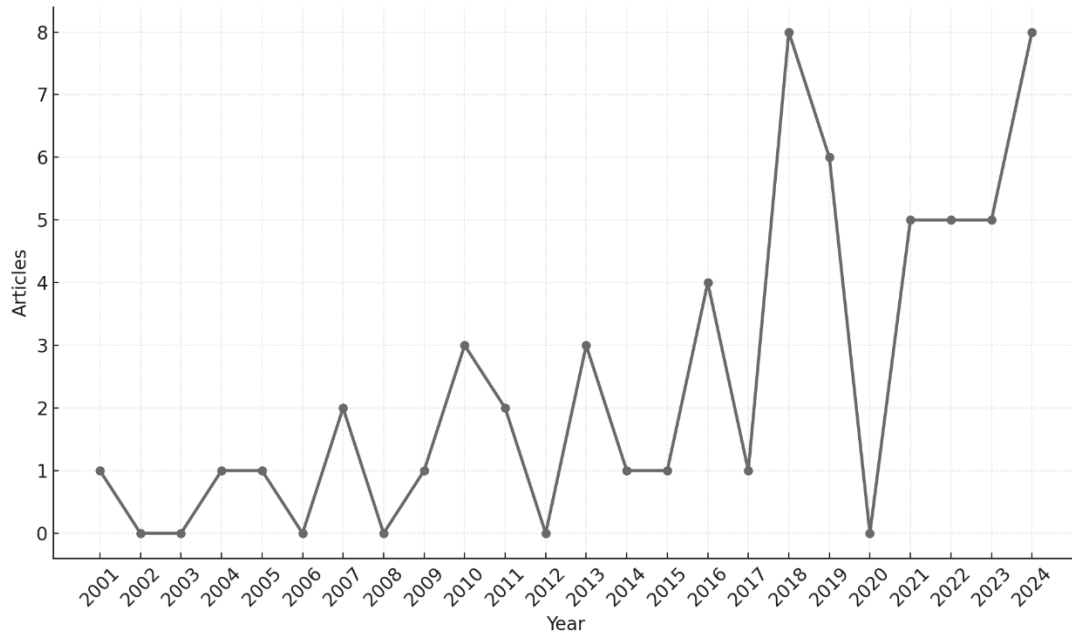
Several validation procedures were implemented throughout this process (Cobben et al., 2022): i) the development of a comprehensive list of keywords, validated by three experts, to construct search queries; ii) conducting exploratory searches to ascertain whether articles fell within the scope of the study and to identify additional keywords; iii) maintaining traceability records that included details such as the full search history, search dates, and reasons for article exclusion; iv) following categorization, testing the analytical procedures with a sample of randomly selected journal articles from the total set to assess the coding structure and confirm that the approach effectively captured the relevant information; v) making the database accessible to other researchers for evaluation; and, vi) structuring the analysis procedures and classification schemes based on previous systematic reviews of the literature.

3. Results

Although the central focus of this study is conceptual, certain bibliometric aspects are highlighted to provide additional context. Figure 3 illustrates the distribution of published articles over time, highlighting the evolution of academic interest in the field under study. The data spans from 2001 to 2024 and reveals notable fluctuations in the number of publications. While the early years demonstrate a relatively low output, a significant increase can be observed starting in 2016, with a peak in 2018 and 2024. These trends suggest a growing emphasis on

the topic in recent years, possibly reflecting advancements in the field or increased recognition of its relevance.

Figure 3 - Academic Publications Over Time



Source: Prepared by the author.

A total of 58 articles were ultimately included in the analysis, comprising 11 literature reviews and 47 empirical studies. Of these empirical studies, 33 were conducted in developed countries context, 13 in emerging economies context, and one examined both contexts. This distribution suggests a higher degree of scholarly attention or density of the subject in developed nations, potentially reflecting stronger institutional frameworks and research capabilities in those settings.

The articles included in this review were published across 36 different academic journals, reflecting the interdisciplinary nature and wide-ranging interest in the field. Among these, the *Journal of Technology Transfer* stands out as the most frequent outlet, with six publications, highlighting its prominent role in the topic. Following this, *Research Policy* accounts for five articles, and both *Technology in Society* and the *International Journal of Technology Management* contribute three articles each.

The Figure 4 illustrates the comprehensive framework developed in this study. The analysis began by categorizing the different types of BU, distinguishing between formal structures and informal mechanisms. This classification provided the foundation for understanding the range of roles performed by BU, which encompass internal interfaces, mediatory, and external interfaces. Building on this understanding, the study identified key

challenges faced by BU, with particular attention to how these challenges vary across institutional and cultural contexts, contrasting the dynamics in developed and emerging economies.

Figure 4 - Analytical framework

Types of Boundary Units	Boundary Units Roles	Challenges
<i>Formal [F]:</i> [F.1] Technology Transfer Offices (TTOs) [F.2] Business Incubators [F.3] Science and Technology Parks [F.4] Collaborative Research Centers [F.5] Student Entrepreneurship Centers [F.6] Spin-Offs and Entrepreneurial Ventures	<i>Internal Interface [II]:</i> [II.1] Technology Identification and Evaluation [II.2] Intellectual Property Management [II.3] Researcher Engagement [II.4] Strategic Alignment [II.5] Management of Facilities [II.6] Supporting New Venture [II.7] Knowledge Co-Creation [II.8] Developing and Training	[CH.1] Lack of Objectives Alignment [CH.2] External Pressures and Growing Complexity [CH.3] Resource Scarcity [CH.4] Access to Funding Sources [CH.5] Fragile Intermediary Structures and Inexperienced Staff [CH.6] Fragility of Socio-Economic and Industrial Structures [CH.7] Legal Framework Reliability and Trust [CH.8] Cultural Differences Between Academia and External Stakeholders [CH.9] Limited Commercial Capabilities and Risk Aversion [CH.10] Scientific Profile and Role Overload [CH.11] Administrative Complexity in Technology Transfer Processes [CH.12] Geographical Proximity Between Universities and Industries
<i>Informal [I]:</i> [I.1] Principal Investigators (PIs) [I.2] Personal Networks [I.3] Technicians and Internal Collaborators	<i>Mediatory [MT]:</i> [MT.1] Alignment of Objectives and Expectations [MT.2] Network and Trust Building, [MT.3] Development of Specialized Digital Transfer Instruments [MT.4] Technology Transfer Strategies [MT.5] Contract Management <i>External Interface [EI]:</i> [EI.1] Technology Licensing [EI.2] Market Analysis and Technology Promotion [EI.3] Facilitating Partnerships with Investors [EI.4] Revenue Generation and Financing Mechanisms [EI.5] Information Dissemination	
Institutional and Cultural Context – Developed and emerging countries		

Source: Prepared by the author.

In the following sections, each of these topics will be discussed in detail, and this framework will guide a critical discussion, including an exploration of the divergent realities faced by BU in developed and emerging countries.

3.1. Types of Boundary Units

Boundary Units serve as essential intermediaries that mediate the complex interactions between universities and external stakeholders, playing an important role in facilitating knowledge exchange and fostering innovation. As detailed in Table 2, these units can be categorized into formal, such as TTO and incubators, and informal, such as personal networks and Principal Investigators (PI), the lead researcher responsible for overseeing and managing a research project, contacts. This dual classification highlights not only the structural diversity of BU but also their ability to adapt to varying institutional and regional contexts. Formal units, being institutionalized entities, benefit from structured roles, dedicated resources, and established processes. Conversely, informal units leverage personal relationships and adaptive mechanisms, filling critical gaps where formal structures may be absent or underdeveloped. Over time, these units have evolved from simple transactional mechanisms to dynamic, networked models that accommodate the shifting landscapes of innovation (Krücken et al., 2007; Albats et al., 2022; Cunningham et al., 2022; Conlé et al., 2021).

Among the most prominent formal BU are TTO, which are responsible for managing intellectual property, patents, and licensing agreements. Sandström et al. (2018) highlight how TTO act as important brokers in developed economies, aligning academic outputs with industrial needs and fostering long-term partnerships. For instance, O’Kane et al. (2021) document how TTO in New Zealand integrate non-market strategies, including alignment with political frameworks, to enhance their effectiveness in commercialization. In contrast, Temel et al. (2021) reveal that TTO in emerging economies often face systemic constraints such as insufficient funding and weaker organizational structures, limiting their ability to support innovative collaborations.

Another formal BU is the academic incubator, which supports startups by offering mentorship, infrastructure, and access to funding. Good et al. (2019) describe how incubators in North America and Europe benefit from robust venture capital networks, enabling them to foster high-growth companies. Wonglimpiyarat (2016) provides insights from Thailand, where incubators adopt hybrid models that combine public and private funding to address resource gaps in the local innovation ecosystem. Science and Technology Parks further extend the reach

of formal BU by co-locating universities, industries, and startups in shared spaces designed to facilitate collaboration. Cunningham et al. (2022) document their success in fostering innovation through advanced facilities and interdisciplinary networks in developed regions.

Collaborative Research Centers represent another form of formal BU, designed to bring together diverse stakeholders to address interdisciplinary challenges. Hailu (2024) provides an example from Africa, where such centers have been instrumental in advancing sustainability issues through university-industry linkages. Student Entrepreneurship Centers are becoming increasingly relevant as universities embrace their third mission. Audretsch et al. (2024) describe how these centers nurture entrepreneurial skills and support student-led ventures, aligning educational programs with regional innovation systems. Ghanadinezhad & Ghane (2024) emphasize that these centers also act as incubators for early-stage ideas, enabling students to develop practical solutions from academic concepts.

Spin-offs and entrepreneurial ventures directly translate academic research into market-ready innovations, serving as drivers of regional economic development. Fontes (2001) provides evidence from Portugal, where spin-offs have significantly contributed to economic growth despite challenges such as limited venture capital availability. These ventures exemplify how universities can directly impact local economies through knowledge commercialization.

On the informal side, PI can play an important role as boundary spanners, leveraging their networks and expertise to align academic research with external demands. Cunningham et al. (2018) highlight how PI contribute to quadruple helix ecosystems by fostering collaborations among academia, industry, government, and civil society. Baglieri & Lorenzoni (2014) provide further evidence from Italy, where PIs have successfully navigated academic, and market demands to establish spin-offs and collaborative projects.

Personal networks and technicians also play significant roles in informal knowledge transfer mechanisms. Hayter (2016) underscores the importance of personal networks in initiating collaborations and overcoming systemic barriers, especially in resource-constrained environments. Noke et al. (2024) highlight the contributions of technicians, who act as intermediaries by translating academic innovations into practical applications. Their role is particularly important in ensuring alignment between researchers and industry partners in technical and operational contexts.

The evolution of BU reflects broader trends in innovation systems. Developed economies have embraced advanced models such as Germany's "Transfer Scouts", with specialized and autonomous team in TT (Noack & Jacobsen, 2021), and cooperation models

which blur traditional boundaries between universities and industry, fostering seamless collaboration (Krücken et al., 2007). According to these authors, in these contexts, BU often operates within dynamic, networked ecosystems, balancing academic goals with market demands. Conversely, in emerging economies, systemic challenges such as resource scarcity and institutional fragility necessitate greater reliance on informal mechanisms to sustain innovation activities (Maresova et al., 2019; Szulczewska-Remi & Nowak-Mizgalska, 2023). While these mechanisms are often adaptive and resilient, they can also limit the ability of BU to transition to more sophisticated models of interaction.

Of course, emerging economies feature BU that play significant roles in university knowledge transfer, however, these units often face systemic challenges, such as limited resources, weaker organizational structures, and lower absorptive capacity, which hinder their ability to adopt sophisticated models (Maresova et al., 2019; Thamae et al., 2016; Alibekova et al., 2019). As a result, many BU in these countries remain bound to linear models characterized by bureaucratic processes and minimal interaction with other stakeholders in the innovation ecosystem. Krücken et al. (2007) highlight how such models focus predominantly on administrative tasks like TT and patenting, often failing to foster dynamic and collaborative innovation.

Table 2 - Types of Boundary Units

Types of BU	Subtypes	Description	Authors
[F] Formal	[F.1] Technology Transfer Offices (TTO)	TTO are formal entities managing intellectual property, patents, and licensing agreements, serving as a bridge for transfer technology and promote university innovations	Sandström et al., 2018; O’Kane et al., 2021; Markman et al., 2005; Siegel et al., 2004; Temel et al., 2021; Schaeffer & Matt, 2016; Kotha et al., 2018; Fini et al., 2018
	[F.2] Incubators	Academic incubators support startups, providing mentorship, infrastructure, and funding opportunities. They play an important role in fostering entrepreneurship	Good et al., 2019; Wonglimpiyarat, 2016; Santos et al., 2023; Martin et al., 2019; Pacheco et al., 2024
	[F.3] Science and Technology Parks	These parks act as innovation hubs, offering co-location opportunities and resources to promote collaboration among universities, startups, and industries	Cunningham et al., 2022; Good et al., 2019; Santos et al., 2023; Martin et al., 2019
	[F.4] Collaborative Research Centers	These centers foster interdisciplinary research by bringing together diverse stakeholders to address societal and technological challenges	Santos et al., 2023; Martin et al., 2019; Hailu, 2024
	[F.5] Student Entrepreneurship Centers	Emerging as hubs for student innovation, these centers focus on developing entrepreneurial skills and launching student-led ventures	Audretsch et al., 2024; Ghanadinezhad & Ghane, 2024

	[F.6] Spin-Offs and Entrepreneurial Ventures	Spin-offs translate academic research into market-ready products, driving regional and economic development	Fontes, 2001
[I] Informal	[I.1] Principal Investigators (PI)	PIs act as informal boundary spanners, leveraging their networks and expertise to align academic research with external needs	Baglieri & Lorenzoni, 2014; Chen et al., 2024b; Cunningham et al., 2018
	[I.2] Personal Networks	Informal networks between academics and external stakeholders are important for initiating collaborations and overcoming systemic barriers	Hayter, 2016
	[I.3] Technicians and Internal Collaborators	Often overlooked, technicians provide practical support in applying academic research to real-world challenges	Noke et al., 2024

Source: Prepared by the author.

3.2. Boundary Units Roles

Boundary Units play a multifaceted role in bridging academia and external stakeholders, with their functions adapting to the specific contexts and challenges of their environments. These roles can be broadly categorized into internal interface roles, which focus on identifying and evaluating technologies developed, and support the researchers; mediatory roles, which facilitate alignment and trust among stakeholders; and external interface roles, which emphasize market orientation and collaboration. This categorization can be seen in Table 3.

Internal interface roles are foundational operations of BU, ensuring that university resources, research outputs, and infrastructure are effectively aligned with innovation goals. Some activities in this domain include technology identification and evaluation, IP management, researcher engagement, and internal strategic alignment. For example, TTO often lead in technology identification and IP management, creating pathways for translating academic research into marketable innovations (Chen et al., 2024a)

Management of facilities and developing and training initiatives are another important role. Noke et al. (2024) emphasize the role of technicians in optimizing facility use and ensuring that academic research aligns with industrial requirements. These often-overlooked actors act as important links in ensuring operational efficiency and technical alignment between university labs and external collaborators. Similarly, Fini et al. (2018) note the growing importance of training programs that equip researchers and students with the skills needed to navigate complex innovation ecosystems, particularly in regions transitioning to knowledge economies.

Mediatory roles emphasize the relational aspects of BU, focusing on building trust, aligning objectives, and managing partnerships. Alignment of objectives and expectations is a

recurrent challenge, as universities and industries often operate under differing priorities - academic institutions prioritize long-term, fundamental research, while industries seek immediate, application-driven results (Krücken et al., 2007; Ankrah et al., 2013). Effective mediation by BUs is critical in reconciling these differences and ensuring mutually beneficial collaborations. Network and trust building is another cornerstone of mediatory roles. Siegel et al. (2004) illustrate how TTO in the United States have successfully developed long-term partnerships by acting as honest brokers, fostering trust through transparent and consistent practices.

Incorporating digital transfer instruments has become an emerging alternative for mediatory roles. Noack & Jacobsen (2021) highlight how Germany's "Transfer Scouts" have integrated digital tools to streamline communication and facilitate real-time knowledge exchange. Albats et al. (2022) suggest that such tools can be particularly impactful in bridging physical and cultural divides, enabling more inclusive innovation processes.

External interface roles extend beyond the university's boundaries to engage directly with markets and external stakeholders. These roles include technology licensing, market analysis, and facilitating partnerships with investors. For example, Audretsch et al. (2024) highlight how partnerships with investors can provide the financial resources necessary to scale innovations, particularly in startup ecosystems. However, Szulczewska-Remi & Nowak-Mizgalska (2023) point out that in emerging economies, weak financial ecosystems and fragmented industrial structures often limit the effectiveness of such roles.

Another aspect of external interface roles is revenue generation and financing mechanisms, where BU often serve as intermediaries between funding bodies and academic researchers. Wonglimpiyarat (2016) provides insights into how incubators in Thailand leverage mixed funding models to support innovation, balancing public and private sector contributions. These efforts highlight the importance of adaptive financing strategies in addressing resource constraints.

Understanding the varied roles of BU is essential for improving their adaptability and effectiveness across different contexts. Categorizing these roles into internal interfaces, mediatory, and external interfaces provides a structured framework for analyzing and allocating responsibilities. This division fosters flexibility in decision-making, an important factor for emerging economies grappling with resource constraints. By clarifying specific roles that can be assumed by researchers, technical staff, intermediaries, or even external collaborators, universities can better utilize resources and address existing gaps.

The effectiveness of BU roles is deeply influenced by the context in which they operate. In advanced economies, where institutional support and resources are more robust, BU can focus on strategic in the innovation ecosystem (Angrisani et al., 2022). For example, O'Kane et al. (2021) indicate that TTO can effectively anticipate and integrate non-market strategies, such as political and legislative actions. These countries often demonstrate a more balanced approach across the three categories of BU roles - internal interfaces, mediatory roles, and external interfaces - allowing for a comprehensive engagement with stakeholders and a stronger alignment with both academic and market demands.

In contrast, BU in emerging economies frequently face systemic challenges, such as resource scarcity and institutional fragility. Temel et al. (2021) note that these conditions often restrict BU to internal interface roles, limiting their capacity to engage in broader, market-oriented activities. To address these limitations, Albats et al. (2022) suggest leveraging digital platforms and developing network-orchestrating activities to enable more efficient knowledge exchange and foster faster connections between academia and the private sector.

As BU evolve, their roles are increasingly characterized by bidirectional knowledge exchange, where mutual learning and co-creation between academia and external actors replace traditional unidirectional TT. This shift is particularly evident in advanced models, such as China's integrated BU, which emphasize market-oriented roles and dynamic collaboration (Conlé et al., 2021).

Table 3 - Boundary Units roles

Main role	Subtypes	Authors
[II] Internal Interface Roles	[II.1] Technology Identification and Evaluation	Chen et al., 2024a; Bäumle et al., 2023; Iqbal et al., 2018
	[II.2] Intellectual Property Management	Chen et al., 2024a; Siegel et al., 2004; Albats et al., 2022; Temel et al., 2021
	[II.3] Researcher Engagement	Good et al., 2019
	[II.4] Internal Strategic Alignment	O'Kane et al., 2021; Good et al., 2019; Santos et al., 2023
	[II.5] Management of Facilities	Noke et al., 2024; Santos et al., 2023
	[II.6] Supporting New Venture Creation	Cunningham et al., 2022; Yusof & Jain, 2010; Khodaei et al., 2022
	[II.7] Co-Creation of Knowledge and Technologies	Noack & Jacobsen, 2021; Santos et al., 2023; van Winden et al., 2019
	[II.8] Developing and Training	Temel et al., 2021; Santos et al., 2023; Fini et al., 2018
[MT] Mediatory Roles	[MT.1] Alignment of Objectives and Expectations	Krücken et al., 2007; Hailu, 2024; Chen et al., 2024a; Ankrah et al., 2013

	[MT.2] Network and Trust Building	Siegel et al., 2004; Good et al., 2019; Bäumle et al., 2023; Santos et al., 2023
	[MT.3] Development of Digital Transfer Instruments	Noack & Jacobsen, 2021; Albats et al., 2022
	[MT.4] Technology Transfer Strategies	Good et al., 2019; Santos et al., 2023
	[MT.5] Contract Management	Fini et al., 2018
[EI] External Interface Roles	[EI.1] Technology Licensing	Siegel et al., 2004; Good et al., 2019; Santos et al., 2023
	[EI.2] Market Analysis and Technology Promotion	Temel et al., 2021; Szulczewska-Remi & Nowak-Mizgalska, 2023
	[EI.3] Facilitating Partnerships with Investors	Audretsch et al., 2024; Good et al., 2019
	[EI.4] Revenue Generation and Financing Mechanisms	Siegel et al., 2004; Wonglimpiyarat, 2016; Santos et al., 2023
	[EI.5] Information Dissemination	Bäumle et al., 2023

Source: Prepared by the author.

3.3. Challenges

Finally, after understanding the types of BU and their roles, it is possible to identify and better understand the challenges. As presented below, BU must navigate structural, cultural, and institutional obstacles that are often context specific (Sandström et al., 2018; Maresova et al., 2019). These variances highlight the adaptability required of BU, as they must tailor their approaches to address the distinct needs and limitations of their respective environments.

This review identified twelve primary challenges that impact the dynamics of TT. In analyzing the challenges faced by BU, we recognize that these challenges often transcend strict categorizations and contextual boundaries. Many of the identified challenges could be associated with multiple categories and contexts. However, for the sake of analytical clarity, this study seeks to assign each challenge to the category and context where it is most prominently observed, thereby enabling a structured and nuanced discussion of the issues (Table 4).

Table 4 - Boundary Units challenges in TT dynamics

Challenges	Description	Authors	Category	Context
[CH.1] Lack of Objectives Alignment	This misalignment often stems from differing priorities, where academic goals may focus on fundamental research, while the private sector seeks immediate application and commercial returns. Without a shared vision, partnerships can suffer from inefficiencies and reduced mutual benefits.	Sandström et al., 2018; Cunningham et al., 2022; Noack & Jacobsen, 2021; Puerta-Sierra et al., 2021; Johnson et al., 2023; Hailu, 2024; Ghanadinezhad & Ghane, 2024; Colyvas, 2007	Mediatory	Developed countries
[CH.2] External Pressures and Growing Complexity	The increasing prevalence of "grand challenges", such as climate change, global health, and sustainability, amplifies the need for innovation and interdisciplinary collaboration. These challenges demand BU to act as orchestrators of diverse stakeholders, navigating complex networks to foster impactful solutions.	Audretsch et al., 2024; Bäumle et al., 2023	External interface	Developed countries
[CH.3] Resource Scarcity	Resource scarcity is a persistent challenge for BU particularly in contexts where funding, infrastructure, and human capital are limited. The lack of adequate resources hampers the ability of BU to facilitate effective TT and innovation processes.	Alibekova et al., 2019; Iqbal et al., 2018	Internal interface	Emerging countries
[CH.4] Access to Funding Sources	Insufficient financial resources can hinder the operational capacity of BU, limiting their ability to foster external collaborations and support high-potential projects.	Chen et al., 2024a; Fontes, 2001; Iqbal et al., 2018	External interface	Emerging countries
[CH.5] Fragile Intermediary Structures and Inexperienced Staff	Weak organizational frameworks often fail to provide the necessary support and resources for effective external collaborations. Additionally, inexperienced personnel may lack the expertise to manage complex innovation processes, further limiting their effectiveness.	Sandström et al., 2018; Hunter et al., 2011; Wonglimpiyarat, 2016; Conlé et al., 2021; Kotha et al., 2018	Mediatory	Emerging countries
[CH.6] Fragility of Socio-Economic and Industrial Structures	Unstable socio-economic conditions and fragmented industrial ecosystems often undermine the ability of BU to establish sustainable partnerships. The lack of a relevant industrial mass particularly hinders these processes in peripheral regions, where limited economic activity reduces opportunities for effective collaboration and innovation.	Temel et al., 2021; Thamae et al., 2016	External interface	Emerging countries
[CH.7] Legal Framework Reliability and Trust	Unclear or inconsistent legal frameworks can create significant obstacles, undermining trust and complicating the TT process. Predictable and transparent regulatory environments are essential to foster long-term partnerships and enable innovation.	Temel et al., 2021; Athreye et al., 2023; Tuunainen & Knuuttila, 2009; Hailu, 2024	External interface	Emerging countries
[CH.8] Cultural Differences Between Academia and External Stakeholders	These differences may include variations in organizational priorities, communication styles, and expectations regarding project timelines and outcomes. Such misalignments can lead to misunderstandings, reduced trust, and inefficiencies in TT processes.	Krücken et al., 2007; Siegel et al., 2004; Puerta-Sierra et al., 2021; Martin et al., 2019; Padilla-Meléndez et al., 2013; Hailu, 2024	Mediatory	Both
[CH.9] Limited Commercial Capabilities and Risk Aversion	Universities often struggle to navigate commercial processes due to insufficient expertise and support systems. Additionally, risk aversion within academic settings hinders the willingness to engage in entrepreneurial ventures or high-stakes innovation projects.	Cunningham et al., 2022; Markman et al., 2005; Siegel et al., 2004; Temel et al., 2021; Hailu, 2024; Alibekova et al., 2019; Sinell et al., 2015; Kotha et al., 2018	External interface	Both
[CH.10] Scientific Profile and Role Overload	Researchers often prioritize academic achievements over external collaboration, leading to a focus on publishing and teaching rather than engagement in TT activities. Additionally, the accumulation of multiple responsibilities, including administrative tasks and project management, can dilute their capacity to participate effectively in innovation efforts.	Baglieri & Lorenzoni, 2014; O'Kane et al., 2021; Chen et al., 2024b; Szulczewska-Remi & Nowak-Mizgalska, 2023; Johnson et al., 2023; Tuunainen & Knuuttila, 2009; Urbano & Guerrero, 2013; Xia et al., 2018	Internal interface	Both
[CH.11] Administrative Complexity in Technology Transfer Processes	Complex administrative procedures and rigid frameworks often result in delays and inefficiencies, discouraging active engagement from stakeholders. These constraints can also stifle innovation by prioritizing compliance over flexibility.	Siegel et al., 2004; Albats et al., 2022	Internal interface	Both
[CH.12] Geographical Proximity Between Universities and Industries	While close physical distance facilitates interactions and trust, it can also lead to a "dark side", where proximity without personal linkage results in non-interactive learning. This dynamic highlight the importance of balancing proximity with effective relationship-building strategies	Giones, 2019	Mediatory	Both

Source: Prepared by the author.

Internal interface roles are particularly impacted by challenges such as resource scarcity [CH.3], scientific profile and role overload [CH.10], and administrative complexity [CH.11]. These challenges hinder the ability of BU to perform foundational tasks effectively, leading to inefficiencies in translating research into marketable innovations (Chen et al., 2024a; Alibekova et al., 2019).

Mediatory roles are challenged by lack of alignment of objectives [CH.1], fragile intermediary structures [CH.5], cultural differences [CH.8], and geographical proximity issues [CH.12]. These challenges complicate efforts to build cohesive partnerships and reconcile differing priorities between universities and external stakeholders (Sandström et al., 2018; Temel et al., 2021).

External interface roles are deeply affected by challenges like external pressures and growing complexity [CH.2], access to funding [CH.4], fragility of socio-economic structures [CH.6], legal framework reliability issues [CH.7], and limited commercial capacity and risk aversion [CH.9]. These pressures necessitate robust strategies to overcome systemic challenges and foster innovation ecosystems (Thamae et al., 2016; Albats et al., 2022).

The challenges are examined within the specific environments of developed and emerging countries, as well as those that span across both. The following topics are the result of a thorough analysis of Table 4. This analytical effort aims to highlight the distinct barriers faced by BU in each context, while also identifying shared obstacles that transcend national boundaries

1. *Developed Country Contexts:* Challenges such as the lack of alignment in objectives are more pronounced in developed countries, where well-established institutional frameworks and innovation ecosystems have a greater intensity. Additionally, external pressures and the need to address grand challenges, such as climate change and societal resilience, place significant demands on BU to adapt and innovate within these mature systems. Here, the focus often lies on refining collaboration, optimizing TT processes, and developing strategies to navigate these complex, high-stakes environments.
2. *Emerging Country Contexts:* In emerging economies, BU frequently face chronic resource scarcity, marked by limited funding, infrastructure, and human capital, which constrains their capacity for effective TT and innovation. Insufficient financial resources and weak organizational frameworks further restrict their ability to manage complex innovation processes, often exacerbated by inexperienced personnel. Unstable socio-economic conditions and fragmented industrial ecosystems hinder the establishment of

sustainable partnerships, particularly where a lack of robust industrial activity reduces opportunities for productive collaborations. Moreover, unclear or inconsistent legal frameworks erode trust and complicate TT efforts, highlighting the need for predictable, transparent regulations to foster enduring partnerships and support innovation in these challenging contexts.

3. *Cross-Context Challenges:* Certain challenges, such as cultural differences between academia and private sector, transcend specific contexts, impacting both developed and emerging economies. Additionally, deficiencies in the commercial profiles of researchers and their role overload often hinder effective engagement in TT activities, regardless of the context. Geographic proximity issues also play a significant role, as physical distances between collaborators can exacerbate communication barriers and reduce the efficiency of knowledge exchange. However, the nature and impact of these challenges may vary, with emerging countries potentially facing more acute manifestations due to less mature systems of collaboration.

As can be observed, emerging countries face more complex structural and institutional challenges. Therefore, university administrators and public officials must exercise considerable caution when attempting to replicate models from developed countries, as the necessary conditions for success may not be in place (Sandström et al., 2018).

By analyzing these challenges through the dual lenses of categories and contexts, this study provides a comprehensive understanding of the multifaceted challenges in TT. This approach highlights the need for tailored strategies to navigate the complexities of different institutional and economic environments. The importance of the local context must be acknowledged, as innovation dynamics can vary significantly across different environments. Adopting a holistic view of the innovation ecosystem is essential for understanding the complex relationships among the various actors involved (Good et al., 2019).

4. Discussion – Institutional and Cultural Context

A critical examination of the existing literature underscores the divergent trajectories of BU operating in developed versus emerging economies. While substantial progress has been achieved in advanced countries, where formalized structures and robust institutional frameworks allow for greater flexibility and experimentation, emerging economies often grapple with foundational hurdles such as inadequate infrastructure, limited funding, and weak institutional support (Thamae et al., 2016; Alibekova et al., 2019). These systemic obstacles

hinder the transition from linear, technology-centered models towards more integrative and networked forms of innovation, as Krücken et al. (2007) propose.

Moreover, the discrepancy in resources and ecosystem maturity significantly shapes the allocation of BU efforts across internal interfaces, mediatory roles, and external interfaces (Sandström et al., 2018; Bäumle et al., 2023). In mature environments, institutional stability affords BU the opportunity to adopt proactive strategies, devoting considerable energy to relationship-building and anticipatory technological foresight (O’Kane et al., 2021; Noke et al., 2024).

Conversely, resource-scarce settings lead to a focus on internal interface roles. At the same time BU are required to assume an orchestrating role, bridging fragmented networks and compensating for systemic weaknesses (Temel et al., 2021; Schaeffer & Matt, 2016; Szulczewska-Remi & Nowak-Mizgalska, 2023). As a result, a disproportionate amount of time and energy is often invested in basic TT processes and capacity-building initiatives, relegating the strategic potential of BU to a secondary concern. One way to try to address this challenge is to invest in effective communication and feedback systems, which are essential for facilitating knowledge transfer, as they enhance mutual understanding, reduce ambiguity, resolve conflicts, and ensure better coordination among partners (Hailu, 2024; Audretsch et al., 2024).

The disparities also manifest in other challenges encountered. While advanced economies may wrestle with the alignment of objectives and optimizing collaboration strategies in well-established innovation ecosystems, emerging countries frequently face deeper structural obstacles (Athreye et al., 2023). Fragile institutional environments constrain managerial autonomy and can slow the establishment of robust BU roles. In such regions, decentralized approaches, where tasks are distributed among individual faculties and research centers, can help mitigate bureaucratic bottlenecks and facilitate localized responses to innovation challenges (Athreye et al., 2023). Nonetheless, a decentralized model requires a nuanced understanding of internal capabilities and external demands, especially in contexts marked by limited absorptive capacity and frequent regulatory shifts (Thamae et al., 2016).

A further challenge stems from the inherent restrictions placed on universities, many of which operate as public sector entities or hold tax-exempt status, thereby facing stricter regulations regarding their engagement in commercial activities (Tuunainen & Knuuttila, 2009). Compounding these issues is the limited professional experience of many managers in emerging economies, who often lack robust track records in TT process (Kotha et al., 2018).

This gap in expertise, coupled with high turnover rates and reliance on scholarship-supported personnel, undermines the continuity and stability of BU.

An additional avenue for overcoming systemic challenges in emerging economies involves the adoption of alternative mechanisms and organizational structures. For example, digital platforms have begun to complement or even replace physical BU, offering more agile channels for knowledge exchange and hastening connections between academia and the private sector (Albats et al., 2022). Moreover, best practices gleaned from more mature ecosystems in emerging economies, such as market oriented 'New R&D Institutes' (NRDIs) in China, underscore the potential of collaborative research centers to achieve a more holistic engagement of stakeholders (Conlé et al., 2021). Likewise, technical and administrative staff, whose expertise spans operational and managerial dimensions, can play an important BU role in translating research findings into actionable projects, especially in contexts with limited resources and staff shortages, as emerging economies (Noke et al., 2024). These approaches illustrate how targeted innovations in structure, technology, and human capital can inspire emerging economies to circumvent entrenched constraints and advance toward more integrated and effective models of knowledge transfer.

Another point of attention is the implementation of public policies. A holistic perspective is essential for designing Science, Technology, and Innovation (STI) policies that align with the advancement of collaboration and the broader innovation ecosystem (Puerta-Sierra et al., 2021). Therefore, an in-depth understanding of the context and underlying dynamics is fundamental before introducing interventions to ensure that policies are both relevant and impactful (Giones, 2019; Duruflé et al., 2018; Clauss et al., 2018). Haeussler and Colyvas (2011), for example, argue that the focus should extend beyond merely the quantity of innovative outputs, emphasizing instead the nature and distribution of various types of relationships.

Policymakers should be cautious when attempting to replicate successful initiatives from advanced economies in emerging contexts. The success of such initiatives often depends on specific legal, institutional, and regional factors, as well as the entrepreneurial capabilities of universities (Sandström et al., 2018). Instead of applying ready-made models, they should focus on developing strategic policies relevant to the local context (O'Kane et al., 2021). Adopting a long-term perspective is also essential, enabling universities to rethink and adapt their present and future strategies within the broader higher education landscape (Guerrero & Menter, 2024; Mayer, 2010). Additionally, geographic factors must be considered in this

dynamic, such as regional disparities shape management, leadership, and the ability to overcome obstacles (Ghanadinezhad & Ghane, 2024).

Critically, these findings emphasize that one-size-fits-all approaches or direct policy transplants from advanced contexts are unlikely to yield optimal results (O’Kane et al., 2021; Sandström et al., 2018). As pointed by Tuunainen & Knuuttila (2009), “boundaries in science are not always created at will, but rather arise from the complex historical evolution and wide-ranging societal role of academic institutions”. Addressing these issues ultimately requires a cultural shift, one that is gradual, demands considerable effort, and remains frequently underdeveloped (Martin et al., 2019).

Concluding, since the majority of studies originate from developed countries, where a fundamentally different culture has taken root, it becomes exceedingly difficult to conceive any straightforward form of “adaptation”. The literature points to a more deliberate strategy of tailoring BU models, activities, and policy interventions to local realities, while drawing lessons selectively from global best practices (Guerrero & Menter, 2024). Ultimately, the critical insights drawn from contrasting contexts underscore that the success of BU depends not only on internal attributes or managerial expertise but also on the broader structural conditions underpinning knowledge transfer and innovation.

5. Discussion – Future Research Agenda

Based on the gaps and tensions identified in this systematic review, we propose a future research agenda structured around three core axes: contextualization, dynamism, and interdisciplinarity. These axes were selected because they capture the most salient limitations and emerging needs in the current literature. First, contextualization emphasizes the importance of understanding how distinct socio-economic and institutional environments shape the design and effectiveness of BU, particularly in emerging economies. Second, dynamism reflects the need to investigate how BUs continuously evolve in response to technological, organizational, and policy changes, including the growing influence of digitalization. Third, interdisciplinarity acknowledges the complex, multi-actor, and multi-level nature of BU, which requires integrating diverse theoretical perspectives and analytical levels. The following table summarizes these three axes, detailing specific topics and their corresponding research opportunities.

Table 5 - Proposed Research Agenda: Axes, Topics, and Descriptions

Axis	Topic	Description
1. Contextualization	1.1. Understanding the evolution of BU in emerging economies	Investigate how BU in resource-constrained environments develop hybrid models combining formal and informal mechanisms to overcome institutional and structural limitations. Investigate how informal practices become institutionalized, especially within emerging innovation ecosystems.
	1.2. Analyzing the role of public policies across institutional regimes	Explore how STI policies influence the design, functioning, and effectiveness of BU across different national contexts. Focus on identifying conditions under which policies succeed and how policy instruments can be tailored to avoid ineffective replication of models from developed economies.
2. Dynamism	2.1. Exploring the impact of digitalization on BU functions	Examine how digital platforms and tools are transforming the functions of BU, introducing new intermediation practices. Investigate the capabilities required for their effective adoption and the specific barriers posed by limited digital infrastructure, particularly in emerging economies.
	2.2. Examining transitions from linear to collaborative BU models	Study the factors enabling BU to shift from transactional, unidirectional roles to co-creative, networked engagements with external stakeholders. Longitudinal studies could reveal how these units evolve and adapt over time.
3. Interdisciplinarity	3.1. Investigating the role of underexplored actors	Analyze how technicians, personal networks, and other informal actors contribute to the functioning and efficiency of BU, particularly in contexts with institutional weaknesses. Explore how these actors interface with formal structures and the extent of their recognition within organizations.
	3.2. Developing multi-level theoretical models	Construct integrative models that capture the interactions between micro (individual), meso (organizational), and macro (institutional and policy) levels. Encourage interdisciplinary approaches combining perspectives from management studies, innovation policy, and higher education research.

Source: Prepared by the author.

By pursuing these avenues, future research can advance a more nuanced and comprehensive understanding of BU, particularly in underrepresented contexts. This agenda underscores the importance of embracing contextual sensitivity, recognizing the dynamic nature of knowledge transfer mechanisms, and fostering interdisciplinary approaches capable of capturing the multifaceted realities of BU activities in diverse innovation ecosystems.

6. Conclusion

The primary objective of this study was to examine the role of university BU across different socio-economic contexts. To achieve this goal, we employed a configurative systematic literature review, identifying and analyzing 58 scholarly works that discuss the design, roles, and challenges of these BU. This methodological approach allowed us to capture a broad range of perspectives and contexts, thereby enabling an in-depth exploration of how universities engage in knowledge exchange and technological transfer in environments with distinct institutional, cultural, and economic characteristics. The framework used in this analysis focuses on understanding contextual differences, especially about emerging and developed countries. First, it was necessary to present the types of BU, followed by an understanding of their roles, and finally, identifying the challenges.

Building on the proposed framework, this study has adopted a comparative lens that underscores how diverse national realities influence every dimension of university BU operations. By addressing the observed gap in the extant literature, which has traditionally centered on developed nations, it incorporates the realities of emerging countries, characterized by less mature innovation ecosystems, limited resources, and divergent policy regimes. Incorporating insights from both developed and emerging contexts, the findings highlight not only the interplay between local contextual factors and broader innovation ecosystems, but also the importance of adaptable, inclusive strategies for fostering knowledge exchange and technological advancement. Consequently, this study offers a more holistic and context-sensitive point of view, laying the groundwork for stakeholders to devise robust strategies for collaboration across diverse socio-economic settings.

Despite these contributions, certain limitations must be acknowledged. The reliance on existing literature and the uneven distribution of research across countries might constrain the generalizability of the findings. Moreover, the analysis may have overlooked nuanced local dynamics that can only be captured through extensive fieldwork or mixed-method designs. Future studies could address these gaps by conducting multi-case empirical research on the operationalization of BU in diverse settings, as well as by applying quantitative methods. Such endeavors would contribute to a more comprehensive understanding of how BU roles across varied institutional terrains and further enhance the impact of knowledge transfer.

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Paper 2: The Influence of Technology Transfer Offices Role Orientations on Technology Transfer Performance

The Influence of Technology Transfer Offices Role Orientations on Technology Transfer Performance

Abstract

Universities play a central role in innovation ecosystems, with technology transfer offices (TTO) serving as key intermediaries that facilitate interactions between academia and external stakeholders. Despite extensive research on TTO, gaps remain in understanding how their strategic orientation influences early- and late-stage technology transfer (TT) outcomes, particularly in emerging economies. Adopting a process-oriented perspective, this study examines how TTO roles, categorized into internal and external interfaces, impact early- and late-stage TT outcomes in Brazil. Using robust regression analyses on data from the 2019-2023 FORTEC Innovation Survey, we find that a predominant internal interface orientation significantly enhances early-stage outcomes (e.g., invention disclosures) but shows no statistically significant impact on late-stage outcomes. Conversely, TTO with a stronger external interface focus demonstrate superior performance in late-stage outcomes, particularly licensing agreements. These findings advance theory on the organizational design of TTO and boundary unit activities, showing how distinct role orientations differentially shape TT effectiveness. In practice, the study offers insights for university administrators and policymakers on strategically balancing TTO roles, fostering ecosystem-oriented strategies to maximize innovation impact in emerging economies.

Keywords: Technology Transfer Offices; Role Orientations; Internal Interface; External Interface; Universities; Emerging Economies.

1. Introduction

With increasing emphasis on the university's third mission, the transfer of knowledge and technology beyond the academic environment has assumed a fundamental role in innovation ecosystems (Guerrero et al., 2023; Molas-Gallart et al., 2002; Schaeffer et al., 2024). Within these ecosystems, interactions are often facilitated by Boundary Units (BU), entities that operate at the intersection of internal and external organizational environments (Chau et al., 2017). Technology transfer offices (TTO) are examples of BU strategically positioned to bridge the gap between academic research and market application. Consequently, TTO are an important agent in economic growth, technological advancement, and societal progress. Given the multifaceted nature of their functions, a holistic and in-depth understanding

of TTO is essential for optimizing their impact on innovation ecosystems (Chen et al., 2024; Good et al., 2019).

One of the key approaches to ensuring success in technology transfer (TT) is establishing models firmly grounded in well-structured processes (Maresova et al., 2019). These processes influence and are influenced by various organizational elements, shaping the dynamics of TT (Xia et al., 2018). In line with this perspective, previous studies have explored the diverse roles of TTO, highlighting how their functions are embedded within and dependent on these structured processes. For instance, Maresova et al. (2019) analyze models, processes, and the roles assumed by different actors within the ecosystem at a macro level, but do not delve into micro-level dynamics. Meanwhile, Santos et al. (2023) provide a broader taxonomy of intermediaries, identifying 22 distinct roles that range from technology evaluation to strategic alignment. Drawing on existing taxonomies of intermediary roles, and adopting a process-oriented perspective, this study systematically categorizes TTO roles into two primary domains: internal and external interface roles. This categorization grouped specific activities based on whether they primarily involve interactions within the university or with external stakeholders, as detailed in Table 6 and Table 7.

This study's premise is that internal configurations significantly influence TT outcomes (Sánchez-Barrioluengo & Benneworth, 2019; Schneider, 2024). Consequently, how TTO operationalize their roles is expected to shape TT performance. This performance can be measured through several indicators, including creating spin-offs, establishing partnerships, and generating and commercializing intellectual property (Guerrero & Menter, 2024; Haeussler & Colyvas, 2011; Siegel et al., 2004). In line with Soares and Torkomian (2021) and given the focus on TTO and the availability of relevant data, this study examines two key outcome indicators: invention disclosures as an early-stage indicator and licensing agreements as a late-stage indicator in the TT process.

Several factors influence TT outcomes, ranging from internal organizational elements to external environmental conditions (Szulczewska-Rem & Nowak-Mizgalska, 2023). Internally, critical factors include TTO design and structure (Temel et al., 2021; Siegel et al., 2004), the presence of dynamic and ordinary capabilities (Guerrero & Menter, 2024), the entrepreneurial orientation of universities (Chen et al., 2024; Hunter et al., 2011), and resource allocation strategies (Siegel et al., 2004). Externally, contextual factors encompass stakeholder diversity (O'Kane et al., 2021), goal alignment (Audretsch et al., 2024; Sandström et al., 2018), public policies and regulatory frameworks (O'Kane et al., 2021), and institutional

configurations at national and regional levels (Sandström et al., 2018; Szulczewska-Remi & Nowak-Mizgalska, 2023). While the literature acknowledges the importance of these internal and external factors, the underlying mechanisms through which TTO role orientations influence TT outcomes remain underexplored (Guerrero & Menter, 2024).

Despite growing recognition of the role of intermediary organizations, including TTO, in enhancing TT outcomes such as patent applications (Temel et al., 2021), the specific impact of TTO orientations on early and late-stage outcomes is not well understood (Guerrero & Menter, 2024). Previous studies suggest that the mere presence of intermediary organizations does not necessarily lead to significant differences in patenting activity, highlighting the need to explore the strategic orientations and operational dynamics of TTO. Notably, existing research is often limited to specific national contexts (e.g., Turkey) and does not examine long-term outcomes, underscoring the need for further investigation into the influence of TTO orientations on different stages of the TT process (Temel et al., 2021).

There is a growing interest in state-of-the-art TT models in emerging economies, as these contexts present unique challenges that hinder effective TT processes (Maresova et al., 2019). Universities in these regions face significant constraints due to structural barriers and the lack of a critical mass of external actors, making it imperative to understand the dynamics that foster socioeconomic development (Schaeffer et al., 2024). To address the need for a deeper understanding of how TTO roles influence the early and late stages of the TT process, particularly in the context of an emerging economy such as Brazil, this study aims to answer: How do TTO orientations toward internal and external roles, influence the early and late stages of the TT process within an emerging economy?

The study adopts a quantitative approach to address this question, utilizing secondary data from the 2019 to 2023 FORTEC Innovation Survey and additional institutional sources. Negative binomial regression models were employed to examine the influence of TTO role orientations on early and late-stage TT outcomes, categorized as internal and external interface. Control variables were incorporated to account for internal and external factors influencing TT dynamics, ensuring a robust and reliable statistical analysis.

As contributions, this study addresses Schneider's (2024) call for different perspectives on capacity building in TT processes and contributes to the literature by expanding the discussion on TTO and their underlying roles. Furthermore, by examining how TTO role orientations shape each stage of the TT process, this study advances theoretical discussions by demonstrating that it is not merely the presence of a TTO that influences TT outcomes, but

rather the degree to which it effectively supports researchers in important dimensions (Sandström et al., 2018). Additionally, by focusing on an emerging country, this research responds to the need for studies on entrepreneurial university initiatives in South America. This area remains underexplored, according to Sandström et al. (2018).

Beyond theoretical contributions, this study provides practical insights to support the strategic management of TTO processes in emerging economies. In this context, universities must strategically manage their capabilities and innovation potential to enhance their entrepreneurial orientation and optimize TT processes (Maresova et al., 2019). Given resource constraints, role allocation requires a creative approach to ensure the efficient use of available resources, thereby maximizing economic, technological, and societal advancements (Guerrero & Mertens, 2024). In this regard, access to high-quality information is essential for refining strategic positioning, improving procedural efficiency, and optimizing the design and operation of TTO (Schneider, 2024). Accordingly, the findings of this study aim to assist university administrators and policymakers by providing valuable information/insights to enhance TT effectiveness, ultimately fostering innovation-driven regional development.

2. Technology Transfer Offices Roles

The configuration and roles of TTO vary significantly across different contexts, reflecting institutional goals and regional demands (Cunningham et al., 2022; Hailu, 2024; Hunter et al., 2011). TTO are formal entities responsible for managing intellectual property, patents, and licensing agreements, functioning as bridges for transferring technology and promoting university innovations (Fini et al., 2018; Sandström et al., 2018; Temel et al., 2021).

Over time, these configurations have evolved from simple transactional mechanisms into dynamic, networked models that accommodate shifts in the innovation landscape and regional requirements (Albats et al., 2022; Conlé et al., 2021; Krücken et al., 2007). According to O’Kane et al. (2021), the role of TTO extends beyond mere intermediaries between universities and the private sector, positioning them as pivotal cross-level brokers within innovation ecosystems. Moreover, recent studies demonstrate that universities with some intermediary organizations tend to achieve better TT outcomes, as evidenced by increased patent applications (Temel et al., 2021).

The complexity of these processes is evident in the extensive range of roles identified by Santos et al. (2023) in their literature review. These authors highlight key functions, including identifying and evaluating internally developed technologies, managing intellectual

property, prospecting external partners, and negotiating and overseeing TT contracts. A major organizational challenge for entrepreneurial universities is selecting the appropriate formal organizational architecture to support the various stages of TT (Cunningham et al., 2022). Drawing on these insights and inspired by the works of Chau et al. (2017) and Prysor and Henley (2017), this study proposes a streamlined categorization of TTO roles into two primary domains: internal and external interface roles.

2.1 Internal Interface

Internal interface roles operate exclusively within the internal environment of universities, focusing on strengthening institutional capabilities for TT. These roles are fundamental in structuring and optimizing the TT process, ensuring that academic innovations are effectively identified, protected, and strategically aligned with institutional goals (Chen et al., 2024). Based on the analysis of various studies, key internal interface roles that define the function of TTO have been identified and are summarized in Table 6.

Table 6 - Internal interface roles

Internal interface	Description	Authors
Technology Identification and Evaluation	These processes aim to identify internally developed technologies and assess their commercialization potential.	Chen et al., 2024; Good et al., 2019; Wonglimpiyarat, 2016; Bäumle et al., 2023; Iqbal et al., 2018
Intellectual Property Management	Encompasses the oversight of patents and copyrights to safeguard university innovations, which are essential for maintaining institutional competitiveness.	Hayter, 2016; Albats et al., 2022; Temel et al., 2021; Szulczewska-Remi & Nowak-Mizgalska, 2023;
Researcher Engagement	By fostering researchers' involvement in the TT process, TTO not only increase the visibility of academic work but also cultivate an entrepreneurial mindset within universities.	Good et al., 2019
Strategic Alignment	Internal coordination between central administration, BU, and researchers ensures that institutional objectives are harmonized, creating an environment conducive to effective TT.	O'Kane et al., 2021; Good et al., 2019; Santos et al., 2023
Development and Training	Capacity-building initiatives organized by TTO enhance researchers' and students' ability to engage in TT and innovation processes	Temel et al., 2021; Santos et al., 2023; Fini et al., 2018

Source: Prepared by the author.

As observed, these activities operate independently of external actors and thus rely primarily on the universities' structural conditions, resources, and strategic direction. These are generally related to a linear and document-driven model, emphasizing the identification and formal protection of internally developed technologies (Krücken et al., 2007). According to these authors, such a model generates limited outcomes for TTO.

Importantly, internal interface roles are directly linked to the foundational stages of the TT pipeline. Activities such as technology identification, intellectual property management, and

researcher engagement shape the upstream flow of potential inventions by increasing the volume, quality, and formalization of research outputs entering the TT process. By systematically supporting disclosure preparation, prior art searches, patentability assessments, and internal training, TTO strengthen the institutional capacity to identify market-relevant inventions and convert them into protectable intellectual assets.

Furthermore, academic researchers who receive support from their TTO, an aspect of the internal interface role, are more likely to access the necessary resources to file invention disclosures, a proxy for early-stage TT outcomes (Hunter, 2011). Temel et al. (2021) also identify a positive relationship between the presence of BU, regardless of their specific focus, and patenting performance, another indicator of early-stage TT outcomes. However, neither analysis accounts for late-stage TT outcomes.

Taken together, the literature suggests that internal interface roles perform a “pipeline activation” function: they enhance the generation and formalization of inventions but do not, on their own, create pathways for external engagement or market access. As a result, internal efforts tend to strengthen early-stage outcomes, such as invention disclosures and patent filings, while their influence on late-stage outcomes remains limited.

Building on these theoretical foundations, universities concentrating on internal interface roles tend to limit TT outcomes to early-stage results, such as invention disclosures and patent filings, which do not require interaction with external stakeholders. By prioritizing these activities while overlooking those that foster greater engagement with external actors, research outcomes are less likely to progress toward commercialization. Consequently, the first two hypotheses of this study are formulated as follows:

H1: A greater focus on internal interface efforts leads to better early-stage outcomes in the technology transfer process of TTO.

H2: A greater focus on internal interface efforts is not significantly associated with late-stage outcomes in the technology transfer process of TTO.

2.2 External interface

External interface roles encompass functions that facilitate interactions between universities and external stakeholders, including industry partners, government agencies, and investors. These roles extend beyond university boundaries, aiming to foster collaboration, knowledge exchange, and commercialization opportunities (Audretsch et al., 2024). Based on

the analysis of various studies, several activities directly related to the external interface role of TTO have been identified, as presented in Table 7.

Table 7 - External interface roles

External interface	Description	Authors
Technology Licensing	TTO facilitate technology licensing, enabling universities to transfer intellectual property rights to external partners. This enhances the visibility and commercial application of academic research.	Siegel et al. (2004); Good et al. (2019); Santos et al. (2023)
Market Analysis and Technology Promotion	By identifying promising innovations and aligning them with market demands, TTO increase commercialization success and bridge the gap between research and industry.	Good et al. (2019); Temel et al. (2021); Santos et al. (2023); Szulczewska-Remi & Nowak-Mizgalska (2023); Chen et al. (2024)
Alignment of Objectives and Expectations	Reconciles differing goals among stakeholders by fostering a shared vision. This alignment enhances collaboration by ensuring that academic and private sector objectives are harmonized.	Krücken et al., 2007; Chen et al., 2024; Colyvas, 2007; Santos et al., 2023; Hailu, 2024; Ankrah et al., 2013
Network and Trust Building	Establishes strong networks and fosters trust between academia and external stakeholders. These efforts enhance collaboration effectiveness and strengthen the university's position in the innovation ecosystem.	Chen et al., 2024; Siegel et al., 2004; Good et al., 2019; Bäumle et al., 2023; Schaeffer & Matt, 2016; Santos et al., 2023
Facilitating Partnerships with Investors	TTO connect researchers with investors, securing funding to accelerate commercialization. Despite its importance, this role remains underexplored in the literature.	Audretsch et al., 2024; Good et al., 2019
Revenue Generation and Financing Mechanisms	TTO develop financial models such as royalty agreements and equity sharing, ensuring universities generate revenue and reinvest in research.	Chen et al. (2024); Siegel et al. (2004); Good et al. (2019); Wonglimpiyarat (2016); Santos et al. (2023); Iqbal et al. (2018)
Information Dissemination	TTO promote university technologies through events and outreach, fostering industry engagement and collaboration.	Bäumle et al., 2023

Source: Prepared by the author.

These external interface roles are intrinsically linked to interactions with external stakeholders and follow a cooperative model of TT, in which collaboration and engagement beyond institutional boundaries drive innovation and commercialization (Krücken et al., 2007). In more advanced ecosystems, these authors suggest that this approach can evolve into the "blurring of boundaries" (BoB) model, wherein distinctions between academic and external actors become increasingly fluid. Thus, in mature environments, such as those in developed countries, effectively executing these roles is essential for TTO to act as pivotal actors, facilitating seamless knowledge exchange and technological advancement (Chen et al., 2024).

In emerging economies, where the industrial critical mass is smaller, universities play an even more significant role in generating new technologies and establishing connections with external stakeholders (Conlé et al., 2021; Schaeffer et al., 2024). Facilitating the transition from a less developed innovation ecosystem to one where universities play a central role requires

understanding the evolving function of TTO (Schaeffer & Matt, 2016). According to these authors, over time, BU' activities must incorporate brokerage, network orchestration, and the articulation of shared objectives, reinforcing the strategic role of TTO in fostering collaboration beyond institutional limits.

Furthermore, Conlé et al. (2021) demonstrate that market-oriented New R&D Institutes (NRDIs) in China, prioritizing external engagement, tend to achieve better outcomes than traditional TTO. Similarly, TTO adopting a bridging approach through formalized structures and communication procedures enhance the likelihood that university-industry collaborations will result in exploitative innovations, a late-stage outcome of the TT process (Rossi et al., 2022).

Taken together, these findings indicate that external interface roles operate as the “downstream engine” of the TT pipeline. They enable the conversion of protected or validated academic technologies into market-oriented outputs by mobilizing networks, aligning expectations, reducing information asymmetries, and expanding access to financial, technical, and industrial resources. Thus, these activities primarily shape late-stage TT outcomes, such as licensing agreements, collaborative R&D contracts, spin-off formation, and revenue generation.

Conversely, because external interface activities focus on matchmaking, negotiation, alignment, and resource mobilization at later stages of the pipeline, their influence on generating invention disclosures or patent applications is expected to be limited. Early-stage outputs emerge largely from the internal scientific and administrative routines that precede external engagement. This asymmetry mirrors the complementary, and often inversely related, nature of internal and external interface efforts: an increased orientation toward outward-facing roles typically reallocates resources and strategic attention away from internal routines, and vice versa.

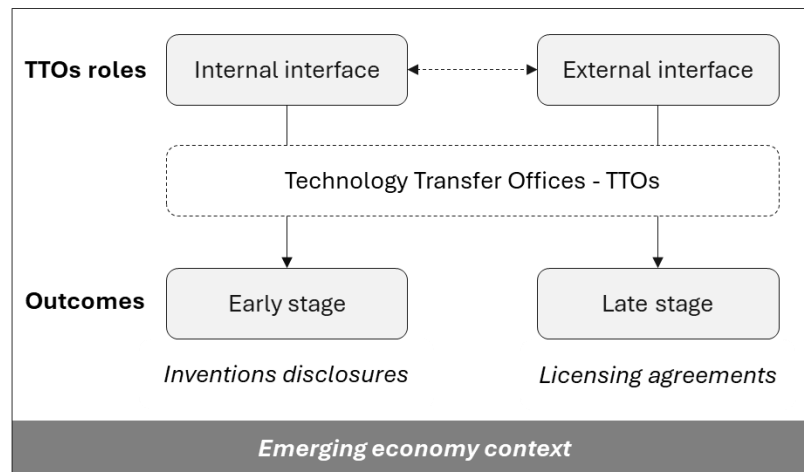
Building on these theoretical foundations, external interface roles, which foster partnerships and extend the university's boundaries, are therefore expected to contribute primarily to late-stage outcomes by strengthening connections with industry, government, and other stakeholders within the innovation ecosystem. Accordingly, this study proposes the following hypotheses:

H3: A greater focus on external interface efforts leads to better late-stage outcomes in the technology transfer process of TTO.

H4: A greater focus on external interface efforts is not significantly associated with early-stage outcomes in the technology transfer process of TTO.

The conceptual framework of this study is grounded in the role of TTO as key facilitators in the TT process, particularly within the context of emerging economies. As illustrated in Figure 5, TTO assume two primary roles, internal interface and external interface, with a bidirectional information flow, influencing TT outcomes at different stages.

Figure 5 - Conceptual Framework



Source: Prepared by the author.

The first and second hypothesis suggests that the internal interface role is associated with early-stage TT outcomes, such as invention disclosures, and does not influence the late-stage results. In contrast, the third and fourth hypotheses propose that external interface roles emphasize long-term TT outcomes, such as licensing agreements, and do not influence early-stage results. The study aims to empirically validate these relationships through these hypotheses, assessing how the role orientation of TTO affects TT outcomes.

3 Methodology

3.1 Data and variables

This study employs a quantitative approach based on secondary data analysis. Data collection was conducted using two primary sources: the 2019 to 2023 Fortec Innovation Survey, carried out by the National Forum of Innovation and Technology Transfer Managers (Fortec), and additional secondary data obtained from official documents, institutional websites, and the Brazilian Institute of Geography and Statistics (IBGE) platform.

The Fortec Innovation Survey provided information regarding the orientation of TTO toward different roles, TT process outcomes, and various institutional characteristics related to

both TTO and universities. This survey has been conducted since 2016 and has been widely used by researchers to analyze the current landscape of TTO operations and *TT* activities in Brazil (Fanhaimpork & De Melo, 2023; Santa Rita et al., 2023; Soares & Torkomian, 2021; Soares, Torkomian & Nagano, 2020). The entire data handling, treatment, and analysis process was conducted using MS Excel and Stata 16, ensuring robustness and reliability in the statistical modeling applied to the discussion of results.

Although recognizing that third mission outcomes can take various forms, this study focuses on the innovation dynamics within the TT process, given the role of TTO and data availability. Inspired by Soares and Torkomian (2021), two performance indicators were considered: one representing the early-stage and another the late-stage of the TT process. For the early-stage, the number of invention disclosures received by each university was used as an indicator, while for the late-stage, the number of licensing agreements completed by each university was considered (Hunter et al., 2011; Maresova et al., 2019). The difference in sample size across models is due to missing values in the dataset for the number of license agreements, which led to their exclusion from that model. As a result, the analyses for early-stage outcomes use a larger sample (n=489) than those for late-stage outcomes (n=431).

In the Fortec Innovation Survey, TTO report the percentage of their personnel assigned to specific roles, and these responses were used as proxies for the previously defined categories. Four of the six available responses were of particular interest, aligning with the three identified categories, as summarized in Table 8. These categories were established based on reviewed literature, adhering to the process approach and distinguishing among internal and external interface roles.

Table 8 - Explanatory variables

Roles	Proxy/Survey	Hypotesis
Internal interface	“Intellectual Property Prospecting” and “Intellectual Property Protection”	Positive influence on early-stage outcomes
External interface	“Acquisition, Guidance, and Facilitation of Collaborative Research Projects with Independent Inventors, Companies, or Other Entities” and “Technology Transfer”	Positive influence on late-stage outcomes

Source: Prepared by the author.

In addition to the explanatory variables, it is recognized that various internal and external factors influence the dynamics of TT (Compagnucci & Spigarelli, 2020; Szulczewska-

Rem & Nowak-Mizgalska, 2023). Therefore, efforts were made to identify and control key factors that may impact TT outcomes as shown in Table 9.

Table 9 - Control variables

Control Variable	Description	Data Source
University Maturity	University Age (measured in years)	Various Data Sources
TTO Maturity	TTO Age (measured in years)	Fortec Innovation Survey
TTO Operational Capacity	Number of full-time employees in the TTO	Fortec Innovation Survey
University Innovative Capacity	Intellectual Property Stock (patent applications) up to the year of analysis	Fortec Innovation Survey
Public University	Dummy variable indicating whether the university is public (equal to 1 if affirmative)	Fortec Innovation Survey
Polytechnic University	Dummy variable indicating whether the university is polytechnic (equal to 1 affirmative)	Fortec Innovation Survey
Region of the country	Dummy variables for each region of the country	IBGE
University Size	Number of students enrolled at the university	Various Data Sources
Local Economic Activity	Gross Domestic Product (GDP) per capita of the city	IBGE

Source: Prepared by the author.

The control variables include: i) the maturity of educational institution (EI) and TTO (Kotha et al., 2018; Sandström et al., 2018), ii) the operational capacity of TTO (Guerrero & Menter, 2024; Temel et al., 2021), iii) the EI's innovative capacity (Chen et al., 2024; Hunter et al., 2011), iv) EI's type and size, local economic activity (O'Kane et al., 2021), v) regional characteristics (Szulczewska-Remi & Nowak-Mizgalska, 2023; Wurth et al., 2024), and vi) year-specific controls. These theoretical insights guided the definition of control variables, which were selected based on data availability and alignment with previous studies (Guerrero & Menter, 2024; Radko et al., 2023; Schaeffer et al., 2024; Soares & Torkomian, 2021).

3.2 Method of analysis

The data analysis began with descriptive statistics and illustrative graphs to provide an overview of the dataset and understand the behavior of the variables. Subsequently, multiple regression techniques for count data were applied. Specifically, given the nature of the dataset, Poisson regression was initially considered, as it is well-suited for modeling count data (Cameron & Trivedi, 2005). However, a goodness-of-fit test revealed overdispersion in the sample. This diagnosis was further confirmed by the likelihood-ratio (LR) test for $\alpha = 0$ in all

estimated models (Table 10 and Table 11), which was highly significant ($p < 0.01$), rejecting the Poisson specification in favor of the negative binomial model. To address this issue, a negative binomial model was employed (Green, 2021), following the same approach adopted by Soares and Torkomian (2021) and Schaeffer et al. (2024) in similar datasets.

The econometric model was structured to capture the effect of the explanatory variables (TTO roles) on the dependent variable (early and late-stages TT outcomes). To ensure greater robustness in determining the effects of the explanatory variables, four models were estimated for each response variable: one excluding the explanatory variables, two considering each explanatory variable separately, and a fourth incorporating both simultaneously. Below is the most comprehensive econometric model, including the previously identified control variables.

$$Y_i = \beta_0 + \beta_1 Int_i + \beta_2 Ext_i + \beta_3 X_i + \varepsilon$$

Where:

Y_i represents the early-stage or late-stage TT outcome of university i ;

Int_i represents the percentage of time allocated to the internal interface role in TTO from university i ;

Ext_i represents the percentage of time allocated to external interface roles in TTO from university i ;

X_i is a vector of control variables.

and ε is the error term.

Clustered standard errors were applied to account for potential correlations among observations from the same university. This approach ensures that observations are independent across groups (clusters) but not necessarily independent within groups. Although the suitability of panel estimators was examined, a pooled negative binomial model was selected. The key explanatory variables exhibit greater between-unit than within-unit variation ($SD_{between} = 0.14$ vs. $SD_{within} = 0.13$ for Internal, and $SD_{between} = 0.11$ vs. $SD_{within} = 0.10$ for External) and the panel is short and unbalanced. Under these conditions, fixed-effects count estimators would rely on limited within-unit variation and suffer from efficiency losses. Given this structure and the presence of overdispersion, the pooled negative binomial model with cluster-robust standard errors provides the most appropriate specification. Furthermore, some robustness test models were also estimated using patent filings as an alternative early-stage outcome (Hunter et al., 2011; Soares & Torkomian, 2021).

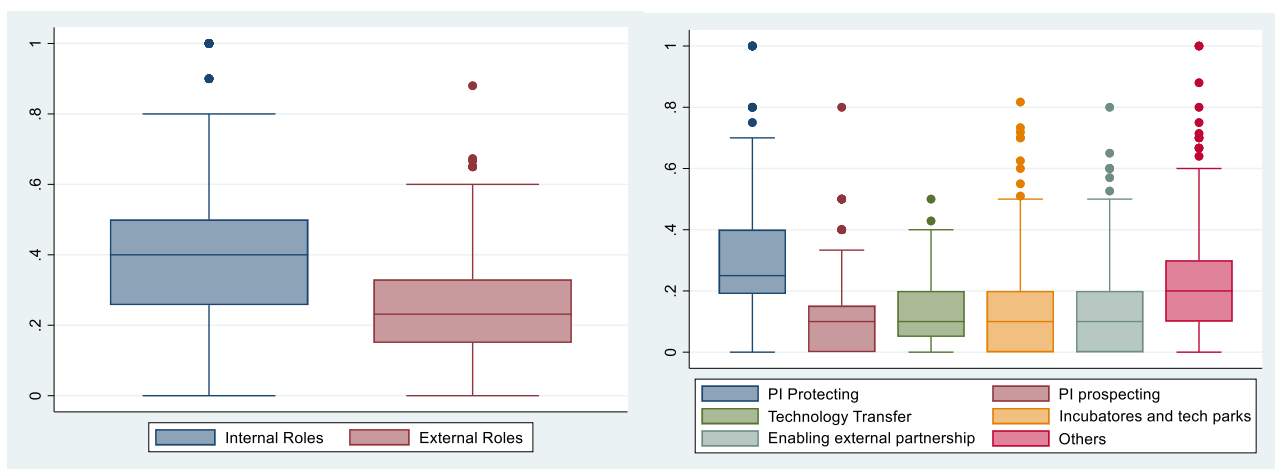
4 Results

4.1 Descriptive Analysis

Initially, two boxplot graphs were generated to better understand the explanatory variables' characteristics, as illustrated in Figure 6. The first graph presents the distribution of

TTO efforts across internal and external interface roles. The second graph provides a detailed breakdown of all the options indicated by TTO managers in the Fortec Innovation Survey. It is important to highlight that the internal interface role is represented by the sum of "IP Protecting" and "IP Prospecting" activities. Meanwhile, the activities "Technology Transfer" and "Enabling External Partnership" for the external interface roles were considered. As they are not directly linked to these roles, other categories were excluded from econometric analysis. Both graphs use percentage values, indicating the proportion of the workforce each TTO allocates to these activities.

Figure 6 - Explanatory variables analysis

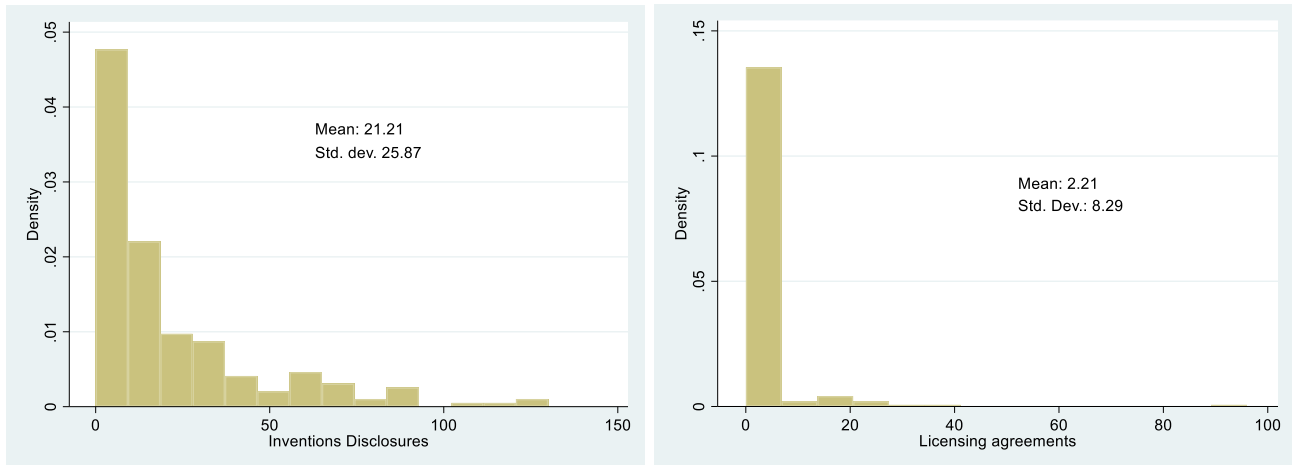


Source: Prepared by the author.

The first graph reveals that Brazilian TTO allocate a larger share of their efforts to the internal interface role, to the detriment of external interface roles. While the median for the internal interface role is approximately 40%, with an average of 37.84%, the external interface roles exhibit lower values, with an average of 24.83% and a median below 30%. Another relevant observation from the second graph shows that the activity with the highest mean values is "IP Protecting", referring to intellectual property protection activities. In conjunction with the findings from the first graph, these results reinforce the idea that, in Brazil and in other countries that have the same TTO maturity level, many TTO still operate under linear models, primarily focusing on bureaucratic and administrative processes. This approach tends to constrain the effectiveness and outcomes of these organizational structures (Krücken et al., 2007; Maresova et al., 2019).

Regarding the dependent variables, the primary objective of the descriptive analysis is to understand their distribution. Two histograms were generated for the dependent variables: invention disclosures and licensing agreements, as illustrated in Figure 7.

Figure 7 - Dependent variables distribution



Source: Prepared by the author.

The graphs reveal a typical pattern for count data, suggesting the presence of overdispersion in the sample. A goodness-of-fit test was conducted to confirm this, validating the presence of overdispersion. Additionally, the challenge of converting early-stage results into late-stage results is evident from the difference in means (21.21 and 2.21), where licensing agreements account for approximately 10% of invention disclosures and exhibit a higher concentration around zero in the second histogram. This finding, combined with the stronger emphasis on the internal interface role, reinforces Hypothesis 1 (H1) of this study, which posits that TTO with a greater focus on the internal interface tend to achieve results predominantly limited to the initial stages of the TT process.

4.2 Regression model results

A negative binomial regression was applied to address overdispersion in the sample (Green, 2021), with standard errors clustered by university. The model results are presented in Table 10 and Table 11, assessing the influence of explanatory variables on invention disclosures (early-stage) and licensing agreements (late-stage), respectively.

Table 10 - Negative binomial models estimating the influence of role orientation in early-stage results

Invention disclosures		Model		
Variables	(1) -	(2) Internal	(3) External	(4) Both
<i>Internal Interface</i>		0.6607 ***		0.6538**
<i>External interface</i>			-0.3254	-0.2586
<i>Stock IP (ln)</i>	0.5653***	0.5656***	0.5661***	0.5657***
<i>TTO age</i>	-0.0037	-0.0008	-0.0025	-0.0008
<i>TTO full time employees</i>	0.0038	0.0066	0.0036	0.0065
<i>Public EI (dummy)</i>	0.4084**	0.3734**	0.3856**	0.3720**
<i>Polytechnic EI (dummy)</i>	-0.2618	-0.2683	-0.2599	-0.2680

<i>EI age</i>	-0.0093***	-0.0094***	-0.0095***	-0.0094***
<i>Students (ln)</i>	0.2829**	0.2717***	0.2890***	0.2723***
<i>GDP per capita (ln)</i>	-0.1225	-0.1343	-0.1305	-0.1348
<i>Region and year control</i>	Yes	Yes	Yes	Yes
<i>Constant</i>	-0.8778	-0.9546	-0.7922	-0.9475
LR test (chibar ²)	3397.11***	3330.21***	3382.62***	3328.91***
Log-likelihood	-1776.76	-1772.90	-1776.19	-1772.90
Pseudo R ²	0.1026	0.1046	0.1029	0.1046
n	489	489	489	489

*p-value < 0.1; **p-value < 0.05; *** p-value < 0.01

Source: Prepared by the author.

Models (1) and (5) provide estimates considering only the control variables. Meanwhile, models (2) and (3) in Table 10 and (6) and (7) in Table 11 incorporate each explanatory variable separately, along with the control variables. These estimations were performed to prevent potential misinterpretations arising from overlapping effects between the internal and external interface roles. Finally, the last model in each table, (4) and (8), presents the estimates for the full model, which includes all explanatory variables simultaneously. Since the results of models (2), (3), (6), and (7) do not exhibit significant differences compared to the full models (4) and (8), there is no indication of overlapping issues or bias in the results. Therefore, the main interpretations will be derived from analyzing the full models (4) and (8).

Table 11 - Negative binomial models estimating the influence of role orientation in early-stage results

Licensing agreements	Model			
Variables	(5) -	(6) Internal	(7) External	(8) Both
<i>Internal Interface</i>		0.5344		1.4402
<i>External interface</i>			2.4011**	2.9820***
<i>Stock IP (ln)</i>	0.4608***	0.4612***	0.4985***	0.5093***
<i>TTO age</i>	-0.0256	-0.0254	-0.0323	-0.0325
<i>TTO full time employees</i>	0.0223	0.0242	0.0276*	0.0338**
<i>Public EI (dummy)</i>	0.2557	0.2293	0.2350	0.1604
<i>Polytechnic EI (dummy)</i>	-0.5186	-0.5413	-0.4429	-0.4817
<i>EI age</i>	0.0123	0.0118	0.0144	0.0137
<i>Students (ln)</i>	0.1961	0.2063	0.1070	0.1068
<i>GDP per capita (ln)</i>	0.6627	0.6766	0.6579	0.6871
<i>Region and year control</i>	Yes	Yes	Yes	Yes
<i>Constant</i>	-12.6176**	-13.0989**	-12.0984*	-13.1431**
LR test (chibar ²)	1596.20***	1594.97***	1574.15***	1576.32***
Log-likelihood	-558.07	-557.91	-555.45	-554.37
Pseudo R ²	0.0872	0.0874	0.0915	0.0932
n	431	431	431	431

*p-value < 0.1; **p-value < 0.05; *** p-value < 0.01

Source: Prepared by the author.

In Table 10, the analysis of the internal interface role provides the confirmation for H1, which posits that a stronger focus on the internal interface positively influences the number of invention disclosures. This effect is evident in both Model (2) and Model (4), where the null hypothesis that the coefficient is equal to zero is rejected ($p\text{-value} < 0.01$ or 0.05), confirming a positive relationship. The H2 is supported by Table 11, which indicates that allocating efforts to the internal interface does not significantly influence licensing agreements (late-stage outcomes). This result is observed in both Model (6) and Model (8), where the null hypothesis that the coefficient is equal to zero is not rejected ($p\text{-value} > 0.1$). Thus, efforts directed toward the internal interface positively affect early-stage outcomes, and there is no statistically significant evidence to suggest they contribute to late-stage outcomes, thereby supporting H1 and H2.

Regarding external interface roles, Table 10 indicates no significant effect on the number of invention disclosures (early-stage outcomes), whether analyzed in isolation (Model 3) or in the full model (Model 4), confirming H4. This lack of effect is evidenced by the failure to reject the null hypothesis that the coefficient is equal to zero ($p\text{-value} > 0.1$). Conversely, in Table 11, these roles have a positive and statistically significant effect on the licensing agreements (late-stage outcomes), both in the isolated model (Model 7) and in the full model (Model 8). The rejection of the null hypothesis confirms that the coefficient equals zero ($p\text{-value} < 0.05$ in Model 7 and $p\text{-value} < 0.01$ in Model 8). Thus, efforts directed toward external interface roles tend to positively impact late-stage outcomes and not affect early-stage outcomes, confirming Hypotheses 3 and 4 of this study.

The analysis of control variables was structured into three levels: (i) TTO, (ii) university, and (iii) regional. Among TTO characteristics, the office's time in operation had no significant effect on the dependent variables. In contrast, operational capacity, measured by the number of full-time employees, positively and significantly influenced licensing agreements (late-stage) but not invention disclosures (early-stage), suggesting its role in long-term outcomes. Regarding universities characteristics, innovative capacity, represented by the cumulative stock of intellectual property, showed a strong positive effect ($p\text{-value} < 0.01$) on both early- and late-stage outcomes. Public universities exhibited a positive effect on invention disclosures but no influence on licensing agreements, while polytechnic status was not significant in any model. Additionally, university age had a negative and statistically significant effect on invention disclosures, an unexpected finding. University size, measured by the logarithm of enrolled students, had a positive and statistically significant effect on invention disclosures, indicating

that larger institutions tend to generate more early-stage results, however, its effect was not statistically significant for licensing agreements. At the regional level, neither the city's economic activity (GDP per capita) nor regional control variables showed statistical significance, indicating that institutional factors within universities and TTO may influence TT outcomes more than macroeconomic conditions.

4.3 Robustness checks

To check the robustness of the results, two procedures were applied: (a) substituting invention disclosures with intellectual property (IP) filings as a proxy for early-stage outcomes (Hunter et al., 2011; Soares & Torkomian, 2021) and (b) estimating the models using the bootstrap technique to generate more robust confidence intervals, particularly in cases of overdispersion (Manly, 2011). The results, presented in Table 12, are structured by model.

Table 12 - Robustness checks

Intellectual property filings	Model		
Variables	(9) <i>PI filed</i>	(10) <i>Bootstrap invent. discl.</i>	(11) <i>Bootstrap licens. agreem.</i>
<i>Intern Interface</i>	0.5536***	0.6538**	1.0792
<i>External interface</i>	0.0841	-0.0259	3.1405**
<i>Stock IP (ln)</i>	0.6826***	0.5657***	0.5629**
<i>TTO age</i>	-0.0012	-0.0007	-0.0464
<i>TTO full time employees</i>	0.0005	0.0065	0.0333
<i>Public EI (dummy)</i>	0.2532*	0.3720**	0.0415
<i>Politecnico EI (dummy)</i>	0.0078	-0.2681	-0.5360
<i>EI age</i>	-0.0031	-0.0094***	0.0126
<i>Students (ln)</i>	0.0408	0.2723***	0.1176
<i>GDP per capita (ln)</i>	-0.1404	-0.1348	0.6297
<i>Region and year control</i>	Yes	Yes	Yes
<i>Constant</i>	19.903	-0.9475	-11.7611
LR test (chibar ²)	989.58***	3328.91***	1606.01***
Log-likelihood	-1618.11	-1772.90	-557.07
Pseudo R ²	0.1790	0.1046	0.0888
N	490	489	431

*p-value < 0.1; **p-value < 0.05; *** p-value < 0.01

Source: Prepared by the author.

Model (9) uses the total number of IP filings as the response variable, while models (10) and (11) apply the bootstrap technique, maintaining invention disclosures and licensing agreements as dependent variables, respectively. As shown, the interpretation of the explanatory variables remains consistent with previous findings, reinforcing the robustness of the results.

5 Discussion

This study advances the understanding of how the strategic orientation of TTO influences early-stage and late-stage outcomes in the TT process within universities in an emerging economy, specifically Brazil. Adopting a process-oriented perspective (Maresova et al., 2019), the study categorizes TTO orientations into two distinct roles: internal interface and external interface. This classification allows for a nuanced exploration of how these roles interact to shape TT dynamics, providing a theoretically grounded framework for understanding TTO functions.

The findings reinforce Hunter's (2011) assertion that TTO support for researchers (internal interface) positively influences invention disclosures. Additionally, the results align with Temel et al. (2021), who highlight that the presence of intermediaries enhances patent-related performance, particularly in the early stages of the TT process. However, a stronger focus on the internal interface role did not significantly contribute to late-stage outcomes, thereby validating H1 and H2, which posit that a predominant orientation toward the internal interface confines results in the initial stage of TT and do not influence the late-stage results. Combined with the observation that most TTO exhibit an internal interface orientation focused on administrative and documentation-related activities, as shown in Figure 6, these findings suggest that many Brazilian TTO still operate within a document-driven model, emphasizing the identification and formal protection of internally developed technologies, which often result in limited outcomes (Krücken et al., 2007). This pattern likely reflects structural challenges in emerging economies, such as resource scarcity and institutional inefficiencies, including structural gaps (Alibekova et al., 2019; Athreye et al., 2023; Cao & Shi, 2021; Temel et al., 2021).

However, these limitations do not apply uniformly to all TTO, as the study also identified a positive relationship between TTO with a stronger emphasis on external interface roles and late-stage outcomes. This finding aligns with Rossi et al. (2022), who argue that TTO adopting a collaborative approach and fostering closer relationships with external partners achieve superior performance in exploitative innovations, a late-stage outcome of the TT process. Additionally, these results are consistent with studies highlighting the important role of TTO as mediators, particularly in goal alignment and trust-building, which are key factors in successful TT outcomes (Martin et al., 2019; Perkmann & Schildt, 2015). These insights confirm H3 and H4, which propose that a stronger orientation toward external interface roles leads to improved late-stage results and does not influence early-stage results.

Improving the conversion of early-stage results into late-stage outcomes requires a more balanced approach and a concerted effort to strengthen external interface roles. This aligns with the notion that intermediary actors, such as TTO, must evolve beyond their traditional transactional function and assume a dynamic and central role in network formation and innovation ecosystem orchestration (Albats et al., 2022; Conlé et al., 2021). In this regard, the present study underscores the need for universities to strategically manage their operational and innovation capabilities to optimize the TT process (Guerrero & Mertens, 2024; Maresova et al., 2019).

While the establishment of intermediaries, such as TTO, is a common strategy, or even mandatory as in Brazilian public higher education institution, to bridge structural gaps in knowledge networks, this study corroborates Sandström et al. (2018) in arguing that their mere presence does not inherently resolve these gaps. The effectiveness of these intermediaries depends on their capacity to function as proficient brokers, facilitating the flow of information and resources and connecting previously unlinked actors. However, intermediaries may fail to bridge structural gaps due to network limitations or a lack of legitimacy among stakeholders. Therefore, it is important that intermediary implementation is accompanied by strategies that ensure effective network integration rather than assuming that their mere existence will resolve structural deficiencies.

Regarding the control variables, the most notable finding is the positive and significant relationship between university innovative capacity, measured by IP stock, and both early-stage and late-stage outcomes, corroborating Soares and Torkomian (2021). This relationship likely reflects TTO' reliance on identifying researchers with entrepreneurial characteristics and research relevant to patenting and technology licensing (O'Kane et al., 2021). Among other university characteristics, public status was positively associated only with early-stage outcomes, while polytechnic status was not significant in any model. At the TTO level, the number of full-time employees exhibited a positive and significant relationship exclusively with late-stage outcomes, reinforcing the importance of operational capacity in achieving robust results (Guerrero & Menter, 2024; Temel et al., 2021).

Beyond its theoretical contributions, this study offers practical implications by examining the relationship between TTO roles and TT outcomes. Audretsch et al. (2024) highlight that universities must play a central role in addressing grand challenges, working alongside policymakers and entrepreneurs, with TTO serving as key facilitators in network creation and management. By demonstrating the need for stronger engagement in external

interface roles to improve late-stage outcomes, this study provides valuable insights for university and TTO managers to restructure processes in response to evolving TT demands. As noted by Schneider (2024), one of the primary barriers to TT effectiveness is the lack of clarity regarding TTO responsibilities, with many university administrators uncertain about their expected role. This study addresses this knowledge gap, highlighting the importance of distinct TTO roles in the TT process. Thus, we reaffirm the argument put forth by O’Kane et al. (2021) that TTO must enhance their ability to integrate and balance strategic initiatives at the macro and meso levels while simultaneously ensuring operational efficiency and effectiveness in TT at the micro level. Moreover, policy implications arise from these findings, particularly concerning incentive mechanisms and the design of new institutional structures to strengthen external interface functions.

Finally, the lower stakeholder multiplicity in emerging economies further complicates TT process outcomes (O’Kane et al., 2021), making greater engagement with external actors even more challenging in regions with a less developed industrial base (Schaeffer et al., 2024). To overcome this, universities could explore alternative strategies, such as digital platforms, which provide agile channels for knowledge exchange and accelerate university-industry connections (Albats et al., 2022). Additionally, best practices from emerging economies with mature innovation ecosystems, such as China’s market-oriented NRD, highlight the potential of collaborative research centers in fostering stakeholder engagement (Conlé et al., 2021). Similarly, technical and administrative staff, whose expertise spans both operational and managerial functions, can play a pivotal role in overcoming workforce limitations, a common challenge in resource-constrained contexts (Noke et al., 2024).

6 Final Remarks

This study contributes to a deeper understanding of how the strategic orientation of TTO influences early-stage and late-stage TT outcomes within universities in an emerging economy. Adopting a process-oriented perspective, this research highlights the distinct roles TTO assume, such as internal and external interface; it also examines how their strategic positioning affects different stages of the TT process. The findings indicate that a predominant internal interface orientation positively impacts early-stage outcomes, such as invention disclosures, yet does not significantly contribute to late-stage outcomes. Conversely, TTO with a stronger focus on external interface roles demonstrates a greater ability to achieve more advanced results, particularly in licensing agreements.

These findings reinforce the idea that the mere presence of TTO is insufficient to guarantee success in TT. Instead, their effectiveness examines a balanced strategic orientation that extends beyond administrative functions, emphasizing proactive engagement with external stakeholders. This aligns with the argument that TTO should transition from being transactional entities to central orchestrators of innovation ecosystems. Consequently, universities must strategically manage their capacities to optimize TT processes, particularly by strengthening external collaboration and fostering an innovation-driven institutional culture.

From a theoretical standpoint, this study advances the literature by addressing a gap concerning the mechanisms through which TTO influence TT outcomes, particularly within the context of an emerging economy. By differentiating the impact of distinct role orientations, this research extends prior discussions on BU and technology intermediaries, providing new insights into how institutional contexts shape TTO effectiveness. Additionally, this study responds to Schneider's (2024) call for a more critical perspective on capacity building in TT processes, reinforcing the need for models that account for the specific dynamics of TT in emerging markets.

From a practical perspective, the findings provide valuable insights for university administrators, TTO managers, and policymakers. They highlight the need for institutional decision-makers to reassess how TTO are structured and managed, ensuring that these offices evolve beyond documentation-driven models toward more dynamic and integrative approaches. Additionally, the results underscore the importance of policies that incentivize greater engagement in external interface roles, particularly in economies with limited industrial mass and fragmented innovation ecosystems. Strategies such as leveraging digital platforms, adopting collaborative research models, and optimizing the role of technical and administrative staff emerge as potential avenues to enhance TTO efficiency.

However, this study is not without limitations. First, the findings are based on data from Brazil, an emerging economy in which TT is strongly shaped by a national legal framework that institutionalizes university innovation governance. Public research institutions are required to maintain a TTO to support their innovation policy and manage TT processes. In addition, Brazil's R&D intensity has remained relatively modest (around 1.19% of GDP in 2022–2023), which may affect the availability of complementary industry capabilities and the scale of downstream commercialization opportunities. While the stage-contingent pattern observed here is informative, its direct generalizability to emerging economies with different regulatory arrangements and innovation investment profiles should be considered with caution. Future

research could test whether the same internal- versus external-interface advantages hold under alternative institutional settings and levels of R&D effort. Second, as with most quantitative studies, this analysis offers a limited understanding of the underlying mechanisms driving the observed relationships. A complementary qualitative approach, such as in-depth case studies or interviews with key stakeholders, could provide richer insights into the nuances of TTO dynamics.

In conclusion, this study highlights the pressing need for universities and policymakers to rethink how TTO are structured and how their functions are strategically aligned to maximize TT outcomes. The transition from an administrative to an ecosystem-oriented model is essential to overcoming structural barriers in emerging economies and fostering more effective technology commercialization processes. By addressing these challenges, universities can strengthen their contribution to national and regional innovation ecosystems, ultimately advancing socioeconomic development.

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Paper 3: Bridging Universities and Innovation Ecosystems: Boundary Unit Roles and Social Capital across Two Different National Contexts

Bridging Universities and Innovation Ecosystems: Boundary Unit Roles and Social Capital across Two Different National Contexts

Abstract

Universities have expanded their engagement in technology transfer (TT) as part of their third mission, increasingly relying on Boundary Units (BU) to mediate interactions with industry and other external actors. While prior research has identified organizational and contextual determinants of TT outcomes, less attention has been paid to how BU enact and coordinate their internal, mediatory, and external interface roles in practice. Drawing on social capital theory and adopting a comparative, process-oriented perspective, this study examines how structural, relational, and cognitive social capital are mobilized across BU roles in Brazil and Italy. Based on a qualitative research design and Gioia-based data analysis, first-order concepts, second-order themes, and aggregate dimensions, the findings reveal that similar micro-level social capital mechanisms are activated across the two national settings studied; however, their effectiveness depends on two structuring dimensions: organizational embeddedness and ecosystem maturity within the scope of our cases. Organizational embeddedness shapes the emphasis placed on internal versus ecosystem-oriented roles, by affecting access, legitimacy, and governance ties, while ecosystem maturity conditions the stabilization, scaling, and institutionalization of boundary-spanning practices over time through repetition, routinization, and professionalization dynamics. The results further indicate that cognitive social capital is particularly salient in reported challenges, suggesting that interpretative alignment and shared frameworks emerge as promising leverage points for strengthening TT processes. By integrating micro-level enactment, multidimensional social capital, and contextual evolution, the study advances a process-based conceptual framework of BU dynamics. It contributes to the TT literature by moving beyond outcome-centered explanations, refines theoretical understandings of BU as distributed and complementary systems, and offers context-sensitive managerial and policy implications for the long-term consolidation of university-industry engagement.

1. Introduction

Over the years, universities have increasingly engaged in technology transfer (TT) and broader knowledge exchange activities alongside their traditional missions of teaching and research, a transformation commonly associated with the third mission (Audretsch, 2014; Sandström et al., 2018; Guerrero & Lira, 2023). Within this context, TT has become a key

mechanism through which universities interact with industry, government, and other external actors (Etzkowitz & Leydesdorff, 2000; Schaeffer et al., 2024). These interactions are rarely direct and are often mediated by organizational arrangements, namely Boundary Units (BU), such as technology transfer offices (TTO), incubators, science and technology parks, and related intermediaries, which organize relationships, coordinate activities, and facilitate the translation of academic knowledge into external applications, including license agreements, partnership contracts, creation of academic spin-offs and startups, among others (Perkmann et al., 2013; Wurth, Mackenzie & Howick, 2024). Yet, when these boundary arrangements fail to coordinate expectations, routines, and interpretations, TT tends to become slower, more fragmented, and harder to scale beyond isolated successes.

Existing research has identified a wide range of organizational and contextual factors associated with TT outcomes, including the design and structure of TTO, universities' capabilities and strategic orientation, and broader institutional environments (Chen et al., 2024; Siegel et al., 2004; Temel et al., 2021; Guerrero & Menter, 2024; O'Kane et al., 2021). While this literature offers valuable insights into the conditions under which TT takes place, it provides more limited explanations of the micro-level mechanisms through which BU enact these conditions in practice. In particular, less attention has been paid to the processes through which BU perform and coordinate their roles over the course of the TT process. Building on prior work that distinguishes BU activities related to the internal interface, mediatory functions, and external interface, this study focuses on how these roles are operationalized and combined at the micro level. This process-oriented perspective directs attention to the functions, interactions, and routines through which BU translate organizational arrangements and contextual conditions into concrete TT activities, aligning with micro-level approaches to the study of TT (Guerrero & Siegel, 2025; Ma et al., 2023).

To examine these micro-level dynamics, this study draws on social capital theory as an analytical lens, given that BU activities rely heavily on relationships, interactions, and coordination across organizational boundaries. Social capital is commonly defined as resources embedded in and mobilized through networks of relationships and is typically conceptualized along structural, relational, and cognitive dimensions (Nahapiet & Ghoshal, 1998). In university–industry collaboration contexts, this multidimensional perspective enables an examination of how network structures, trust, shared norms, and cognitive alignment shape coordination and knowledge exchange among heterogeneous actors (Iturrioz et al., 2015; Sa'a & Asplund, 2025). Prior studies indicate that social capital supports TT by facilitating access to

information, reducing coordination frictions, and strengthening relational ties among participants (Grzegorzczuk, 2019; Steinmo & Rasmussen, 2018; Camps & Marques, 2014; Fletcher et al., 2026). However, this literature has paid less attention to how different dimensions of social capital relate to the specific roles performed by BU, and it has largely focused on particular organizational forms, such as TTO, rather than considering a broader set of BU' arrangements, as pointed by Good et al. (2019). As a result, we still lack a process explanation of which social capital dimensions matter for which boundary roles and when they enable (or constrain) coordination across the transfer trajectory.

In addition to organizational and relational dynamics, the operation of BU and the creation and utilization of social capital in university-industry links are shaped by the national contexts in which they are embedded (Grzegorzczuk, 2019). A comparative perspective is therefore useful for examining how similar BU roles and configurations of social capital are enacted under different settings. The choice of Brazil and Italy was guided by a contrastive research design that enables observing boundary work under distinct innovation system conditions, including their positioning in different economic and innovation system contexts, often associated with the Global South and Global North, respectively. This comparison helps separate what is context-specific from what may reflect more general micro-level role enactment dynamics.

This previous body of work has predominantly adopted outcome-oriented perspectives, offering limited insight into how BU enact and coordinate their roles in practice. In particular, it still lacks a fine-grained understanding of (i) how different categories of BU roles are configured at the micro level, (ii) how distinct dimensions of social capital are mobilized in support of these roles, and (iii) how such configurations vary across different contexts. Therefore, this study addresses the following research question: *How do university boundary units enact and coordinate their roles through different configurations of social capital?* To answer this question, the article analyzes the micro-level mechanisms through which BU translate organizational and contextual conditions into TT activities and outcomes, drawing on comparative evidence from Brazil and Italy. Consistent with our process-oriented approach, our findings suggest that similar micro-level social capital mechanisms emerge across contexts, but their effectiveness depends on organizational embeddedness and ecosystem maturity, with cognitive alignment becoming especially salient in reported challenges.

This study contributes to the TT literature in several ways. First, by adopting a comparative and process-oriented approach, it responds to calls for more holistic assessments

of how TT practices vary across territorial and organizational contexts (Grzegorzczuk, 2019; Good et al., 2019), moving beyond predominantly static and outcome-focused analyses. Second, the study advances theoretical understanding of BU by examining the micro-level processes through which their roles are enacted and coordinated in practice. By integrating organizational routines with individual-level behaviors and interaction dynamics, the analysis sheds light on how different categories of social capital shape the functioning of internal interface, mediatory, and external interface roles, addressing calls for more fine-grained analyses of inter-organizational collaboration in TT (Steinmo & Rasmussen, 2018; Sa'a & Asplund, 2025). From a practical standpoint, by adopting a holistic perspective that does not restrict the analysis to specific types of BU, the findings provide university managers, BU leaders, and policymakers with robust evidence to support more informed and context-sensitive strategic orientation of universities and their intermediary structures (Good et al., 2019).

This article is structured as follows. Section 2 develops the theoretical framework, combining the literature on university BU roles, social capital, and contextual challenges across national settings. Section 3 outlines the qualitative research design, including case selection, data collection, and analytical procedures. Section 4 presents the empirical results, detailing how BU enact internal, mediatory, and external interface roles, the configurations of cognitive and relational social capital observed, and the challenges faced across contexts. Section 5 discusses the findings by highlighting the complementarities among BU, the organizational limitations of TTO, and alternative boundary arrangements that emerge in response to structural and operational constraints. The analysis shows that, although similar social capital mechanisms are mobilized across contexts, their effectiveness depends on organizational embeddedness and ecosystem maturity rather than on national context alone. Finally, Section 6 concludes by summarizing the contributions and implications of the study for theory and practice.

2. Theoretical framework

This section develops a sensitizing theoretical framework to explain how university BU enact and coordinate TT roles in practice. We integrate (i) role categories (internal interface, mediatory, and external interface), (ii) multidimensional social capital (structural, relational, and cognitive), and (iii) contextual conditions shaping coordination demands. The goal is not to advance deterministic propositions, but to build analytical anchors that guide a comparative, process-oriented interpretation of micro-level mechanisms across settings.

2.1. University boundary units roles

Boundary units are organizational arrangements whose primary purpose is to mediate and structure interactions and knowledge flows between universities and external actors throughout the TT process. They may take formal forms, such as TTO, academic incubators, science and technology parks, collaborative research centers, and university spin-offs, or involve more informal boundary work enacted by principal investigators, technicians, and interpersonal ties (Sandström et al., 2018; Good et al., 2019; Cunningham et al., 2022; Audretsch et al., 2024). Rather than expanding typologies, our focus is on how BU enact and coordinate role configurations across the TT process under varying organizational and ecosystem conditions.

Prior research describes multiple boundary-spanning activities but offers limited clarity on how BU combine and coordinate different role categories over the course of the TT process. To address this gap, we organize BU roles into three analytical categories, internal interface roles, mediatory roles, and external interface roles. Rather than assuming fixed or hierarchical functions, this categorization supports a process-oriented examination of how role emphasis is enacted in practice.

Internal interface roles refer to activities oriented toward the university's internal environment, including technology identification and evaluation, intellectual property management, researcher engagement, internal strategic alignment, facility management, support for venture creation, co-creation activities and training initiatives (Siegel et al., 2004; Good et al., 2019; Fini et al., 2018; Noke et al., 2024; Chen et al., 2024). These roles involve close interaction with researchers, technical staff and students and encompass not only formal administrative procedures but also relational and operational support that enables research results to be mobilized beyond academic settings (Iqbal et al., 2018; Santos et al., 2023).

Mediatory roles emphasize the relational and coordinative dimensions of BU, focusing on managing interactions between heterogeneous actors. Core activities include the alignment of objectives and expectations, trust and network building, contract management and the development of TT strategies and digital instruments (Krücken et al., 2007; Ankrah et al., 2013; Siegel et al., 2004; Noack & Jacobsen, 2021; Albats et al., 2022). These roles address the structural and cognitive differences that characterize university–industry relationships and support communication, negotiation, and coordination across organizational boundaries.

External interface roles are oriented toward engagement beyond the university, connecting academic knowledge with markets, investors and broader innovation ecosystems. This category includes activities such as technology licensing, market analysis and promotion, partnership facilitation, revenue generation, financing mechanisms, and information dissemination (Siegel et al., 2004; Wonglimpiyarat, 2016; Temel et al., 2021; Audretsch et al., 2024). These activities often require coordination with both internal and external actors, reinforcing the interdependence between internal, mediatory, and external interface roles (Good et al., 2019; Santos et al., 2023).

Building on this framework, prior studies suggest that the relative emphasis placed on different categories of roles may be associated with the organizational positioning of BU. BU primarily embedded within university structures, such as TTO and related administrative arrangements, are often described as being closely connected to internal activities, including technology identification, intellectual property management, and researcher engagement (Chen et al., 2024; Temel et al., 2021). In contrast, boundary arrangements that maintain sustained interaction with firms, investors, and broader innovation ecosystems, such as academic incubators, science and technology parks, collaborative research centers, and university spin-offs, are frequently portrayed as engaging more intensively with external actors (Good et al., 2019; Cunningham et al., 2022; Audretsch et al., 2024). However, rather than assuming predefined associations between embeddedness and role emphasis, this study examines how such relationships are enacted in practice.

We conceptualize organizational embeddedness as the degree to which a BU is structurally and operationally anchored within university governance and routines versus positioned in hybrid or ecosystem arrangements. Higher within embeddedness is expected to privilege internal interface work (e.g., compliance-oriented routines, IP procedures, internal coordination), whereas ecosystem embedded may enable sustained mediatory and external interface engagement. Importantly, embeddedness is treated as a relational and dynamic attribute, and we examine how its implications for role emphasis are enacted rather than presumed. To guide this analysis, the following sub-question is proposed:

Q1: How is the organizational embeddedness of university boundary units associated with the emphasis of internal, mediatory, and external interface roles?

2.2. Social capital and the boundary units

Social capital is a foundational concept in the social sciences, traditionally associated with the resources embedded in social relationships (Bourdieu, 1986). In organizational and interorganizational settings, it is commonly conceptualized as a multidimensional construct comprising structural, relational, and cognitive dimensions (Nahapiet & Ghoshal, 1998). The structural dimension concerns the configuration of ties among actors, the relational dimension captures the quality of these ties, such as trust and mutual obligations, and the cognitive dimension refers to shared understandings and interpretative frameworks. This multidimensional perspective is particularly relevant for examining the roles of BU, as these organizations operate at the interface between internal university structures and external actors and rely on social relationships to coordinate activities and facilitate interaction (Fletcher et al., 2026; Grzegorzczuk, 2019; Steinmo & Rasmussen, 2018). Further recent research emphasizes the centrality of social relationships for understanding the dynamics of university-industry collaboration and the functioning of intermediaries, reinforcing the relevance of social capital for analyzing BU' roles in such settings (Sa'a & Asplund, 2025).

Empirical studies on university–industry collaboration consistently point to the relevance of cognitive and relational social capital for coordinating interactions across organizational boundaries. These dimensions are particularly salient in contexts characterized by divergent logics, where shared interpretations and trust-based relationships support knowledge transfer and collaboration (Steinmo & Rasmussen, 2018). Iturroz et al. (2015) emphasizes that trust, reciprocity, and shared meanings are central to sustaining cooperative innovation efforts, reinforcing the importance of cognitive and relational social capital in BU' roles. Recent evidence suggests that more formal and research-oriented collaborations rely primarily on cognitive social capital, while less structured and network-based interactions depend more strongly on relational social capital to enable direct and trust-based exchanges (Sa'a & Asplund, 2025).

Furthermore, experienced organizations tend to base collaborations on shared cognitive frameworks, subsequently reinforced by relational ties, whereas less experienced actors often rely initially on trust and personal relationships, which later support the development of shared understandings (Steinmo & Rasmussen, 2018). Complementary, research on TTO demonstrates that multiple benefits of social capital, such as access to information, influence, and solidarity are present in intermediary activities, explicitly framed around internal and external interfaces, and are shaped by organizational and cultural contexts (Grzegorzczuk, 2019).

Therefore, social capital should be managed strategically rather than treated as an automatic asset, as it enables intermediary innovation mechanisms rather than constituting an end in itself (Camps & Marques, 2014). In intermediary contexts, social capital also plays a stabilizing role, with intermediaries acting as “glue providers” that sustain shared values and long-term cooperation within innovation networks (Iturrioz et al., 2015).

Based on this, BU do not mobilize social capital uniformly; instead, the structural, relational, and cognitive dimensions provide a sensitizing framework to trace how BUs build ties, sustain trust, and produce interpretative alignment while enacting internal, mediatory, and external interface work (Steinmo & Rasmussen, 2018; Sa’a & Asplund, 2025). Rather than mapping fixed social-capital dimensions to specific roles, we examine how these dimensions are mobilized, combined, and reconfigured across roles and over time as coordination demands shift. From this perspective, the following sub-question guides the analysis:

Q2: How are structural, cognitive, and relational dimensions of social capital mobilized and combined across internal, mediatory, and external interface roles performed by university boundary units?

2.3. National context and challenges

The dynamics through which BUs operate are not uniform across settings, since the boundaries between academia and external actors are shaped by institutional arrangements and the availability of support infrastructures (Sandström et al., 2018; Mars & Rios-Aguilar, 2010; Beck et al., 2022). While national context provides an important backdrop for these dynamics (Grzegorzczak, 2019), it is not treated here as a deterministic driver. Instead, we adopt organizational stability and ecosystem maturity as analytical dimensions to characterize the conditions under which BU seek to formalize, stabilize, and sustain boundary-spanning practices. This perspective allows comparative analysis without relying on broad “advanced vs. emerging economy” typologies.

At the same time, this perspective does not imply neglecting national-level comparisons, instead, we build on prior scholarships that contrast advanced and emerging economies as a heuristic to describe how national conditions tend to enable or constrain BU activities. In advanced economies, more consolidated organizational frameworks and infrastructural support facilitate the formalization of BU’s activities and allow BU to experiment with different organizational configurations and coordination mechanisms (Fai et al., 2018). By contrast, BU in emerging economies often operate under conditions marked by limited funding,

infrastructural constraints and weaker institutional support, which shape both the scope and sequencing of their activities (Thamae et al., 2016; Alibekova et al., 2019). These conditions can affect the transition from linear, documental, technology-centered models toward more integrative and network-oriented approaches, as discussed by Krücken et al. (2007).

Therefore, contextual disparities are reflected in the types of challenges faced by BU. In developed economies, challenges are more frequently associated with aligning objectives and optimizing collaboration strategies within already established innovation ecosystems (Hailu, 2024; Cunningham et al., 2022; Noack & Jacobsen, 2021). In emerging economies, however, BU often contend with more fundamental structural constraints (Alibekova et al., 2019; Cao & Shi, 2021). These constraints are compounded by limitations in professional experience among BU managers, many of whom have limited prior exposure to TT processes (Kotha et al., 2018). High turnover rates and reliance on scholarship-supported personnel further affect the continuity and stability of BU, influencing how roles are enacted and how social capital is accumulated and sustained over time. Nevertheless, such arrangements require careful coordination, particularly in settings characterized by limited absorptive capacity and frequent regulatory changes (Thamae et al., 2016).

These patterns suggest that national contexts may shape not only how BU roles are configured, but also the types of challenges encountered in sustaining BU' activities. Rather than presupposing systematic differences between different national contexts, it is important to examine how organizational environments influence the constraints, coordination demands, and organizational conditions under which BU operate. From this perspective, the following sub-question guides the comparative analysis of contextual challenges:

Q3: How do organizational environments shape the types of challenges encountered by university boundary units in enacting their internal, mediatory, and external interface roles?

Beyond role configuration, national contexts may also influence how social capital is mobilized to support coordination and interaction. Organizational stability, ecosystem maturity, and regulatory dynamics may condition whether BU rely more heavily on shared cognitive frameworks, relational trust, or particular structural configurations of networks (Grzegorzczak, 2019; Steinmo & Rasmussen, 2018; Sa'a & Asplund, 2025; Iturrioz et al., 2015). Rather than assuming that specific dimensions of social capital prevail in certain contexts, it becomes necessary to explore how BU adapt their coordination mechanisms to their organizational environments. Accordingly, the following sub-question further frames the comparative inquiry:

Q4: How are structural, cognitive, and relational dimensions of social capital mobilized and reconfigured across different contexts?

Taking these contextual considerations together, BU roles and the configurations of social capital that support them cannot be fully understood without accounting for national organizational environments. Rather than assuming uniform trajectories or predefined functional adaptations, a context-sensitive perspective calls for examining how BU enact and coordinate their internal interface, mediatory, and external interface roles under distinct structural conditions, resource constraints, and coordination demands. This perspective provides the analytical foundation for exploring how similar BU' roles may be enacted differently across national settings, informing the comparative analysis undertaken in this study.

Building on the theoretical framework developed in the previous section, this study seeks to understand how university BU enact internal, mediatory, and external interface roles, how these roles are supported by different configurations of social capital, and how contextual challenges shape these dynamics across national settings. To provide an analytical synthesis of these relationships, Table 13 consolidates the sub-questions (Q1–Q4). These anchors are used as sensitizing devices; our first-order coding remained informant-centric and inductive.

Table 13 - Sensitizing anchors guiding the analysis

Sub questions	Theoretical foundation	Key references	Analytical focus
Q1: How is the organizational embeddedness of university boundary units associated with the emphasis of internal, mediatory, and external interface roles?	BU differ in their organizational positioning and relational embeddedness, which shapes the relative emphasis placed on internal, mediatory, and external interface roles.	Sandström et al. (2018); Good et al. (2019); Cunningham et al. (2022); Chen et al. (2024); Audretsch et al. (2024)	Guides attention to how variations in organizational embeddedness are reflected in the emphasis and sequencing of internal, mediatory, and external interface roles across the TT process.
Q2: How are structural, cognitive, and relational dimensions of social capital mobilized and combined across internal, mediatory, and external interface roles performed by university boundary units?	Social capital is multidimensional and is mobilized differently depending on role orientation, interaction complexity, and degree of formalization.	Nahapiet & Ghoshal (1998); Steinmo & Rasmussen (2018); Sa'a & Asplund (2025); Grzegorzczak (2019)	Sensitizes the analysis to how structural, cognitive, and relational social capital are mobilized, combined, and adjusted across roles as coordination demands evolve over time.
Q3: How do organizational environments shape the types of challenges encountered by university boundary units in enacting their internal, mediatory, and external interface roles?	Organizational environments shape resource availability, stability, and coordination demands, influencing how BU operate and adapt.	Fai et al. (2018); Alibekova et al. (2019); Cao & Shi (2021); Cunningham et al. (2022); Hailu (2024)	Guides attention to how organizational environments shape perceived constraints, coordination demands, and adaptive responses, as reflected in the types of challenges encountered during role enactment.
Q4: How are structural, cognitive, and relational dimensions of social capital mobilized and reconfigured across different contexts?	Organizational maturity influences whether coordination relies more on shared cognitive frameworks or trust-based relational mechanisms.	Grzegorzczak (2019); Steinmo & Rasmussen (2018); Iturrioz et al. (2015); Sa'a & Asplund (2025)	Helps trace how social-capital configurations are reconfigured across different contexts, including shifts in reliance on cognitive alignment, relational trust, and network structures to support coordination.

Source: Prepared by the author.

3. Methodology

3.1. Research design

This study adopts a qualitative, comparative research design aimed at examining how university BU operationalize their internal interface, mediatory, and external interface roles throughout the TT process, and how these roles are supported by different configurations of structural, relational, and cognitive social capital across national contexts. Given the study's focus on micro-level processes, interaction dynamics, and the enactment of BU' roles, a qualitative approach is particularly suitable for capturing mechanisms through which social capital is mobilized and translated into TT activities, processes that are not readily observable through quantitative methods (Eisenhardt, 1989; Eisenhardt & Graebner, 2007).

More specifically, the research follows a multiple case study design. In this study, the case is defined as a university BU (e.g., TTO, incubator, science park), treated as the primary unit of analysis. Italy and Brazil function as comparative contexts, within which BU are examined through multiple informants occupying distinct organizational positions in different organizations. This approach enables an in-depth examination of heterogeneous organizational arrangements while supporting analytical comparison across contexts (Yin, 2017). Rather than treating cases as isolated entities, the study adopts a comparative logic that emphasizes patterns of similarity and divergence in role configurations and social capital mobilization.

3.2. Case selection and sampling strategy

Case selection followed a purposive sampling strategy, consistent with theory-building research and comparative qualitative studies (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). This approach ensures the inclusion of two different national contexts, thereby elucidating key aspects of proximity and divergence between them (Marginson & Sawir, 2006). The objective was not statistical representativeness but analytical variation, seeking to capture diversity in organizational forms, longevity, and relational positioning of BU within each national context.

To contextualize the comparative analysis between Brazil and Italy, this study considers key economic and innovation indicators that characterize the national environments. In 2024, according to the World Bank, Italy's nominal GDP was approximately USD 2.38 trillion, while Brazil's GDP reached around USD 2.18 trillion, placing both countries among the world's largest economies. However, substantial differences emerge in terms of economic development, as reflected in GDP per capita: Italy recorded approximately USD 40,200, compared to USD 10,250 in Brazil (World Bank, n.d.). These disparities are mirrored in innovation performance.

According to the Global Innovation Index (GII) 2025, Italy ranked 28th, whereas Brazil ranked 52nd among 139 economies, indicating differences in organizational capacity, innovation infrastructure, and ecosystem maturity (World Intellectual Property Organization, 2025). Differences are also observed in research and development (R&D) investment: Italy's gross domestic expenditure on R&D was approximately 1.5% of GDP, while Brazil's stood at around 1.1 % in recent years (World Bank, n.d.). Together, these indicators provide a structured backdrop for the comparative analysis, highlighting contrasts in economic development and innovation systems.

In total, 22 semi-structured interviews were conducted: 9 in Italy and 13 in Brazil. It's pursued maximum variation by selecting BU that differs in organizational form, longevity (years operating), and relational positioning (low or high interaction), enabling analytic comparison across role configurations, as shown in Table 14 in the data collection topic below.

3.3. Data collection

Data collection relied primarily on semi-structured interviews, complemented by document analysis, allowing for triangulation and enhancing the robustness of the empirical material (Eisenhardt, 1989; Yin, 2017). Interviewees occupied diverse positions, including directors and managers of BU, and academic researchers involved in TT and external engagement. In total, the interview corpus comprised 1,222 minutes of audio: 512 minutes in Italy (mean duration 57 minutes per interview) and 710 minutes in Brazil (mean duration 55 minutes per interview), yielding an overall average interview length of approximately 56 minutes. To ensure confidentiality, organizational and individual identities are anonymized in the analysis, and interviewees are referred to by country and functional role only. Interviews were conducted in person or online, via Google Meet platform, audio-recorded with participants' consent, and transcribed verbatim. When conducted in Portuguese, transcripts were translated into English using a Open AI tool, and key excerpts were backchecked for meaning equivalence. The details of each interviewee are presented in Table 14.

Table 14 - Interview details

ID	Country	City	Type of BU	Longevity (years)	Interaction	Date	Duration
1	Italy	Turin	Incubator	18	High	12/16/24	1 h 26 min
2	Italy	Bari	Tech Park	42	High	01/24/25	58 min
3	Italy	Turin	ILO	7	High	02/27/25	1 h 02 min
4	Italy	Turin	Professor			02/11/25	53 min

5	Italy	Palermo	Innovation Agency	1	Low	02/17/25	52 min
6	Italy	Turin	PhD			02/19/25	1 h 02 min
7	Italy	Turin	TTO	24	Low	02/20/25	1h 03 min
8	Italy	Milan	Professor			02/28/25	30 min
9	Italy	Bologna	Professor			03/26/25	46 min
10	Brazil	Viçosa	Foundation	46	High	06/18/25	1 h 03 min
11	Brazil	Viçosa	TTO	26	Low	07/03/25	58 min
12	Brazil	Viçosa	Tech Park	14	High	07/21/25	37 min
13	Brazil	Viçosa	Tech Park	14	High	07/21/25	44 min
14	Brazil	Viçosa	TTO	26	Low	08/04/25	1 h
15	Brazil	São Paulo	Innovation Agency	21	High	10/31/25	56 min
16	Brazil	Chapecó	Professor			11/05/25	59 min
17	Brazil	Campina Grande	TTO	17	Low	11/13/25	31 min
18	Brazil	Naviraí	Incubator	15	Low	11/10/25	55 min
19	Brazil	Viçosa	Professor			11/10/25	57 min
20	Brazil	Ilhéus	TTO	16	High	11/12/25	1 h 15 min
21	Brazil	Belém	Tech Park	15	High	11/13/25	55 min
22	Brazil	Maracanaú	Incubator	7	Low	11/17/25	1 h

Source: Prepared by the author.

While the number of interviews differs across countries, data collection in both contexts followed the principle of analytical saturation, with interviews conducted until recurrent patterns related to roles, coordination practices, and challenges became evident (Guest, Bunce & Johnson, 2006). We monitored saturation by tracking the emergence of new first-order concepts after each interview; after interview [7] in Italy and [19] in Brazil, no substantively new concepts related to role enactment and coordination practices were observed.

The semi-structured interviews were designed to elicit detailed accounts of BU activities and interaction patterns. Interview questions were organized around three analytical blocks corresponding to the roles identified in the theoretical framework: internal interface roles, mediatory roles, and external interface roles. While social capital did not appear explicitly in the interview questions, the protocol was designed to capture relational dynamics, shared understandings, coordination mechanisms, and interaction routines, which later informed the analytical interpretation of social capital dimensions. The interview protocol was iteratively refined and validated by three experts in TT and university-industry collaboration prior to data collection. Interviews were adapted to the interviewees' profiles and organizational positions, allowing flexibility while maintaining a consistent analytical focus. The full interview guide is provided in Appendix A.

Documentary sources were collected for each BU primarily to corroborate timelines, formal role descriptions, and reported coordination practices. These materials included Brazilian institutions' Institutional Development Plans (Planos de Desenvolvimento Institucional) and Italian universities' strategic plans, complemented by BU presentations and program/event materials, as well as relevant information from institutional websites. Consistent with the Gioia methodology, interviews constituted the primary analytic basis; documentary evidence was treated as secondary, providing contextual and corroborative input that was coded accordingly and triangulated against interview accounts.

3.4. Data analysis

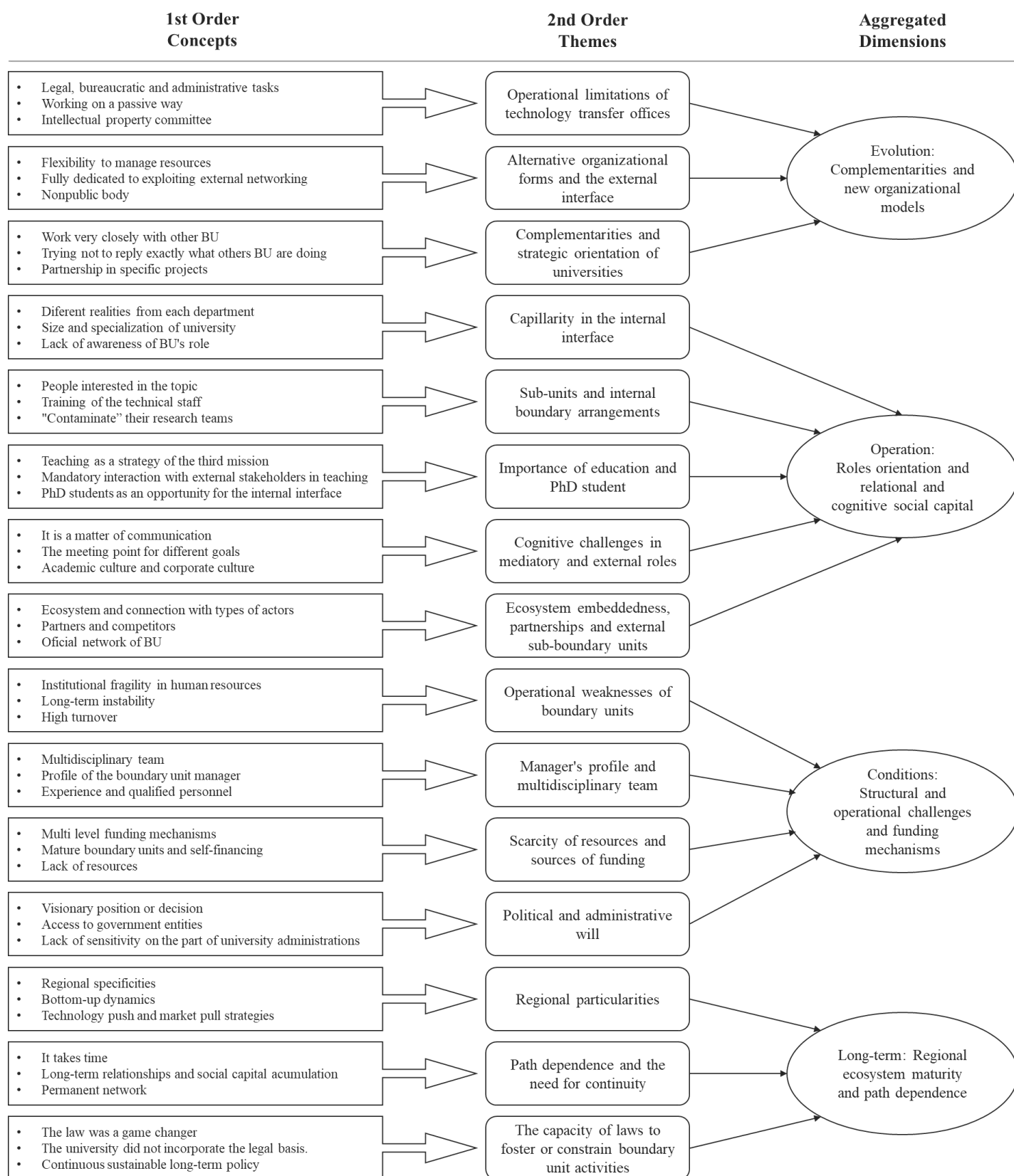
Data analysis was primarily guided by the Gioia methodology (Gioia, Corley, & Hamilton, 2013), which offers a systematic and rigorous approach for inductive theory building from qualitative data while preserving informants' voices and enabling higher-order theoretical abstraction. Rather than treating the method as a rigid protocol, the analysis followed Gioia et al.'s (2013) recommendation to adapt its procedures to the research context and objectives, maintaining methodological rigor while allowing analytical flexibility. The analysis unfolded through an iterative, multi-stage process, structured around the core elements of the Gioia methodology: the development of first-order concepts, second-order themes, and aggregate dimensions (Magnani & Gioia, 2022).

In the first stage, all interviews were fully transcribed and subjected to an open, inductive coding process using Atlas.ti. This phase involved a close reading of the transcripts to identify salient concepts, practices, actions, and meanings expressed by the interviewees. Coding at this stage adhered closely to informants' own terms and interpretations, deliberately avoiding the premature imposition of theoretical categories. This approach ensured fidelity to the empirical material and allowed patterns to emerge organically from the data, consistent with the first-order coding logic proposed by Gioia et al. (2013).

In the second stage, the large set of first-order concepts was systematically examined for similarities, differences, and recurring patterns. Through constant comparison and iterative refinement, these concepts were clustered into second-order themes, which reflect more abstract, theoretically informed interpretations of the data. At this stage, the analysis explicitly engaged with relevant literatures on university-industry interaction, BU, and social capital, enabling the transition from informant-centric descriptions to researcher-centric theoretical sensemaking.

In the third stage, related second-order themes were further distilled into a smaller number of aggregate dimensions, capturing the core dynamics underlying TT activities. These aggregate dimensions represent higher-level theoretical constructs that synthesize the empirical findings. Together, the three analytical levels, first-order concepts, second-order themes, and aggregate dimensions, constitute the study's data structure (Magnani & Gioia, 2022; Gioia et al., 2013), which is presented in in Figure 8. Rather than depicting a linear causal chain, the data structure highlights configurational patterns and relational linkages among organizational roles, social capital configurations, and contextual conditions.

Figure 8 - Data structure



Source: Prepared by the author.

Following the Gioia-based inductive analysis, a complementary round of theory-informed coding was conducted to deepen interpretation and support systematic comparison across contexts. Specifically, the empirical material was further coded around three analytically relevant dimensions: (i) BU roles (internal interface, mediatory, and external interface); (ii) dimensions of social capital (structural, cognitive, and relational); and (iii) organizational and contextual challenges. In parallel, a set of a priori descriptive codes, including country, type of BU, interviewee position, and organizational maturity, was applied to all interviews. These codes did not guide theory building *per se* but served as analytical markers to facilitate cross-case comparison and to examine how the Gioia-derived themes manifested across national and organizational contexts. The full code map is presented in Appendix B.

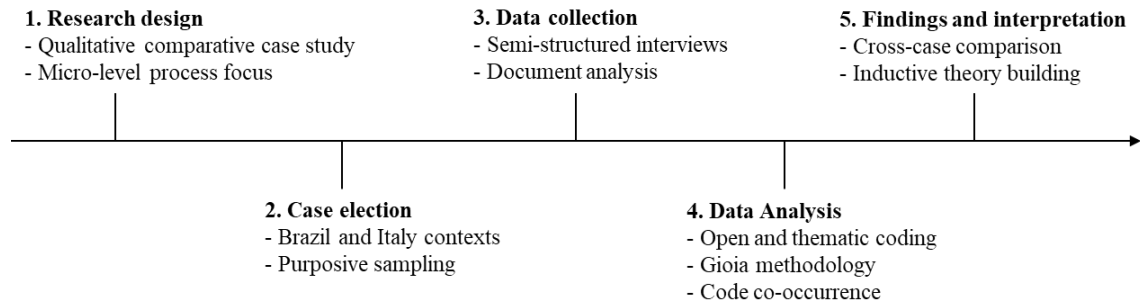
Importantly, this additional coding step was not intended to replace or constrain the Gioia-based inductive logic, but rather to complement the discussion and enhance analytical clarity, particularly in the comparative sections of the analysis. To support cross-country comparison, basic descriptive statistics and code co-occurrence analyses were conducted using Atlas.ti and Excel. These techniques were employed as tools to identify patterns of emphasis, association, and divergence between the Brazilian and Italian cases, rather than for hypothesis testing in a statistical sense. Interpretation of these patterns relied on qualitative content analysis and systematic cross-case comparison, consistent with a process-oriented and relational analytical strategy.

Several features contribute to the rigor of the analytical approach. First, the Gioia methodology ensures transparency and traceability by explicitly linking empirical evidence to higher-order theoretical constructs through the data structure. Second, the iterative movement between data and theory strengthens analytical depth and internal consistency. Third, the use of qualitative data analysis software supports systematic coding and enhances reliability. Finally, data triangulation across interviews and documentary sources increases the credibility of the findings. To enhance transparency and credibility, we maintained an audit trail (coding memos and versioned codebooks), conducted peer debriefing sessions to challenge emerging interpretations, and actively searched for negative cases.

As with all qualitative research, the study has limitations. The purposive nature of the sample and the unequal number of interviews across countries limit statistical generalization. However, the objective of the study is analytical generalization and theory development, rather than representativeness (Yin, 2017). These limitations are therefore consistent with the exploratory, comparative, and process-oriented focus of the research.

Figure 9 synthesizes the methodological design adopted in this study, outlining the main stages of the qualitative comparative analysis conducted in Brazil and Italy. The figure summarizes the research design, case selection criteria, data collection procedures, analytical strategy, data analysis and findings and interpretation.

Figure 9 - Methodology description and steps



Source: Prepared by the author.

4. Results

This section presents the empirical findings of the study, structured around the four aggregate dimensions that emerged from the Gioia-based data analysis. These dimensions synthesize the core patterns identified across first-order concepts and second-order themes, capturing the main dynamics shaping TT activities within university BU across the two national contexts. Representative interview quotes are presented throughout the subsections to illustrate the underlying empirical patterns, while a more extensive compilation of supporting quotations is provided in Appendix C.

To support and enrich the qualitative interpretation, some aggregate dimensions are accompanied by tables reporting code frequencies and co-occurrence patterns derived from a complementary round of coding. In these tables, a reference denotes a coded excerpt (i.e., a segment of interview text) assigned to a given code. Percentages refer to the share of references within each country subset or role category, and co-occurrence indicates that two codes were applied to the same excerpt at least once.

Consistent with the Gioia methodology, the presentation of results prioritizes theoretical sensemaking and process explanation, using these quantitative summaries as heuristic descriptors to enhance transparency and facilitate cross-country comparison rather than as statistical evidence, particularly given differences in the number of interviews across settings.

4.1. Evolution: Complementarities and new organizational models

This section examines how organizational embeddedness shapes the configuration and redistribution of BU' roles within universities, contributing to an understanding of how internal, mediatory, and external interface roles are emphasized across different organizational arrangements. By focusing on the aggregate dimension Evolution: Complementarities and new organizational models, the analysis sheds light on how universities combine distinct BU to respond to organizational constraints and ecosystem demands, thereby helping to address sub-question Q1.

The findings indicate that organizational embeddedness is closely associated with the orientation and scope of BU activities, particularly regarding the balance between internal coordination and outward-facing engagement. BU strongly embedded within university administrative structures, most notably traditional TTO, tend to emphasize internal interface roles. Interviewees recurrently described these units as primarily engaged in legal, bureaucratic, and administrative tasks, including intellectual property management and formal compliance procedures, often characterizing their operation as procedurally driven and reactive rather than proactive. These patterns are reflected in first-order concepts such as “legal, bureaucratic and administrative tasks,” “working on a passive way,” and “intellectual property committee,” which converge into the second-order theme Operational limitations of TTO.

In contrast, BU characterized by stronger external ecosystem embeddedness exhibit a greater emphasis on mediatory and external interface roles. These organizational forms, such as incubators, science and technology parks, and industry liaison offices, are associated with greater managerial flexibility, dedicated engagement with external networks, and, in some cases, non-public or hybrid governance arrangements. First-order concepts including “flexibility to manage resources,” “fully dedicated to exploiting external networking,” and “non-public body” underpin the second-order theme Alternative organizational forms and the external interface, highlighting how closer ties to innovation ecosystems enable more intensive outward-facing activities.

Importantly, the findings do not suggest a simple substitution between internal and external interface roles. Instead, they point to a complementary and distributed organizational logic, in which multiple BU coexist and specialize in distinct but interrelated functions, corroborating with Good et al., (2019). Interviewees emphasized the importance of coordination and differentiation among BU, frequently noting efforts to “work very closely with other BU,” “avoid replicating what others are doing,” and establish “partnerships in specific

projects.” These first-order insights coalesce into the second-order theme Complementarities and strategic orientation of universities, indicating that universities increasingly rely on plural and interconnected organizational arrangements to manage the complexity of TT processes.

To complement this qualitative interpretation of organizational embeddedness and role configuration, Table 15 provides a structured overview of how BU roles are distributed across interfaces, types of enactment (practices and challenges), and national contexts. Although the table does not classify units by degree of embeddedness, it offers comparative evidence that refines the understanding of how internal, mediatory, and external roles are emphasized in Brazil and Italy.

Table 15 - Roles of boundary units in different national contexts

BU Roles	Total	Practices	Italy	Brazil	Challenges	Italy	Brazil
Internal Interface							
Internal Interface - Technology Identification and Assessment	15%	14%	13%	14%	18%	29%	12%
Internal Interface - Intellectual Property Management	11%	14%	9%	16%	7%	0%	12%
Internal Interface - Researcher Engagement	21%	15%	9%	17%	31%	33%	29%
Internal Interface - Strategic Alignment	19%	15%	16%	14%	25%	24%	26%
Internal Interface - Facilities Management	1%	2%	3%	2%	0%	0%	0%
Internal Interface - Support for New Ventures	7%	9%	9%	10%	2%	5%	0%
Internal Interface - Knowledge Co-creation	2%	2%	6%	0%	2%	5%	0%
Internal Interface - Development and Capacity Building	24%	29%	34%	27%	15%	5%	21%
Total Internal Interface	150	95	32	63	55	21	34
<i>% shared of Internal Interface roles</i>	39%	35%	31%	37%	48%	51%	46%
External Interface							
External Interface - Technology Licensing	2%	1%	0%	2%	3%	0%	4%
External Interface - Market Analysis and Technology Promotion	22%	23%	26%	21%	18%	18%	17%
External Interface - Facilitation of Partnerships with Investors	0%	0%	0%	0%	0%	0%	0%
External Interface - Revenue Generation and Funding Mechanisms	20%	9%	9%	10%	50%	55%	48%
External Interface - Information Dissemination	18%	19%	24%	16%	18%	27%	13%
External Interface - Relationship with External Organizations	38%	48%	41%	52%	12%	0%	17%
Total External Interface	130	96	34	62	34	11	23
<i>% shared of total roles</i>	34%	35%	33%	36%	30%	27%	31%
Mediator							
Mediator - Alignment of Objectives and Expectations	31%	23%	32%	16%	58%	67%	53%
Mediator - Network and Trust Building	52%	60%	54%	64%	27%	22%	29%
Mediator - Development of Digital Instruments	3%	4%	3%	4%	0%	0%	0%
Mediator - Technology Transfer Strategies	6%	7%	5%	9%	4%	0%	6%
Mediator - Contract Management	7%	6%	5%	7%	12%	11%	12%
Total Mediator Role	108	82	37	45	26	9	17
<i>% shared of total roles</i>	28%	30%	36%	26%	23%	22%	23%

Source: Prepared by the author.

At the aggregate level, the distribution of references across the three interfaces is relatively balanced. However, cross-national differences emerge. In Brazil, internal interface roles account for the largest share of total references (37%), whereas in Italy mediatory roles represent the most prominent category (36%). This contrast suggests variation in the relative salience of internal coordination versus mediation activities across contexts, without implying a substitution between them.

Focusing on practices, internal interface activities related to Development and Capacity Building are the most salient in both countries, though more prominent in Italy (34%) than in Brazil (27%). Intellectual Property Management receives greater emphasis in Brazil (16%) than in Italy (9%), while Researcher Engagement appears in both contexts, albeit with different intensities. Such a pattern resonates with the argument advanced by Krucken et al. (2007), who note the difficulty of overcoming a predominantly documentary model, predominantly in Brazil context, in favor of more interactive and cooperation-based approaches. Within the external interface, Relationship with External Organizations is particularly salient in Brazil (52%), whereas Italian cases show comparatively greater emphasis on Information Dissemination (24%) and Market Analysis and Technology Promotion (26%). In mediatory roles, Network and Trust Building constitutes the most frequent practice in both contexts, especially in Brazil (64%), while Alignment of Objectives and Expectations is more pronounced in Italy (32%).

The distribution of challenges further nuances this comparison. Within the internal interface, Researcher Engagement and Strategic Alignment emerge as recurrent difficulties in both countries. Technology Identification and Assessment is more frequently reported as a challenge in Italy (29%) than in Brazil (12%), whereas Intellectual Property Management challenges appear only in Brazilian cases (12%). In the external interface, Revenue Generation and Funding Mechanisms concentrate half of all reported challenges (50%), a pattern observed in both contexts. Among mediatory roles, Alignment of Objectives and Expectations represents the most salient challenge overall (58%), particularly in Italy (67%), followed by Network and Trust Building, which appears with comparable frequency across contexts.

Taken together, the results portray an evolutionary pattern in which universities move away from reliance on a single BU' structure toward complementary organizational models. Through the strategic alignment of internally embedded units and externally embedded interfaces, universities reconfigure their TT architectures over time, enabling differentiated yet coordinated role enactment across internal, mediatory, and external interfaces. The following subsections unpack this aggregate dimension by examining in detail the second-order themes

that emerged from the data, thereby clarifying the specific organizational mechanisms and complementarities underlying this evolutionary dynamic.

4.1.1. Operational limitations of technology transfer offices

Across both national contexts, interviewees consistently describe TTO as strongly oriented toward internal interface roles, particularly those related to intellectual property management. This orientation is closely linked to legal and administrative responsibilities, which absorb a significant share of organizational capacity.

In Italian countries, this internal focus is often framed in terms of bureaucratic constraints. One respondent from an innovation agency emphasized that, in practice, the office was limited to administrative functions: *“there was an office handling bureaucracy – legal and administrative tasks – but no training, no dissemination, no bridging... there was a tech transfer office, but it was only doing administrative work”* (Interview 5 – Innovation agency – Italy). A similar perception was expressed by a TTO representative, who noted that the office was *“focusing on all the procedures that cannot be left alone”*, while adopting a largely reactive posture toward researchers’ initiatives (Interview 7 – TTO – Italy).

In Brazilian contexts, the prominence of internal interface roles is even more explicit. Several respondents described patent drafting and filing as highly demanding processes requiring sustained interaction with researchers and specialized expertise. As one interviewee explained, *“...writing and drafting patent claims is almost like a thesis defense. You have to talk a lot with the inventor, because the claims must be precise to ensure proper protection”* (Interview 10 – Foundation – Brazil). This characterization illustrates how limited resources and operational capacity tend to confine TTO to document-intensive and internally oriented activities (Krücken et al., 2007).

At the same time, the interviews reveal a growing awareness of the limitations of this predominantly “cartorial” model. Particularly in Brazilian cases, respondents explicitly acknowledge that intellectual property management should not exhaust the mission of BU. One TTO representative stated that *“the main goal of the TTO is technology transfer; we do not understand the TTO as a registry office... we were born as an intellectual property commission, so we spent a long time focused on legal protection”* (Interview 11 – TTO – Brazil). Similarly, a professor observed a recent shift toward more proactive internal engagement, noting that *“I now perceive the NIT as much more active in awareness-building, which I did not see before”* (Interview 19 – Professor – Brazil).

Overall, these findings align with prior studies that associate university-embedded BU with internal-facing activities such as technology identification, intellectual property management, and researcher coordination (Krücken et al., 2007; Chen et al., 2024; Temel et al., 2021). However, the evidence also suggests that operational constraints may reinforce an inward-looking orientation, limiting the expansion of TTO into mediatory and external interface roles.

4.1.2. Alternative organizational forms and the external interface

The interview evidence indicates that, although TTO were formally conceived as BU responsible for bridging universities and external actors, operational constraints have progressively narrowed their scope of activities. Across both Italian and Brazilian contexts, respondents consistently report that the increasing workload associated with intellectual property protection has limited the capacity of TTO to perform external interface roles in practice. As one interviewee explained, *“the entry door is a TTO, according to the law. But many actors enter, for example, through the technology park. It is not its formal role, but it can function as this intermediary”* (Interview 10 – Foundation – Brazil). This statement illustrates the gap between formal attribution and effective role enactment, opening space for alternative organizational forms to assume externally oriented functions.

As a result, other BU have gained prominence in engaging with markets and innovation ecosystems. Interviewees consistently associate incubators, science and technology parks, and industry liaison offices with more proactive external engagement. A representative from a technology park in Italy emphasized its intermediary position, stating that *“we are exactly in the middle, that is, we are between a world where basic and applied research are developed by universities and, on the other side, small companies”* (Interview 2 – Tech Park – Italy). Similarly, an incubator manager highlighted the outward orientation of these units, noting that *“we mostly reach out to companies; we try to build relationships proactively”* (Interview 1 – Incubator – Italy). In Brazilian cases, a technology park representative observed that *“companies contact us because they have several demands, ranging from technology validation to access to technical and specialized services”* (Interview 13 – Tech Park – Brazil).

In Italian contexts, the establishment of industry liaison offices further reflects this organizational differentiation. One interviewee noted that *“the formal institution setting up this office was seven years ago; before that there was only a traditional technology transfer office... now we are fully dedicated to exploiting networking with companies and institutions”* (Interview 3 – ILO – Italy). This shift is reinforced by references to structured networks of

collaborating firms (Interview 4 – Professor – Italy) and by TTO representatives who acknowledge that *“we have an industrial liaison office that is going to have this relationship with companies”* (Interview 7 – TTO – Italy).

A comparable redistribution of roles is observed in Brazilian contexts, where technology parks increasingly lead open innovation initiatives. One respondent emphasized that *“we have an open innovation program, we work closely with the TTO, and we connect the university with large companies”* (Interview 12 – Tech Park – Brazil). While collaboration with TTO remains present, these initiatives are frequently led by units more deeply embedded in innovation ecosystems.

4.1.3. Complementarities and strategic orientation of universities

Building on the previous sections, the empirical evidence indicates that TT activities are distributed across multiple BU that perform complementary roles rather than being concentrated within a single organizational arrangement in both contexts.

In Italian contexts, this complementarity is evident in the division of labor between TTO, industry liaison offices, and incubators. While TTO remain primarily focused on intellectual property protection and formal commercialization procedures, incubators and related units concentrate on network-building, entrepreneurial training, and sustained engagement with external actors. As one interviewee noted, *“traditionally this activity is merged into the technology transfer office and it's mainly focused on patents... So, this activity, the one we are doing, it's more creating the networks and making them sustainable through time”* (Interview 3 – ILO – Italy). Similarly, respondents emphasized that educational and entrepreneurial training activities are more frequently hosted by incubators than by TTO: *“the university TTO it's not holding like as much as courses like educational courses as the incubator”* (Interview 6 – PhD – Italy). Rather than duplicating functions, these units actively seek coordination, as illustrated by a TTO representative: *“we are trying not to reply exactly what they are doing, but just to work together”* (Interview 7 – TTO – Italy).

The interviews further indicate that these complementarities depend on close and sustained interaction among BU. One interviewee described this process as continuous co-working: *“we work very closely with the TTO of the university... when we work on a project, we also work on the protection of IP, and if necessary, on the commercialization process”* (Interview 1 – Incubator – Italy). Another respondent highlighted the role of industry liaison offices as connectors between firms and internal university actors, requiring constant coordination with TTOs (Interview 7 – TTO – Italy). These accounts suggest that

complementarities are actively produced through relational coordination rather than emerging automatically from organizational design.

Beyond operational coordination, the interviews highlight the importance of a clear strategic orientation at the university level to stabilize and amplify these complementarities. This orientation was often described as a “visionary” decision by university governance to create dedicated structures for external engagement, even with limited resources: *“there was a visionary position... by the governance that decided to set up a small office, but to start this dedicated activity”* (Interview 3 – ILO – Italy). The Butterfly Area initiative in Turin exemplifies this process as *“a university initiative... born with the role of the government, and having infrastructure, that can be accessed both by researchers, companies and students”* (Interview 3 – ILO – Italy). This arrangement reflects the emergence of hybrid organizations that blur traditional organizational boundaries and facilitate sustained interaction across university, industry, and government spheres (Etzkowitz & Leydesdorff, 2000; Krücken et al., 2007; Cunningham et al., 2022).

In Brazilian contexts, strategic orientation is similarly important but is more frequently operationalized through collaborative projects and policy-induced coordination mechanisms. Interviewees highlighted partnerships involving TTOs, technology parks, and public innovation agencies, such as EMBRAPPII (Empresa Brasileira de Pesquisa e Inovação Industrial): *“we carry out joint events with EMBRAPPII... and the people from the technology park”* (Interview 11 – TTO – Brazil). These initiatives are often supported by funding schemes that explicitly require network-based collaboration, thereby encouraging the connection of innovation environments (Interview 12 – Tech Park – Brazil).

4.2. Operation: Role’s orientation and relational and cognitive social capital

This section focuses on the operational dimension of BU activities and examines how different interface roles are associated with distinct configurations of social capital. By addressing how structural, cognitive, and relational dimensions of social capital are mobilized and combined across internal, mediatory, and external interface roles, the analysis contributes directly to sub-question Q2. Consistent with prior literature, social capital emerges as a strategic resource that underpins the capacity of BU to coordinate activities internally and to sustain interactions across organizational boundaries (Camps & Marques, 2014; Iturrioz et al., 2015).

Structural social capital is recognized in this study as a necessary condition for the enactment of BU’ activities, insofar as network ties, formal connections, and interaction channels enable the very possibility of interaction between actors. However, because these

structural elements are relatively observable and tend to function as baseline prerequisites across BU roles, they offer more limited analytical leverage for explaining variation in role orientation and operational dynamics. For this reason, the analysis places greater emphasis on cognitive and relational dimensions of social capital, which capture the interpretive alignment, trust, and meaning-making processes through which interactions are sustained and differentiated in practice.

The findings indicate that internal interface roles are predominantly associated with cognitive social capital, reflecting the importance of shared interpretations, common language, and aligned expectations for coordinating innovation-related activities within universities. This pattern is particularly evident in the second-order themes “Capillarity in the internal interface” and “Sub-units and internal boundary arrangements”, which highlight how internal diversity across departments, research fields, and organizational structures creates the need for intensive sensemaking and translation work. First-order concepts such as “different realities from each department,” “size and specialization of university,” and “lack of awareness of BU’s role” illustrate how BU rely on cognitive alignment to navigate internal fragmentation and to legitimize their role within the academic community.

Educational activities further reinforce this cognitive orientation. The second-order theme “Importance of education and PhD student” captures how teaching, training, and the involvement of doctoral students function as mechanisms for disseminating innovation-related norms and practices internally. First-order concepts including “teaching as a strategy of the third mission”, “mandatory interaction with external stakeholders in teaching” and “PhD students as an opportunity for the internal interface” indicate that educational spaces support the gradual construction of shared understandings, which stabilizes internal interface operations. This finding aligns with prior evidence that formal, research-oriented, and intra-organizational interactions depend more heavily on cognitive social capital (Sa’a & Asplund, 2025).

In contrast, mediatory and external interface roles are more strongly associated with relational social capital, emphasizing trust-based relationships and repeated interactions with heterogeneous external actors. The second-order theme “Ecosystem embeddedness, partnerships and external sub-boundary units” underscores the relevance of dense relational networks for accessing firms, intermediaries, and public actors within innovation ecosystems. First-order concepts such as “ecosystem and connection with types of actors,” “partners and competitors,” and “official network of BU” illustrate how BU engaged in outward-facing activities depend on relational ties to sustain collaboration over time. This pattern is consistent

with the view of BU as “glue providers” that connect otherwise loosely coupled actors across organizational boundaries (Iturrioz et al., 2015).

Despite the predominance of relational social capital in mediatory and external roles, the interviews reveal that cognitive challenges remain central, particularly in mediation processes. The second-order theme “Cognitive challenges in mediatory and external roles” reflects recurrent difficulties related to language, goal alignment, and cultural differences between academic and non-academic actors. First-order concepts such as “it is a matter of communication”, “the meeting point for different goals” and “academic culture and corporate culture” suggest that relational ties often compensate for persistent cognitive gaps rather than eliminating them. This dynamic resonates with previous studies showing that cognitive and relational social capital evolve jointly, especially in early stages of collaboration, where trust can temporarily offset misalignment in meanings and expectations (Steinmo & Rasmussen, 2018).

Figure 10 provides complementary support for these findings by presenting the relative frequency of cognitive, relational, and structural social capital across internal, mediatory, and external interface roles. Figure 10 presents a 2x2 analytical matrix contrasting Italian and Brazilian contexts across practices and challenges. Each quadrant is constructed from the co-occurrence of codes, with percentages indicating the relative distribution of structural, relational, and cognitive social capital within BU roles. This relational approach allows for the identification of recurring configurations linking how BU enact their roles and the forms of social capital mobilized or constrained in practice.

The co-occurrence matrix reveals a high degree of similarity between the Brazilian and Italian contexts with respect to practices, suggesting that, at the micro level, BU mobilize social capital in broadly comparable ways when enacting their roles across different national settings. In both contexts, relational social capital emerges as particularly salient in mediatory roles, displaying higher co-occurrence levels than cognitive social capital. In the Brazilian case, relational social capital shows a stronger association with internal interface roles, reflecting the reliance on interpersonal ties to support coordination within universities. In contrast, in the Italian context, cognitive social capital is more strongly associated with mediatory roles. With respect to challenges, the matrix points to an even greater convergence between the two national contexts. Across both Brazil and Italy, challenges are predominantly associated with cognitive social capital across all categories of BU roles. Therefore, strengthening cognitive social capital

appears to represent an important pathway for enhancing the effectiveness and resilience of BU' activities.

Figure 10 - Matrix of co-occurrence roles and social capital

		Italy					Brazil		
Practices		Internal	Mediator	External			Internal	Mediator	External
	Structural	59%	35%	88%		Structural	52%	43%	89%
	Cognitive	29%	26%	12%		Cognitive	26%	15%	9%
	Relational	12%	39%	0%		Relational	21%	43%	2%
	Total	17	31	25		Total	42	40	53
Challenges		Internal	Mediator	External			Internal	Mediator	External
	Structural	21%	0%	60%		Structural	24%	7%	46%
	Cognitive	57%	78%	40%		Cognitive	64%	71%	38%
	Relational	21%	22%	0%		Relational	12%	21%	15%
	Total	14	9	5		Total	25	14	13

Source: Prepared by the author.

Overall, the results suggest that the operational orientation of BU is associated with role-specific yet interconnected social capital configurations. Internal interface roles emphasize cognitive alignment to manage internal heterogeneity, while mediatory and external roles rely more strongly on relational ties to sustain engagement across organizational boundaries. Across all roles, however, cognitive and relational dimensions are jointly activated, reflecting the adaptive and relational nature of BU' activities within university innovation systems. The following subsections develop the aggregate dimension by examining the second-order themes in detail.

4.2.1. Capillarity in the internal interface

One of the most salient challenges for BU operating at the internal interface is achieving capillarity across large and heterogeneous academic organizations. Several interviewees stressed that building shared cognitive frameworks at scale is particularly difficult in comprehensive universities. An incubator manager from Italy explained that “*building relationships with departments is not easy*,” as each department requires a different approach and levels of interest vary significantly depending on individuals and disciplinary cultures (Interview 1 – Incubator – Italy). A similar concern was echoed by a technology park representative in Italian context, who emphasized the necessity of developing innovation-related capabilities “*in each department*” through systematic internal education and information efforts (Interview 2 – Technology Park – Italy). From the perspective of a TTO in

Italy, the sheer size of the university makes it “*not always easy to find the right person*” or to map all instruments and expertise available internally (Interview 7 – TTO – Italy). Brazilian country interviewees expressed analogous concerns, highlighting the “*fragmentation and anarchic*” distribution of laboratories and innovation-related activities across campuses (Interview 21 – Technology Park – Brazil).

4.2.2. Sub-units and internal boundary arrangements

In response to these capillarity challenges, several interviewees described alternative organizational arrangements aimed at strengthening cognitive social capital internally. A recurrent strategy involves the creation of internal “sub-boundary units” or delegated roles embedded within departments or laboratories. For example, a TTO manager from Brazil described efforts to “*train highly qualified technical staff from the university itself, who already have links with laboratories, to act as multipliers of the TTO*” (Interview 11 – TTO – Brazil). Comparable approaches were identified in Italian context, where professors formally responsible for third mission activities act as internal focal points for public engagement, knowledge transfer, and relations with companies (Interview 4 – Professor – Italy). Similar bridging roles were also mentioned by professors in Brazil, who described faculty members engaged in entrepreneurship as the “*arms of broader programs*” within their campuses (Interview 16 – Professor – Brazil). These arrangements illustrate how BU seek to extend their internal reach by embedding cognitive translation capacities closer to academic communities.

4.2.3. Importance of education and PhD student

Education emerged as an important alternative for fostering long-term cognitive social capital within universities. Several interviewees emphasized that students represent a key vector for achieving organic and sustainable capillarity. As one professor from an Brazil noted, “*through students, we achieve capillarity, but in a more organic way*”, adding that resistance to innovation-oriented activities has been progressively reduced “*through students*” (Interview 16 – Professor – Brazil). Similar views were expressed across contexts, with professors in Italy and Brazil highlighting institutional rules and curricular practices that systematically connect teaching activities with external actors, such as inviting managers of SMEs (Small and Medium Enterprises) to participate in courses and projects (Interview 9 – Professor – Italy) or structuring integrated projects closely linked to firms (Interview 18 – Incubator – Brazil).

In the Brazilian context, this finding is particularly relevant considering the national policy on the curricularization of extension activities, as established by the National Education Plan (Lei nº 13.005/2014) and operationalized by Resolution CNE/CES nº 7/2018, which

mandates that at least 10% of undergraduate curricula be dedicated to extension activities involving structured interaction with external actors. From a social capital perspective, this policy may be interpreted as a formal mechanism to strengthen cognitive social capital, insofar as it normalizes external engagement within teaching practices and contributes to the construction of shared understandings regarding the role of universities within innovation ecosystems.

Beyond undergraduate education, the interviews consistently underscored the strategic role of postgraduate students, particularly PhD candidates, in internal interface activities. An innovation agency representative in Italy described targeted training programs for PhD students as a deliberate bottom-up strategy, arguing that they are “*easy to target*,” can even be required to attend, and subsequently “*contaminate their research teams by acting as second-step bridges to senior colleagues*” (Interview 5 – Innovation Agency – Italy). This perception was widely shared. An incubator manager in Italy highlighted the PhD school as an important entry point for entrepreneurship and startup creation, especially given that many PhD graduates are not absorbed by academia (Interview 1 – Incubator – Italy). A PhD student from an Italian context similarly argued that basic exposure to innovation and entrepreneurship topics should be imposed on all doctoral students (Interview 6 – PhD – Italy). In Brazil, technology park and innovation agency representatives also emphasized that “*postgraduate students are often the most entrepreneurial actors within universities*”, as they face critical career decisions at this stage (Interview 12 – Technology Park – Brazil), while also noting the historical “*absence of entrepreneurship-related content in graduate curricula*” (Interview 15 – Innovation Agency – Brazil).

4.2.4 Cognitive challenges in mediatory and external roles

One of the most frequently mentioned challenges in mediatory and external roles concerns communication and translation across heterogeneous actor groups. An incubator representative noted that mediatory work is “*also a matter of communication*,” stressing the need to clearly convey research activities to stakeholders (Interview 1 – Incubator – Italy). Similarly, a professor referred to a widespread “*disability to explain clearly and honestly the idea behind the project*,” arguing that the core challenge is not selling research but “*learning how to tell the story beyond the project*” to convince external partners (Interview 4 – Professor – Italy). This issue was also emphasized by a PhD student, who noted that “*the most difficult part as a scientist is speaking with someone that is not a scientist*,” highlighting the need for a

“bridging person capable of translating” expectations and academic ideas in *“very simple and basic terms”* (Interview 6 – PhD – Italy).

Beyond language, misalignment of objectives and expectations between universities and firms emerged as another critical cognitive challenge, particularly in Brazilian context. A TTO manager observed that firms are often reluctant to invest because *“technologies are still at a very low level of development”* implying a risk profile company is unwilling to assume (Interview 11 – TTO – Brazil). Another TTO representative emphasized that companies are not interested in academic-style explanations but rather in *“concrete information about cost, timing, and how”* (Interview 14 – TTO – Brazil). Professors further highlighted the difficulty researchers face in transitioning from scientific work to entrepreneurial activity, noting that *“they are learning from scratch how to operate as entrepreneurs”* (Interview 19 – Professor – Brazil).

Cultural differences between academia and external actors further compound these challenges. A PhD student reported that firms often *“perceive universities as slow and bureaucratic, leading to reluctance to cooperate”* (Interview 6 – PhD – Italy). In Brazilian context, a TTO representative described boundary work as *“living on the border inside the institution itself,”* framing it as a behavioral and cultural frontier that must be continuously navigated (Interview 20 – TTO – Brazil). Together, these findings indicate that even where relational social capital predominates, mediatory and external roles remain highly sensitive to unresolved cognitive misalignments.

4.2.5. Ecosystem embeddedness, partnerships and external sub-boundary units

A recurrent theme in the interviews is the role of BU as integral components of local and regional innovation ecosystems. In Italian context, interviewees emphasized systematic mapping and coordination with ecosystem actors. An incubator manager described the use of an *“ecosystem map to structure connections with diverse stakeholders”* (Interview 1 – Incubator – Italy), while an ILO representative highlighted *“strong collaboration with local industrial associations”* (Interview 3 – ILO – Italy). Participation in professional and sectoral associations, such as European networks of TTO professionals, was also described as a key mechanism for strengthening relational ties and shared practices across organizations (Interview 7 – TTO – Italy).

In Brazilian context, respondents highlighted structured networks among TTO at the state level as platforms for training and coordination (Interview 10 – Foundation – Brazil), as well as partnerships with funding agencies, development secretariats, innovation foundations

and technology parks (Interview 11 – TTO – Brazil). In large universities, alternative governance arrangements were mentioned, including external organizations managing incubators or operating in close partnership with technology parks, reflecting adaptive responses to institutional complexity (Interview 15 – Innovation Agency – Brazil).

Several interviewees explicitly described how ecosystem organizations may function as external sub-boundary units. In Italian context, professors highlighted their roles in industry clusters characterized by shared leadership between company executives and academic researchers, forming hybrid governance structures that facilitate mediation (Interview 8 – Professor – Italy). In Brazilian context, incubator and TTO representatives emphasized the involvement of organizations such as Sebrae (Serviço Brasileiro de Apoio às Micro e Pequenas Empresas - Brazilian Micro and Small Business Support Service), chambers of commerce, development secretariats and entrepreneurial associations, which often “*do the same work of mediation and connection,*” forming a parallel system that complements university-based BU (Interview 2 – Tech Park – Italy; Interview 18 – Incubator – Brazil).

These partnerships were consistently framed as essential for strengthening organizational visibility and representativeness within innovation ecosystems. Interviewees stressed the importance of “*bringing more people in, including local politicians, entrepreneurs and support organizations*” to enhance the relevance of BU (Interview 20 – TTO – Brazil), while others linked organizational relevance to the ability to connect “*strongly with other external institutions*” (Interview 21 – Technology Park – Brazil).

4.3. Conditions: Structural and operational challenges and funding mechanisms

This section examines the structural and operational conditions that shape the functioning of university BU across different national contexts, focusing on how such conditions constrain their activities over time. By addressing Q3, the analysis highlights recurring patterns of fragility, resource constraints, and organizational support that cut across roles while manifesting differently depending on the context.

The findings indicate that operational weaknesses of BU, particularly those related to organizational fragility in human resources, long-term instability, and high staff turnover, constitute a pervasive constraint in both contexts. As shown in Table 16, Weak Intermediary Structures and Inexperienced Staff emerge as the most frequently cited challenge overall, accounting for 59 references. This challenge is especially salient in Brazil, where it represents 35% of all challenge-related references, compared to 25% in Italy. This pattern is consistent

with prior research emphasizing that BU in emerging economies, as Brazil, often operate under conditions of limited funding, infrastructural constraints and fragile organizational support, which shape both the scope and sequencing of their activities (Thamae et al., 2016; Alibekova et al., 2019; Cao & Shi, 2021). In contrast, challenges related to Lack of Goal Alignment are proportionally more prominent in Italy (18%) than in Brazil (8%), suggesting that in more mature innovation systems, constraints are increasingly associated with coordination complexity and strategic alignment rather than foundational capacity building (Cunningham et al., 2022; Hailu, 2024; Noack & Jacobsen, 2021).

A second set of conditions relates to scarcity of resources and sources of funding, encompassing first-order concepts such as lack of resources, dependence on short-term funding mechanisms, and uneven access to public support. Table 16 shows that Access to Funding Sources is frequently mentioned in both contexts, suggesting that financial constraints are not exclusive to emerging economies, such as Brazil, but assume different meanings across settings. In this context, funding scarcity is often associated with basic operational survival and limited scaling capacity, whereas in Italy it is more closely connected to strategic autonomy and the ability to sustain diversified portfolios of activities. Finally, the analysis highlights the role of political and administrative will as a conditioning factor influencing BU performance. First-order concepts such as visionary leadership, access to government entities, and the sensitivity of university administrations help to explain variation across cases.

Table 16 - Distribution of coded references of challenges

Challenges	Total	Italy	% Italy	Brazil	% Brazil
Lack of Goal Alignment	19	9	18%	10	8%
External Pressures and Increasing Complexity	10	1	2%	9	7%
Resource Scarcity	0	0	0%	0	0%
Access to Funding Sources	24	7	14%	17	13%
Weak Intermediary Structures and Inexperienced Staff	59	13	25%	46	35%
Fragility of Socioeconomic and Industrial Structures	11	3	6%	8	6%
Reliability and Trust in the Legal Framework	8	1	2%	7	5%
Cultural Differences between Academia and External Stakeholders	10	2	4%	8	6%
Limited Commercial Capabilities and Risk Aversion	7	5	10%	2	2%
Scientific Profile and Role Overload	12	4	8%	8	6%
Administrative Complexity in Technology Transfer Processes	22	6	12%	16	12%
Total	182	51	100%	131	100%

Source: Prepared by the author.

Taken together, these patterns illustrate how structural and operational conditions operate as contextual constraints that shape the scope, stability, and evolution of BU activities. The following subsections examine the second-order themes in greater detail, clarifying how

operational weaknesses, managerial profiles, funding structures, and political-administrative support interact to condition BU' dynamics across different organizational environments.

4.3.1. Operational weaknesses of boundary units

The interviews reveal that operational fragility and high staff turnover are central challenges, particularly in Brazilian context, directly affecting the continuity of BU' activities. A recurrent issue concerns the difficulty of recruiting professionals with adequate profiles for BU roles, a challenge acknowledged even in Italian context: *"the real problem that we have is that it's very difficult to find people already equipped for this kind of work"* (Interview 2 – Tech Park – Italy). In Brazil, this difficulty is exacerbated by the absence of formal career paths and institutionalized positions, as highlighted by one interviewee: *"the heterogeneity is absurd. It is absurd. Why? Because there is no career for occupying a technology transfer office"* (Interview 10 – Foundation – Brazil). Consequently, BU struggle to accumulate organizational know-how, as turnover interrupts learning processes and weakens organizational memory.

Many professionals also enter BU without prior training for intermediary roles, relying primarily on experiential learning. This dynamic appears across contexts, *"the main important thing of our work is learning by doing"* (Interview 7 – TTO – Italy), but is particularly pronounced in Brazil, where interviewees frequently reported entering the field without prior experience in innovation management: *"I arrived without knowing exactly what I would find. I had never worked with this innovation area"* (Interview 13 – TTO – Brazil). These conditions are further compounded by reliance on scholarship-based personnel, generating instability: *"we are always worried about instability. We are many scholarship holders"* (Interview 11 – TTO – Brazil) and limiting long-term consolidation: *"the TTO will never be strong... a wave comes and takes the sandcastle away"* (Interview 13 – TTO – Brazil).

High turnover directly undermines the accumulation of cognitive and relational social capital within BU. Frequent personnel changes disrupt shared understandings, weaken trust-based relationships and hinder the gradual learning processes required to stabilize intermediary roles (Camps & Marques, 2014; Steinmo & Rasmussen, 2018). As a result, operational fragility emerges not only as a managerial issue but as a structural barrier to the sustained mobilization of social capital, particularly in emerging economy contexts, such as Brazil, marked by organizational volatility and limited absorptive capacity (Thamae et al., 2016; Cao & Shi, 2021).

4.3.2. Manager's profile and multidisciplinary team

Alongside structural constraints, the interviews underscore the critical role of managerial profiles and team composition in mitigating operational challenges and enhancing BU performance. As one interviewee noted, *“our team combines different backgrounds, and our goal is to extract connections, to build bridges between university research and companies”* (Interview 1 – Incubator – Italy). Similarly, the ability to jointly mobilize complementary expertise is seen as essential for effective intermediation: *“you can provide solutions or innovation together, where lawyers and market researchers work together”* (Interview 3 – ILO – Italy). In Brazilian context, interviewees also highlighted the functional complementarity between administrative staff and academic personnel, emphasizing how diverse profiles contribute to operational continuity and governance (Interview 22 – Incubator – Brazil).

Beyond team composition, the presence of an active and entrepreneurially oriented manager emerges as a decisive factor. Interviewees consistently stressed that proactive leadership is required to navigate regulatory ambiguities and sustain BU activities: *“the president’s mindset was always about taking risks... if there is any legal gap, let’s take the risk and do it”* (Interview 11 – TTO – Brazil). Conversely, the absence of dynamic leadership was associated with stagnation and underperformance: *“he stayed 12 years as a manager and did nothing”* (Interview 21 – Tech Park – Brazil). These findings align with studies emphasizing that, particularly in emerging economies, such as Brazil, BU often rely on individual agency to compensate for organizational fragilities (Athreye et al., 2023).

Finally, prior professional experience of managers appears as an important enabler of BU effectiveness, as it brings pre-existing stocks of social capital that can be strategically mobilized. Interviewees with industry or intermediary backgrounds emphasized how accumulated relational and cognitive capital facilitated cross-boundary interactions: *“I have 25 years of experience promoting small and medium enterprises... I have a view on both sides”* (Interview 3 – ILO – Italy); *“I know how industry thinks because I came from the pharmaceutical industry”* (Interview 9 – Professor – Italy). In Brazil, similar patterns were observed, with managers’ prior experience in consultancy or innovation brokerage playing a stabilizing role amid high turnover (Interview 12 – Tech Park – Brazil).

4.3.3. Scarcity of resources and sources of funding

Scarcity of financial resources emerges as a recurrent challenge in both Italian and Brazilian contexts, although it is more structurally constraining in the latter. Interviewees across settings emphasized that stable funding is a prerequisite for sustaining BU activities: *“for that,*

they need access to direct funding – that’s our main challenge” (Interview 5 – Innovation Agency – Italy). In Brazil, financial constraints are described as systemic and closely tied to organizational fragility, with state-level research foundations perceived as indispensable: *“if it were not for the state research foundation, we would not have a TTO”* (Interview 14 – TTO – Brazil). Limited budgets impose clear operational constraints and reinforce instability, particularly where scholarship-based staffing predominates: *“it has a very small budget, an extremely limited one”* (Interview 21 – Tech Park – Brazil).

In Italy, funding structures are more diversified, enabling BU to combine regional, national and supranational resources. Interviewees highlighted the central role of European Union programs, complemented by national and regional initiatives: *“there are several programs, basically from the European Union, to stimulate technology transfer and entrepreneurship”* (Interview 1 – Incubator – Italy); *“one third of our balance is made by projects financed at different levels: regional, national, European Union”* (Interview 2 – Tech Park – Italy). This multi-level funding landscape reduces dependence on single sources and supports greater strategic flexibility. Across both contexts, more mature BU seek to reduce reliance on public funding through self-financing or hybrid models, although such arrangements appear feasible only after organizational consolidation. Examples include fully self-financed incubators in Italian context (Interview 1 – Incubator – Italy) and innovation agencies in Brazil that rely partly on licensing revenues (Interview 15 – Innovation Agency – Brazil). Finally, the evidence indicates that funding mechanisms not only mitigate resource scarcity but also shape the strategic orientation and outreach of BU, supporting expanded service provision in Italian context (Interview 3 – ILO – Italy) and socially oriented capacity-building initiatives in Brazil (Interview 21 – Tech Park – Brazil).

4.3.4. Political and administrative will

Political and administrative will emerges as a salient factor in the empirical material, with stronger predominance in Brazilian contexts. While governance support is also mentioned in Italian cases, interviews in Brazil consistently indicate that the continuity and effectiveness of BU activities depend heavily on the priorities and commitment of university leadership and public authorities. In Italian contexts, political will appears primarily as a trigger for the creation of BU’ structures, as illustrated by the decision to establish a dedicated external interface office based on *“a visionary position or decision by the governance”* (Interview 3 – ILO – Italy).

In Brazil, however, interviewees emphasize that vision must be accompanied by sustained commitment and concrete action. Several respondents point to a lack of prioritization

by university administrations, which often defer engagement with BU agendas: *“I think there is a lack of sensitivity from university administrations to treat this as a priority”* (Interview 10 – Foundation – Brazil). Others stress the role of senior leadership, particularly rectors, in advocating for BU at the national level: *“my hope was that rectors would start confronting this issue in favor of the TTO”* (Interview 14 – TTO – Brazil). These challenges are compounded by administrative inertia and limited legal appropriation of innovation frameworks, leading to delays in policy implementation (Interview 21 – Tech Park – Brazil).

Across both contexts, respondents acknowledge that decisions made by actors positioned *“above” the unit can redefine priorities and organizational trajectories: “it really depends on the will of people that are over your head”* (Interview 7 – TTO – Italy). In Brazil, this dependence is more acute, as leadership changes or shifts in public policy can directly undermine previously consolidated initiatives, interrupting ongoing processes and altering strategic directions (Interview 13 – Tech Park – Brazil). Political polarization and the stigmatization of public universities are also cited as constraints on engagement with external actors and on the consolidation of BU’ agendas (Interview 16 – Professor – Brazil).

The consequences of weakened political support are particularly severe in fragile organizational contexts. One interviewee reports that the withdrawal of support from a state research funding foundation resulted in an abrupt reduction in personnel: *“we went from having eight people working with us to suddenly having only one”* (Interview 20 – TTO – Brazil). Respondents therefore emphasize the need for more systemic and coordinated governance approaches at the national level, rather than isolated organizational efforts: *“we need to work on this systemically, each actor doing their part”* (Interview 20 – TTO – Brazil). These findings align with the literature showing how fragmented policies and inconsistent political support constrain the consolidation of BU’ roles in emerging economies, such as Brazil (Cao & Shi, 2021; Thamae et al., 2016).

4.4. Long-term: Regional ecosystem maturity and path dependence

The aggregate dimension Long-term: Regional ecosystem maturity and path dependence captures how historically accumulated regional conditions shape the stability and sustainability of BU over time. Within the Gioia data structure, this dimension integrates three second-order themes grounded in informant-centric first-order concepts and articulating these themes, the discussion contributes to answering Q4.

The first second-order theme, “Regional particularities”, is grounded in first-order concepts such as “regional specificities”, “bottom-up dynamics”, and “technology push and

market pull strategies”. These codes reflect informants’ descriptions of how BU operate within territorially embedded contexts that influence interaction logics and engagement models. The emphasis is not on national-level differentiation per se, but on how local configurations shape the organization of boundary activities.

The second theme, “Path dependence and the need for continuity”, encompasses first-order concepts including “long-term relationships and social capital accumulation”, “permanent network”, and the recognition that “it takes time”. These concepts derive directly from informants’ accounts stressing that BU effectiveness depends on sustained interaction cycles rather than short-term initiatives. The idea that ecosystem development and partnership consolidation require time reflects a path-dependent process in which accumulated relationships and repeated exchanges progressively stabilize organizational roles and expectations.

The third theme, “The capacity of laws to foster or constrain BU activities”, incorporates first-order concepts such as the perception that “the law was a game changer,” the view that “the university did not incorporate the legal basis,” and references to “continuous sustainable long-term policy”. These elements indicate that regulatory frameworks and their organizational incorporation affect the continuity and formalization of boundary activities. Informants describe legal changes either as enabling clearer mandates and expanded action or as remaining formally present but weakly embedded in university governance structures.

To support the comparative analysis, Table 17 summarizes the distribution of coded references across these dimensions, further differentiating between practices and challenges and comparing Brazilian and Italian contexts.

Table 17 - Distribution of coded references across social capital dimensions

Social Capital	Total	Practices	Italy	Brazil	Challenges	Italy	Brazil
Structural social capital	167	145	52	93	22	7	15
% structural social capital	52%	61%	59%	63%	25%	23%	26%
Relational social capital	60	47	19	28	13	5	8
% relational social capital	19%	20%	22%	19%	15%	16%	14%
Cognitive social capital	97	44	17	27	53	19	34
% cognitive social capital	30%	19%	19%	18%	60%	61%	60%

Source: Prepared by the author.

After considering these qualitatively grounded mechanisms, the aggregate distribution of social capital was analyzed to provide complementary insight. The table shows that structural social capital predominates across the dataset (52% of total references), with similar proportions in Italy (59%) and Brazil (63%) contexts. Relational social capital accounts for 19% overall,

while cognitive social capital represents 30% of total references and appears more frequently among reported challenges. The similarity of these distributions across national settings suggests that national contexts does not translate into substantially different proportional compositions of social capital. These results partially diverge from strands of literature that associate more mature ecosystems with stronger reliance on cognitive social capital and less stable environments with greater dependence on relational ties (Grzegorzczak, 2019; Steinmo & Rasmussen, 2018; Sa'a & Asplund, 2025).

Instead, as indicated by the second-order themes, maturity operates through continuity, accumulated relationships, and the organizational embedding of boundary activities over time. In the present data, the proportional configuration of social capital dimensions remains comparable across contexts, while long-term dynamics are better explained by regional particularities, path dependence, and the institutionalization of legal frameworks. The following subsections examine each second-order theme in greater detail.

4.4.1. Regional particularities

Although no systematic differences were identified in the appropriation of social capital dimensions across national contexts, the interviews indicate that ecosystem and BU maturity is more decisive at the micro level than country context per se. Local configurations and organizational trajectories shape how social capital is mobilized more strongly than whether BU operate across national contexts.

Evidence from Italian context shows that low-maturity environments may persist despite favorable national frameworks. As noted by an interviewee from an innovation agency, *“the center here is not yet launched; it’s something we are working on now”* (Interview 1 – Innovation Agency – Italy), indicating that national-level sophistication does not automatically translate into consolidated local arrangements. Conversely, highly mature environments can also be found within Brazil. One interviewee emphasized that the agency already operates with a consolidated partner portfolio and that *“for the entry of a new partner, it has to be something strategic for the agency”* (Interview 5 – Innovation Agency – Brazil). In large and heterogeneous countries, multiple local realities coexist within the same national system: while some universities must *“organize a queue”* due to high firm demand, others are still *“carving out a perception of a reality that does not yet exist,”* struggling to justify professionalization and dedicated teams (Interview 7 – University Interface – Brazil).

The interviews further suggest that universities can act as regional innovation catalysts, particularly in less mature ecosystems. A professor noted that the university’s arrival *“gave a*

boost to this movement of changing the economic matrix” (Interview 14 – Professor – Brazil), while an incubator manager highlighted the role of *“implanting an innovation culture”* in contexts where such practices were previously absent (Interview 15 – Incubator – Brazil).

4.4.2 Path dependence and the need for continuity

Across both national contexts, the interviews strongly emphasize that BU require time and continuity to become sustainable, reflecting a clear pattern of path dependence. As noted by a tech park manager in Brazil, such initiatives are *“20-year, 30-year enterprises”* and expectations of short-term results are fundamentally misaligned with their nature (Interview 2 – Tech Park – Brazil). Similarly, a TTO respondent described the process as *“a slow, painful, ant-like job”*, where results gradually accumulate through persistent effort (Interview 3 – TTO – Brazil).

Time is also essential for the development and consolidation of social capital. Interviewees from Italian contexts highlighted that building relationships with researchers and firms involves long-term trust formation, human affinity and accumulated experience (Interviews 1 – Incubator – Italy). Trust was repeatedly identified as a time-dependent asset. As highlighted by an incubator respondent in Italy, *“it takes time because you are building trust... you’re working on human affinity”* (Interview 1 – Incubator – Italy). Similar arguments emerged from other Italian respondents, who stressed the importance of permanent networks (Interview 2 – Tech Park – Italy).

Despite these gradual advances, interviewees also pointed to persistent difficulties in converting intermediate outputs into final TT outcomes. A TTO manager in Brazilian context expressed frustration with the limited effectiveness of transfer itself, noting that while protection mechanisms are functioning, *“in the transfer part, we are still struggling... we want it to reach outside the university”* (Interview 14 – TTO – Brazil). This highlights the challenge of translating accumulated social capital and early-stage outputs into concrete downstream impact.

4.4.3 The capacity of laws to foster or constrain boundary unit activities

The interviews indicate that regulatory and legal frameworks play a central role in shaping the operation and strategic orientation of BU, influencing access to resources, organizational practices and the formal legitimacy of university–industry interactions.

In Italian contexts, legal changes were described as highly impactful. An incubator manager characterized the introduction of a specific legal status for innovative startups and certified incubators as *“a game changer”*, as it enabled access to dedicated funding lines and

restructured the innovation support landscape (Interview 1 – Incubator – Italy). At the same time, legal frameworks can also constrain BU autonomy. A TTO respondent noted that recent legislation requiring all professors to contact the TTO reduced proactive scouting activities, making “*that part of scouting... less important than in the past*” and shifting the office toward a more centralized and reactive role (Interview 7 – TTO – Italy).

In Brazilian contexts, respondents emphasized both the potential and the limitations of regulatory environments. An interviewee questioned the absence of political debate around strengthening TTO, noting that such issues rarely appear in congressional discussions on innovation (Interview 10 – Foundation – Brazil). Across Brazilian cases, interviewees converged on the need for stable and long-term public policies. A technology park manager emphasized the importance of “*continuous support policies, especially for incubators*” (Interview 12 – Tech Park – Brazil), while TTO respondents argued that innovation policy should be treated as a state-level commitment to capacity building, rather than relying on short-term governmental agendas (Interview 20 – TTO – Brazil).

5. Discussion

Building on the empirical findings presented in the previous section, this discussion advances an integrative interpretation of the results and positions them within broader theoretical and practical debates on university BU. Drawing on the inductive logic of the Gioia methodology, the first subsection consolidates a coherent conceptual model. The second subsection then articulates the study’s theoretical contributions, clarifying how the findings refine existing understandings of organizational embeddedness, social capital mobilization, and ecosystem maturity in university–industry engagement. Finally, the third subsection discusses managerial and policy implications, translating the conceptual insights into actionable considerations for university leaders and policymakers. Together, these sections move from empirically grounded model building to theoretical advancement and practical relevance, ensuring analytical continuity between the results and their broader implications.

5.1 A Conceptual Framework of Boundary Unit Dynamics

Building on the micro-level analysis and Gioia methodology, this study advances a conceptual framework that integrates BU roles, configurations of social capital, and contextual conditions shaping university–industry interaction. Rather than relying on national-level categorizations, the framework synthesizes the empirical findings by positioning BU dynamics along two analytical dimensions: organizational embeddedness and ecosystem maturity. This approach captures how BU’ activities are structured at the intersection of internal university

arrangements and external innovation environments, and how these arrangements evolve as ecosystems consolidate over time. The framework responds directly to an important insight emerging from the interviews: although cognitive and relational social capital are mobilized through broadly similar micro-level practices across countries, the conditions under which these mechanisms stabilize, scale, and translate into sustained outcomes differ markedly.

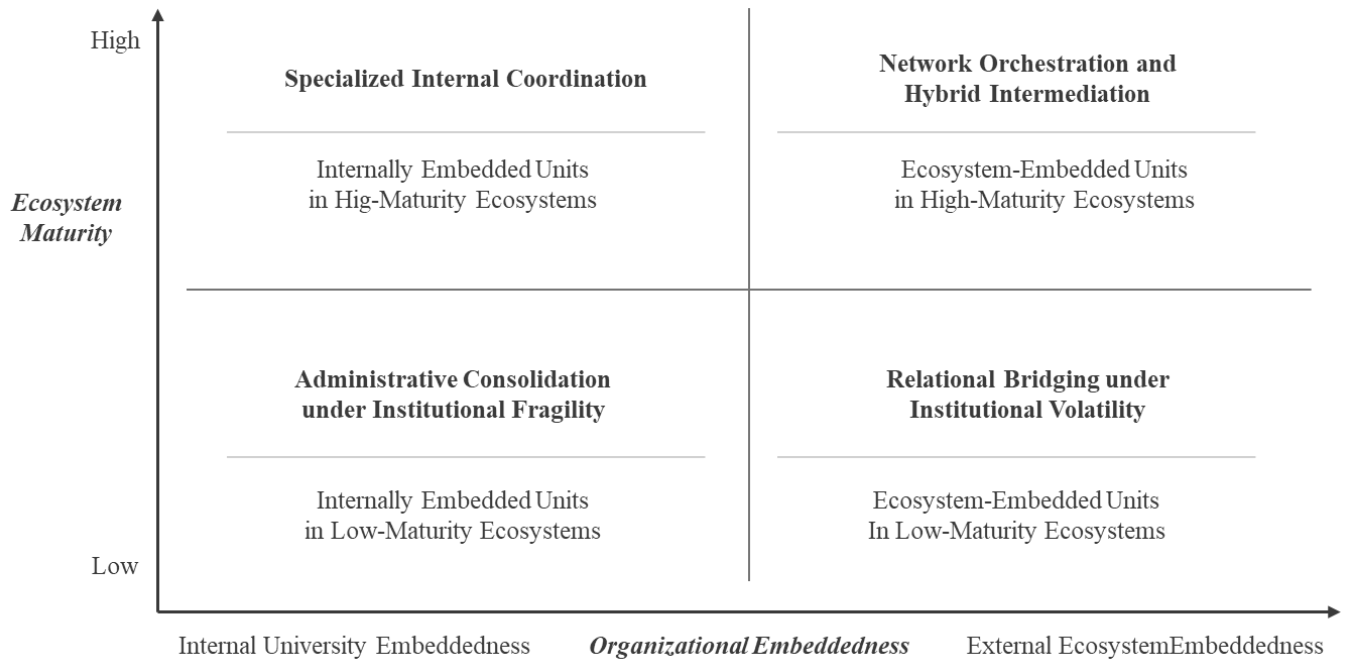
The first dimension, organizational embeddedness, refers to the degree to which BU are structurally and operationally integrated within the university or embedded in external innovation ecosystems. At one end of this continuum, internally embedded units, most notably TTO, are closely aligned with university governance, administrative routines, and legal frameworks. These units primarily perform internal interface roles, such as intellectual property management, compliance, and coordination with academic actors, relying heavily on cognitive social capital in the form of shared language, procedural alignment, and formal legitimacy. At the opposite end, BU are more strongly embedded in markets, networks, and inter-organizational arrangements. Incubators, science and technology parks, industry liaison offices, and hybrid intermediary organizations exemplify this positioning, emphasizing mediatory and external interface roles that depend more intensively on relational social capital, including trust, reputation, and sustained interpersonal ties.

Importantly, organizational embeddedness is conceptualized as a relational and dynamic attribute, rather than a binary condition. The empirical evidence indicates that universities increasingly operate through distributed boundary systems, in which different units occupy complementary positions along this continuum while remaining interdependent. This finding underscores that BU' effectiveness emerges not from a single organizational form, but from coordinated arrangements across multiple BU.

The second dimension, ecosystem maturity, captures the extent to which regional innovation systems have accumulated stable organizations, experienced actors, funding mechanisms, and shared expectations regarding university–industry collaboration. High-maturity ecosystems are characterized by dense and enduring networks, diversified funding sources, professionalized intermediary roles, and longer trajectories of interaction. In contrast, low-maturity ecosystems exhibit fragmented structures, high turnover, dependence on short-term funding, and limited institutionalization of BU' practices. Crucially, ecosystem maturity is treated as a micro- and meso-level condition, rather than a purely national attribute. The interviews reveal that highly consolidated and weakly structured environments coexist within both countries, reinforcing the analytical relevance of this dimension beyond country-level

distinctions. Figure 11 summarizes the proposed framework by positioning BU configurations along the dimensions of organizational embeddedness and ecosystem maturity.

Figure 11 - Conceptual framework based on organizational embeddedness and ecosystem maturity.



Source: Prepared by author.

Together, these two dimensions generate a four-quadrant framework that captures distinct but non-exclusive configurations of BU activity. Internally embedded units operating in low-maturity ecosystems tend to prioritize administrative consolidation and compliance-oriented tasks, stabilizing internal processes but struggling to generate sustained transfer outcomes due to weak external relational ties. In high-maturity ecosystems, internally embedded units benefit from organizational support and professionalization, enabling specialized internal coordination within broader, well-articulated boundary systems. Conversely, ecosystem-embedded units in low-maturity environments rely heavily on relational social capital and individual agency to bridge organizational gaps, sustaining interaction under volatile conditions but facing difficulties in consolidating cognitive social capital and long-term routines. Finally, ecosystem-embedded units operating in high-maturity contexts function as network orchestrators, combining dense relational ties with codified cognitive frameworks that support scalability, coordination, and sustainability.

From a theoretical perspective, the framework clarifies why similar social capital mechanisms at the micro level produce heterogeneous outcomes across contexts. While relational and cognitive social capital are consistently mobilized in BU work, their relative roles depend on the organizational positioning of BU and the maturity of ecosystem. Relational social

capital plays a particularly critical enabling role in early or volatile contexts, especially for ecosystem-embedded units. Over time, however, the consolidation and scaling of boundary activities increasingly depend on cognitive social capital, which supports coordination, reduces uncertainty, and limits reliance on ad hoc interpersonal solutions. This temporal dynamic helps explain why cognitive challenges persist even in settings characterized by strong interpersonal relationships.

The analysis indicates that path dependence and accumulated experience play an important role in shaping BU dynamics. More mature contexts benefit from longer trajectories of interaction, which facilitate the gradual consolidation of common interpretative schemes and standardized coordination mechanisms. In contrast, less mature environments rely more heavily on adaptive and experience-based learning, where continuity depends on the repeated enactment of practices rather than on institutionalized routines. This temporal dimension highlights the importance of adopting a long-term perspective on social capital formation. Social capital does not emerge instantaneously, nor does it operate independently of time. Instead, it develops through sustained interaction, iterative coordination, and the gradual alignment of expectations

5.2 Theoretical Contributions

This study advances theoretical understanding of university BU by integrating a process-oriented, micro-level perspective with a comparative and context-sensitive analytical framework. Building on the empirical findings and the conceptual model developed in Section 5.1, the contributions unfold across four interrelated domains: TT literature, BU research, social capital theory in university-industry collaboration, and comparative organizational analysis.

First, the study contributes to the TT literature by shifting analytical attention from outcome-oriented explanations toward the micro-level processes through which BU enact and coordinate their roles. While prior research has predominantly emphasized determinants of TT performance, such as organizational design, institutional environment, and strategic orientation (e.g., Siegel et al., 2004; Guerrero & Menter, 2024), the present findings clarify how these conditions are operationalized in practice.

Second, the study refines theoretical understandings of BU by conceptualizing organizational embeddedness as a relational and continuous dimension rather than a categorical distinction between types of units. Existing literature often treats TTOs, incubators, science parks, and other intermediaries as discrete organizational forms (Good et al., 2019; Cunningham et al., 2022). The present findings suggest instead that BU occupy positions along

a continuum of embeddedness, ranging from internal administrative integration to ecosystem-oriented positioning, and that their role emphasis varies accordingly. Mechanistically, the findings show that complementarities across units reduce role overload and coordination gaps: internally embedded units stabilize compliance and internal alignment, while ecosystem-embedded units sustain external engagement and network orchestration, attending the call of Good et al. (2019) to understand better the complementarities of those BU.

Third, the study contributes to social capital theory in the context of university-industry collaboration by specifying how different dimensions of social capital, structural, relational, and cognitive (Nahapiet & Ghoshal, 1998), are mobilized across BU roles and under varying contextual conditions. Prior research has established the relevance of social capital for TT (Steinmo & Rasmussen, 2018; Sa'a & Asplund, 2025; Iturrioz et al., 2015), yet has offered limited differentiation regarding how these dimensions operate across specific BU roles. The findings demonstrate that internal interface roles rely more intensively on cognitive social capital to manage internal heterogeneity and formal legitimacy, whereas mediatory and external roles depend more strongly on relational social capital to sustain engagement across heterogeneous actors. At the same time, the co-occurrence analysis reveals that challenges across roles are predominantly associated with cognitive misalignment, suggesting that cognitive social capital plays a stabilizing and scaling function over time. Importantly, the study also advances existing debates regarding the relationship between social capital and ecosystem maturity. Contrary to strands of literature that associate national context to the dynamics of BU (Sandström et al., 2018; Grzegorzczuk, 2019), the comparative evidence indicates that the proportional composition of social capital dimensions remains broadly similar across contexts.

Fourth, the study contributes to comparative analysis by demonstrating that national context alone does not sufficiently explain variation in BU dynamics. Although Brazil and Italy are commonly positioned within different context categories, the empirical results show substantial convergence in micro-level practices and social capital configurations. Variation emerges more clearly when considering ecosystem maturity and organizational embeddedness. By distinguishing national context from ecosystem maturity as analytically separate dimensions, the study refines comparative approaches to university-industry engagement and responds to calls for more nuanced, context-sensitive analyses (Grzegorzczuk, 2019; Good et al., 2019). This distinction allows for the coexistence of high- and low-maturity configurations within the same country, thereby avoiding deterministic interpretations of organizational environments.

Across the four domains, the theoretical “delta” is that organizational embeddedness and ecosystem maturity operate as structuring conditions that shift which form of social capital is decisive (relational for initiating/bridging; cognitive for scaling/institutionalizing), thereby explaining heterogeneity in TT outcomes without resorting to country-level determinism. Taken together, these contributions advance a more integrated theoretical understanding of BU dynamics. The study positions organizational embeddedness and ecosystem maturity as structuring conditions that shape how social capital is mobilized across internal, mediatory, and external interface roles. By connecting micro-level enactment, multidimensional social capital, and contextual evolution, the analysis provides a process-based and relational account of TT that complements and extends existing outcome-centered explanations.

5.3. Managerial propositions

The conceptual framework proposed in Section 5.1 offers a diagnostic and strategic tool for managers and policymakers by positioning BU configurations along two analytical dimensions: organizational embeddedness and ecosystem maturity.

From a managerial perspective, the framework enables university leaders to identify where their BU are situated within the 2x2 matrix and to assess whether their current configuration is coherent with ecosystem conditions and organizational ambitions. For example, internally embedded units operating in low-maturity ecosystems tend to prioritize compliance-oriented and administrative routines, often associated with TTO. In such settings, managers should recognize that incremental improvements in procedural efficiency are unlikely to generate substantial increases in transfer outcomes unless accompanied by deliberate investments in relational social capital and external network building. Strategic actions may include establishing formal partnerships with incubators and science parks, creating liaison roles dedicated to industry engagement, and incentivizing staff participation in regional innovation networks.

Conversely, for ecosystem-embedded units operating in low-maturity contexts, the findings suggest that reliance on interpersonal trust and informal networks, while essential, is insufficient for long-term consolidation. Managers should prioritize the institutionalization of routines and the gradual codification of practices to strengthen cognitive social capital. This may involve formalizing partnership procedures, developing standardized evaluation criteria for collaborative projects, investing in training programs for BU professionals. The empirical evidence on operational fragility and high staff turnover indicates that human resource

stabilization is not merely an administrative concern but a structural condition for sustaining both relational and cognitive social capital over time.

For organizations operating in high-maturity ecosystems, the framework encourages a more differentiated strategic orientation. Internally embedded units can specialize in high-level intellectual property governance and internal coordination, while ecosystem-embedded units may assume orchestrating roles, leveraging dense relational networks and codified interaction mechanisms. The managerial challenge in such contexts is less about initiating connections and more about coordinating distributed boundary systems to avoid duplication, mission drift, or fragmented engagement strategies.

5.4. Policy Implications

At the policy level, the framework shifts attention from short-term output metrics (e.g., number of patents or licenses) to systemic capacity building. Policymakers seeking to strengthen university-industry collaboration should tailor interventions according to ecosystem maturity rather than assuming uniform national solutions. In low-maturity ecosystems, policies should prioritize continuity and stability. Multi-year funding schemes, professionalization of intermediary roles, and legal frameworks that clearly define BU mandates can foster cumulative social capital formation. Importantly, legal reforms alone are insufficient if not institutionally embedded within university governance structures. Regulatory changes must be accompanied by implementation support, training, and monitoring mechanisms that ensure alignment between formal mandates and operational practices.

In more mature ecosystems, policy priorities may shift toward scaling and coordination. Support mechanisms can focus on enhancing interoperability among BU, promoting shared digital infrastructures for partnership management, and encouraging cross-regional or international collaboration. Here, the objective is not simply to generate more interactions but to increase the quality and sustainability of existing networks, reinforcing cognitive alignment across heterogeneous actors.

Across all quadrants, the results highlight a critical insight: mobilizing between quadrants is a gradual and path-dependent process. Movement from low to high ecosystem maturity cannot be engineered through isolated projects; it requires sustained interaction cycles, stable funding, and long-term relational accumulation. Similarly, shifting along the organizational embeddedness dimension entails strategic decisions about governance models, autonomy levels, and complementarities strategies. Policymakers can facilitate such transitions

by creating hybrid organizational formats, incentivizing inter-organizational collaboration, and supporting experimentation with alternative boundary arrangements.

Finally, the findings underscore the importance of balancing relational and cognitive social capital. In volatile or emerging contexts, relational ties often compensate for institutional weaknesses, but overreliance on interpersonal trust may limit scalability and resilience. Strengthening cognitive social capital through shared language, professional standards, and institutionalized routines enhances coordination capacity and reduces dependence on individual agency. Therefore, managerial and policy interventions should not treat social capital as an abstract resource but as a strategically cultivated asset requiring investment in people, processes, and organizational continuity.

By reframing BU effectiveness as a function of organizational embeddedness and ecosystem maturity, this study provides university leaders and policymakers with an analytically grounded framework to diagnose structural constraints, design targeted interventions, and support the long-term consolidation of TT systems.

6. Conclusion

This study examines how university BU enact and coordinate internal, mediatory, and external interface roles across the TT process through configurations of structural, relational, and cognitive social capital in Brazil and Italy. Key takeaway: BU activate similar micro-level social capital mechanisms across settings, yet their effectiveness depends on how they are positioned within the university and on the maturity of the surrounding innovation ecosystem.

The findings suggest that, although similar social capital mechanisms are mobilized across contexts, variation in BU dynamics is better accounted for by organizational embeddedness and ecosystem maturity than by national context alone. Organizational embeddedness influences the relative emphasis placed on internal coordination or ecosystem-oriented engagement, while ecosystem maturity shapes the degree to which boundary-spanning practices become stabilized, institutionalized, and scalable over time. Together, these two structuring conditions clarify why comparable boundary work can produce different levels of continuity and consolidation.

The study further highlights the complementary nature of BU within universities. Rather than operating as isolated intermediaries, BU often function as interconnected arrangements in which differentiated internal, mediatory, and external interface roles are coordinated. Recognizing and managing such complementarities appears as an important condition for strengthening TT processes. Moreover, the prominence of cognitive social capital in reported

challenges indicates that interpretative alignment, shared language, and institutionalized routines are pivotal mechanisms for reducing coordination frictions and enabling the stabilization and scaling of boundary-spanning practices over time.

By integrating micro-level processes, multidimensional social capital, and contextual conditions, the proposed framework advances a more process-sensitive account of TT. Specifically, it (i) decouples national context from ecosystem maturity as an explanatory condition, (ii) theorizes how embeddedness shifts role emphasis while maturity conditions stabilization and institutionalization, and (iii) reconceptualizes BU as distributed and complementary systems rather than stand-alone intermediaries. It clarifies how boundary-spanning effectiveness emerges from the interplay between organizational positioning and ecosystem development, providing a grounded basis for future empirical refinement and testing.

As with any qualitative and comparative study, certain limitations must be acknowledged. The analysis focuses on two national contexts and relies on interview-based evidence, which, while rich in processual insight, does not aim at statistical generalization. Future research could (i) broaden the comparative scope to refine boundary conditions of the framework, (ii) incorporate longitudinal designs to trace how relational and cognitive mechanisms evolve as ecosystems mature, and (iii) adopt mixed-method approaches to examine whether embeddedness and maturity systematically shape role coordination and TT trajectories.

Despite these limitations, the study advances understanding of how BU translate organizational and contextual conditions into TT activities. By reframing BU effectiveness as a function of relational positioning, social capital mobilization, and ecosystem evolution, the findings contribute to a more process-sensitive and context-aware perspective on university-industry engagement and its long-term consolidation. Ultimately, BU effectiveness is not a fixed organizational attribute but a process outcome shaped by relational positioning, social capital mobilization, and ecosystem evolution.

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Final Conclusions

This thesis sets out to examine how university BU influence the dynamics of TT across different contextual and regional settings. Overall, the thesis shows that BU effectiveness is explained less by national context per se than by how ecosystem maturity and organizational embeddedness enable role coordination and social-capital accumulation over time. Responding to calls in the literature for more integrated analyses of TT, the study adopted a three-paper design combining configurative mapping, quantitative performance analysis, and comparative qualitative examination to capture the contextual, organizational, and relational dimensions shaping the operation of BU. By structuring the thesis as a collection of three interrelated papers, the research provides a cumulative and coherent explanation of how BU operate, adapt, and generate outcomes within heterogeneous innovation ecosystems. This three-paper design strengthens inference by combining configurative mapping, stage-specific performance testing, and comparative mechanism tracing.

Rather than treating BU as isolated organizational entities or assuming that performance can be explained solely through structural design or managerial attributes, the findings collectively indicate that BU effectiveness is relational and configurational. It is shaped by the balance among internal interface, mediatory, and external interface roles; by the degree of organizational embeddedness; and by the maturity of the innovation ecosystem.

The first article demonstrates that contextual environments shape the structural conditions under which BU emerge and operate. The configurative literature review highlights contrast between developed and emerging economies in terms of regulatory stability, availability of intermediary support organizations, and the overall maturity of innovation ecosystems, among other factors. In developed contexts, BU tend to operate within more consolidated regulatory and support frameworks, which can enable greater specialization and proactive engagement in networking and foresight activities. In contrast, BU in emerging economies frequently operate under conditions marked by gaps in support structures, structural limitations, and limited organizational support, which constrain their strategic scope and reinforce a focus on internal interface activities and basic TT functions. This evidence specifies contextual conditions that affect whether BU can move from basic interface work to coordinated role specialization and sustained external engagement.

At the same time, the the first article cautions against one-size-fits-all approaches and the uncritical transplantation of models from developed contexts into emerging economies. The evidence suggests that differences in development trajectories, governance arrangements, and

cultural norms shape how BU are configured and how their roles are prioritized. As such, the effectiveness of BU is influenced not only by internal attributes, but also by broader structural and cultural conditions underpinning TT processes. Accordingly, the thesis advances theoretical generalization about coordination and embedding mechanisms, while treating specific governance arrangements, development trajectories, and cultural norms as context-defining boundary conditions.

Beyond identifying contextual contrasts, the first article also develops a structured categorization of BU roles, distinguishing among internal interface, mediatory, and external interface functions. This role-based configuration provides an analytical lens for understanding how BU allocate effort across internal coordination and external engagement with stakeholders. By clarifying these differentiated roles, the study establishes a conceptual foundation that allows BU' activities to be examined not only in structural terms, but also in terms of functional orientation.

Building on this contextual and role-based foundation, the second article advances an quantitative analysis by examining how the strategic orientation of TTO relates to early-stage and late-stage outcomes of the TT process in an emerging-economy setting. In this study, role orientation is operationalized primarily through internal interface and external interface emphases; mediatory functions are not directly estimated as a separate quantitative construct and are addressed more explicitly in the qualitative analysis developed in the third article. The findings show that TTOs predominantly oriented toward internal interface roles tend to be associated with stronger early-stage results (e.g., invention disclosures) yet display limitations in converting these outcomes into late-stage commercialization outcomes. This pattern is consistent with the persistence of document-driven and administratively focused models, which are particularly prevalent in resource-constrained and less consolidated environments. While the quantitative design does not directly observe coordination mechanisms, the stage-contingent pattern can be interpreted as consistent with contexts in which embeddedness and ecosystem maturity constrain the routinization and scaling of early-stage gains into late-stage commercialization.

Conversely, TTOs with a stronger emphasis on external interface roles exhibit superior performance in late-stage outcomes, highlighting the importance of active engagement with external stakeholders. Crucially, the quantitative evidence indicates that no single role emphasis is, on its own, sufficient to explain performance across stages. Rather, sustained outcomes appear to depend on how internal routines, external engagement capabilities, and broader

coordination arrangements jointly support continuity across the TT process. In this sense, the findings reinforce the argument that BU should not be evaluated in isolation, as their performance reflects broader organizational capabilities, network integration, and strategic orientation.

While the first two articles emphasize contextual and organizational differences across and within countries, the third article introduces critical refinement by shifting attention to the everyday BU' practices. Contrary to expectations of sharp divergence between Italy and Brazil, the qualitative comparative analysis reveals substantial convergence in how BU operationalize their roles at the level of individual actors and daily interactions. Across both contexts, BU work relies on similar relational and cognitive mechanisms aimed at reducing uncertainty, coordinating expectations, and sustaining interaction across organizational boundaries. This convergence raises a central integrative question for the thesis: if everyday practices are broadly comparable across contexts, why do TT outcomes remain uneven?

These finding challenges dichotomous interpretations that attribute TT effectiveness primarily to national context. Instead, the analysis suggests that recurring coordination demands generate similar micro-level boundary-spanning logics across settings. Differences between national contexts become more visible in how these micro-level practices are embedded, accumulated, and reinforced over time. In this sense, ecosystem maturity and organizational embeddedness emerge as central explanatory factors shaping whether every day practices consolidate into durable routines.

At the same time, this does not imply that national context is irrelevant. Rather, its influence becomes more salient in relation to broader structural conditions, such as regulatory frameworks, alternative organizational forms, funding models, and governance arrangements, which shape the opportunities, constraints, and trajectories of BU. In this sense, ecosystem maturity and organizational embeddedness operate as linking constructs that connect role enactment, organizational configuration, and broader contextual conditions.

The third article further highlights the temporal dimension of BU dynamics. While relational practices are broadly similar, more mature ecosystems benefit from longer trajectories of interaction that allow individual practices to crystallize into shared routines, interpretative frameworks, and standardized coordination mechanisms. In less mature environments, BU rely more heavily on adaptive, experience-based learning, where continuity depends on repeated enactment by individuals rather than on formalized structures. As a result, social capital accumulation is more fragile and more dependent on personal trajectories. This temporal lens

helps explain why similar relational practices can yield different levels of routinization, scalability, and resilience in TT performance.

Importantly, the qualitative analysis indicates that persistent challenges faced by BU are often associated less with limitations in relational social capital and more with constraints in cognitive social capital. While trust and interpersonal relationships can compensate for organizational gaps in the short to medium term, the sustainability and scalability of TT activities increasingly depend on the development of shared cognitive frameworks, including common language, aligned expectations, and clear role interpretations. Accordingly, cognitive alignment becomes a key lever through which governance and management may reduce fragmentation without relying solely on interpersonal trust.

Taken together, the three articles support the central argument of this thesis: the effectiveness of university BU in TT is not reducible to structural design, national context, or individual agency alone, but emerges from interactions among contextual conditions, organizational role configuration, and everyday BU practices over time. The first article shows how contextual environments shape the structural opportunities and constraints within which BU operate; the second demonstrates how the balance and configuration of internal and external interface emphases shape how these units translate potential into measurable outcomes; and the third shows that everyday boundary-spanning practices are largely comparable across national contexts, while their cumulative impact depends critically on organizational embeddedness and ecosystem maturity. In this sense, BU function as integrative nodes within innovation ecosystems, whose effectiveness derives from their capacity to connect contextual conditions, organizational strategy, and relational dynamics into a coherent and evolving configuration.

By adopting an integrated perspective across three complementary studies, the thesis moves beyond fragmented and atomistic approaches that analyze BU as isolated organizational entities. Instead, it shows that overlaps among BU roles and activities can reflect complementarities rather than redundancy. Effective TT emerges from the coordinated interplay of internal interface, mediatory, and external interface roles, supported by the cumulative development of social capital and reinforced through organizational embeddedness and ecosystem maturity. This implies a governance shift: performance appears to depend on strategic coordination across BU rather than on the presence, form, or presumed “best practice” of any single intermediary.

Building on this integrated perspective, the thesis advances a set of theoretical contributions to the literature on TT and university BU. It develops a relational and

configurational framework in which contextual conditions, organizational role orientation, and micro-level enactment are analytically connected rather than treated as independent explanatory domains. By clarifying how organizational embeddedness and ecosystem maturity structure the mobilization of social capital across roles and over time, the study offers a process-based account of BU dynamics that complements and extends outcome-centered and structurally deterministic explanations.

First, the thesis refines comparative perspectives by distinguishing national context from ecosystem maturity. While prior research often associates TT dynamics with broad country-level categories, the findings indicate that national context alone does not sufficiently explain variation in BU practices or outcomes. By analytically separating broader structural conditions from the developmental stage of the innovation ecosystem, the thesis enables a more nuanced understanding of how similar practices can operate under different structural configurations.. This distinction avoids deterministic interpretations of national contexts and allows for the coexistence of heterogeneous maturity configurations within the same country.

Second, the thesis extends role-based analyses of TTO and other BU by demonstrating that performance can be configurational rather than structural. It is not merely the presence of a TTO, nor its formal organizational type, that influences TT outcomes, but the balance and coordination among internal interface and external interface roles. By linking role orientation to different stages of the TT process, the study advances capacity-building discussions and clarifies how strategic emphasis shapes early- and late-stage outcomes. In doing so, it moves beyond administratively centered models and highlights the strategic orientation of BU work.

Third, the thesis shifts analytical attention from outcome-centered explanations toward the processes through which BU enact and coordinate their roles in everyday practice. By conceptualizing organizational embeddedness, the study challenges categorical distinctions among intermediaries and introduces the notion of distributed and complementary boundary systems. TT effectiveness is shown to emerge from coordinated plural arrangements rather than from isolated intermediary performance. Furthermore, by specifying how structural, relational, and cognitive social capital are mobilized across different boundary roles, the thesis refines social capital theory in the context of university–industry collaboration. The findings indicate that cognitive social capital plays a stabilizing and scaling function over time, particularly in environments where shared routines and coordination mechanisms remains incomplete.

Taken together, these contributions advance a process-based, relational, and configurational theory of BU dynamics. Organizational embeddedness and ecosystem maturity

are positioned as structuring conditions that mediate how social capital is mobilized and how BU's practices accumulate, stabilize, and generate outcomes. By integrating evidence from configurative review, quantitative analysis, and qualitative comparison, the thesis complements and extends existing literature that has predominantly emphasized structural determinants or performance metrics. The resulting framework provides a more comprehensive account of how TT evolves across diverse contextual and regional contexts.

Building on its theoretical advances, the thesis also offers a set of integrated practical contributions for university leaders, BU managers, and policymakers engaged in strengthening TT systems. Rather than proposing universal best practices, the findings emphasize context-sensitive and configuration-oriented decision-making grounded in ecosystem maturity and organizational embeddedness.

First, the research supports policymakers in moving beyond uniform national policy prescriptions. The comparative evidence indicates that interventions should be calibrated according to ecosystem maturity rather than solely to country classification. In low-maturity ecosystems, priority should be given to stability, continuity, and cumulative capacity building through multi-year funding schemes, professionalization of intermediary roles, and governance arrangements that formally embed boundary functions within university structures. In more mature ecosystems, policy efforts may shift toward coordination, interoperability, and scaling, fostering alignment among distributed BU and enhancing the quality and sustainability of existing networks rather than merely increasing output indicators. Evaluation and funding instruments should therefore reward complementary roles and cognitive alignment, not merely the formal creation of new units.

Second, the findings provide diagnostic guidance for university administrators and BU managers. The thesis demonstrates that TT performance depends not only on the presence of a BU, but on the balance among internal interface and external interface roles. Administrators are therefore encouraged to reassess documentation-driven and compliance-oriented models and to evaluate whether current role configurations are coherent with organizational ambitions and ecosystem conditions. The framework suggests that internally embedded units in low-maturity contexts may require deliberate investment in external engagement capabilities, while ecosystem-oriented units must prioritize the formalization of routines to avoid overreliance on interpersonal networks. Strategic decisions concerning governance models, autonomy levels, staff professionalization, and complementarities across BU emerge as central levers for strengthening performance.

Third, the thesis underscores that effective TT requires sustained investment in both relational and cognitive social capital. While relational ties can compensate for contextual fragilities in the short term, long-term consolidation depends on the development of shared language, standardized procedures, and stable coordination mechanisms. Managers should therefore treat social capital not as an incidental by-product of interaction, but as a strategically cultivated resource supported by training, human resource stabilization, formalized partnership processes, and continuity in BU roles.

Across the thesis, a central practical insight emerges. Transitions toward more effective configurations are gradual and path dependent. Shifts in ecosystem maturity or organizational embeddedness cannot be achieved through isolated initiatives or short-term projects. Instead, they require sustained interaction cycles, long-term commitment, and alignment between regulatory reforms, governance structures, and everyday operational practices. By positioning BU effectiveness within a two-dimensional framework of organizational embeddedness and ecosystem maturity, the thesis provides decision-makers with a structured tool to diagnose structural constraints, design targeted interventions, and support the long-term consolidation of university–industry collaboration systems.

While this thesis advances an integrated and configurational understanding of BU dynamics in TT, several limitations delimit the scope of its conclusions and open avenues for further investigation.

First, although the comparative design strengthens analytical depth, the empirical focus on two national contexts necessarily constrains generalizability. Brazil and Italy provide meaningful contrast in development trajectories and ecosystem maturity, yet they do not capture the full diversity of university–industry systems across regions such as North America, Asia, or other parts of Europe and Latin America. Future research could extend the comparative framework to a broader set of countries, particularly those representing hybrid or transitional configurations. Expanding the geographical scope would allow for more systematic testing of the analytical distinction between national context and ecosystem maturity.

Second, the thesis places strong emphasis on BU as focal organizational actors within universities. Although the analysis recognizes distributed and complementary boundary systems, it does not fully capture the perspectives of external industry partners, investors, or regional development agencies as primary units of analysis. Future research could incorporate multi-actor designs to examine how ecosystem maturity is co-constructed across organizational boundaries and how perceptions of embeddedness vary among stakeholders.

Third, the temporal dimension identified in the third article suggests that TT consolidation is gradual and path dependent. However, the empirical design does not fully trace long-term evolutionary trajectories of BU. Longitudinal case studies or panel-based analyses could provide deeper insight into how boundary configurations evolve, how cognitive social capital stabilizes over time, and under which conditions shift across quadrants in the organizational embeddedness–ecosystem maturity matrix become feasible.

Finally, although the thesis integrates evidence from three complementary analytical approaches, future research could further formalize the dynamic interactions among these different perspectives. Simulation models or configurational methods, such as fsQCA applied across countries and ecosystem stages, may help identify multiple equifinal paths toward effective TT. Such approaches could refine the configurational logic proposed here and test its robustness across diverse settings. Taken together, these avenues suggest that BU dynamics remain a fertile area for multi-method, longitudinal, and cross-regional research.

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APPENDIX A

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INTERVIEW PROTOCOL

Research Project: Boundary functions in universities: characterization and influence on the third mission's results

Principal Researcher: Breno Valente Fontes Araújo

Advisor: Prof Ana Claudia Azevedo (UFV)

Co advisor: Adriana Ferreira de Faria (UFV)

Co advisor (Italy): Canio Forlano (UNITO)

The main objective is to understand, from different perspectives and considering the transfer of knowledge from the university to the private sector, how universities perform their boundary functions and the importance given to each.

To this end, we intend to talk to individuals in pivotal strategic and operational positions in university bodies, and researchers who have played key roles in the process of technology development and transfer. Their insights are crucial in understanding and improving the knowledge transfer process.

INTERVIEW PROTOCOL

Personal information:

Name:

Gender:

Age:

Position:

Time of service:

Academic background:

Other information:

Institution information:

Name:

Time since foundation:

Type of institution:

Other information:

Internal body where the interviewee works:

Name:

How long the interviewee has been in this position:

Activities performed:

Other bodies with which the interviewee interacts:

Other information:

Questionnaire for members of the knowledge transfer office

Analysis dimension: Internal interface functions

1. On the process of mapping competencies and technologies developed:
 - a. How are the university's competencies and capabilities mapped?
 - b. How is the mapping of developed technologies carried out?
 - c. Is this done systemically?
 - d. What are the main challenges of this activity?
 - e. Do you have any suggestions for improving this process?
2. On the process of interacting with researchers:
 - a. How do you contact researchers at the institution?
 - b. How often is this contact made?
 - c. Is there a systemic process for this contact?
 - d. Are there specific events or projects related to this?
 - e. What are the main challenges of interacting with researchers?
 - f. Do you have any suggestions for improving this process?
3. On the operationalization of intellectual capital protection:
 - a. What is the flow of formalizing the invention analysis request?
 - b. Do you participate in operationalizing the protection of the university's intellectual capital?
 - c. What are the responsibilities of each person involved?
 - d. Is this process systematized?
 - e. What are the main challenges of IP prospecting?
 - f. Do you have any suggestions for improving this process?

Analysis dimension: External interface functions

1. Prospecting for private sector partners
 - a. How is a survey of potential private sector partners carried out?
 - b. How is the first approach made? Who is responsible?
 - c. Is this process systematized?
 - d. What are the main challenges in prospecting private sector partners?
 - e. Do you have any suggestions for improving this process?
2. On the university's institutional representation process outside the academic environment:
 - a. Are you responsible for representing the university at external events?
 - b. In these cases, are links created that generate future partnerships?
 - c. Give an example of your role in these events.
 - d. Do you have any suggestions for improving this process?
3. On the process of interaction with other external actors:
 - a. How does the interaction itself take place with actors outside the university?
 - b. How frequent are these interactions?
 - c. Give an example of how these interactions take place.
 - d. What are the main challenges of prospecting interaction with actors outside the university?

- e. Do you have any suggestions for improving this process?

Analysis dimension: Mediating functions

1. On participation in negotiation in the technology transfer process:
 - a. How involved are you in negotiating the TT process?
 - b. Are there any guidelines to follow?
 - c. Have you been trained for this? Is there support from other departments or intermediary institutions?
 - d. What are the main challenges of the negotiation process?
 - e. Do you have any suggestions for improving this process?
2. About the technology valuation process:
 - a. Do you participate in the technology valuation process? How is it conducted?
 - b. Are there guidelines to be followed?
 - c. Have you been trained? Is there support from other departments or intermediary institutions?
 - d. What are the main challenges of the valuation process?
 - e. Do you have any suggestions for improving this process?
3. On the process of operationalizing technology transfer:
 - a. Do you take part in the process of formalizing technology transfer? How is it conducted?
 - b. Have you been trained for this? Is there support from other departments or intermediary institutions?
 - c. What are the main challenges of the TT process?
 - d. Do you have any suggestions for improving this process?
4. On the process of monitoring and evaluating the results of transfers made:
 - a. Are there any actions to monitor and verify the results of projects with civil society?
 - b. How are these activities carried out?
 - c. What are the main challenges in this process?
 - d. Do you have any suggestions for improving this process?

Questionnaire for members of the incubator and technology park

Analysis dimension: Internal interface functions

1. On the process of mapping competencies and technologies developed:
 - a. How are the university's competencies and capabilities mapped?
 - b. How is the mapping of developed technologies carried out?
 - c. Is this done systemically?
 - d. What are the main challenges of this activity?
 - e. Do you have any suggestions for improving this process?
2. On the process of interacting with researchers:
 - a. How do you contact researchers at the institution?
 - b. How often is this contact made?
 - c. Is there a systemic process for this contact?
 - d. Are there specific events or projects related to this?
 - e. What are the main challenges of interacting with researchers?
 - f. Do you have any suggestions for improving this process?
3. On the process of supporting the transformation of a technology into a business:
 - a. How is the flow of formalizing an idea/technology analysis?
 - b. Are you involved in this analysis? What paths can researchers follow?
 - c. What are the responsibilities of each person involved?
 - d. Is this process systematized?
 - e. What are the main challenges of IP prospecting?
 - f. Do you have any suggestions for improving this process?

Analysis dimension: External interface functions

1. About prospecting for private sector partners:
 - a. How is a survey of potential private sector partners carried out?
 - b. How is the first approach made? Who is responsible?
 - c. Is this process systematized?
 - d. What are the main challenges in prospecting private sector partners?
 - e. Do you have any suggestions for improving this process?
2. On the university's institutional representation process outside the academic environment:
 - a. Are you responsible for representing the university at external events?
 - b. In these cases, are links created that generate future partnerships?
 - c. Give an example of your role in these events.
 - d. Do you have any suggestions for improving this process?
3. On the process of interaction with other external actors:
 - a. How does the interaction itself take place with actors outside the university?
 - b. How frequent are these interactions?
 - c. If possible, give an example of how these interactions take place.
 - d. What are the main challenges of prospecting interaction with actors outside the university?
 - e. Do you have any suggestions for improving this process?

Analysis dimension: Mediating functions

1. On business development support programs:
 - a. How involved are you in support programs for new business development?
 - b. Is there a scope and activities to be followed?
 - c. Have you been trained for this? Is there support from other departments or intermediary institutions?
 - d. What are the main challenges of this process?
 - e. Do you have any suggestions for improving this process?
2. About the advisory and mentoring process:
 - a. Do you participate in the advisory and mentoring process?
 - b. Are there guidelines to follow?
 - c. Have you been trained for this? Is there support from other departments or intermediary institutions?
 - d. What are the main challenges of the valuation process?
 - e. Do you have any suggestions for improving this process?
3. On the process of supporting the formalization of the business:
 - a. Do you participate in supporting the formalization of the business? How is it conducted?
 - b. Have you been trained for this? Is there support from other departments or intermediary institutions?
 - c. What are the main challenges of this process?
 - d. Do you have any suggestions for improving this process?
4. On the process of monitoring and evaluating the results of supported projects:
 - a. Are there any actions in place to monitor and verify the results of projects supported by the incubator?
 - b. How are these activities carried out?
 - c. What are the main challenges in this process?
 - d. Do you have any suggestions for improving this process?

Questionnaire for project team members who have been through a knowledge transfer mechanism

Analysis dimension: Internal interface functions

1. Were you contacted by someone within the university who identified potential in the developed technology, or did you need support?
2. Who was the first person or internal university department you contacted to start the technology transfer process?
3. How was this process conducted?
4. Which people/sectors of the university were involved in this dynamic? Briefly describe each person's role in the process.
5. What were the main challenges of this interaction with other internal teams?
6. Do you have any suggestions for improving this process?

Analysis dimension: External interface functions

1. Were you contacted directly by someone outside the university?
2. If so, what was this person's job title, and how was this contact made?
3. Did any internal university staff support your interaction with external agents?
4. How was this support provided?
5. What were the main challenges of this interaction with people outside the university?
6. Do you have any suggestions for improving this process?

Analysis dimension: Mediating functions

1. Throughout the technology transfer process, did you have the support of any internal university staff?
2. How was this support provided?
3. Did you participate in any specific university programs/actions to develop the idea/technology or for technology transfer?
4. Did you carry out any technology protection, valuation, and transfer activities without the support of other teams?
5. How was the process carried out?
6. What were the main challenges of these intermediate processes?
7. Do you have any suggestions for improving these processes?

APPENDIX B

Coding Scheme Used for Interview Analysis

A Priori Codes

1. National Context
 - 1.1 Emerging Country
 - 1.2 Developed Country
2. Affiliated Organization
 - 2.1 Technology Transfer Office (TTO)
 - 2.2 Science or Technology Park
 - 2.3 Business Incubator
 - 2.4 Academic Researcher
 - 2.5 Innovation Agency

A Posteriori Codes

3. Roles of University Boundary Units
 - 3.1 Internal Interface
 - 3.1.1 Technology Identification and Evaluation
 - 3.1.2 Intellectual Property Management
 - 3.1.3 Researcher Engagement
 - 3.1.4 Strategic Alignment
 - 3.1.5 Facilities Management
 - 3.1.6 Support for New Ventures
 - 3.1.7 Knowledge Co-creation
 - 3.1.8 Training and Capacity Building
 - 3.2 External Interface
 - 3.2.1 Technology Licensing
 - 3.2.2 Market Analysis and Technology Promotion
 - 3.2.3 Facilitation of Partnerships with Investors
 - 3.2.4 Revenue Generation and Funding Mechanisms
 - 3.2.5 Information Dissemination
 - 3.3 Mediator Role
 - 3.3.1 Alignment of Objectives and Expectations
 - 3.3.2 Network Building and Trust Development
 - 3.3.3 Development of Digital Instruments
 - 3.3.4 Technology Transfer Strategies
 - 3.3.5 Contract Management
4. Social Capital
 - 4.1 Structural Social Capital
 - 4.1.1 Network Configuration
 - 4.1.2 Connectivity
 - 4.1.3 Structural Holes
 - 4.1.4 Network Stability
 - 4.2 Relational Social Capital
 - 4.2.1 Trust
 - 4.2.2 Reciprocity
 - 4.2.3 Commitment

- 4.2.4 Reputation and Legitimacy
 - 4.2.5 Power Asymmetry
 - 4.3 Cognitive Social Capital
 - 4.3.1 Shared Vision
 - 4.3.2 Shared Goals
 - 4.3.3 Shared Language
 - 4.3.4 Cultural Alignment
- 5. Challenges
 - 5.1 Lack of Goal Alignment
 - 5.2 External Pressures and Increasing Complexity
 - 5.3 Resource Scarcity
 - 5.4 Access to Funding Sources
 - 5.5 Fragile Intermediary Structures and Inexperienced Staff
 - 5.6 Fragility of Socioeconomic and Industrial Structures
 - 5.7 Reliability and Trust in the Legal Framework
 - 5.8 Cultural Differences between Academia and External Stakeholders
 - 5.9 Limited Commercial Capabilities and Risk Aversion
 - 5.10 Scientific Profile and Role Overload
 - 5.11 Administrative Complexity in Technology Transfer Processes
 - 5.12 Geographic Proximity between Universities and Industries

APPENDIX C

Table 18 - Illustrative quotes for the data structure

Aggregated dimensions	Second order themes	First order concepts and "quotes"
Evolution: Complementarities and new organizational models	Operational limitations of technology transfer offices	Legal, bureaucratic and administrative tasks <i>"There was an office handling bureaucracy — legal and administrative tasks — but no training, no dissemination, no bridging. ...there was a tech transfer office, but it was only doing administrative work" (Italy 5 - Innovation agency)</i> <i>"The TTO is an agent that provides support and is essential for this to happen, due to the bureaucratic procedures." (Brazil 10 - Foundation)</i>
		Working on a passive way <i>"So basically right now we are working on a passive way." (Italy 7 - TTO)</i> <i>"When I arrived, I saw a TTO that very much looked like an intellectual property committee—very internally oriented and very passive." (Brazil 14 - TTO)</i>
		Intellectual property committee <i>"We build the relationship with the university's KTO because this is a crucial part of IP management." (Italy 1 - Incubator)</i> <i>"So our most consistent activity is registration, systematic filing" (Brazil 17 - TTO)</i>
		Flexibility to manage resources <i>"It's important that you have flexibility to manage resources." (Italy 1 - Incubator)</i> <i>"So, at the tech park we had financial autonomy and administrative autonomy; I had the capacity to invest in training and in hiring staff in an organized way." (Brazil 21 - Tech Park)</i>
	Alternative organizational forms and the external interface	Fully dedicated to exploiting external networking <i>"So, our office is within this area, but we are fully dedicated to exploiting networking with the companies and institutions" (Italy 3 - ILO)</i> <i>"(Open innovation unit) we operate as an open innovation arm, supporting these companies in building connections both with our researchers and with the companies in the park." (Brazil 13 - Tech Park)</i>
	Complementarities and strategic orientation of universities	Non public body <i>"If you are organized as a public body, you have many bureaucratic hurdles to face in order to hire people, to find professionals, or to buy services or whatever. You need to be flexible and quick." (Italy 1 - Incubator)</i> <i>"Public administration has a very different limitation compared to the private sector, which is why the foundation has to complement it and has to be involved. Under public administrative law, a public entity can only do what is determined by law." (Brazil 10 - Foundation)</i>
		Work very closely with other BU <i>"We work a lot with the incubator and they are doing this. So we are trying not to reply exactly what they are doing, but just to work together." (Italy 7 - TTO)"</i> <i>"In Open Innovation, we work a lot with the TTO; we work on connecting the university with large companies." (Brazil 12 - Tech Park)</i>

Aggregated dimensions	Second order themes	First order concepts and "quotes"
Operation: Roles orientation and relational and cognitive social capital	Capillarity in the internal interface	Trying not to reply exactly what others BU are doing <i>"Okay, for instance, that the university TTOs it's not holding like as much as courses like educational courses as the incubator like the Incubator" (Italy 6 - PhD)</i> <i>"A program run jointly by the TTO and the Tech Park: the spin-off program. The NIT goes as far as, like... "oh, is it legitimate to pursue this as entrepreneurship or not?" That's as far as they go. From that point on, it already goes to the park. The TTO doesn't get involved anymore, unless it's a matter of valuation." (Brazil 19 - Professor)</i> Partnership in specific projects <i>"So, we work very closely with the KTO of the university. That means that when we work on a project, we also work on the protection of IP, and if necessary, on the commercialization process." (Italy 1 - Incubator)</i> <i>"Projects in partnership with SIF, involving Embrapii, so we run some joint events with Embrapii and the Tech Park team." (Brazil 11 - TTO)</i>
		Diferent realities from each department <i>"Each department has it. On paper. So each department has a person in charge for the third mission... So, it depends, it's not really standardized within the univeristy" (Italy 4 - Professor)</i> <i>"Because the university is very large, we have many laboratories, many places where this happens in a very anarchic way, right?" (Brazil 21 - Tech Park)</i>
		Size and specialization of university <i>"Which is quite complicated for university as ours because we are not a specialized university. we don't go by department view, which is would be quite impossible" (Italy 3 - ILO)</i> <i>"(technology mapping) This was something that started last year. Up until last year, this activity didn't exist, but I believe that's due to the university's size and scale." (Brazil 15 - Innovation agency)</i>
		Lack of awareness of BU's role <i>"I spent a lot of words with the university by explaining that this capacity must be developed in each department. So it should be absolutely necessary to introduce this kind of information and education inside the faculty." (Italy 2 - Tech Park)</i> <i>"One day I went to a meeting at a science center to explain what the TTO did. When I finished, someone said, "Wow, I didn't know you did all of that. I thought you only drafted patents." I was shocked. If the academic community doesn't know what the TTO does, how is it going to be valued? " (Brazil 14 - TTO)</i>
	Sub-units and internal boundary arrangements	People interested in the topic <i>"I'm the responsible of the third mission here in my department, and that is a format of public engagement. I'm delegate for the third mission. So everything that is related to public engagement, knowledge transfer companies relation" (Italy 4 - Professor)</i> <i>"So today we consider that those professors who carry out entrepreneurship actions on the campuses are, in our dialogue with them, the arm of the program where they are." (Brazil 16 - Professor)</i> Training of the technical staff <i>"Training some universities' higher-level technical staff, who already have ties to the laboratories, to act as multipliers for the TTO." (Brazil 11 - TTO)</i>

Aggregated dimensions	Second order themes	First order concepts and "quotes"
		<i>"Administrative staff find it very easy to work in this boundary unit, because we actually work a lot with management." (Brazil 22 - Incubator)</i>
	Contaminate their research teams	<i>"PhD can then "contaminate" their research teams, becoming second-step bridges between the course's content and their senior colleagues. It's a sort of bottom-up contamination." (Italy 5 - Innovation agency)</i> <i>"I go a lot to graduate seminars to talk a bit about innovation management. So when I speak, I'm already speaking to everyone. I think it's an easy way for me to give them a message: "I'm going to send you an email. Pass it on to your professors." (Brazil 14 - TTO)</i>
	Teaching as a strategy of the third mission	<i>"For example, we try to increase a little bit, the entrepreneurship sense of the young because there is nothing to do with the old" (Italy 4 - Professor)</i> <i>"I'll tell you that we've already broken down a lot of that resistance, and we've broken down a lot of that resistance through the students." (Brazil 16 - Professor)</i>
	Importance of education and PhD student	Mandatory interaction with external stakeholders in teaching <i>"One of the rules is to keep this connection and invite the managers of SMEs and retail companies to their courses and projects. This is a rule at the University" (Italy 8 - Professor)</i> <i>"Since we started, we set it as a goal to be very close to companies, okay? So in the Business Administration program we have what we call integrated projects." (Brazil 18 - Incubator)</i> PhD students as an opportunity for the internal interface <i>"I would say every PhD school to have some kind of introduction to the topic as in their courses.... I would impose to every student, a little introduction of this world because otherwise people would be somehow solely dependent on their like PIs funding and decisions." (Italy 6 - PhD)</i> <i>"We already knew that the one who most often becomes an entrepreneur is the graduate student, not the professor, not the researcher, but the graduate student, because there comes a point in their life when they have to make that decision, right?" (Brazil 12 - Tech Park)</i>
	Cognitive challenges in mediatory and external roles	It is a matter of communication <i>"I'm really convinced that we don't have to sell, we just have to learn how to tell the story beyond the project to convince them. It's different the approach" (Italy 4 - Professor)</i> <i>"Either the professor comes... the professor goes to give a class for the company and will show... because then there was a student who did that... it's like that academic kind of thing. The company isn't interested in that. The company wants to know cost, when, how." (Brazil 14 - TTO)</i>
		The meeting point for different goals <i>"(most challente) I would say helping find The meeting point, the common point of interest between someone who makes research and needs to make publications and someone who has a very practical money" (Italy 3 - ILO)</i> <i>"But the TRLs are low, usually they're below what a company reading it thinks they will be. So, many times, the company itself also comes in with a somewhat mistaken expectation." (Brazil 19 - Professor)</i>

Aggregated dimensions	Second order themes	First order concepts and "quotes"
	Ecosystem embeddedness, partnerships and external sub-boundary units	Academic culture and corporate culture <i>"So a company that is objective oriented, like achievement reactive that wants things to get done, feels sometime, I've heard a lot of time that they are not really willing to cooperate with university because they feel like it takes ages to do a thing" (Italy 6 - PhD)</i> <i>"Challenges, first, this issue of companies having greater flexibility when interacting with the university." (Brazil 13 - Tech Park)</i>
		Ecosystem and connection with different types of actors <i>"We call it the ecosystem map. We're connected to several types of actors." (Italy 1 - Incubator)</i> <i>"And then I understood that, for us to be relevant as an institution, we needed to connect a lot with other external institutions." (Brazil 21 - Tech Park)</i>
		Partners and competitors <i>"A system made of subjects like us or different, but we do sometimes together, and sometimes one against the other exactly the same work." (Italy 2 - Tech Park)</i> <i>"We have outsourced some activities, hiring some firms to help us with this kind of patent drafting." (Brazil 11 - TTO)</i>
		Official network of BU <i>"European Association of Technology Transfer Professionals. That means the association of professional like us. So people that work in the technology transfer offices of the University all over Europe" (Italy 7 - TTO)</i> <i>"It's a very well-structured network (RMPI). And all of this is meant to provide training for TTO teams." (Brazil 10 - Foundation)</i>
Conditions: Structural and operational challenges and funding mechanisms	Operational weaknesses of boundary units	Institutional fragility in human resources <i>"This is a very important question because the real problem that we have is that it's very difficult to find people already equipped for this kind of work" (Italy 2 - Tech Park)</i> <i>"The heterogeneity is absurd. It is absurd. Why? Because there is no career for occupying a technology transfer office" (Brazil 10 - Foundation)</i>
		Long-term instability <i>"The coordinator, the one who has the greatest command over the processes, doesn't have that stability, any security." (Brazil 11 - TTO)</i> <i>"That's bad because the TTO is never going to be strong. When we start, start, start, then that wave comes and washes the sandcastle away." (Brazil 14 - TTO)</i>
		High turnover <i>"Right now, we are a bit struggling about those things because we were many people before and we lose just two people in the later months" (Italy 7 - TTO)</i> <i>"We know that one of the biggest challenges in this area is precisely team turnover." (Brazil 13 - Tech Park)</i>

Aggregated dimensions	Second order themes	First order concepts and "quotes"
	Manager's profile and multidisciplinary team	Multidisciplinary team <i>"So our team combines different backgrounds, and our goal is to extract connections - to build bridges between university research and companies." (Italy 1 - Incubator)</i> <i>"But I have a very good team... Because I also see it as a mission of mine... So I keep pushing people along. I bring in my experience as well, but they're the ones who carry it forward; we just keep providing support." (Brazil 19 - Professor)</i>
		Profile of the boundary unit manager <i>"Our background is the hard science background I mean we are two biotechnologists and we managed all the negotiations so yeah. I mean we had a little training on that of course but the main important thing of our work is learning by doing" (Italy 7 - TTO)</i> <i>"But having someone like her leading it right now, for me, has been wonderful. Because at the same time that problems come up, she's working alongside us to solve them." (Brazil 19 - Professor)</i>
		Experience and qualified personnel <i>"I have 25 years of experience in promoting small, and medium enterprise. So, I have a view on both sides" (Italy 3 - ILO)</i> <i>"I was already doing this kind of interaction; I was already working with it. I already had the profile, I already had experience in relating both with the productive sector and with academia." (Brazil 13 - Tech Park)</i>
Scarcity of resources and sources of funding		Multi level funding mechanisms <i>"And on the other side, one third of our balance is made by projects financed in different levels. Regional, national, European Union" (Italy 2 - Tech Park)</i> <i>"Push especially from European, Italian and local fund institution, to local funding pushed." (Italy 3 - ILO)</i>
		Mature boundary units and self-financing <i>"We are self-financed. Because we work for this job, we need money to perform this activity" (Italy 1 - Incubator)</i> <i>"The main source of funding for the payroll is the percentage from royalties on technologies licensed through the Innovation Agency." (Brazil 15 - Innovation agency)</i>
		Lack of resources <i>"But for that, they need access to direct funding - that's our main challenge." (Italy 5 - Innovation agency)</i> <i>"Because the big difficulty when we work from the bottom up is that the base has no budget; the management is the one that has the budget. So we were always nibbling around the edges." (Brazil 16 - Professor)</i>
		Visionary position or decision <i>"And then there was a visionary position or decision about by the the governance that decided to set up a small office, but to start this dedicated activity" (Italy 3 - ILO)</i> <i>"What will underpin everything is our view that, to promote development through technology-based innovation, there is no other model than the Triple Helix." (Brazil 12 - Tech Park)</i>
Political and administrative will		Access to government entities <i>"I must mention that the local government and the Milan municipality are involved in all four steps" (Italy 8 - Professor)</i> <i>"We need the MDIC to play a more decisive role in this, tying together resources that come in so they are directed toward solving sectoral problems." (Brazil 20 - TTO)</i>

Aggregated dimensions	Second order themes	First order concepts and "quotes"
Long-term: Regional ecosystem maturity and path dependence	Regional particularities	Lack of sensitivity on the part of university administrations <i>"It also depends on the the will of people that are over your head that can decide for everything so it really depends also on the or the policy maybe in that moment in the within the university" (Italy 7 - TTO)</i> <i>"I think there's a real lack of sensitivity from university administrations, to treat this as a priority, instead of hiding behind things like, "there's no career path," "we can't do it." (Brazil 10 - Foundation)</i>
		Regional specificities <i>"The difference (between Colombia and Italy) is striking - there, the focus is on micro-entrepreneurship. Here in Europe, everyone chases unicorns and scalability." (Italy 5 - Innovation agency)</i> <i>"A lack of seriousness about reducing regional asymmetries... that drives people away... So, we need a redesign of our system." (Brazil 20 - TTO)</i>
		Bottom-up dynamics <i>"But because our movement was much more organic, much more grassroots, we usually say that we kept working in spite of the institution, in spite of the institutional management." (Brazil 16 - Professor)</i> <i>"There's a funding mechanism, the Informatics Law, and there are some companies that are close to us... it would be foolish not to take advantage of it. Let's see what common interests we have with them and try to work out this relationship." (Brazil 20 - TTO)</i>
		Technology push and market pull strategies <i>"We have a basically both our researchers that want to establish new contexts with companies, or... The input may also come from the other side, so from companies" (Italy 3 - ILO)</i> <i>"And then you end up in a technology-push model, where viability is very low, whereas I could, right, work in a more market-pull model." (Brazil 12 - Tech Park)</i>
	Path dependence and the need for continuity	It takes time <i>"It takes time because you are building trust. So, it's not just about having a database where you list people with technical skills - commercial, legal, IP, whatever. You're working on human affinity" (Italy 1 - Incubator)</i> <i>"It's ant-like work, little by little. Then the good results start to appear. It's something that takes time. It's something that comes through hardship." (Brazil 14 - TTO)</i>
		Long-term relationships and social capital acumulation <i>"And when you build these long-term relationships, you gain experience and trust. Losing that and starting over is very costly. So, sharing the rewards across the knowledge supply chain" (Italy 1 - Incubator)</i> <i>"Because it's not easy to secure these partnerships, since you're dealing with the top hierarchy of these large companies, so it's not overnight that a company decides to hold an innovation meeting, and you're dealing with very sensitive information." (Brazil 13 - Tech Park)</i> Permanent network <i>"The other situation is that we have a permanent network that is important" (Italy 2 - Tech Park)</i> <i>"Through the Agency, we already have, for example, a number of partners who already take part in projects, funding initiatives, and events." (Brazil 15 - Innovation agency)</i>

Aggregated dimensions	Second order themes	First order concepts and "quotes"
		The law was a game changer <i>"This law really changed things — it was a game changer in 2012. Because this status of “innovative startup” also introduced the certified incubator." (Italy 1 - Incubator)</i> <i>"Right now we are in another position, so the change of the national law changed also a little bit the strategy of the office" (Italy 7 - TTO)</i>
	The capacity of laws to foster or constrain boundary unit activities	The university did not incorporate the legal basis. <i>"But we started to run into problems with the university's bureaucracy because of state legislation." (Brazil 20 - TTO)</i> <i>"The University's legal office hasn't fully taken on board the Legal Framework for Innovation... Things end up taking a very long time to be implemented." (Brazil 21 - Tech Park)</i> Continuous sustainable long-term policy <i>"You need a continuous support policy, especially for business incubators... But the incubators that are out there, especially the university incubators, are withering away because they don't have financial sustainability." (Brazil 12 - Tech Park)</i> <i>"These boundary units, these technology transfer mechanisms, need to be strengthened as a national public policy, not just by the decision of one rector or another who happens to have that vision, right? ... Many of these projects, these policies, are government policies, not state policies." (Brazil 22 - Incubator)</i>

Source: Prepared by the author.