University of Strathclyde

Doctoral Thesis

Exploring Translational Assets: A New Classification Framework

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in the

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Declaration of Authorship

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signature:

Date:………11/04/2025…………………………….

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List of Abbreviations

TA	Translational Asset
R&D	Research and Development
TRL	Technology Readiness Level
HEI	Higher Education Institution
RDI	Research, Development and Innovation
OECD	Organisation for Economic Co-operation and Development
SE	Scottish enterprise
HIE	Highlands and Islands Enterprise
STI	Science, Technology and Innovation
PI	Principal Investigator
SME	Small and Medium Enterprises
EA	Exploratory Assets
PA	Plug Assets
DA	Development Assets
CTO	Chief Technology Officer
CEO	Chief Executive Officer
COO	Chief Operation Officer
RL	Regional Launch
SI	Specialised Independent
SIS	Strategic Industry Support
AT&I	Advanced Technology & Innovation

Abstract

This research introduces a novel classification framework for Translational Assets (TAs) within the Scottish Innovation ecosystem. Translational assets, distinct Research and Development (R&D) organisations that bridge academia and industry by facilitating knowledge exchange, driving innovation and promoting technology transfer, play a critical role in enhancing national innovation capabilities. Despite their importance, the existing literature on TAs is notably sparse, particularly concerning qualitative investigations that explore their unique operational modes and contextual adaptability. Moreover, the lack of a comprehensive classification framework has led the challenges in understanding and leveraging these organisations' diverse roles and contribution within the innovation ecosystem.

To address this gap, this study proposes a continuum-based classification framework that captures the multifaced nature of TAs, moving beyond traditional discrete categories to better reflect the diversity of these entities. The research adopts a qualitative methodology comprising a comprehensive literature review, empirical analysis of 19 case studies conducted in Scotland and in-depth interviews with key stakeholders across different TAs.

The findings reveal that while TAs in Scotland vary significantly in their size, structure, funding sources, and organisational objectives, certain recurring patterns emerge, allowing for the identification of five distinct TA models. These models range from "Demand-Led" assets responding directly to industry needs to "Advanced Technology and Innovation" assets focusing on high-tech, industry-aligned research. The final classification framework introduces multiple dimensions, including organisational structure, funding model, stakeholder engagement, and research focus, each positioned on a continuum to capture the flexible and evolving nature of TAs.

This thesis contributes to both theory and practice. Theoretically, it addresses the need for an adaptable classification framework, overcoming limitations in past approaches, by introducing a multidimensional, continuum-based approach. Practically, it offers a valuable tool for policymakers, researchers, and industry leaders to better understand and strategically engage with TAs, facilitating more effective resource allocation, policy development, and collaborative

partnerships within the Scottish innovation landscape. The framework's potential applications beyond Scotland, providing a foundation for comparative research across different regional and national contexts, open up new avenues of exploration and inspire further research.

Chapter 1

1 Introduction, Objectives and Methodology Outline

1.1 Introduction

In the current dynamic global landscape, the economy is heavily driven by knowledge, which serves as a catalyst for innovation and economic growth (Arthur et al., 2023). Many countries recognise the pivotal role of the knowledge economy in their development and are dedicated to cultivating an environment that fosters various metrics, including knowledge creation, dissemination and application. However, many countries, including the UK, are still suffering from a period of stagnation due to stagnant productivity growth, which is represented in a broad sense by the scarce role played by innovation within the companies (OECD, 2024; O'Sullivan, 2024). This is particularly true for SMEs, whose innovation capacities require analysis and incentives to become more competitive and cope with challenging scenarios, such as the COVID-19 pandemic (OECD, 2021; Lepore, 2023).

In light of these challenges, countries must take proactive measures to address these issues, and a more collaborative approach must be taken from the stakeholders of the innovation systems (Lepore, 2023). However, linking different stakeholders is challenging and many knowledge barriers could hamper firms from accessing a collaborative system for innovation. To address these obstacles, there are third-organisations positioned at the centre of the innovation ecosystem that fosters innovation and manages collaborative relationships with one or more entities (Lepore, 2023). This is particularly significant in countries where it is difficult to translate scientific and research excellence into commercial success for the industry. For instance, Arthur et al. (2023) highlight the challenge faced by certain regions in the UK, where businesses encounter difficulties in addressing innovation challenges through collaboration with universities due to a potential lack of infrastructures, relationships or other factors.

Governments can play a vital role in promoting innovation by actively fostering the creation of new markets and supporting businesses in distinguishing themselves from competitors. They can do this by building relationships among academia, the public sector and the private sector. Additionally, they can help break down the barriers that separate different business areas from academic fields (Arthur et al., 2023). They have implemented various policy instruments, such as research grants, R&D tax incentives and public-private partnership initiatives to strengthen these connections (Terbullino, 2023). A novel form of university-industry collaboration in STI proposed by governments or regional innovation authorities is the investment for assets that support this collaboration (Arthur et al., 2022) to address specific challenges in industries or technology sectors. This includes "Translational Assets" (TAs), which can take different forms of Research and Development (R&D) organisations (Strazzullo et al., 2021). The TA concept was first introduced in the UK in the Hauser Report (2010). The report describes these entities as "organisations focused on the exploitation of new technologies, through an infrastructure that bridges the spectrum of activities between research and technology commercialisation." It emphasises the critical role of TAs in bridging the gap between research and commercialisation, often referred to as the "Valley of Death".

Translational Assets (TAs) are presented by past scholars and policymakers in a diverse and multifaceted form of Research and Development (R&D) organisations, each with unique characteristics and complex operational models. **This diversity underscores the need for a more comprehensive understanding of TAs as distinct entities, particularly in terms of how they can be classified based on their operational models and strategic roles within the innovation ecosystem**. This research gap highlights the urgency of further exploration and understanding of TAs in the context of innovation and economic development.

1.2 Why Focus on Scotland?

The innovation landscape in Scotland presents a distinctive opportunity for an in-depth examination of the role of translational assets within a specific national context. Scotland has a rich history of scientific research and technological advancement, supported by a robust network of universities, research institutions and government bodies. However, the country also faces challenges in translating research into marketable innovations, leading to many promising technologies failing to scale or gain commercial traction. This dual reality of success and challenge underscores the need to better understand the organisations responsible for bridging the gap between research and industry.

By focusing on Scotland, this research aims to provide insights into the diverse range of TAs operating within the country's innovation ecosystem. These insights can contribute to a broader understanding of how TAs operate within Scotland and other regions with similar innovation landscapes. The Scottish case serves as a valuable context for testing and refining a classification framework that could be adapted for use in other national or regional innovation systems.

1.3 Research Gap and Challenges

In the context of a rapidly evolving research and innovation system, the ability to understand and effectively support TAs has never been more important. These entities are widely recognised in countries such as the UK, the EU and the USA, albeit under different names. However, despite their growing prominence, there is a lack of clarity regarding their classification and the factors that define their operating models (Cruz-Castro et al., 2020; Philbin et al., 2014).
Policymakers and academics alike have encountered significant challenges in classifying these organisations due to the diverse nature of their research activities, organisational structures and funding sources (Giachi and Fernandez-Esquina, 2020; Cruz-Castro et al., 2020).

Existing classifications are oversimplistic, relying on discrete categories that fail to capture the complex, hybrid nature of many TAs. For instance, some TAs may engage in both exploratory and applied research, while others may focus on specific industry collaborations or policy-oriented projects. Such diversity makes it difficult to place TAs into rigid categories, necessitating a more flexible and adaptable classification framework.

Another key challenge is the lack of a standardised definition of TAs across different countries and innovation systems. Terminology varies widely, with some regions referring to these entities as technology transfer offices, innovation hubs or research centres. This terminological diversity complicates efforts to develop a universal classification system, further justifying the need for a context-specific framework that can accommodate the unique characteristics of TAs in a given region, such as Scotland.

This research addresses a crucial gap by proposing a flexible and empirically grounded classification framework tailored to the Scottish innovation landscape. It responds to the call of stakeholders across the Scottish innovation landscape who have highlighted the absence of clear tools for identifying and understanding the purpose, structure, and value of TAs. One of the experts explained, "A well-defined classification framework is the cornerstone that enables us to understand how a TA actually operate". Similarly, a high-profile of university-based TA noted the lack of transparency in how many translational assets are designed: "There is a blueprint in the person's head, but it has never been put down on paper". This study brings that "blueprint" to light, enabling organisations to reflect on their structures and purpose and helping new initiatives model themselves more effectively. Other experts emphasised the benefits such a tool could bring to academics designing new initiatives, funders seeking to direct investments strategically, and SMEs looking for the right partners.

Although scepticism remains about developing a universal classification, especially given issues with inconsistent terminology and fragmented innovation systems, this only reinforces the importance of a flexible, context-aware framework. As one expert noted, “Many attempts of classification in Scotland were made in the past, but so far, they have never worked because there is always a terminology issue”. This research, therefore, takes a pragmatic and user-informed approach to classification: one that recognises the unique characteristics of each TA while still offering a structure robust enough to guide ecosystem-level decisions.

Ultimately, this research matters because a well-defined classification framework does more than categorise: it enables better collaboration, more strategic investment, and more effective translation of research into real-world impact. It becomes a shared language for academia, industry, and policy actors, helping them navigate the innovation ecosystem with greater clarity and purpose.

1.4 Aim and Objectives

The central thesis aims to bridge the existing gap by developing a novel classifying framework for translational assets, with a specific focus on the Scottish innovation landscape. The objective is to create a flexible and context-specific system that reflects the diverse operational models and strategic roles of TAs. To achieve this, the research will focus on the following objectives:

- Defining the primary factors used to classify translational assets by synthesising research on the Triple Helix, translational asset definitions, international translational asset programs and previous classifications.
- Developing a conceptual framework for TAs by expanding on the literature review to propose a more flexible classification system that can represent TAs along a continuum, reflecting their hybrid and multifaceted nature.
- Refining the conceptual framework through empirical investigation of a sample of Scottish translational assets, adapting the framework to reflect the specific characteristics of the Scottish innovation ecosystem.

1.5 Research Questions

Two fundamental research questions guide this research, each tailored to address the existing gaps in knowledge concerning the classification of translational assets and their operating models, particularly within the context of Scotland. These questions are essential for achieving the overarching aim of the research, which is to develop a comprehensive and adaptable classification framework for TAs. Through the exploration of these questions, the study aims to contribute to both academic understanding and practical application within innovation ecosystems.

This exploratory study, which is crucial for understanding the classification of TAs, aims to address the following research questions:

> R.Q. 1: What are the defining factors for classifying the translational assets, and how can they be represented along a continuum to enhance understanding of translational assets?

The first research question aims to identify and synthesise the key characteristics that can be used to classify translational assets. While existing literature provides some insight into the operational models and structures of R&D organisations, these insights are often fragmented or overly focused on specific contexts.

This question seeks to uncover the specific factors that define TAs and differentiate them from other R&D entities. Additionally, the goal is to move away from rigid, discrete classification methods towards a more dynamic representation that reflects the fluidity and hybridity of TAs. By proposing a continuum-based classification, this research will provide an understanding of the operational diversity of TAs, capturing the varying degrees of emphasis on different characteristics.

> R.Q. 2: What key factors should be considered in developing a comprehensive classification framework for translational assets in Scotland and how can they be adapted or improved to create a classification system tailored to a specific context?

The second research question is more applied in nature, focusing on the Scottish context. Scotland presents a unique innovation landscape, with diverse translational assets operating across different sectors, from healthcare to digital technologies and renewable energy. However, a tailored classification framework is needed to accommodate the specific characteristics and

challenges faced by TAs in Scotland, such as the funding limitations, the need for regional economic development and the integration of academic, industry and government support.
This question seeks to identify how the general factors uncovered in the first question can be adapted and enhanced to fit the Scottish context. It explores how the local conditions, such as government policies, industrial needs and academic strengths, shape the operational models of TAs in Scotland. The goal is to create a classification framework that not only reflects the diversity of TAs but also serves as a practical tool for policymakers, universities and industries within Scotland.

1.6 Contribution to Knowledge

This research makes theoretical and practical contributions to the understanding of translational assets. The theoretical contribution is achieved by addressing the gap in the existing literature review by proposing a new classification framework that moves from discrete categories towards **a continuum-based model** that reflects the dynamics and hybrid nature of TAs. Therefore, by representing the translational assets on a continuum, it aims to address the misclassification issue in the discrete classification (Strazzullo et al., 2021). This continuum approach can provide a more nuanced dynamic understanding of TAs, advancing theory and practice in the field. According to the author's knowledge, there is only one similar study conducted by Rincon Diaz and Albors Garrigos (2017) that demonstrates the potential of such a method, where they proposed the use of a hierarchical cluster analysis to represent the adaptation levels of Valencian Research and Technology Organisations (RTO) through a continuum.

From a practical perspective, this thesis offers valuable insights for academics, managers and policymakers involved in R&D organisations. The development of a holistic framework, in other words, not taking one generic model, provides a tool for better decision-making in terms of resource allocation, access to top talent, partnership development and policy design, particularly in contexts like Scotland, where the innovation landscape is both vibrant and complex.

1.7 Research Methodology Outline

This research project adopts a multi-case study design (Yin, 2014) to address the research questions effectively. This method is particularly appropriate for studying the classification of Translational Assets (TAs) because it focuses on an under-explored research topic where more reflexive and qualitative analysis is needed. Using case study research, this inductive approach

aims to generate new insights into "how" TAs can be classified, contributing to both theory and practice (Yin, 2014). The researcher incorporates these findings into the existing body of knowledge and discusses the discoveries in the broader context of innovation ecosystems.
For several reasons, a qualitative multi-case study approach was chosen over a quantitative design. This method allows for a comprehensive exploration of diverse actors, offering a deeper understanding of key aspects such as the organisational structure, funding models and activities of TAs. Additionally, conducting multi-case studies within a specific geographical context (Fraser, 2020) allows for the detection of heterogeneity among TAs operating within the same innovation ecosystem. This heterogeneity is critical to refining the classification framework and capturing the diverse characteristics of TAs.

The unit of analysis in this study is a combination of Scottish TAs and high-profile management with an emphasis on high-profile management as a key decision-maker who has been involved within the organisation since the early days or who has a good understanding of the establishment of the organisation within which they operate. The decision to investigate Scottish institutions was partly opportunistic, driven by geographical proximity, which offered advantages in terms of accessibility and logistics.

The focus on Scottish TAs offers unique advantages for this study. Scotland, with its rich and diverse landscape of translational assets, including universities, research institutes, government laboratories and private R&D centres, provides a unique opportunity to explore a wide range of organisational structures and operational models. The high density of heterogeneous TAs within a relatively small geographical area offers an ideal opportunity to investigate how these organisations operate and how they might be classified, making Scotland an ideal location for this research.

The TAs in this study were selected based on the following criteria:

1. The TA must be involved in **translational research**;
2. It must belong to the **science, technology and innovation sector**;
3. At least one management-level employee with extensive experience since the organisation's early years must be available to participate.

It is important to point out that translational research is not a ubiquitous approach in medical disciplines, but also in the engineering and science fields. Sometimes, this term is presented in the literature as “translational research and development” to apply this approach beyond the medical research field (Bazan, 2019). This type of research is identified as a mechanism to span the Valley of Death. Then, at its core, translational research transfers knowledge from academic researchers to the community of practice to address real-world challenges (Gagliardi and Amanatidou, 2023; Bazan, 20219).

To meet the research objectives, the analysis is divided into theoretical and empirical parts. The theoretical part involves a thorough literature review, which provides an understanding of the characteristics and classifications of R&D organisations. Sources for the literature review included digital databases such as ScienceDirect and technical reports from bodies like Innovate UK, Catapult, Technopolis and the OECD. A snowball sampling method was used to gather further documentation, ensuring that the literature review was wide-ranging and included various perspectives.

The empirical part focuses on developing the classification framework. The sampling strategy was purposeful rather than random, allowing the researcher to consider cases that provide the right information about the topic under investigation. With high-profile management as a unit of analysis, access to at least one of these staff members was important for the selection of the cases.

In this research have been considered 18 TAs. It is not an exhaustive number of TAs in Scotland, but rather, the number of TAs was determined by the researcher's network and the availability of participants to support his research. Not all TAs contacted were willing or suitable to participate in the research. However, the selected sample provides a representative cross-section of Scottish TAs involved in translational research in the science, technology and innovation sectors.

Data was gathered through semi-structured interviews with high-profile management (e.g., Project Managers, CTOs, CEOs, and COOs) from the selected TAs. These individuals were chosen because they had been involved in the organisation's design and strategy from its inception.

Conducting interviews with multiple participants within each TA was challenging, and in some cases, only one senior representative could be interviewed per organisation. Despite this limitation, the study prioritised the quality of the interviews over quantity, focusing on participants with the deepest knowledge of the organisation's development and operational models.

A final sample of 25 informants was considered to achieve data saturation. According to Hennink and Kaiser (2022), this is a reasonable sample size for qualitative research involving organisational structures of varying sizes and hierarchies. The researcher employed data triangulation, using multiple data sources to enhance the credibility and validity of the findings and ensure comprehensive coverage of the research topic.

In summary, the methodology is structured into three main parts:

1. **Theoretical analysis**: A review of the literature on TAs and the factors used to classify them.
2. **Empirical data collection**: Interviews with high-profile management from the selected Scottish TAs.
3. **Application of the theoretical model**: The development and testing of the proposed classification framework in the context of Scottish TAs, leading to a discussion of the results and conclusions.

Throughout this research, the study maintained transparency and reflexivity by acknowledging the limitations and potential biases inherent in the research process. This ensured that the findings were accurate, reliable and could inform future studies on translational assets and their role in innovation ecosystems.

1.8 Dissertation outline

The outline of this thesis is as follows. In the following chapter, the researcher describes translational assets based on prior studies, where the main factors considered by the scholars to classify translational assets are described and categorised. The third chapter explains the research design used to undertake this investigation. Continuing with the fourth chapter, the research presents the main results obtained from the literature review by proposing a new classification framework. The fifth chapter shows the improvement of the classification framework by considering the experts' insights from Scottish TAs. Finally, in the sixth chapter, the author discusses and comments on the implications of the research and proposes suggestions for further investigation. Figure 1 shows an overview of the thesis outline.

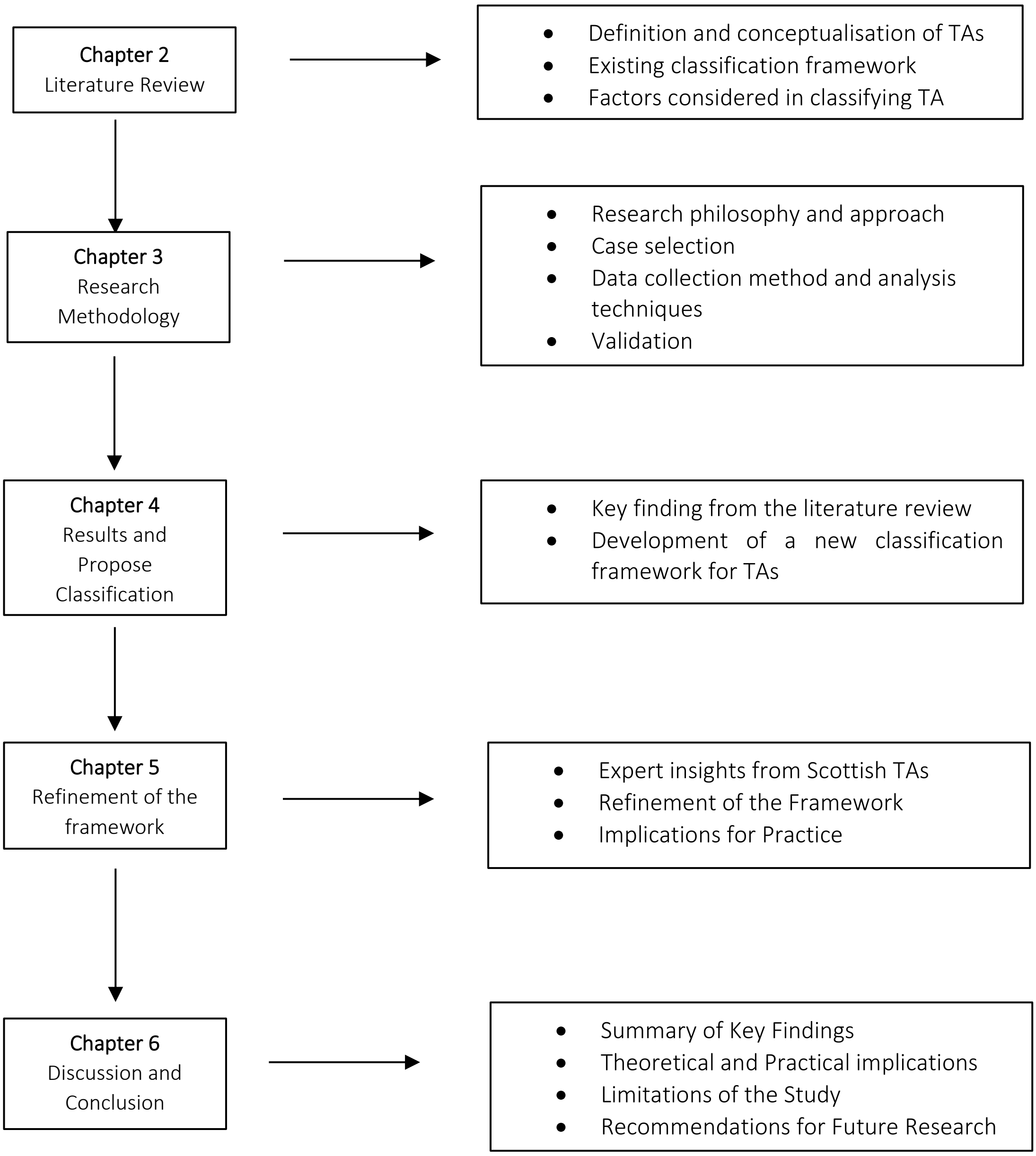

Figure 1 - Methodology Outline Thesis Scheme

Chapter 2

2 The theoretical elaboration of the concept of TAs

2.1 Defining the Problem: The Need for Action

The business landscape for both large organisations and small-to-medium enterprises (SMEs) is evolving rapidly. To survive, grow and remain competitive, firms must continuously innovate. This need for increased industrial competitiveness is deeply tied to the transformation of a country's Research and Development (R&D) system. In today's globalised and highly competitive market, nations are under pressure to enhance their economic performance by driving innovation, technological advancements and productivity gains (National Science Board, 2012). R&D with its transformative potential to generate new knowledge, develop cutting-edge technologies and translate research into practical, real-world applications, is a key player in shaping the global economy.

Numerous countries are revamping their R&D systems through new policies, public funding schemes and strategies aimed at empowering research organisations to enhance competitiveness. These changes aim to foster an environment that supports innovation and collaboration between academia, industry and other stakeholders (Kang, 2019; Giachi and Fernandez-Esquinas, 2020). However, differing expectations, market knowledge and perspectives often hinder effective collaboration between academia and industry, creating barriers to seamless cooperation.

In response to these challenges, many countries have implemented policies and created mechanisms to establish Translational Assets (TAs)—R&D organisations designed to bridge the gap between theoretical research and practical applications. Notable examples include the American National Institute of Advanced Institute Science and Technology (AIST), the Netherlands Organisation for Applied Scientific Research (TNO), Germany's Fraunhofer Institutes and the UK's Catapults (Kang, 2019; Kerry and Danson, 2016). Other global examples include Japan's RIKEN, South Korea's KIST and China's CAS. These organisations are labelled 'translational' because their primary mission is to convert academic research and innovative ideas into commercially viable products and services.

The term "translational" refers to the process of taking fundamental research and applying it in real-world contexts to stimulate innovation in both processes and products. While this concept is widely used in the medical field, it has not been adopted as readily in engineering or related disciplines despite its clear relevance (Bazan, 2019). Additionally, the term "asset" in this context refers not only to the physical infrastructure of these organisations but also to the intangible resources, such as the talent and expertise, that drive their R&D activities. Unlike traditional business assets, which are typically tangible, TAs encompass a broader range of tangible and intangible resources (Silva and Oliveira, 2020; Strazzullo et al., 2021).

2.2 The Knowledge Economy and Innovation

Globalisation and technological revolutions have transformed the (successful) modern economy, like the UK's, into the "knowledge economy" (KE) or 'Knowledge-based economy" (KBE). This term was coined by Drucker, who created the term "knowledge society" (Drucker, 1969). The term knowledge economy is not always clearly defined. However, a good example of a definition comes from Powell and Snellman (2004) who viewed it as "the production of services and goods based on knowledge-intensive activities and greater reliance on intellectual capabilities". Schumpeter (1934) and many economists have been studying the market of knowledge, such as Nelson (1959) and Arrow (1962) and have highlighted the importance of knowledge being a type of market and market of reference for innovation, which Schumpeter acknowledged as the "market introduction of a technical or organisational novelty".

In the knowledge-based economy, firms and countries' primary economic growth and competitiveness drivers are building their own innovation ecosystem and investing in people and firms (Yigitcanlar et al., 2019). This economic paradigm has emerged as a dominant force in the global landscape. In fact, it affects the transformation of industrialised economies and many developing economies for those that want to join this transformation journey. This is because a gap exists between countries with different economies in a "knowledge capitalism" era. To shrink this gap, countries invest in R&D. However, firms that invest in R&D within innovative industries often experience apprehension. This because of the elevated risk associated with many cutting-edge investments. Another concern is the uncertainty of adequately appropriating the outcome of a successful investment. As David and Foray (1995) underline, the channels and mechanisms by which knowledge distribution and utilisation are accomplished have become a critical component of innovation systems, at least as significant as the capacity to develop new knowledge. Therefore, governments must provide many incentives to firms in several ways and for different purposes. For instance, some of the programs of support are about fostering university-industry collaboration through setting up appropriate bridging organisations to establish the Triple Helix model partnership and to ease the paces to exiting knowledge (Yigitcanlar et al., 2019; Etzkowitz, 2008; Capron, 2001). In fact, according to the UK Government's Innovation Strategy (BEIS, 2017), "the innovation process occurs in an ecosystem in which companies, public research institutions, further education providers, financial institutions, charities, governmental bodies and many other players interact through the exchange of skills, knowledge and ideas, both domestically and internationally".

In summary, research organisations are integral to the knowledge-based economy, serving as key drivers of knowledge creation, technology development, talent cultivation, collaboration and economic development. Their contributions extend beyond the boundaries of academia, influencing industry competitiveness, regional growth and policy formulation. Recognising and supporting the critical role of research organisations is crucial for nurturing an innovation-driven economy that leverages knowledge to create sustainable economic and societal benefits (Acworth, 2008).

2.3 A Theoretical Reflection of R&D Organisations

Having identified Translational Assets (TAs) as key organisations in the science and technology landscape, particularly in their role in fostering collaboration between higher education institutions and the private sector, it is essential to consider a theoretical approach to better understand and classify these R&D entities. Scholars have employed various theories to investigate the R&D landscape, yet many studies do not explicitly mention the theoretical frameworks used to explore research organisations. For those that do, several theories have been applied, including inter-organisational relationship (IOR) theories, transaction cost theory, organisational networks and strategic behaviour and management theories like resource dependency theory and the resource-based view (Gray and Boardman, 2010).

For example, Boardman and Gray (2010), Boardman and Bozeman (2007) and Youtie et al. (2006) employed human capital theory to clarify aspects related to research output, teamwork and the career progression of academic staff. Similarly, Di Maggio and Powell (1983) used institutional theory to investigate how research organisations are shaped and influenced by broader institutional environments, including norms, rules and regulations. Additionally, innovation system theories (Edquist, 2005) have been used to examine the dynamics of R&D organisations, focusing on the systemic nature of innovation where various actors, organisations and policies interact to generate and diffuse knowledge.

Among the most prominent of these theoretical frameworks is the Triple Helix theory, which emphasises the interactions between universities, industry and government. The Triple Helix provides a robust framework for understanding the collaborative nature of research organisations like TAs and their role within the innovation ecosystem. This theory is particularly relevant for analysing the relationships, knowledge flows, and interactions among research organisations, industries, and governments, all of which are central to the function of TAs. By applying the principles of the Triple Helix, scholars and practitioners can develop a more holistic understanding of how research organisations contribute to innovation, as well as the dimensions of collaboration, knowledge exchange and technological development within these entities.

Given the variety of theoretical perspectives used to study R&D organisations, it is clear that no single theory can fully capture the complexity of translational assets. However, the Triple Helix theory, with its focus on the synergistic interaction between universities, industry and government, emerges as an ideal framework for studying and classifying translational assets. It provides a comprehensive lens through which to explore the multifaceted roles of TAs, particularly in their capacity as intermediaries in the innovation ecosystem. While it overlaps with other theories, the Triple Helix offers a foundational starting point for developing a more comprehensive theory that can accurately describe the translational assets' environment and operational models.

2.3.1 Triple Helix

Collaboration between diverse nature organisations is a driver for an effective innovation ecosystem (Kerry and Danson, 2016). However, companies need to establish a reliable and competitive strategy to promote innovation. This requires investment in R&D, in-house or through a partnership with other organisations such as the university or research-oriented and translational organisations. Companies of any size and background widely adopt the last strategy due to the high costs of technologies and to acquire competitive advantages by capitalising on resources that are outside the firm's boundaries. This industry trend of building alliances with their external environment through exploring, exploiting and expanding knowledge is known as open innovation (Yusuf, 2008; Lichtentharler, 2011). This differs from the closed model, where companies generate their ideas to develop and commercialise within their boundaries. Therefore, companies seek to leverage their internal capability. Chesbrough proposed this type of model in 2003. This consisted of a model in which the organisations join efforts to innovate by combining internal and external resources. He presented the model below, which is considered the knowledge within the company and those outside the business's boundaries to accelerate internal innovation (Fig.2). However, not all of the players involved in open innovation have the same level of openness. The degree of openness and decision-making are defined based on the relationship established with the external partners (Chesbroug, 2003).

Figure 2 - Open Innovation Model (Chesbrough, 2003)

This shift in thinking from a closed to an open approach has been the primary driver of the Triple Helix (TH) model (Etzkowitz, 2003). The TH model aims to explain how innovation dynamics work in the knowledge society based on how these three institutional spheres (universities, industries and governments) work together (Etzkowitz y Leydesdorff, 2000). Mentioning Ivanova (2014), "the Triple Helix model describes the interaction among three institutional actors: Science (S), Industry or Business (B) and Government (G). These three sub-dynamics reflect three selection mechanisms, exchange among themselves functions of knowledge production, wealth creation, and normative control" (Figure 3). This is dissimilar from the past mode of knowledge production labelled Etatistic or Mode 1 and Laissez-Faire or Mode 2. With the Etatistic approach, the Government controlled the market. In contrast, the Laissez-Faire model, designed in response to the Etatistic model's failure, consists of different institutional domains with dividing and solid borders and extremely constrained ties within them individually (Etzkowitz & Leydesdorff, 2000). Alternatively, the TH model is represented through the partial overlap of these institutional spheres. The TH model indicates that governments would increasingly try to foster learning processes among the three "helixes": communication, resource sharing, worker mobility and learning processes (Etzkowitz, 2008). One of these strategies would be the creation of organisations which operate in the overlapping area of the spheres and incorporate and blend features from the TH spheres in their institutional architecture to foster innovation. These are known as intermediary or hybrid organisations (Champenois and Etzkowitz, 2018). As Ahuja (2000) points out, intermediaries or hybrid organisations emerge when structural gaps exist and they aim to connect and close the gap between disconnected individuals and encourage network dynamics. These structural gaps occur when players ignore information flow outside their groups, resulting in gaps in information and knowledge flows, generating problems and making the system dysfunctional. They arise in the research and industrial sectors, which are primarily science-based, non-profit organisations, promoting inter-organisational collaboration between corporations, governments and universities to address long-term, multidimensional problems (Kirkels & Duysters, 2010).

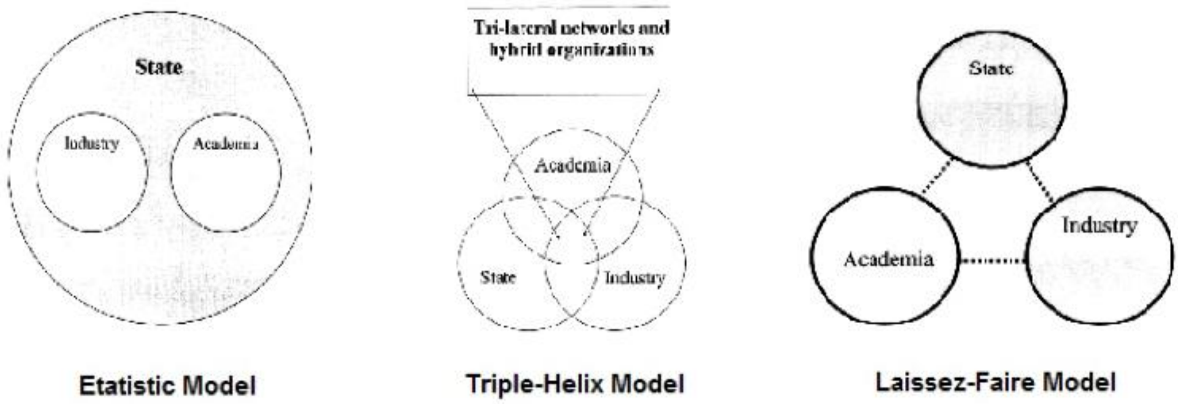

Figure 3 - Triple Helix Model Variation (Etzkowitz and Leydesdorff, 2000)

In a knowledge-based society, the Triple Helix model sees the university playing a critical role in the innovation system through knowledge creation and transfer (Arthur et al., 2022). The TH model emphasises the university's redefined role as an "entrepreneurial university" in the innovation ecosystem. Initially, the university, referred to as the ivory tower, adjusted its focus from the two missions, research and education, to a third mission that provides a societal and economic impact (Etzkowitz & Leyesdorff, 2000).

2.4 Change of Role

The term "knowledge society" has had exponential relevance in the last two decades because it drove the European countries, in particular, to develop an economy based on knowledge to be more competitive in research and innovation, in all of its forms and to have a better political and socio-economic impact. The knowledge-based economy placed in this period of transformation brought about a sizable shift in the field of research (Bazan, 2019). Predominantly, the university had a significant shift in playing a unique role in generating innovative knowledge.

The TH model has highlighted the shift of the traditional university's mission to one that incorporates business sector norms, values and practices, such as risk-taking, competitive individualism, the importance of innovation and the search for economic benefit. Etzkowits (2003) has developed the term "entrepreneurial university" to highlight these changes in academic organisations. This perspective does not imply that universities have put aside their two traditional missions (teaching and research) but that they have to integrate new activities into their traditional business model (Miller et al., 2021). This involves not just engaging in "third mission" activities, such as the transfer and commercialisation of knowledge, but also making significant changes to their main activities in teaching and research. Many universities have expanded their mission by creating new teaching programs, improving facilities, seeking international opportunities, broadening their academic focus to include knowledge transfer and technology commercialisation and encouraging more collaboration with industry in both basic research and commercialisation (Miller et al., 2021).

This new mission sees the university seek reciprocal connections with stakeholders, such as industry and government. In doing so, academia fulfils a multiplicity of activities such as technology and knowledge transfer, looking for translational research funding, commercialising the ideas through incubators or spin-offs, research contracts, staff mobility to the industry and other non-traditional academic activities (Etzkowitz et al., 2019). The entrepreneurial university concept was further developed in conjunction with Etzkowitz's and Zhou's (2017) elaboration of the Triple Helix model, which created the propositions in terms of five entrepreneurial university model norms, namely 1) knowledge spillover; 2) hybridisation; 3) units as quasi-firms; 4) entrepreneurial culture; and 5) reflexivity.

Universities are not the only institutions that have embraced a transformation process. The research sector also undertakes change. The research community, both higher education and research organisations, witnessed the shift from individual researchers involved in collaboration with the industry to groups of researchers engaged in cooperation with multiple institutions. Another metamorphosis has been the promotion of embracing an interdisciplinary approach to better address industry challenges.

To promote interdisciplinary and research collaboration, it has been necessary to incorporate policy initiatives and appropriate funding schemes to foster collaboration with non-researcher actors and promote flexibility of management to adapt to the new environment. Research organisations have to adjust to the new ways of conducting research and the training of researchers with broader perspectives is essential (Giachi and Fernadez-Esquinas, 2020; Anzai et al., 2012). Moreover, research collaboration has been considered a factor in distinguishing the several types of translational assets (Di Maggio and Powell, 1983).

With this changing scenario, a complex research environment emerges where it is possible to identify different R&D organisations that tackle research questions and technical and societal challenges differently.

2.5 Understanding and Classification of TAs

2.5.1 Conceptual Definitions of TAs

Although numerous scholars have attempted to analyse these organisations from various perspectives, there remains a need for a deeper understanding of translational assets as a complex phenomenon. They are characterised by open boundaries and significant internal diversity (OECD, 2022).

One of the most significant challenges in the literature is the lack of a clear, universally accepted definition of TAs. The difficulty in providing a "solid" definition stems from the emerging nature of these organisations and the global variability in how they are conceptualised and operationalised. TAs are increasingly widespread as new research organisations arise within various national innovation systems (NIS) to address specific sectoral or technological challenges. However, the lack of consistent terminology has created confusion, with different scholars using varying definitions and labels to describe these institutions (O'Sullivan et al., 2024).

A key issue is the tendency of some scholars to use blanket terms for these organisations, which often results in an oversimplification of their activities and roles, potentially obscuring their unique characteristics (Gray et al., 2013). The use of such labels varies based on context, leading to misunderstandings about the nature of these organisations. For example, the Fraunhofer Institutes in Germany have been described as Cooperative Research Centres (CRCs) by some scholars (Gray et al., 2013), while others (Cruz-Castro et al., 2020) classify them as Public Research Organisations (PROs). This inconsistency in terminology further complicates efforts to define these organisations clearly.

Similarly, government and policy reports often adopt broad labels that group various types of organisations under a single umbrella term. In the UK, for instance, Research Innovation Organisations (RIOs) encompass institutions such as Public Sector Research Establishments (PSREs), Independent Research and Technology Organisations (IRTOs) and Catapult Centres (BEIS, 2015). OECD (2011) uses the term Public Research Institutions (PRIs) to refer to a wide array of entities, including government research labs, technology centres and even science parks. This broad application of terminology complicates the classification of TAs, making it difficult to draw precise distinctions between them and other R&D organisations.

Finally, these entities widely differ in their activity portfolio, business model, autonomy, legal structure, ownership and many other factors (OECD, 2021).

Given these circumstances, defining translational assets is challenging. Previous attempts to define these research organisations are reported in Table 1.

Authors	Definition
Adams et al. (2001)	IURC (Industry University Research Center) are *"small academic centres that depend mostly on industry support,* is a "small academic centre that depends mostly on industry support, and *we expect them to advance the research of member companies."*
Bozeman and Boardman (2003)	A URC is as a *"formal organisational entity within a university that exists chiefly to serve a research mission, is set apart from the departmental organisation, and includes researchers from more than one department."*
EARTO (2005)	RTOs are defined as "*organizations which as their predominant activity provide research and development, technology and innovation services to enterprises, governments and other clients…*"
Boardman and Gray (2010)	A Cooperative Research Centre (CRC) (or Industry-University Research Centre) is *"an organization or unit within a larger organization that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and technology transfer, and ultimately innovation."*

Hauser (2010)	TICs (Technology Innovation Center) are defined as *"organisations focused on the exploitation of new technologies, through an infrastructure that bridges the spectrum of activities between research and technology commercialisation."*
Sanz-Menendez et al. (2011)	Public Research Organisation (PRO) are a *"heterogeneous group of research performing centres and institutes with varying degrees of "publicness."*
Department of Business, Innovation and Skills (BIS) (2015)	RIO (Research Innovation Organisation) are "*non-profit and non-higher education organisations that perform research and development as their main activity, whose existence depends on some degree of public funding, and whose work serves some public policy purpose.*"

Table 1 – Distinction of types of definitions of translational assets across studies

From the small sample of definitions explored, it is clear that there are many perspectives on what constitutes a TA. While the definitions often reflect country-specific policies, government programs, or particular research activities, a common thread is that TAs are organisations primarily focused on R&D activities through multiple stakeholders, including universities, industry, and sometimes government, typically with support from industry and public funding. Their ultimate aim is to facilitate knowledge transfer and innovation, often with an explicit public or economic benefit.

For the purpose of this thesis, the most suitable definition is derived from Hauser's broader conceptualisation of TAs. Hauser defines TAs as entities that collaborate with private and public sectors to add value to the R&D process, using advanced technologies and services to bridge the "Valley of Death"—the gap between research and commercialisation (Strazzullo et al., 2021; Hauser, 2010). Hauser's definition is especially useful for this research because it is inclusive and does not limit TAs to a particular legal status, structure, or funding scheme. This generic yet comprehensive viewpoint allows for the flexible classification of TAs, which is essential given the heterogeneous nature of these organisations. Furthermore, Hauser's definition is recent and developed by a well-regarded expert in the field. This makes his conceptualisation well-suited to the goals of this thesis, which seeks to explore and classify a wide variety of TAs in Scotland and beyond.

In conclusion, the non-standardised terminology surrounding TAs presents a significant challenge in defining and classifying these organisations. To address this, Hauser's definition offers the most appropriate foundation for this research, as it encapsulates the multifaceted roles of TAs while allowing for flexibility across different contexts and sectors.

2.5.2 Example of TAs Initiatives in the World

Translational assets occupy a prominent position in many innovation ecosystems around the world to fill the gap between university and industry. Because each innovation system is unique, these assets have their own role and characteristics that reflect their national innovation system (Intarakumnerd and Goto, 2018) and can vary across a spectrum based on their features. For instance, they can range from being primarily embedded as part of a public sector research system having a scarce relationship with industry to being government-funded institutions that undertake bridging functions between academia and industry.

Although the TA sector is poorly mapped, it is not a new phenomenon and it is possible to cite prominent examples of TAs programs at the international level acknowledged in the literature, such as those in the United States, Europe and Asia-Pacific.

United States Programmes

The United States is one country where collaboration between academia and industry has become institutionalised to a greater extent. The activities of the National Science Foundation (NSF) have been essential in this case. The NSF has encouraged various heterogeneous programmes to form and finance CRC organisations throughout the previous three decades. It is worth noting the programmes: Science and Technology Centres (STC), Engineering Research Centres (ERC), Industry-University Cooperative Research Centres (I/UCRC), the Small Business Innovation Research (SBIR) programme, the Small Business Technology Transfer (SBTT) awards and Proof of Concept Centers (PoCC) (Gray et al., 2013). A significant number of regional University Research Centres (URC) complete this collection.

In the 1980s, the STC program, run directly by the NSF, split off from the ERC program. The primary goal of the STC programme is to conduct fundamental and engineering research in strategic areas from a multidisciplinary standpoint. Moreover, these centres were required to build partnerships with several stakeholders to ensure that research maintains social relevance (Brzakovic and Cozzens, 2016). The STC has a sizable budget and a comprehensive program even though their centres have only received funding for ten years. The STC centres have dual affiliations with the universities and their researchers, typically from several departments and universities. The definition of research lines, in collaboration with other universities and consulting, constitutes the extent of corporate participation in this instance.

The ERC (Engineering Research Centers) program, also known as research centres in engineering (Bozeman and Boardman, 2004), is a slightly older programme. With its large volume of grants, it aims to bridge the gap between basic and applied research with more focused goals that are engineering-related through the creation of jointly used infrastructures (Koschatzky and Stahlecker, 2016). Since businesses play a more significant part in choices that influence the centre, often through bilateral talks, there is a greater industry presence in ERC centres. The ERC centres have produced significant breakthroughs in their respective fields and have steadily emerged as one of the most crucial resources for US science and technology strategy.

The NSF's Program I/UCRC (Industry-University Cooperative Research Centres), also known as Research Centres Collaborative between University and Industry (Cohen et al., 1998; Adams et al., 2001), occupies a position somewhat in the middle of basic research and knowledge transfer. The Program was built to develop research to provide socio-economic support and develop long-term relationships between academia, industry and government. I/UCRC is among the oldest and most established of its kind of Programme and has been stable since its establishment. The Programme, being a university-industry collaboration programme, has surprisingly remained unaffected over the past decades by government policy and politics. One reason is due to the high institutional autonomy of NFS (Koschatzky and Stahlecker, 2016).

The I/UCRC centres frequently need their own infrastructure with business relevance through membership fees and in-kind contributions and, in general, seek to improve the integration of application-oriented research and education. Even though their industrial presence is more significant and direct than the STC and ERC centres, their budget and scope often need to be more significant. The I/UCRC Program, on the other hand, does not attempt to develop on-site cooperation between university academics and industrial researchers. Moreover, while the I/UCRC model requires stringent academic and business competence, it does not seek to establish a "national elite" of centres in specific areas of intervention. On the contrary, it is aimed at universities that have yet to establish a large number of self-motivated partnerships. (Koschatzky and Stahlecker, 2016).

R&D commercialisation and technical development activities are more closely related to smaller federal initiatives, like the SBIR (Small Business Innovation Research), SBTT (Small Business Technology Transfer grants) and the most recent PoCC (Proof of Concept Centres) (Grey, 2011; Melley et al., 2014).

The SBIR, SBTT and PoCC programs are targeted at SMEs, typically through bilateral relationships, in contrast to the STC, ERC and I/UCRC programs, which frequently involve significant corporations. Although evaluating the direct impact on technological innovation is challenging, the SBIR program already has a proven track record and has produced significant economic gains, such as company growth and creation and initiated partnerships between small businesses and academia to have access to the universities' resources (National Research Council, 2009).

There are also programs in the United States that have yet to be started by the NSF and are the result of other federal or state organisations, universities, or other sources.

In this instance, we are talking about university research centres (URCs). According to Bozeman and Boardman (2003), URC centres are typically modest in size and housed inside a university building. Usually more subtly and indirectly and frequently through unofficial connections between academics and professionals, the industry is present in the URC centres. Currently, American universities conduct a significant amount of applied research in the URC centres.

Australia Cooperative Research Centres (CRC) Programme

The CRC Programme was one of several initiatives in Australia at the start of the mass education era that supported scientists in enhancing their entrepreneurial abilities and gaining insights into market prospects and industry collaboration (Cunningham et al., 2021). In particular, the Government of the day sought to direct research to adhere to national proprieties and make Australian institutions competitive with those of other OECD nations, motivated by the then-dominant economic rationalist ideology (Sinnewe et al., 2016).

The programme, which follows the example of the US NSF Engineering Research Centre, is the most extensive collaborative research program in Australia (Liyanage and Mitchell, 1993) and began in 1991. The program promoted ongoing collaboration between industry and public research institutions on applied research challenges to deliver social, economic and environmental benefits to Australia (Peacock, 2015). This is still the intent of the CRC programme (Sinnewe et al., 2016). O'Kane et al. (2020) claim that the CRC program was intended to satisfy four objectives: 1) research excellence; 2) effective collaboration; 3) creation of new educational opportunities; and 4) the translation of research outputs into economic, social and environmental benefits to Australia. Some of the aspects distinctive to the program are the formation of an independent intermediate management structure and the requirement that CRC participants' cash and in-kind contributions at least match the funds sought from the program (Turpin et al., 2011).

For an initial seven-year period, the CRC program funded projects in the six main areas (manufacturing technology, information and communication technology, mining and energy, agriculture and rural-based manufacturing, environment, and medical and science technology). At the end of the cycle of funding, the centres then had to come up with the funds on their own to ensure their ongoing existence (e.g. commercial funds). However, it has been shown that self-sustainability after the initial funding period represented one of the challenges for the program because companies had to see value in financing project in-kind contribution, at least at the same level (Sinnewe et al., 2016).

Unlike past centres, CRCs have a strong industry focus and must engage at the Triple Helix level by involving individuals and groups from the academic, governmental and commercial sectors (Liyanage and Mitchell, 1993). In any instance, public support can come from academic or scientific partners, who are often public institutions or are part of the CSIRO (the network of public research institutes controlled by the Australian Government), even though private involvement in the financial endeavour is also possible.

Howard Partners (2003) conducted an analysis that revealed the origins of three types of centres based on their orientation towards the national public good research, industrial focus and commercial benefits. However, these three types of centres only sometimes correlate to the first three organisational models (academic, corporate and integrated, respectively) described in the program's early stages by Liyanage and Mitchell (1993). On the other hand, Garrett-Jones and Turpin (2002) conducted a more academic review that revealed the difficulties in measuring the centres' results through quantitative indicators while also outlining some ideas and mechanisms for generating evaluation measures with a higher qualitative component. Recent evaluation reports (Productivity Commission, 2007) have emphasised the importance of refocusing programme objectives and adopting a more flexible approach. Indeed, the program shifted its goals to deal with new challenges in end-user-focused activities (Turpin et al., 2011).

In addition to the CRC initiative, the Australian Government supports additional forms of science-industry partnership such as CSIRO National Research Flagships, Rural Research and Development Corporations, Australian Research Council programmes and Joint Research Engagement (Allen Consulting Group, 2012). Regional states play a growing role in science, technology and innovation policy (Garrett-Jones, 2004). There is a trend towards regionalisation of these policies, where local players (regions, municipalities, universities, associations and local businesses) collaborate and build structures to carry out collaborative innovative projects (Kilpatrick and Wilson, 2013).

At the conclusion of the review of the Australian Programme, two key factors relating to the employees engaged in the CRCs should be highlighted, distinguishing between researchers employed in the centres and personnel of the enterprises participating in the partnership. The Australian experience, according to the research staff, demonstrates the problems that can be experienced in building hybrid environments, including university workers whose careers respond to the operational logic of academic organisations. Both evaluation reports and academic research have emphasised the existence of "cultural" adaptation issues on the side of the workforce in this regard. One probable explanation for these challenges is that, in the case of the CRC program, the research personnel of the centres were, for the most part, university professors or comparable positions inside public research organisations. On the other hand, while company engagement in these centres was rather extensive, it implied a different level of collaboration between business researchers and industrial technologists than, say, in the United States. This is owing to the differing makeup of the Australian industrial fabric, which is substantially smaller in size and has fewer enterprises with excellent scientific capabilities.

Research Programmes in the Asia-Pacific Area

The research landscape in the Asia-Pacific region is characterised by a vibrant and dynamic innovation system, with diverse countries actively engaged in fostering research, development and technological advancements. These countries have recognised the critical role of research and innovation in driving economic growth, addressing societal challenges and improving the quality of life for their citizens. To develop their research programs, they have drawn inspiration from established Western research models to compete in the global economy (Bozeman and Boardman, 2004). The ability of Asian countries to develop their research programs by adapting and learning from Western models demonstrates their adaptability, learning capacity and determination to excel in research and innovation. By blending best practices from Western research programs with their own strengths and cultural contexts, they have created research ecosystems that are tailored to their specific needs and priorities.

Countries in the region, such as Japan, South Korea, Singapore, China, Taiwan, and others, have made substantial investments, between 2% and 5% of GDP, in education, research infrastructure, and human capital to establish themselves as global leaders in innovation (OECD, 2022). They have created well-developed innovation ecosystems that encourage collaboration between academia, industry and government, facilitating the translation of research outcomes into practical applications and commercialisation.

These countries have also focused on building strong research institutions and universities that attract top talent and drive scientific advancements. By fostering collaboration, interdisciplinary research and state-of-the-art facilities, these institutions contribute to generating cutting-edge knowledge and the development of innovative solutions to societal challenges.

Examples of research programs in the region further exemplify the commitment to research, innovation and collaboration. The National Natural Science Foundation of China (NNSFC) supports fundamental and applied research in natural sciences and foster scientific talent excellence and technological advancements. Another example of a Chinese program is the Chinese National Engineering Research Centre (CNERC), which provides technical assistance to SMEs in specific technology areas (World Bank Group, 2020). In Taiwan, the Ministry of Science and Technology (MOST) and the Industrial Technology Research Institute (ITRI) oversee research programmes that support industries in staying competitive and sustainable (Wang et al., (2021). The Korean Institute of Science and Technology (KIST) conducts research across various domains, overcome the lack of technological capabilities and supporting Korea's economic growth (Park and Kim, 2020). The Japan Science and Technology Agency (JST) funds research programs focussed on applied research, such as the National Institute of Advanced Industrial Science and Technology (AIST), that promote collaboration between academia and industry, and reducing dependence on foreign technology (Park and Kim, 2020).

Overall, the Asia-Pacific region's research landscape showcases a dynamic and evolving system that fosters scientific excellence, promotes collaboration, addresses societal challenges and drives economic growth. Moreover, it should be emphasised that, in the case of the Asia-Pacific region, little information is currently available regarding the development of collaborative science-industry programs undertaken in this area. As a result, the literature reviewed for this region is merely illustrative. This is due, among other things, to the great geographical, cultural and linguistic distance between these countries.

European Programmes

The European scenario is complex due to the high heterogeneity among the countries. In Europe, it is possible to distinguish between two strands: on one side, there is the European Paradox, which emphasises the quality of Europe's educational and scientific base but particularly its inability to translate this advantage into outstanding technical and economic performance (Rodríguez-Navarro and Narin, 2018). On the other hand, different governments try to promote collaboration between universities and industry to boost the productivity level of the country.

In this sense, the Framework Program has been an important element in addressing this gap by "reinforcing collaboration between university research and industry" (European Commission 2010). In fact, EU countries issued different policies at national and regional levels to support university-industry collaboration. Among those, it is possible to distinguish at the community (EU) level network of collaborative research centres (CRCs) such as Centres of Competence (CoC) and Centres of Excellence (CoE), promoted by the Common European Research Area (ERA) to conduct applied research in priority regional sectors in collaboration with leading enterprises and the network of innovative communities (KIC, Knowledge and Innovation Community) supported by the European Institute of Innovation and Technology (Interreg Europe, 2020). While at the national level, there are programs like Fraunhofer Institutes in Germany, the Flemish Government's Excellence Centre, the TNO centres in the Netherlands, the Approved Technology Service program in Denmark, the Centre for the Development of Industrial Technology and Innovation (CDTI Innovation) in Spain and the Catapult Centres in the UK (OECD, b 2011). All of these initiatives aim to develop the national science and innovation system's capacities by fostering applied research in technology areas of strategic relevance and by establishing more direct relationships with industry and national enterprises. The wide variety of programs makes it difficult to define a common model between the programs and the different typologies of research organisations.

At the regional level are promoted initiatives like clusters, associations or collaboration programs with local universities or industries.

As is shown, European initiatives are very complex and heterogeneous. However, despite the great diversity of contexts and experiences, most European initiatives would reflect similar trends, albeit with different organisational forms, which would likely depend on the composition and capabilities of the actors, as well as the specific orientation of the innovation policies. This means that these trends are oriented towards hybridisation with the involvement of different private and public actors - different to the trends in those nations with the most advanced technologies where there has been a separation between the university sector and the sector of public technological institutes, oriented towards the market but with little formal participation from it (Arnold et al., 2010).

2.5.3 Distinctive Factors Used in the Previous Classification of TAs

Unlike the university and the private sector landscape, the TAs have received only attention from academics and practitioners in recent decades. As mentioned, the literature studied to develop a clear understanding of the topic remains scattered and a useful exercise would be to analyse the differences between types of R&D organisations. In recent years, there has been much interest in categorising the various programs and experiences for joint research and university centres since it is a necessary first step for creating hypotheses on how the TAs operate (Bozeman and Boardman, 2004). This issue has gained more attention in particular as a result of the relevance that experiences outside the geographic context of the Anglo-Saxon countries that have accumulated the majority of the experiences (USA, Australia, Canada) have started to have and the recognition given by academic researchers as strategic research sites to observe the dynamics of innovation systems and the results of public policies that affect them (Grey et al., 2013; Lal and Boardman, 2013).

Several scholars, including Cruz-Castro et al. (2012), Sanz-Menéndez et al. (2011), Crow and Bozeman (1987 a,b), Bozeman and Crow (1990) and Arnold et al. (2010), have attempted to build the classification of TAs.

The word classification has different meanings in the literature and is often known as typology or taxonomy. According to Mayr (1968), a classification is a communication system, and the optimal one combines the most information content with the most excellent ease of retrieval. Moreover, a classification recognises essential structure and relationships and provides a foundation for theory creation and hypothesis testing (Rich, 1992). Since the researcher's objective is to classify TAs by building a typology of a specific type of R&D organisation, it is pertinent to distinguish these two basic classification approaches. However, some scholars may use them interchangeably for simplification. A *typology* is a classification approach based on a priori theories or concepts (Rich, 1992). That is, each dimension identified represents a concept. In contrast, the taxonomy is a categorisation system that aims to classify empirical facts into hierarchically related groupings. The term typology is used in this research to refer to the classification. Typologies, as defined by Collier et al. (2008), are "organised systems of types" that are "useful only if they reduce the redundancy and complexity of many variables" and "to reduce the redundancy and complexity of the competing typologies."

Several criteria of classification were employed to describe a translational asset. The past classification used different approaches that differed in classifying a specific type of entity. For instance, a high cited article by Boardman and Gray (2010) classifies the university-industry cooperative research centre. Another example of the classification of research organisation is about the analysis of different operating models (Philbin, 2014).

The earliest dominant types of translational assets were categorised based on activity, environment, stakeholders, collaboration, organisational structure and resources.

Activity

To understand where the TAs fit in the innovation ecosystem is essential to know what activities they undertake and their scientific and technological capabilities.

R&D includes three primary types of activity: basic research, applied research and development research. The type of activity depends on the strategic goals of the translational asset. These research activities are known to cover the first six levels of technology readiness (APRE, CDTI, 2023). Basic research is mostly undertaken by academic institutions, which aim to create scientific knowledge or products without the intent of the application. Applied research focuses on the creation of a practical idea. Development research embraces activities such as testing, product production, demonstration performance, prototyping, or producing a product in actual condition (Lalienė and Sakalas, 2014). This classification is well described by Arnold et al. (2012) by Pasteur's Quadrant, which categorises research activities as pure research, use-inspired basic research and pure applied research. The first type of activity is undertaken in collaboration with the university to discover new knowledge for its own sake; the second activity is at the interface between the university and business; the last activities are carried out by the researchers that aim to the technological development and to satisfy the firms' interests (Tijissen, 2018). To support Pasteur's Quadrant, there is Bozeman and Boardman's taxonomy (2003). The several activities from the research organisations can vary from simple research activities to more extensive activities, including industrial interaction brokering or community outreach.

Environment

As most organisations, translational assets must face the evolution of their environment, which affects the whole organisation (Aldrich and Herker, 1977). The most relevant studies about the R&D organisations' environment have been carried out by Crow and Bozeman (1987 a,b) and Bozeman and Crow (1990). They investigate the context of the American R&D laboratories developing an environmental taxonomy. Instead of considering traditional legal status or ownership (i.e. public, private or non-profit), they used the government influence (political authority) as an attribute to analyse the organisational environment. The variable more appropriate to describe the state pressure is the "*publicness*" that emphasises "the degree of political authority and endowments affecting the organisations" (Bozeman and Moulton, 2011) regarding the role of the government in shaping the research agenda of the R&D organisation (Fig. 4). Indeed, laboratories can be owned by a public organisation like government and university or private if founded by an industry (Crow and Bozeman. 1987 a).

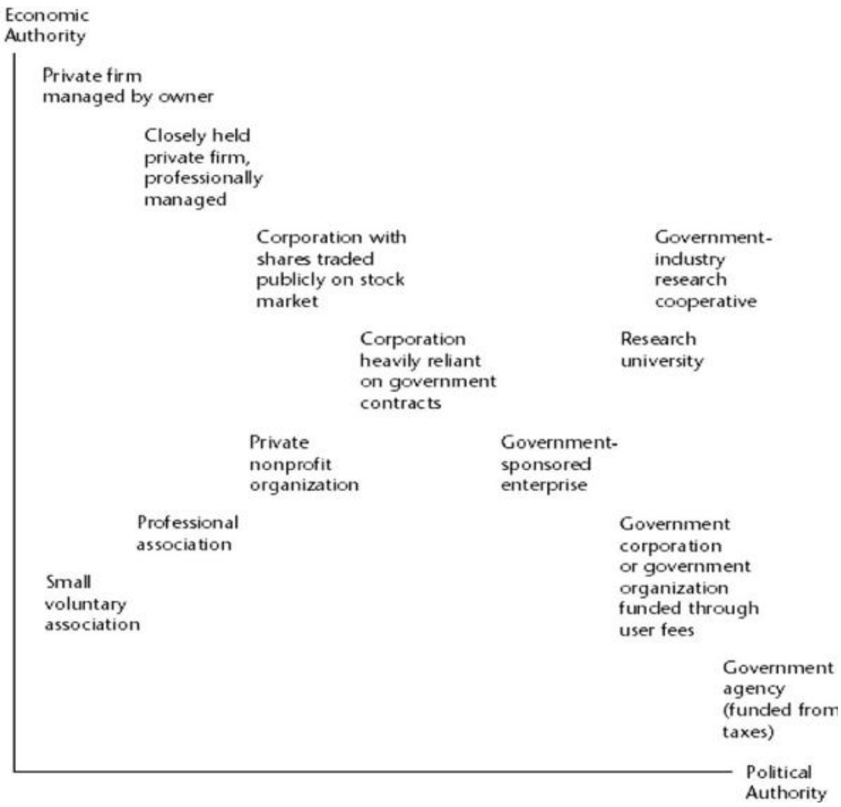

Figure 4 - Empirical Public Grid (Bozeman and Moulton, 2011)

To clarify this concept, the graphic above can also be explained through a scheme to show government influence by using the percentage:

- High publicness: 76-100 % of research funded by government agencies;
- Moderate publicness: 26-75 % of research funded by government agencies;
- Low publicness: 0-25 % of research funded by government agencies.

The use of this percentage is beneficial to understanding the external autonomy that a TA has. The state's influence through the funding allocation and its authority shapes the organisation's character because it leads the organisation to undertake a specific research agenda independently from a private or public status. In 2012, Cruz-Castro and co-workers (2012) reported more recent evidence, analysing external actors' influence on Spanish research organisations based on the different legal statuses and using their funding portfolios. Their study emphasised governmental dependency through a bi-dimensional framework that shows the borders between public and private technology and public and private science (Fig. 5).

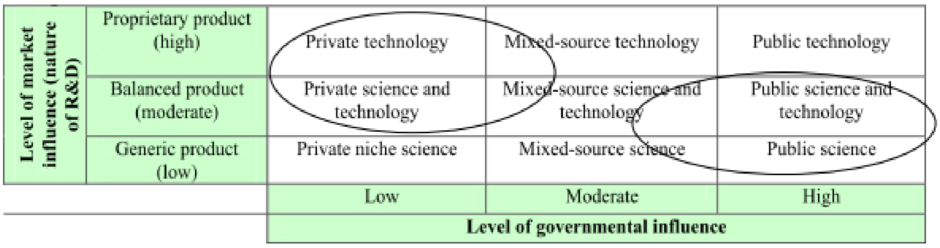

Figure 5 - Classification Framework of Research Centre (Cruz-Castro et al., 2012)

Another attribute related to the environment is the autonomy of the R&D organisation in relation to the political system. This attribute shows the strength of the relationship between TAs and the state (Sanz-Menéndez and Cruz-Castro, 2003). However, authority and autonomy are not necessarily linked. Nowadays, being autonomous for an R&D organisation is critical because even if a government exercises its power on the organisation, this can have a certain degree of autonomy, allowing the management and the TA's researchers to look for external funds.

Stakeholders

Stakeholder is a recurring factor in many classifications because the type of stakeholder is linked to the organisation's themes (e.g. Health, digital economy, energy) and because there are different groups based on the kind of innovation organisation and its objectives. For instance, Hagedoorn et al. (2000) classified the stakeholders into public and private. The public stakeholders embrace university and public research centres, while the firms represent private stakeholders. Bonaccorsi and Piccalunga (1994) share the same perspective, considering stakeholders only the university and the industries. Differently, Adams et al. (2000), Gray (2000), and Leydesdorff and Etzkowitz (1995) stated that the stakeholders for the innovation organisations are represented by the Triple Helix's actors, that is the university, government and industry. Gray et al. (2001) and Andams et al. (2001) affirm that the industries support the research programs run by the innovation organisation through membership and usually contribute with more funds (Lal et al., 2007). The spheres represented by the stakeholders influence the culture of the organisations (Gulbrandsen, 2011).

Collaboration

This variable is one of those used by Bozeman and Boardman (2003) in their report to establish the taxonomy of research organisation. In the TA ecosystem, the university, industry, other TAs and government are the main stakeholders. The partnership between these entities brings advantages to all the parties. For instance, some industries that struggle to be self-sufficient or lack capability, through collaboration with TAs, have access to several resources such as skilled personnel and/or facilities with leading-edge technologies that help them address their challenges. This is possible because of the public funding the TAs receive for building capabilities that their client would not invest in for developing themselves.

On the other hand, the university collaborates with the industry to perceive what the practical problems are. However, Bozeman and Boardman (2003) showed that the external relations depend on the type of the research infrastructure. For instance, some TAs collaborate with other TAs and government funding agencies without engaging the industry (Bozeman and Boardman, 2003).

A clear distinction between the types of collaborations was made by Lind et al. (2013) in their qualitative study of three centres at Swedish Technical University. They distinguished 4 forms of collaboration: 1) distanced, in which there is a weak link with the industry and the research is undertaken from the university; 2) translational, where the research happens in both directions; 3) specified, in this case, the industry lead the research agenda; and 4) development, industry, university and funding agency together set the research agenda.

Even if this collaboration seems to involve only the university and the industry, the translational assets interact with both entities, encompassing the same means. To improve the TA's perception in this collaboration, it is essential to know the driving logic of these R&D organisations since they perform innovation neither as a university nor as an industry. A valuable attribute to understand these institutions' orientation is their proximity to the market, in particular their collaboration with the SMEs. This attribute is relevant because of the reduction of institutional funding over the past decades (Sanz and Cruz, 2003). Moreover, understanding the vicinity of the TAs to the market shows the degree of a TA within the university. Simultaneously, the partnership with the SMEs is an index to understand how close the TAs are to the SMEs to meet their needs and address market failures. The relevance of considering SMEs as the firms of reference is that industries of such size under-invest in R&D activities due to their lack of technical competence and they dominate the business enterprise landscape in most countries.

Organisational Structure

The organisational structure is an essential factor for designing an organisation because it is necessary to choose the appropriate configuration to achieve its goals and be high-performance in its environment. Its importance is because it deals with the reporting lines of authority, information flow between management levels, responsibilities and duties within an organisation (BusinessDictionary.com). The more appropriate attributes to illustrate the organisational structure is the autonomy and the organisation's authority (Cruz-Castro and Menédez, 2018; Boardman, 2012). *Autonomy* can be defined as how the researchers make decisions rather than integrate them (Jordan, 2006). The degree of autonomy can vary in a range based on the autonomy of the researchers within their organisation. The first case sees the relationship between the state and the TA. This relationship is forged by the degree of autonomy that the state links to the affiliate TA. However, currently, the extent of autonomy allocated to the TAs by the government continues to vary as R&D organisations are encouraged to search for new funding sources, which suggests less dependence. This autonomy causes a shift from the traditional mission to a producer of general or specialised knowledge for industries. Thus, the manager and researcher within a TA with low autonomy from the government will not be incentivised to search for external funding (Sanz Menéndez et al., 2003). The increasing degree of autonomy concerning the government and the search for external funding is occurring in most of the R&D organisations. On the other hand, the autonomy of the researcher within the organisation is not equally distributed. It depends on the freedom to set the own research agenda and the attention to how to implement the goals. Additionally, the researchers' autonomy is related to management's level of authority and the research funding allocated.
Regarding the variable authority, it depends on the nature of the management model. One study by Liyanage and Mitchell (1993) identified three different management decision-making models: the executive control model, in which the board takes the most critical management decisions, which are then communicated down through the hierarchy; the consensus model, which expects that the decisions are made in consultation with several organisational layers of management; and

the authoritative model where the direct control is of the executive director or principal researcher. It is possible to find this model in academic research management, where the executive director or principal researcher imprints their vision, interest and goals (Stahler & Tash, 1994). However, the director of this type of R&D organisation needs to have managerial and political skills to build relationships outside the university and obtain resources (Sá, 2008). By contrast, in their multi-institutional collaboration study, Corley et al. (2006) identified two levels of authority and autonomy through the bottom-up and top-down approaches. The first case is an informal approach in which the principal investigators have significant freedom to pursue their research (Philbin, 2011). The second approach differs in that decisions about the research priorities are taken from the director(s) and filtered down to the working unit (Cruz-Castro et al., 2012). This variety of decision-making approaches implies that innovation organisations can be structured with either a flexible management (decentralised) style or a more formal (centralised) one.

Resources

The resources supplied by the TAs can be defined as the assets, capacities, knowledge and individuals that their stakeholders have access to in order to run their operations and ensure a successful collaboration between the innovation actors involved (Schuelke-Leech). Generally, for translational assets, the primary organisational variables considered for classification are financial models, human capital and research infrastructure (equipment). Ikenberry and Friedman (1972) used finance, human resources and physical assets in their heuristic categories of R&D organisations.

Moreover, the type of resources employed by the R&D organisation shows the type of output of the TAs. For instance, a TA that collaborates closely with the university could focus on publishing in a scientific journal or carrying out more fundamental research. On the other hand, the TAs are close to the industry; they will provide consulting, knowledge and technology transfer and commercialisation.

Funding is a crucial parameter in distinguishing the different types of organisations because it has a remarkable influence on the research orientation and how organisations have to set priorities (Etzkowitz and Kemelgor, 1998; Lal et al., 2006). TAs rely on public and private income such as membership subscriptions, fee-for-services, government core funding, contracts for public grant funds or competitive grants from government and industry (Berger & Hofer, 2010). Some TAs rely on public financing, receiving none or a very small percentage of funds from the industry; some are a combination of time-based project financing, R&D programs and membership fees and others that private institutions fund. The funding model varies across countries and TAs depend on public funding based on the importance that governments give to their R&D strategy. Currently, the government's budget has ongoing changes, leading the TAs to increase the level of competitive funding through private and public channels (Arnold et al., 2010; Balthasar et al., 2000).

Moreover, the funders determine the geographical scale of the organisation's operations. In particular, the organisations established and funded by the regional government limit their activities to their home region. At the same time, those who receive funds from the national government address national needs (e.g. Fraunhofer Institutes) (Charles and Ciampi, 2014). It is essential to know that the funders do not support the R&D organisations through the full TRL scale. The sources and the amount of funding received from translational assets show where they fit within the TRL spectrum, but they do not drive the research agenda of the TAs. If an organisation receives most of the funding from a single stakeholder, the management and the researchers pursue their research objectives without neglecting the stakeholder interests (Lal et al., 2007). This is arguable because TAs with several industrial members bring a considerable percentage of funding to the organisation and force the TA's management to satisfy the members' needs.

In contrast, if the funding stream comes from different players, the organisation may cover different directions (Gulbransden, 2011; Crow and Bozeman, 1987). Therefore, various sources allocate funding to the TAs, and it can vary continuously. Indeed, the variation of funding drove many R&D organisations to adopt a new strategy to respond to the new environment by increasing the diverse sources of income because of reducing institutional funds (Sanz-Menéndez and Cruz-Castro, 2003). For such reason, the management of TAs must establish a clear mission and vision to avoid inefficiency and loss of funding in the future.

Human capital is a critical resource for the activities of the TAs. It could be considered the most critical asset of an R&D organisation and must consist of a wide range of skills to transfer knowledge effectively. It consists mainly of scientists, researchers, technicians and researcher students (Adams et al., 2001) with different areas of expertise. There is a distinction between scientists and engineers, for example. Whereby the former focuses on producing knowledge, whereas the latter focuses on producing physical designs, products, and processes (Schuelke-Leech, 2013). Human capital can be further distinguished when considering the type of researcher. Some traditional researchers collaborate with industry without any scope of commercialisation, the researchers that have a strong sense of commercial awareness, the researchers that engage in entrepreneurial activities, and the researchers that are loyal to the traditional research activity but believe and recognise university-industry partnership is largely beneficial (Tijissen, 2018). This resource has a certain level of autonomy because it is influenced by the funding type and its management style (Jordan, 2006). Human capital can be diversified based on the size and the functions of the personnel. For instance, Jordan (2006) reported the classification of the competencies of individuals, as well as a group, considering the level of specialisation with specific expertise and the complexity and diversity of the research teams, while Lal et al. (2007) made the distinction of the personnel as academic faculty, research faculty and research staff. Academic staff face challenges in their role as they must split their time between an academic department and a university research centre to fulfil different educational activities (Boardman and Bozeman, 2007). It is essential for human capital to have formal training and required education to strengthen innovation capability and undertake research and other science and technology activities. Human capital must also possess soft skills such as leadership and management (McNie et al., 2016). For those organisations very close to the market side, it is essential to have dedicated personnel with industrial experience and technical knowledge to identify the industrial pressures and priorities that would not be obvious to people whose experience is limited in the academic field (Arnold et al., 1998). However, some TAs need dedicated personnel. For example, the university-based TA consists of academic and research staff who dedicate only a part of their time to the research activities because they have to carry out other educational activities such as teaching, tutoring, etc.

Research infrastructure is an essential factor for a TA's performance because of the specialised equipment required for experiments and empirical research. However, not all of them have the same equipment and space for specific activities available. For instance, there is not enough laboratory space, workshops, up-to-date instrumentation, and other resources available for R&D organisations based within the university. Therefore, not all TAs can have stability in tasks and resources (Ikenberry and Friedman, 1972). The capability of the TAs facilities depends mainly on the support that the TAs receive. The funding scheme changes affect the scaling up and the upgrade of the infrastructure (Stahler and Tash, 1994). However, many TAs that have capabilities are willing to provide access to the industries. Allowing the use of their scientific capabilities, TAs add another source of income. For the campus-based TAs, this can be another way to build a strategic collaboration with the industry (BIS, 2015).

2.6 Summary

In conclusion, the literature review forms the foundation for understanding the key theoretical concepts underlying this investigation. It highlights the importance of the Triple Helix model and the open innovation concept as crucial theoretical frameworks guiding the study of translational assets. The definition of research organisations used in this research is informed by the work of Hauser, focusing on two core elements:

- The organisation must collaborate with universities and industry;
- The organisation should be engaged in translational research or activities beneficial to both industry and the public.

While these concepts are fundamental, the literature reveals a significant gap in the comprehensive classification of TAs. Much of the debate surrounding TAs arises from their heterogeneity, both internally and externally. Over time, key scholars such as Crow and Bozeman (1987), Arnold et al. (2010) and Cruz-Castro et al. (2012) have attempted to classify R&D organisations under different names. However, these attempts have been limited in scope, focusing on single factors or specific cases without providing a holistic view of TAs' multifaceted nature.

Several factors drawn from R&D organisational theory—including activity, environment, organisational structure, stakeholders, collaboration and resources—provide a useful starting point for developing a more nuanced classification system. Table 2 outlines the suggested factors identifies to design the existing classifications. However, the current literature lacks a comprehensive framework that can effectively account for the diversity and complexity of TAs, particularly in dynamic contexts such as the Scottish innovation landscape.

Sources	Classifications	Characteristics
Crow and Bozeman (1987a, b)	Environment	• Legal status or Ownership • Government Influence • Market Influence
Hagedoorn et al. (2000); Corley et al. (2006)	Collaboration	• Motivation for Collaboration • Organisational Structure • Bottom-up/To-down process/Mixed model
Chompalov et al. (2002); Bonaccorsi and Piccalunga (1994)	Organisational Structure	• Bureaucratisation • Size • Research Autonomy • Scale of Project
Gray (2000); Jordan (2006); Stahler and Tash (1994); Corley et al. (2006); Lal et al. (2007); Balthasar et al. (2000)	Input	• Funding Scheme • Human Capital • Research Infrastructures • Research Project
Hagedoorn et al. (2000); Bonaccorsi and Piccalunga (1994)	Stakeholders	• Public, private and public/private

Table 2 – Factors used for TAs classification in previous studies (Strazzullo et al., 2021)

Moving forward, the factors identified in this review will guide the development of the interview protocol, which will assess their continued relevance among experts. This process will determine whether these factors remain essential for classifying TAs in Scotland or if new elements need to be incorporated to capture the evolving nature of research and innovation organisations.

Overall, this literature review establishes a solid foundation for the study, addressing the gap in the classification of TAs. It sets the stage for improving the classification framework by integrating insights from both theoretical frameworks and empirical research.

Chapter 3

3 Research Methods Overview

3.1 Introduction to Methodology

This chapter provides a comprehensive overview of the methodology employed in this study, focussing on the research philosophy, approach and methods used for data collection and analysis. The research methodology is influenced by the research questions and objectives posed earlier, guiding how the study navigates the complect environment of TAs.

The methodology has utilised Saunder's "research onion" (Saunders et al., 2012) (Fig. 6). The elaboration of the methodology begins with the description of the research strategy that will be discussed in the research philosophy, explaining the choice of ontology and epistemology, which has driven the selection of the research approach. Then, the research design will explain the decision to undertake a qualitative analysis and the employment of the multi-cases study method. The research questions proposed in this thesis are suited for a methodology based on the use of multiple case studies using primary and secondary data sources. The researcher employed this method "out of the desire to understand complex social phenomena" (Yin, 2014). In fact, this research is about investigating a contemporary phenomenon where the researcher has no control over the actual phenomenon. For such a reason, a qualitative analysis is the most appropriate method in order to generate findings that can be employed to inform practitioners and policymakers of the concept studied. Moreover, the multiple case studies approach is used to strengthen theoretical generalisability. The discussion will finish by describing how the sample was analysed and how the data was gathered and then analysed.

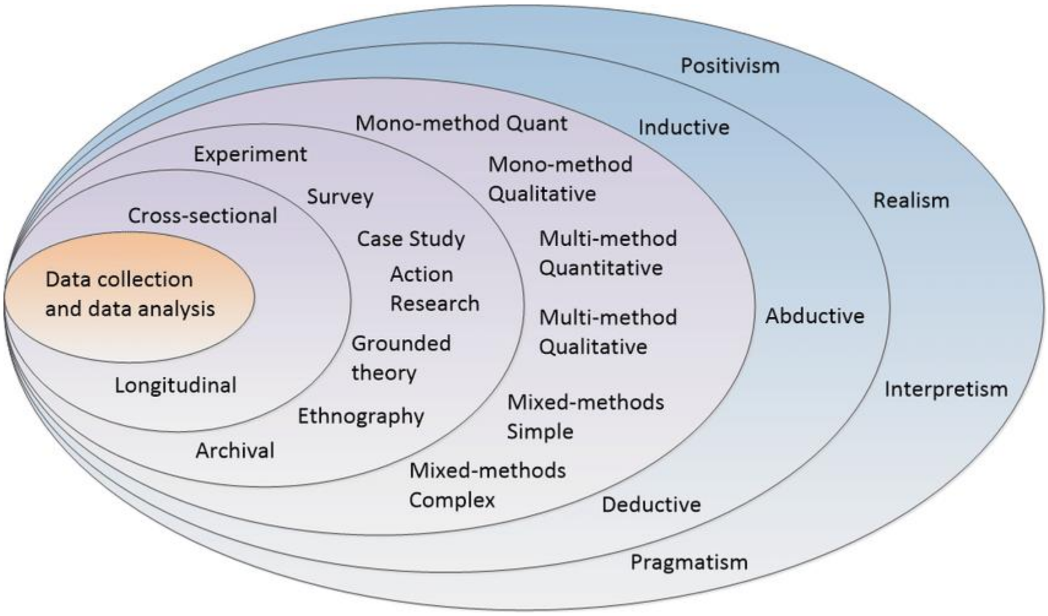

Figure 6 - The Research Onion (Saunders et al., 2012)

Since this research project uses a multi-case study method, the research questions had a broad scope. Then, successively, they were refined during the investigation by analysing the raw data and implementing new aspects linked to the phenomenon investigated (Swarnborn, 2010). Considering the aim of this analysis, the research targets answering the following research questions:

- *What are the main factors for classifying translational assets and how can they be represented along a continuum to enhance understanding?*
- *What key factors should be considered in developing a comprehensive classification framework for translational assets in Scotland, and how can they be adapted or enhanced to create a context-specific classification system?*

To address this scope, a qualitative methodology approach covers the steps below and Figure 7 illustrates those steps through a scheme:

Phase 1:

- A review of relevant literature on translational assets;
- Identify the factor used by scholars to classify the translational asset;

Phase 2:

- Data collection:
    - Develop the interview guide;

- Identify the translational assets in Scotland that met the selection criteria;
- Data collection by interviewing high-management members within each translational asset;

Phase 3:

- Develop the framework from the findings obtained from the literature review to propose a classification of translational assets;
- Defining and refining the factors obtained from the interviews;
- Triangulation with different data sources;
- Constructing the final classification framework for the Scottish translational assets.

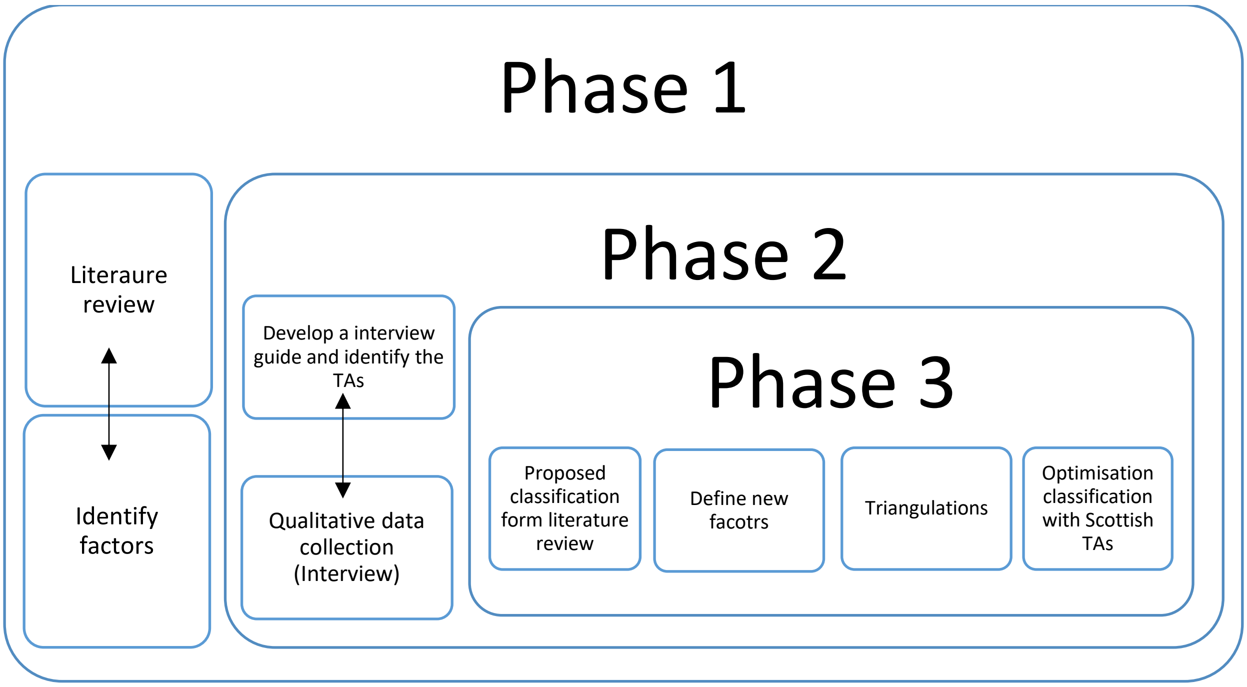

Figure 7 - Research Methodology

3.2 Research Philosophy

To study the phenomenon of TA, it is important to provide theories about the reality that is under investigation and about how the knowledge of this reality is produced and justified. These are the elements that underpin the philosophy and are known as ontological assumptions (the nature of reality) and epistemological assumptions (what can be known) (Creswell 2013).

The debate over what defines "truth" in academic research focuses on both the objective and subjective perspectives. Many scholars have tried to describe this process. For instance, Saunders et al. (2012) claim that the way the topic is approached and the research procedures employed are influenced by the overall choice of ontological and epistemological stance, while Crotty (1998) approached the research process in a more specific way by considering four elements that are: “(a) what methods do we propose to use; (b) what methodology governs our choice and use of method; (c) what theoretical perspective lies behind the methodology in question; and (d) what epistemology informs this theoretical perspective.” However, disagreements over ontology and epistemology have given rise to several paradigms. The two primary research paradigms, positivism and interpretivism, are the prevalent paradigms utilised in philosophy for scientific research and analysis (Junjie and Yingxin, 2022).

In essence, those who support positivism are realists. This implies that the “truth” may be attained independently from individuals’ perceptions. It is a method of social science that emphasises the need for empirical data to gain knowledge of the underlying realities of social systems. According to this, Burrell and Morgan (1979), Saunders et al. (2012), and Bryman and Bell (2015) pointed out that positivism is based on the approach used in natural science, as positivism means that only observable phenomena can supply credible data. Moreover, Easterby-Smith et al. (2015) pointed out that the social world is external and can be studied with empiric methods in positivism. The idea of positivism is aligned with the ontology concept of objectivism. Therefore, a positivist believes in the importance of learning and discovering what is out there (Panya and Nyarwarth, 2022). In epistemology, positivism asserts that knowledge is generated through observations, that is, through empirical evidence with a predominantly quantitative research design (Easterby-Smith et al., 2015).

In contrast, interpretivism has a “relativistic” vision of the social world (Saunders et al., 2012). Reality is a human construct. Hence, reality is all imagination (Holden and Lynch, 2004). According to the interpretivism paradigm, people and their social environments cannot be researched in the same way as physical phenomena. Social science research must be distinct from the natural sciences rather than attempting to imitate it (Panya and Nyarwarth, 2022). This viewpoint contends that there are other methods of learning about the world outside direct observation, especially our perceptions and interpretations of the environment we live in. Therefore, the important belief about knowledge is that it cannot be discovered but is instead obtained subjectively because everything is relative (Holden and Lynch, 2004). This approach shows how interpretivism is aligned with constructionism ontology. As a result, rather than just being dependent on lived experiences, knowledge of the world is based on the researcher's "understanding", which results from their reflection on events (Ormston et al., 2014).

Al-Saadi (2014) displays the distinctions between the paradigms and their assumptions (Fig.8).

ONTOLOGICAL POSITIONS (nature of the world and existence)	
Position	Assumptions
Objectivism	• Reality exists *in*dependently of our beliefs or understanding • Reality can be observed directly and accurately • A clear distinction exists between our beliefs about the world and the way the world is • Only material or physical world is considered 'real' • Social phenomena and their meanings cannot change • Events have causes and determined by other circumstances • The casual links between events and their causes can eventually be uncovered by science • Life is defined in 'measurable' terms rather than inner experiences • Notions of choice, freedom, individuality and moral responsibility are excluded
Constructionism	• External reality exists but is only known through human mind and socially constructed meanings • There is no shared social reality, only a series of different individual constructions of it • Reality is subjective • There exist only estimate or approximate observations or views of reality • Social phenomena and their meanings are continually being accomplished by social actors • Social phenomena and their meanings are produced through social interaction and are in a constant state of revision • Life is defined in 'estimate' terms based on inner experiences of humans where choice, freedom and individual responsibility are appreciated

EPISTEMOLOGICAL POSITIONS (nature of knowledge and how it is acquired)	
Position	Assumptions
Positivism	• The world is independent of and unaffected by the researcher • Facts and values are distinct • Objective and value-free inquiry is possible • Disputes are resolved through observations • Methods of natural science are appropriate for the study of social phenomena • Knowledge is produced through the senses based on careful observation • Only phenomena (and hence knowledge) confirmed by the senses can be genuinely regarded as knowledge • Knowledge is seen as hard, tangible and objective • Knowledge is arrived at through gathering of facts • Social world is approached through the *explanation* of human behaviour
Interpretivism	• The researcher and the social world impact on each other • Facts and values are not distinct • Objective and value-free inquiry is not possible since findings are inevitably influenced by the researchers' perspectives and values • Methods of natural science are *not* appropriate for the study of social phenomena for the social world is not governed by law-like regularities but mediated through meaning and human agency • Knowledge is produced by exploring and understanding the social world of the people being studied • Knowledge is seen as personal, subjective and unique • The researcher understands the social world using both his/her as well as the participants' understanding • Social world is approached through the *understanding* of human behaviour

Figure 8 - Research Philosophy Paradigms (Al-Saadi, 2014)

The most suitable research approach for researching translational assets is an interpretive qualitative method. This method aims to minimise the gap between the researcher and the subject under investigation. Its goal is to develop a practical and theoretical understanding. Therefore, interpretivism allows for a flexible and nuanced understanding of how TAs are perceived, moving away from the rigid positivist approach that might oversimplify this complexity and avoid to have the "whole story" (Crotty, 1998).

3.3 Research Methodology: An Inductive Approach

The research approach is an important choice as it links the research philosophy with the theory employed in the study (Saunders et al., 2009). The researcher can choose between three research approaches: deductive, inductive and abductive. The deductive approach, often associated with a positivist philosophy, starts with existing theory to formulate hypotheses that are then tested through data (Saunders et al., 2012). In contrast, inductive reasoning typically starts with the collection of data to build generalisable theories, making it well-suited for qualitative research (Saunders et al., 2012; Bryman and Bell, 2015. Abductive reasoning, on the other hand, combines elements of both, generating exploratory hypotheses to advance existing theories through empirical research.

The distinctions between the positivist and interpretivist approaches to research technique are shown in Figure 9.

Elements	Positivism	Interpretivism
Truth	Is determined through verification predictions	Depends on who establishes it
Facts	Concrete	All human creations
Aims	Discovery	Invention
Starting Points	Formulation of explicit hypotheses which guide research	Meanings/ Research questions
Research Position (goal investigation)	Prescriptive, causal, deductive, theory confirming, ungrounded	Descriptive
Direction of Research Inquiry	Measurement and analysis of causal relationships between variables that are generalisable across time and context	Development of ideographic knowledge based social experiences such as human ideas, beliefs, perceptions, values etc.
Designs	Experiment, survey	Reflexivity, interviews, participant observations
Methodology	Outcome oriented, verification oriented	Observation, process oriented
Techniques	Measurement	Conversion
Sample Size	Large	Very Small
Data Collection	Structured	Unstructured
Types of Data Gathered	Replicable, discrete elements, statistics	Information-rich, contextual, non-statistical, somewhat subjective reality
Interview Questions	Mainly closed with limited probing	Very open
Interaction of interviewer and phenomenon	Independent and value-free, a one-way mirror	Passionate participant, transformative intellectual
Information per Respondent	Varies (specific to question)	Extensive
Analysis/ Interpretation	Verification/ falsification	Sense-making
Type of Data Analysis	Objective, value-free, statistical methods	Value-loaded, non-statistical
Causality	Cause-effect relations	Not addressed
Outcomes	Causality	Understanding

Figure 9 - Ontologies and Epistemologies in Social Science Research (Adapted from Denzin and Lincoln, 2000)

When studying complex and dynamic phenomena like translational assets, an inductive approach is particularly useful because it allows the researcher to explore new patterns and insights that emerge directly from the data. This is especially relevant when there is a limited existing theoretical framework or established categorisation in the field (Liu, 2016).

However, when investigating translational assets, which are complex and multifaced, it can be difficult to apply a ridged bottom-up approach. In this case, given the absence of a widely accepted definition or framework for classifying translational assets, qualitative content analysis of literature review serves as a valuable tool to identify important trends and insights.

Therefore, the study adopts an inductive approach, where data is collected to build a general theory about TAs rather than testing pre-existing hypotheses. While traditional inductive research often avoids starting with existing theories, some qualitative scholars, like Wolcott (1994), argue that it is “impossible to embark upon research without some idea of what one is looking for”, especially in the initial stages. This process helps the researcher understand the research problem in context, identify gaps, refine research questions and select an appropriate theoretical framework for the study (Gay et al., 2006).

In this research project, the researcher explored the existing literature on translational assets in order to create a problem statement and purpose that not only adds to the current knowledge base but also provides a framework for the research and facilitates the development of a classification framework for TAs.

3.4 Methodology choice: Why Qualitative is the Correct Approach?

Research can be conducted using quantitative, qualitative or mixed methods. The differences between the methods lie in the type of knowledge they seek to acquire and how it is analysed and presented.

Quantitative methods, rooted in a positivist perspective, examine variables and hypotheses using experiments and surveys to collect data that is statistically and objectively measured to test theory and verify hypotheses (Neuman, 2014). In contrast, qualitative research follows constructionism or realistic and interpretative philosophies, aiming to understand and interpret social reality through individuals' experiences. This approach utilises methods such as grounded theory, case studies or ethnography to gather data, allowing for the development of themes that capture participants' perspectives on the phenomenon (Saunders et al., 2012). Finally, mixed methods combine both approaches, offering a comprehensive analysis that explores and explains phenomena while also assessing the trustworthiness of findings (Tashakkori and Teddlie, 2003).

Although both quantitative and qualitative approaches have their strengths, qualitative research is particularly suited to this thesis due to the exploratory nature of its research questions and aligns well with the inductive approach. The qualitative approach allows for an in-depth exploration of the phenomenon of translational assets, facilitating a comprehensive understanding that strengthens organisational theory on their classification. This approach is advantageous because it supports a holistic study of the phenomenon and an interpretative understanding that can yield detailed nuanced findings (Bryman, 2003).

Considering Scotland as a geographical focus, the research employed qualitative data, given the relatively nascent state of TAs in the region. If TAs were more deeply rooted and widespread in Scotland, a quantitative approach using surveys or questionnaires might been feasible, as demonstrated in studies by Bozeman and Crow (1987 a,b) and Castro et al. (2020) in the USA and Spain. The less established nature of TA in Scotland necessitates a qualitative approach to capture the complexity and richness of the phenomenon. However, a quantitative approach would also be possible if, for example, we want to conduct a cluster analysis to classify research organisations. Moreover, it is worth noting that a study lacking a qualitative component is inadequate to recommend actions to managers or inform policy (Merriam, 2009). This is an important contribution that research into R&D organisations aims to address.

3.5 Research Strategy

The research paradigms frequently influence the researcher's belief in choosing the research method. Based on the previous explanations, an inductive methodology and a subjective ontology are considered most appropriate for this research. This leads the researcher to choose from a range of research procedures and approaches, such as case studies, surveys, experiments and participation (Saunders et al., 2012), that would be beneficial for the goals of this research study.

The researcher must align the chosen study paradigm with the selected research method because this will impact how data is collected and how the collected empirical evidence is analysed (Yin, 2014). Then, the research method has to reflect a particular way of thinking about knowledge, not just the use of specific data-gathering technique.

The next section will elaborate on why case studies were chosen over experiments, surveys and researcher engagement. The researcher will seek to explain the selection of case study methods in relation to their own research paradigm as the most appropriate for this type of study despite the strengths and limitations of all four approaches.

3.5.1 Case Study Method – A Multiple Approach

The appropriate strategy to investigate the nature of the TAs providing insights into the theory of R&D organisations and understanding this complex phenomenon was to conduct multi-qualitative case studies (Yin, 2014). According to Yin (2014), having evidence from multiple cases is often considered more compelling, making the overall study more robust and providing a valid basis for understanding.

Case studies address different research goals and are presented in different types, such as explanatory, descriptive, exploratory, theory testing, theory building and theory extension (Saunders et al., 2012; Yin, 2014). It is particularly useful for building theories in areas where current theories are not enough (Chetty, 1996). The explorative and descriptive types are most suitable if the investigator aims to have a holistic understanding and focus on the ‘how’ and ‘what’ questions to study the phenomenon (Yin, 2014). The insights from case-based theory building research can be used as hypotheses or propositions in further research, so case study research is important for advancing a field's body of knowledge.

Based on that, the experiment and the participation methods are not suitable for this study. The main reason is that the former is done when "an investigator can manipulate behaviour directly, precisely and systematically" (Yin, 2012), while the latter is frequently employed in conjunction with the grounded theory approach since they are frequently connected with the ethnographic approach to study. The survey method is employed mainly to address the *what* questions and includes a method such as questionnaires with numerically related items, open-ended questions or both approaches. However, from a theoretical point of view, the survey could be adopted for this investigation, but from a perspective of data access and resources, the case study strategy has been chosen.

According to Yin (2014), a case study is an in-depth investigation into a particular event or topic being studied in its natural environment. Case studies are used for (Eisenhardt, 1989):

- Examine a contemporary phenomenon in its natural environment, especially when the distinctions between the phenomenon and the environment in which it occurs are fuzzy;
- To manipulate theoretically peculiar situations in which various variables encompass a variety of points of interest;
- It depends on the idea that there are multiple sources of information and the data gathered must converge to validate conclusions using techniques like triangulation.

This study uses a multiple-case study design because it enables the researcher to provide solid and reliable findings as well as valuable theoretical contributions through the use of rigorous concepts and constructions, triangulation of several datasets and replication logic. Each case represents a unique context, encompassing different organisational structures, activities, funding mechanisms and other features. Yin (2014) and Baškarada (2014) explain that this strategy should be used to predict similar results (literal replication) or to predict contrasting results but for anticipatable reasons (theoretical replication). By studying commonalities and differences, the researcher has a more robust and comprehensive understanding of the classification process through the identification of patterns and themes across the cases (Regin, 1987; Yin, 2014).

In conclusion, it is crucial to follow the replication logic while using the multiple-case design, as opposed to the sample logic used in the majority of other research method designs. The researcher should carefully choose every case to ensure that it satisfies the criteria of the defined research questions. The instances should serve the aim of a multiple-experiment design, whereby comparable or contrasting results should be sought, as described at the beginning of the empirical investigation, in order to successfully apply the multiple-case study design (Yin, 2014).

3.5.2 Selecting Case Study TAs

The main objective of this study is to empirically investigate translational assets in order to determine how these organisations are established in innovation ecosystems. The investigation's main point of interest is the Scottish innovation ecosystem. Case studies are helpful in this case because they can help the researcher conduct a field-based empirical inquiry and get closer to reality.

One of the most important considerations when choosing case study research is making sure that the cases selected are comparable. This guarantees that the research questions can be answered accurately (Baškarad, 2014). Therefore, there must be uniformity or homogeneity in at least a few variables for each selected case study.

3.5.2.1 Unit of Analysis

The foundation of each case is the unit of analysis (Baškarad, 2014). This study focused on developing a classification framework for TAs. In line with the research objective to identify the distinguishing characteristics of TAs and investigate how and why they are established, the unit of analysis has to be in a strategic position or involved in the decision-making within the TAs. Therefore, the unit of analysis of this research was a combination of TAs based within the Scottish innovation ecosystem and high-profile figures in the TA.

The decision to focus on TAs in Scotland was not merely a matter of convenience but a strategic choice to leverage the strengths of the local innovation ecosystem. Scotland is home to a diverse network of public research centres, university research centres and independent research organisations, making it an ideal environment for studying TAs across multiple sectors.

The selection of TAs in Scotland involved consulting various public domain reports, ranging from academic papers to policy reports related to the Scottish innovation ecosystem. Compared to some countries that have a centralised directory or comprehensive database of research organisations, Scotland currently lacks such a consolidated resource. Therefore, it became imperative to explore multiple sources and engage with professionals in the field to identify and include relevant TAs in this study.

Despite the absence of a centralised directory, the research process was not hindered. Instead, a consultative approach was adopted, allowing for a comprehensive view of the translational assets. This approach enabled the researcher to analyse the identified organisations from a macro perspective, gaining a thorough understanding of the translational assets in Scotland.

3.6 Data collection

Effectively classifying TAs is essential for capturing all the necessary information and identifying the factors that define organisations. Two data collection methods, documentation analysis and semi-structured interviews, have been considered to support this classification exercise.

Documentation analysis was selected for its ability to thoroughly review existing academic papers from major management and innovation journals and reports from various national and international institutions. These documents provided a foundation for identifying the different factors that scholars have previously used to describe and classify TAs. This foundational knowledge was crucial for proposing an initial classification framework.

Semi-structured interviews were chosen as a complementary data collection method due to their adaptability. They allowed for the exploration and refinement of the initial classification through direct engagement with experts and stakeholders in the field. Interviews are particularly valuable as they enable the researcher to delve deeper into the participants' perspectives, capturing nuanced insights that may not be evident from the documentation alone. By using semi-structured interviews, the researcher could probe specific areas while allowing the interviewees to introduce new ideas, thereby enriching the classification model.

Combining document analysis with semi-structured interviews within a multiple-case studies approach enhances the research's validity and credibility through triangulation. Triangulation involves cross-verifying findings from different data sources, which strengthens the reliability of the research conclusion (Daytner, 2006). The factors identified through document analysis provided a starting point for the classification, which was further refined and validated through the insights gained from the interviews.

Figure 10 describes the main techniques used to collect data in this analysis.

Source of Evidence	Options Within Types	Advantages of the Type	Limitations of the Type
Documents	• Public documents: minutes of meeting and newspapers • Private documents: journal, diaries and letters • E-mail discussions	• Enables researchers to obtain the language and words of participants • Can be accessed at a time convenient to the researcher – an unobtrusive source of information • Represents data that are thoughtful, in that participants have given attention to compiling • As written evidence, it saves a researcher the time and expense of transcribing	• May be protected information unavailable to public or private access • Requires the researcher to search out the information in hard-to-find places • Requires transcribing or optically scanning for computer entry • Materials may be incomplete • The documents may not be authentic or accurate
Semi-structured Interviews	• Face-to-face: one on one, in-person interview • Telephone: researcher interviews by phone • Group: researcher interviews participants in a group	• Useful when participants cannot be observed directly • Participants can provide historical information • Allows researcher "control" over the line of questioning	• Provides "indirect" information filtered through the views of interviewees • Provides information in a designated "place" rather than the natural field setting • Researcher's presence may bias responses • People are not equally articulate and perceptive

Figure 10 - Description of Qualitative Source (Creswell, 2013)

3.6.1 Secondary Data - Documentation

Through the investigation, a comprehensive review of documents was conducted. Data were collected from various documentation sources to ensure a thorough research background. This encompassed examining articles from prominent academic journals specialising in business engineering and management, such as Research Policy, Technovation and Technology Forecasting and Social Change. The search for articles was carried out using Science Direct as the primary scientific database, utilising search terms such as 'university research centre', 'R&D laboratories', 'research and technology organisation', 'research centre', 'research institute', 'typology', 'classification' and 'category'.

Additional relevant references were identified using a snowball approach. The literature review focuses on specific information, such as factors used by previous scholars to develop a classification of the TAs. The analysis of these articles considered whether the article provided a typology or highlighted influencing factors for categorising R&D organisations.

Other sources of data included reports, such as annual reviews issued by several government agencies from the UK and Scottish Governments, such as the House of Commons, BEIS, Innovate UK, United Kingdom Research and Innovation (UKRI), Engineering and Physical Science Research Council (EPSRC), Scottish Enterprise (SE), as well as public domain publications from organisations like the Organization for Economic Cooperation and Development (OECD) and the Association for Innovation, Research and Technology Organisations (AIRTO). The bibliography review covered different countries and regions, with a predominant focus on the USA due to its extensive and consolidated tradition in this area.

The literature review has some limitations, including the lack of sources within the electronic database and limited perspectives on the type of translational assets, making the search for secondary data quite challenging. To address this, articles published from 2000 to the present were considered, with only a few relevant pre-2000 articles included. To supplement the secondary data and enhance the study's validation, data was collected from the TAs' website, public available press, presentations, news media and further interviews for each case study.

It is important to note that there is a small identifiable community of scholars who are dedicated to researching these organisational forms, belonging to different disciplinary fields included in the social studies of innovation (Bozeman, 2013). In conclusion, the academic debate on the TAs has reached very few conclusive results, so it is important to consider its implications in the broader debates and abundant cited literature that refers to the collaboration between science and business and, in general, to the organisational dynamics of hybrid organisms in innovation systems.

3.6.2 Primary Data – Semi-structured Interview & Management of Interviewees

Translational assets, as heterogeneous organisations subject to significant changes over their lifetime, present a complex research challenge. Thus, the researcher chose to gather data through direct interaction with the reality investigated and to analyse the data based on the researcher's interpretation. Interviews were selected as the primary source of evidence and data collection strategy.

There are three types of interview techniques: unstructured, structured and semi-structured. Interviews were chosen because they allow certain flexibility in asking questions and obtaining insights from the participants' experiences. The interviewer can change, add or avoid questions, which can be adapted to the interviewees' responses (Yin, 2014). Such flexibility allows new topics to emerge freely (Cohen et al., 2007). To gather data for this study, semi-structured interviews were conducted, as they are optimal for exploratory analysis of complex topics (Louise Barribal and While, 1994).

The interviews were conducted in two phases, each lasting approximately 45-60 minutes. The first phase included two pilot interviews to test the first guide list of questions, which were conducted in person. Based on the outcome of the pilot interviews, the case study protocol was refined and finalised to accommodate the complexity of the topics and participants' varying levels of knowledge (Yin, 2014).

In the second data collection phase, 18 TAs were considered and 25 participants were interviewed (Tab. 2). At this stage, the interviews were performed through phone and video calls due to the restrictions during the COVID-19 pandemic (this phase started between December 2019 and March 2022). There is no substantial difference between face-to-face and phone/video call interviews. Prior to the interview, the participants were explained the ethical principles of data confidentiality and their consent to record and transcribe the interviews was obtained to ensure the integrity of the study.

Finally, at the end of the interview, the respondents were encouraged to bring additional comments and asked for suggestions about other participants that could support this research project. Some of the initial person contacted and keen on supporting the research project suggested interviewing some of their colleagues who could provide further information to strengthen the case.

Overall, the interviews served as a primary method for data gathering in the context of the Eng D researcher, complemented by findings from desk research performed in the form of documentary evidence and archival records.

Translational Assets	Role Interviewee	Sector	Year of Establishment

TA_1	Chief Executive Officer (CEO)	Nanotechnology	2008
TA_2	Interviewee 1: CEO Interviewee 2: Director	Advanced Manufacturing/Future Medicines Manufacturing	2014
TA_3	CEO	Quantum Technologies and Photonics	2012
TA_4	Interviewee 1: CEO Interviewee 2: Innovation Manager	Floating Offshore Wind/Robotics and Automation Systems	2013
TA_5	Impact Manager	Advanced Manufacturing/Robotics and Autonomous Systems	2013
TA_6	Deputy Director	Photonics/Nanotechnology	2005
TA_7	Interviewee 1: COO Interviewee 2: Chief Technology Officer (CTO)	Advanced Manufacturing	2011
TA_8	Interview 1: COO Interview 2: Principal Investigator	Quantum Technologies and Photonics	2014
TA_9	Interview 1: Director Interview 2: CEO	Advanced Manufacturing	2011
TA_10	Project Manager	Advanced Manufacturing	2020

TA_11	Interview 1: Project Manager Interview 2: COO	Data and Digital Technologies	2014
TA_12	Interviewee 1: Knowledge Exchange Manager Interviewee 2: Chief Technology Officer (CTO)	Nuclear	2015
TA_13	Director	Biotechnology	2011
TA_14	Project Manager	Data and Digital Technologies	2013
TA_15	Director	Digital Health	2012
TA_16	Deputy director	Robotics and Automation Systems	2013
TA_17	Director	Biotechnology	1884
TA_18	Director	Advanced Manufacturing	2020

Table 2 – List of interviewees and TAs profile

3.7 Sampling and Sample Size

The sample for this research was drawn from those R&D organisations primarily involved in translational research within the science, technology and innovation sector. To guarantee diversity, representatives were from TAs with different organisational environments to avoid entities being closer to the university or the industry.

Eisenhardt (1989) argues that it is not necessary or preferable to select random cases. Cases should be selected based on their relevance to the research questions rather than their representatives (Carson, Gilmore, Perry and Gronhaug, 2001). When choosing suitable cases, the primary principle is to prioritise cases that offer comprehensive information about the subject being studied. As a result, a purposive sample is considered reasonable. Therefore, mid- and senior-level management profiles in the decision-making and highly informed or directly involved in organisations' setup and implementation were targeted. For instance, the participants were project managers, directors, CTOs and COOs. When focusing on this type of profile as the primary unit of analysis, having access to at least one of the mid- or high-management was a crucial factor in selecting cases. Following Hartley's (1994) guidance, the researcher used connections in academia and personal relationships to create a pool of cases from which to choose. The researcher's established connection with the National Manufacturing Institute of Scotland provided access to research organisations in key sectors, including Energy and Renewables, Manufacturing, Quantum and Enabling Technologies.

Additionally, the investigator aimed to consider participants who had been within the organisation from the early days of its establishment. This was only sometimes possible because members were replaced or left the organisations after a few years of establishment. Participants with knowledge or experience in organisational design have been considered in that case.

Having the researcher chose an interpretative approach for his research, the number of participants is typically small (Holloway, 1997). Most organisations investigated are small and with a short hierarchy (e.g., two levels of hierarchy where the management team is constituted of two to five members). Then, the number of relevant people to be interviewed from each TA was very resizing. Indeed, one or two prominent members of each organisation were interviewed.

Although there is no precise method to establish a best sample size in general (Francis et al., 2010), there are some recommendations. For instance, Eisenhardt (1989) believes that between four and ten cases often work well. Curran and Blackburn (2001) indicate that case studies in small business research are often fewer than ten. Mason (2010) discovered that sample sizes of 20 interviews were most frequently used in Ph.D. Finally, Guest et al. (2020) proved that in qualitative research, specifically focusing on interview-based studies, thematic saturation occurs within the first 12 interviews. For the majority of the studies examined by Guest et al. (2020), the most critical themes emerged within this range, and subsequent interviews rarely added new information.

In this research project, the researcher investigated 18 TAs and interviewed 25 participants. For the people who agreed to support this project, details for the meeting were shared via email along with a 'participant information document' and the interview guide to give an idea about the topics they would have discussed during the interview. All interviewees were provided with an explanation of the project's scope and allowed to ask questions about the study before the interview. Four TAs did not respond, and two were interested in this research.

3.8 Data Analysis Strategy for Case Studies

The data analysis strategy, a crucial component in the case study research, is specifically designed to explore the complex phenomenon of translational assets. By interpreting the experience and opinions of the subjects involved, the researcher aims to gain a comprehensive understanding of this intricate concept. As previously discussed, qualitative research can generate a large amount of unstructured data, posing a significant challenge in terms of interpretation and analysis. To overcome this challenge, the researcher has adopted well-established methods from scholars like Eisenhardt (1989), Miles et al. (1994) and Yin (2014) to guide the data analysis process.

The analysis phase is dedicated to shedding light on the reality of TAs by capturing and reproducing the dynamics of this reality of translational assets as expressed by the interview participants. To achieve this, the researcher used thematic analysis, a widely recognised method in qualitative research. This approach, which involves the systematic categorisation of data, allows for a more structured understanding of the underlying themes that emerge from interviews (Braun and Clarke, 2006).

Thematic analysis was conducted using an inductive approach, where themes were identified directly from the data without imposing preconceived categories. The analysis followed Dey’s (1993) three-stage approach:

1. Data familiarisation: The researcher began by reading interview transcripts, field notes and other documents, as well as listening to interview recordings. During this phase, the researcher made notes on emerging ideas, categories and links between concepts, which helped in reducing that data and grouping it according to identified trends (Miles et al., 1994).

2. **Coding and Theme Development**: The transcripts were read multiple times and a coding process was initiated. Thematic analysis was used to highlight and code the key part of the raw text. The researcher identified and highlighted key parts of the text, using the initial factors from the literature review as a guide while remaining open to new themes that emerged inductively. This stage involved transforming raw data into categories that could be compared with existing theories, eventually leading to the development of a new classification of TAs.
3. **Pattern Matching and Theory Development**: The final stage involved evaluating the coded data by pattern matching, comparing the empirically identified patterns with those anticipated in the literature (Yin, 2014). This technique allowed the researcher to distinguish significant differences and develop theoretically meaningful explanations for the findings. The result was the creation of a novel typology of TAs, which was then situated within the broader context of R&D organisational theory.

This structured approach to data analysis ensures that the research findings are both robust and grounded in empirical data, leading to a comprehensive understanding of the classification of TAs within the Scottish innovation landscape.

3.9 Validation of Case Study Research

Several validation strategies were employed to ensure the accuracy and credibility of the research. One key method was co-coding, where themes were compared and consolidated after regular discussions with my supervisor and with some of the experts interviewed. This inclusive approach helped refine and validate the themes identified during the analysis.

Moreover, another way to make the research findings reliable is to use member checking. The researcher went back to some of the participants who took part in the research and was asked to check if the researcher's interpretation of their views and insights was accurate. The researcher shared the outcome that he drew from the interview analysis. With this process, the researcher reduced the risk of being biased or misinterpreting things.

To further enhance the study's validity and credibility, the triangulation method was applied. Triangulation is particularly valuable when investigating complex phenomena, as it allows the researcher to extend and verify findings through multiple perspectives. Denzin (1989) pointed out that there are four types of triangulations: “(a) source triangulation, (b) investigator triangulation, (c) theory triangulation and (d) methodological triangulation”.

In this analysis, a comprehensive range of data sources were used, including publicly available documents on the TAs’ website, documents shared by the interview participants, documents issued by third parties commissioned to analyse specific TAs, news and media articles and informal interviews with experts from Governmental agencies. By comparing these diverse sources, the researcher could identify both consistencies and interpretations. This process ensured that the conclusions drawn were well-supported by evidence from various angles and instilled confidence in the research findings.

The use of triangulation in this study not only improved the reliability and validity of the findings but also strengthened the robustness of the research methodology. By converging data from multiple sources, the research developed a more comprehensive and robust classification framework for TAs.

3.10 Summary Methodology

In this chapter, the author explored the philosophical and methodological approaches underpinning the study. Firstly, the author describes the research design based on ontology and epistemology, aligning with the interpretivism and inductive approach. While inductive research encourages a fresh perspective, it is recognised that researchers cannot start completely without pre-existing theoretical frameworks. The study used an inductive approach to investigate the complex and multifaceted characteristics of the translational assets. A comprehensive literature review was conducted to identify the different terminology used to describe the translational assets type of organisation, the challenges associated with classifying translational assets and to highlight the key factors used to differentiate them. This approach proves particularly useful in addressing conflicting viewpoints and explanations of the same phenomena. By employing this method, the researcher was able to propose an initial classification that accommodates different perspectives and interpretations of the same phenomena.

The author then introduces the qualitative case study method as the most suitable approach to answering "what" questions and gathering and analysing data for the investigation. Although the qualitative approach allows for deep insights into the classification of TAs, it also presents some limitations. Although the sample size seems to be the right size according to the scholars, it may be relatively small if the findings are generalised to TAs outside Scotland. Additionally, the subjectivity inherent to qualitative research could lead to potential biases in data interpretation. However, the use of triangulation and peer debriefing helped to mitigate these issues. In fact, the case studies were supplemented by discussions with academics and participants and the examination of various data sources, including organisational-level records and publications, to triangulate the results.

Figure 11 provides a visual illustration of the research design topology used in this investigation.

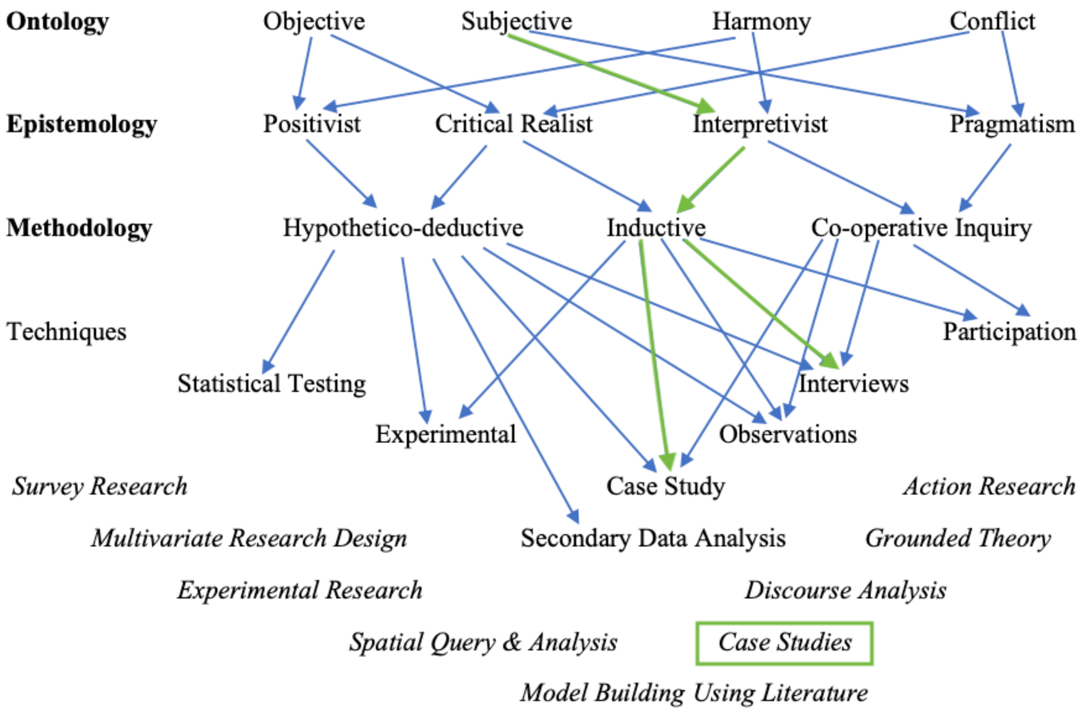

Figure 11 - Investigation's Research Design of this Thesis

Chapter 4

4.1 Results from Literature Review

This chapter summarises the findings from the literature review on the development of a classification framework for translational assets. It emphasises the significance of establishing an effective classification system for TAs to better understand their unique characteristics within the innovation ecosystem. The chapter also discusses the limitations of existing organisational classifications and introduces a multidimensional approach to capture the significant heterogeneity exhibited by TAs.

The introduction highlighted the challenges associated with organisational classification, specifically the oversimplification of reality and the failure to capture the dynamic and multifaced nature of organisations (Plummer et al., 2020). Existing classifications have faced criticism for relying on a limited number of characteristics, often based on one or two dimensions. For instance, the discrete classification proposed by Burnes and Stalker (1961) categorises organisations as either mechanistic or organic. Such binary classifications overlook the spectrum of organisational forms that may exist between these two extremes, leading to instability in classification as organisations adapt to changes in their environments driven by factors such as stakeholder shifts, technological convergence and evolving market dynamics (Arnold et al., 2010).

To address these inadequacies, this research adopts a multidimensional approach to capture the significant heterogeneity exhibited by TAs. By employing this method, the classification framework is better equipped to represent the diversity inherent within these organisations.

Furthermore, TAs are conceptualised along a continuum (Arnold et al., 2012), which offers several benefits. Moving away from rigid categories in favour of a nuanced representation deepens our understanding of the subtleties and complexities of TAs. Variables such as funding models, legal status and other characteristics can now be assessed on a spectrum, allowing for more precise placement of organisations within the classification system. This enhanced granularity enables researchers to differentiate between organisations more effectively, capturing their unique attributes.

Additionally, a continuum-based representation promotes flexibility and adaptability within the classification process. Unlike rigid categories that may exclude certain organisations, such as those that present characteristics from multiple groups, a continuum accommodates the diverse array of research organisations, ensuring that the classification system remains relevant and responsive to the evolving landscape. This adaptability allows researchers to incorporate emerging organisational types that may not fit neatly into predefined categories, facilitating a comprehensive and current understanding of the research ecosystem.

The continuum-based framework also enables more meaningful comparative analyses between research organisations. Instead of relying solely on categorical distinctions, researchers and practitioners can evaluate organisations along specific dimensions represented on the continuum. This approach allows for a thorough exploration of the relative strengths and weaknesses of various organisations, illuminating the factors that contribute to their successes or limitations. As a result, this comparative analysis fosters knowledge exchange, identifies best practices and encourages collaboration within the scientific community. Moreover, a continuum-based framework opens avenues for longitudinal analysis. By tracking the movement of organisations along the continuum over time, researchers and practitioners can gain insights into their trajectories, growth and progress. This longitudinal perspective provides a deeper understanding of the dynamic nature of research organisations, revealing trends and patterns that inform evidence-based decision-making. It enables researchers to assess the impact of interventions, policy changes, or investments, guiding strategic planning and resource allocation.

In summary, the chapter details the key findings derived from the literature analysis on translational assets and culminates in the development of a novel classification framework that represents these factors along a continuum. This approach provides significant advantages and contributes to a more robust and insightful classification process, supporting evidence-based decision-making.

4.2 Describing the Factors for an Initial Classification of TAs – Constructing a Continuum

As part of this research, a literature review was conducted to examine the classification of TAs within the Triple Helix model. The review found that there needed to be more conceptual clarity and consistency in the terminology used, resulting in varied interpretations of the classification framework. However, the findings of the review were instrumental in creating a proposed classification framework for translational assets.

One of the major flaws of previous classifications was categorising organisations into discrete groups based on factors such as mechanistic versus organic organisational structures. This simplistic approach was inadequate as it overlooked the existence of organisations that fall between these two extremes. As a result, the classification became inflexible and failed to account for the dynamic nature of some organisations. The review has emphasised the need to identify organisations with mixed characteristics, considering their unique attributes (Cruz-Castro et al., 2020.

A more comprehensive understanding of TAs can be achieved by considering multiple dimensions. These attributes will then be represented on a continuum. Representing these dimensions on a continuum rather than using a discrete approach offers several advantages. Firstly, a continuum allows for a more nuanced representation of TAs, as it acknowledges the variations and gradations within each dimension. This recognition of variability provides a more accurate reflection of the real-world complexity of TAs and allows for a more precise categorisation. Secondly, a continuum approach accommodates the dynamic nature of TAs. Translational assets can exist on a spectrum rather than being limited to discrete categories. For example, an asset's level of maturity may progress over time, or its funding scheme may change based on evolving policies or collaborations. By representing dimensions on a continuum, the classification framework can capture the fluidity and potential transformations of TAs, making it more adaptable to changing circumstances and facilitating the tracking of asset progression.

To address this issue, a classification is proposed along with criteria that can include the hybridity of the translational assets. The classification is built by considering, according to the investigator, the most relevant factors listed in Table 2 (pag.38) that can be useful for designing and evolving a TA and can capture the role played within its innovation ecosystem. These factors involve attributes not represented through a continuum in the past classifications. A continuum is a valuable representation for identifying the dynamics of an organisation and grasping such a phenomenon (Strazzullo et al., 2020).

Therefore, TAs are classified based on three dimensions: organisational structure, resources, and collaboration. These dimensions are broken down into various factors, attributes and variables to help identify the different types of TAs. Table 4 outlines the factors in the left column, the associated attributes in the central column and the variables considered for each attribute in the right column. By observing the shift from left to right, we can distinguish the different characteristics of each factor.

Factors	Attribute	Spectra of dimensions criteria
Organisational Structure	Internal Authority	Low ◄──► High
	External Autonomy	Low ◄──► High
Resources	Funding	Low. ◄──► High
	Dedicated Human Capital	Low ◄──► High
	Infrastructure Scale	Low ◄──► High
Collaboration	Proximity to the Market	Low ◄──► High
	SMEs Support	Low ◄──► High

Table 3 – Representation of factors to classify TAs along a continuum (Strazzullo et al., 2021)

According to Pugh (1990), the design of high-performance organisations depends heavily on their organisational structure, which involves the hierarchy of authority, flow of information, responsibilities and duties. Two dimensions of organisational structure were emphasised: external autonomy and internal authority of TAs, reflecting their hybrid nature and the need to account for diverse stakeholder expectations (Gustafsson and Lidskog, 2018).

The level of external autonomy exhibited by research organisations can vary from semi-autonomous to fully autonomous. The former category is integrated into universities, reliant on state funding and lacking independent budgets, infrastructure and employment. In contrast, autonomous TAs exhibited solid structures, strategies, facilities and stable relationships with individuals and stakeholders (Sanz-Menendez et al., 2011).

The variable of authority reflected the decision-making autonomy within the organisation. It considered bottom-up and top-down approaches, where principal investigators had the freedom to shape their research agendas or decisions directed by directors and filtered down to the working units. Some organisations adopted intermediate authority mechanisms, such as strong directorial leadership, committees, or advisory boards (Corley et al., 2006; Cruz-Castro et al., 2020).

The review also examined the resources required by TAs, including financial resources, human capital and infrastructure. Financial resources were categorised into public non-competitive funding, public and private competitive funding and private or market funding. The distribution of

these funding sources impacted the nature of ownership and determined the level of core funding versus external funding from industries.
Human capital played a crucial role and various expertise areas were considered, such as researchers, crossover collaboration experts, inventors and entrepreneurs. The review emphasised the importance of formal training, education, and soft skills for researchers, while industry-oriented TAs require personnel with industrial experience and technical knowledge.
Infrastructure was recognised as vital for TA performance, although some organisations relied on external entities for specific activities. Changes in funding schemes posed challenges for scaling up and upgrading facilities and collaborations with industries often involved in providing access to scientific capabilities and expertise (Zakaria et al., 2021).

Collaboration, particularly with the industry, was highlighted as a priority for innovation development. The review noted that TAs played a crucial role as "public-private research actors" and interacted with both universities and industries. Proximity to the market was considered to measure the level of integration with universities. At the same time, collaboration with small and medium-sized enterprises (SMEs) was deemed essential for knowledge transfer and supporting SMEs' innovation processes.

In conclusion, after conducting an extensive literature review, it was identified that the current classification schemes for TAs are not adequate. Therefore, a more comprehensive approach was proposed. The key factors for understanding and categorising TAs used to build a classification scheme are organisational structure, resources and collaboration. These factors are discussed in detail in the publication of Strazzullo et al. (2021) (See Annex I), where the authors provided a detailed analysis of each factor, highlighting the diverse characteristics and considerations associated with TAs in organisational contexts.

4.2.1 Typology of TAs – A Conceptual Framework for a Proposed Classification

The following section outlines the types of TAs based on a comprehensive review of relevant factors identified in the literature. This review is of significant importance as it identifies and synthesises the key factors that shape the nature and characteristics of these organisations, offering valuable insights into their role in supporting innovation.

The author, in the absence of standard terminology, precise organisational mapping and a clear classification for 'mixed' translational assets, has taken the initiative to label TAs according to identifying characteristics. This approach, while different from the conventional terms used in the literature, has led to the identification of three ideal types of TAs: exploratory, plug and development organisations (Strazzullo et al., 2021).

Figure 12 illustrates the distribution of these ideal TAs along a developmental continuum of the main variables in relation to the innovation processes. The term "innovation processes" encompasses a spectrum that ranges from basic research to manufacturing and sales. For instance, TAs that adhere to a university-centric approach tend to focus on fundamental research, while those with a more commercially oriented philosophy prioritise manufacturing and sales.

To accurately classify the ideal types of TAs, the variables identifying each type must align on the same side of the continuum. However, it is important to note that trade-offs may exist for each type of asset; some TAs may not fully conform to the proposed classifications and may extend beyond the defined boundaries. For example, a university-based TA might operate as an independent entity separate from its parent institution, potentially fitting into alternative classifications such as centres of excellence or cooperative research (as indicated by the red intersection between exploratory and plug assets).

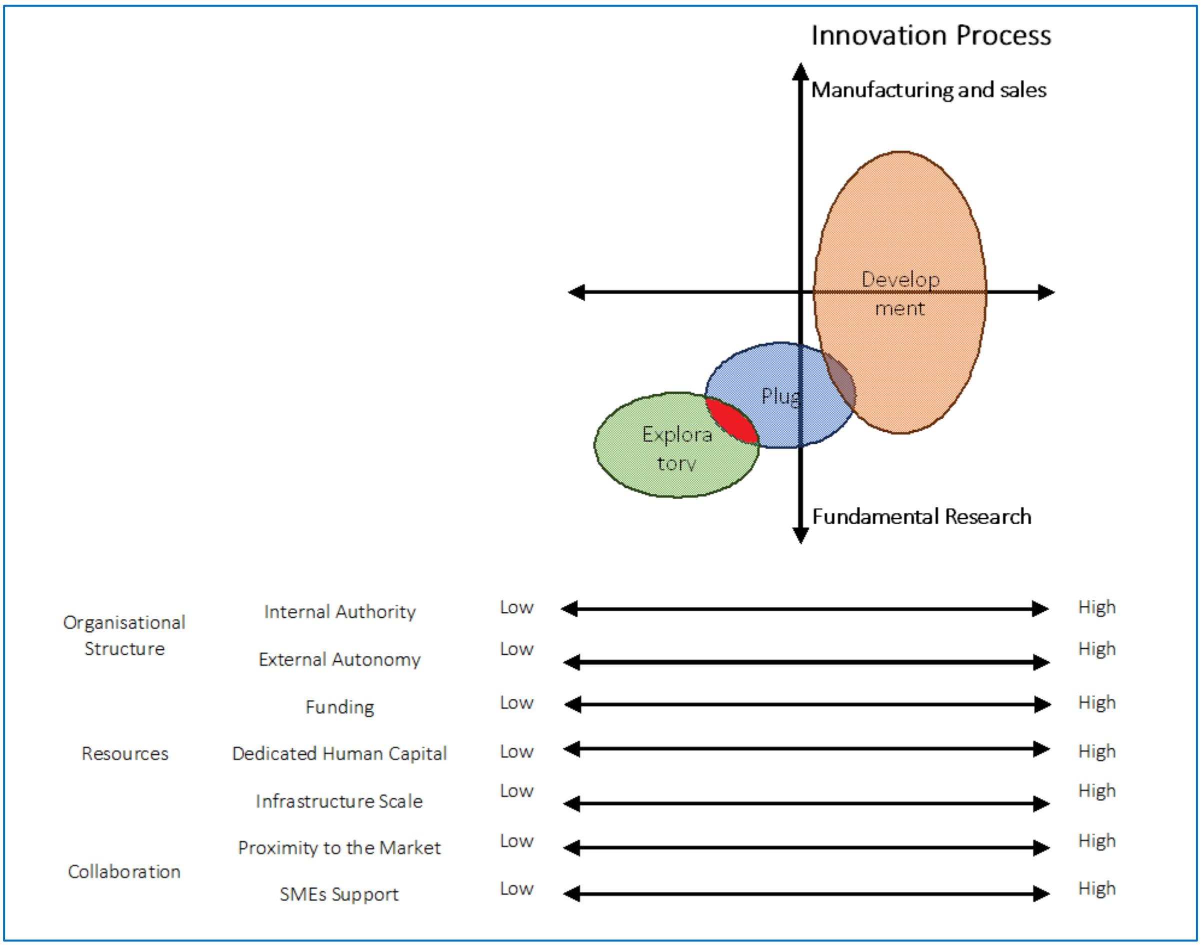

Figure 12 - Proposed Classification of TAs from the Literature Review (Author Representation)

Exploratory Asset

Exploratory Assets (EAs) are R&D organisations that primarily operate within the university framework. They usually are owned and supported by university departments. These TAs are focused on use-inspired basic research, conducting projects that align closely with the university's objectives. They typically have a hierarchical structure, with directors reporting to higher academic authorities such as the Head of the Department, Dean, Chair, or Vice President. While these organisations receive stable government block funding and individual grants, their collaboration with industries is limited. This is because EAs are deeply embedded within the university structure and proximity to the market is relatively low. However, they still engage with industries to facilitate knowledge absorption and provide access to highly qualified students and public funds.

Some cases of this typology can be Imperial College London's Grantham Institute, CNRS Research units in France or ETH Zurich's Centres in Switzerland.

Plug Asset

Plug Assets (PAs) are the second category of translational assets that are established to meet specific industry needs within a particular sector or technology. PAs primarily focus on development activities and also conduct research in the Technology Readiness Levels (TRL) 2–3 with the support of universities. These organisations mostly rely on Government funding, supplemented by private investments and contracts. PAs may operate within a university or another institution or have their own space. Decision-making processes in PAs can involve external players, such as advisory boards consisting of government and private firms. The researchers in PAs possess technical and scientific expertise from diverse backgrounds. Leadership within PAs often includes individuals with industrial experience. While there is a good relationship with the university, PAs face operational limitations due to the market logic they adopt. Industries engage with PAs to access their know-how, expertise and to establish research networks that facilitate collaboration on projects.

These organisations are exemplified by Innovation Centre (Scotland), CSIRO (Australia) and the Netherlands Cancer Institute (Netherlands).

Development Asset

Development Assets (DAs) constitute the third category of translational assets. These organisations focus on applied R&D and technology services, aiming to enhance industry competitiveness. DAs receive a substantial portion of their funding, around 30–50%, from the government. They cover a wide range of TRLs, spanning from 2 to 8, as their research objectives and relationship with the university dictate the extent of their activities. Funding for DAs follows a 1/3 model that includes core funding, competitive funding and private financing. Hierarchical organisational structures in DAs are led by directors with academic and industrial backgrounds and previous management experience. Researchers within DAs have a reasonable degree of autonomy. These organisations possess extensive facilities that are equipped with cutting-edge technology and employ experts from academia and industry. DAs actively interact with the market and maintain a high level of flexibility and operational autonomy to adapt to the changing needs of customers and the market. They provide comprehensive support to industries, including technology transfer, training, consultancy and a wide range of R&D services.

The Fraunhofer Society (Germany), TNO (Netherlands), Catapult (UK), and VTT (Finland) are a few instances of this asset.

In an innovation ecosystem, these ideal TAs contribute in unique ways. EAs mainly focus on generating new knowledge through basic research that is inspired by practical use. They also encourage collaborations with industries to absorb knowledge and provide access to highly qualified students. Additionally, they engage in education functions, mentoring MSc and PhD students and facilitating technology transfer. PAs are specifically designed to address industry needs, providing know-how, expertise and facilitating research networks to support industrial development. They play a crucial role in bridging the gap between research and industry by conducting development activities aligned with societal or technological targets. DAs, with their applied R&D and technology services, support industry competitiveness through technology transfer, training, consultancy and comprehensive R&D support. Their extensive capabilities and close interaction with the market make them vital contributors to the innovation ecosystem, assisting industries in bringing new technologies and products to the market.

4.2.2 Multi-dimensional Model of Translational Assets

The previous paragraph outlined how transactional assets could combine characteristics inherent to public and private sector organisations. By intentionally using different dimensions, it is possible to capture the essence of a transitional asset. This is because these assets generally do not exhibit these characteristics in the same way or to the same extent across all dimensions at the same time. A compelling illustration of this lies in the plausible scenario where an organisation entirely funded by the government concurrently partakes in commercial activities, a phenomenon notably exemplified by numerous state-owned organisations.

In this section, the researcher creates a comprehensive multidimensional model by combining the seven components he discovered that capture the essence of a transitional asset. Using a radar map as a visual aid makes it easier to define a company's heterogeneity identity at a certain point in time. To map a translational asset in this way, it is necessary to develop dimensions that represent its heterogeneity and a system for assigning scores that represent the different levels of heterogeneity. In this regard, the multidimensional model presented here shows qualitative dimensions.

Figure 13 (pag.71) shows a representation of the three types of TAs, which strengthens the results presented in Figure 12. It shows how the operating model of the assets changes against the factors by moving on a scale from “low” to “high.”

Starting with Exploratory Asset, the diagram showcases several key dimensions. The autonomy axis portrays the varying levels of autonomy for researchers within EAs. This indicates that researchers in EAs have to adhere to the research agenda set by directors, but their autonomy can increase with external funding. The collaboration axis illustrates the limited collaboration between EAs and industries, as EAs primarily focus on use-inspired basic research rather than industry partnerships. Considering the proximity to the market axis, EAs, being university-based organisations, are relatively distant from the market. Furthermore, EAs typically have low-scale facilities within the university structure, such as laboratories or workshops.

The Plug Assets, the radar diagram demonstrates the autonomy axis, indicating that researchers in PAs have intermediate levels of autonomy due to the right level of decentralisation control. Regarding collaboration, the diagram shows a stronger interaction between PAs and industries, as PAs are specifically established to meet industry needs. The funding axis reflects the reliance of PAs on both government funding and private investments, including short to medium-term applied research contracts and consultancy services. Compared to EAs, PAs have a closer interaction with the market due to their industry-oriented focus. These organisations may have their own dedicated space or be hosted by universities or other institutions, utilising their administrative functions.

Finally, in the case of Development Assets (DAs), the diagram highlights the autonomy axis, revealing that researchers in DAs enjoy a reasonable degree of autonomy compared to their counterparts in EAs and PAs. The collaboration axis reveals that DAs work closely with industries, providing a wide range of innovation services to improve industry competitiveness. The funding axis shows that DAs adopt a funding model that aims for a balance between core funding, competitive funding and private financing to achieve financial self-sustainability. DAs excel in proximity to the market, maintaining a high level of flexibility and operational autonomy to adapt to evolving industry needs and market demands. With their extensive capabilities and expertise, they possess substantial facilities comprising workshops and laboratories equipped with leading-edge technology.

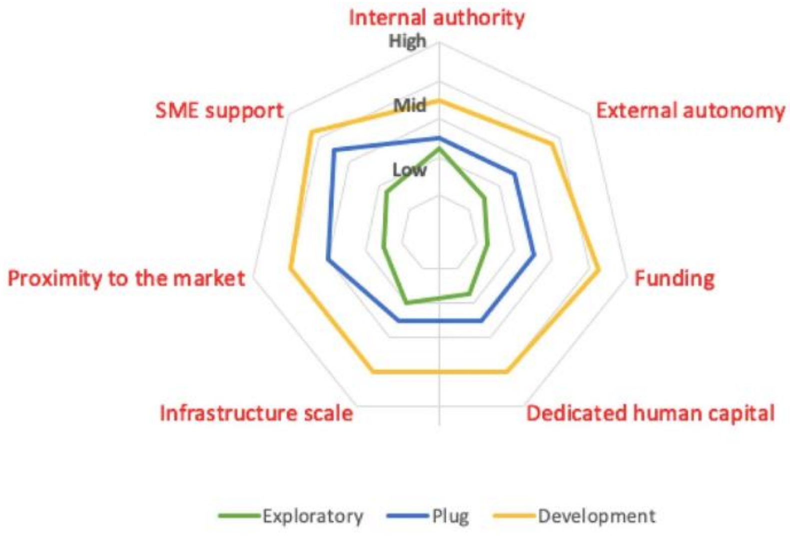

Figure 13 - *Comparison of Ideal TAs (Strazzullo et al., 2021)*

4.3 Summary of Literature Review Findings

In this chapter, the author reflects on the findings from the literature review and presents a proposed classification framework for Translational Assets. This framework accounts for the complex nature of these types of R&D organisations operating within the knowledge economy, offering a holistic approach to their classification.

The outcomes of the literature review revealed that the differences among these ideal TAs are rooted in various factors, including research focus, funding sources, organisational structures, levels of autonomy, proximity to the market and the extent of collaboration with industry. These detailed descriptions illuminate the nuanced characteristics of each TA type, underscoring their distinct contributions within the innovation ecosystem. Understanding these differences is crucial for designing and developing a robust and diverse innovation ecosystem that fosters collaboration, knowledge transfer and maximises societal and economic impact.

Additionally, an academic paper included in the appendix supports this research by providing a comprehensive description of the ideal operating models for translational assets.

The insights gained from this chapter constitute a significant contribution to the theory surrounding R&D organisations. The next step involves applying this classification framework to real-world scenarios. The following chapter will detail how the ideal classification is adapted and refined to fit the specific context of Scotland, thereby enhancing its practical relevance and applicability.

Chapter 5

5 Overview of the Scottish R&D context

This thesis focuses on the TAs that play a key role within advanced economies that are in line with those of the UK. The purpose of this project is to explore the TAs operating within Scotland. To do so, it is important to provide a brief overview of the innovation landscape in Scotland before defining the types of R&D organisations based there.

Agents of R&D and Innovation Ecosystem

Scotland boasts a vibrant and complex innovation ecosystem that plays a pivotal role in shaping the nation's economic landscape. This ecosystem is established by an interconnected network that thrives on collaboration between research organisations, industry and academia. At the heart of this ecosystem is possible to identify four wider categories (Scottish Government, 2023; The Royal Society, 2023). :

- Universities are prominent players within the ecosystem, crucial agents that drive innovation through research education. Institutions such as the University of Edinburgh, the University of Glasgow and the University of Strathclyde stand as pillars of innovation, fostering cutting-edge research, nurturing entrepreneurial talent and creating a robust knowledge base.
- Innovation organisations: complementing academic institutions, there are major components like the CATAPULT Centres that link businesses to advanced research and engineering; Scottish Innovation Centres that are sponsored by the Scottish Government and act as catalysts for collaborative projects, facilitating knowledge exchange. They have diminished in number because they were unable to deliver against the programme's vision; Private non-profit research organisations such as Fraunhofer UK and Independent organisations such as James Hutton Institute and the Institute of Occupational Medicine, which provide R&D services to businesses and public bodies.
- Government organisations: Governmental organisations hold a prominent position in shaping Scotland's innovation landscape. Scottish Enterprise (SE), a national economic development agency that has been successful in creating a vast network of business angels, promotes the technological sector's growth, supports the university spin-outs and enhances Scotland's profile in the knowledge economy. Highlands and Islands Enterprise (HEI) fosters innovation across rural areas in Scotland, ensuring that opportunities are accessible throughout the country. The Scottish Funding Council (SFC) provides financial support to universities and colleges, empowering

institutions to drive innovation and create a skilled workforce for the future. Interface acts as a bridge between businesses and academic expertise, promoting collaboration that sparks innovation across various sectors. Additionally, Scotland benefits from the assistance given by UK-wide organisations; an organisation that promotes R&D and commercialisation across the UK and the seven councils that fund research, collectively known as UK Research and Innovation (UKRI).

- Industry: Scotland's diverse industries, spanning from manufacturing to healthcare, actively engage in the innovation ecosystem, contributing to the country's economic growth by leveraging research outputs and collaboration with universities and innovation organisations to drive innovation within their sectors.

The synergy among these agents is evident in the journey from research to market, driven by knowledge-sharing, competence and capabilities, funding and collaboration (Gagliardi and Amanatidou, 2023). Moreover, this collaboration shows that Scotland's innovation ecosystem operates as a perfect embodiment of the Triple Helix model. As these agents seamlessly collaborate, they demonstrate the model's principles in action, where academic institutions conduct disruptive research, industry drives commercialisation and government fosters an enabling environment. As Scotland continues its economic diversification and sustainable growth journey, the Triple Helix model remains a cornerstone of its strategy. The interplay between academia, industry and Government accelerates technological breakthroughs and fosters a culture of entrepreneurship, problem-solving and continuous learning. Through deep interactions among the helixes, Scotland is set to unlock new dimensions of innovation, enhance its global standing, and secure a prosperous future for its citizens.

Current Situation of the Ecosystem

Scotland is globally recognised for its significant achievements in research and science. However, it still has great potential to evolve into a world-class entrepreneurial and innovative hub (SDCI, 2021). In fact, the Scottish Government considers innovation an essential aspect of the country's culture, society and economy.

To support and increase its innovation level, Scotland includes innovation infrastructure, including universities and colleges, research institutes, RTOs, and innovation and technology incubators. For instance, programmes like Interface and the Innovation Centres have been viewed as valuable assets in Scotland's research environment. These initiatives have fostered collaboration between the public sector, universities and the Government to support industry in developing research for practical application. Additionally, several initiatives, such as the Scottish Co-Investment Fund, the Converge Challenge, and Scotland Can Do, have increased awareness of research and ideas among venture capital (VC) funders, which can facilitate consumer engagement (The Royal Society, 2022).

However, Scotland's landscape presents a mismatch between its strengths in science and its productive industrial demands, leading to inconsistencies in innovation metrics (Scottish Government, 2022). Patent records, one of the main indicators to value the innovation level of a country, show that Scotland performs poorly compared to countries like Finland, France, Japan, Sweden, the United States and the UK overall (Scottish Government, 2024). This disparity may be due to the fact that R&D, often considered a couplet, do not rhyme perfectly in this case. Scotland needs to work on D, which "refers not just to development but the diffusion and dissemination of innovation to the long, lengthening, languishing lower tail" (Haldane, 2018). Scotland needs to work on this aspect and focus on promoting more investment in translational research and business R&D, leveraging money to expand research infrastructure while maintaining a high level of publicly supported revenue for the research base (Royal Society of Edinburgh, 2020). Despite this, Scotland has made significant progress by increasing more than double its Gross Expenditure on R&D (GERD), which comprises R&D undertaken by the Business Enterprise (BERD), Higher Education (HERD), Government (GovERD) and Private Non-Profit (PNP) sectors, as a percentage of the GDP in 2020, from 1.66% in 2019 to 3.13% and above that of the UK (2.96%), EU (2.19%) and OECD (2.67%) (Fig. 14). However, a low Business Expenditure on R&D (BERD) is still a challenge. It was estimated at 1.91% compared to the UK (2.11%) and OECD countries (1.92%). In fact, Scotland's innovation performance is emphasised accounting mainly for a substantial public R&D expenditure (GERD) (1.63% of Scottish GDP in 2018 (Fig. 16)) (Scottish Government, 2023). One of the reasons for the low business investment rate in Scotland compared to other OCED countries is that nations with a more significant manufacturing sector tend to have higher investment percentages, as R&D and capital equipment spend tends to be higher in manufacturing than in services companies (Fraser of Allander Institute, 2021). However, Scotland is not the only one to have a low BERD within the UK. Other nations, such as Wales and Northern Ireland, also report similar low BERD levels, typically around 2% of their regional GDP. By contrast, East of England, West Midlands, South East and North West presented the highest BERD as a % of GPD (Scottish Government, 2024). This pattern highlights a broader structural issue within the UK economy, where R&D investment is highly concentrated in a few regions, which benefit from a stronger manufacturing base and higher prevalence of R&D-intensive industries. In contrast, with a smaller or more service-oriented industrial profiles, like Scotland, tend to underperform in BERD, which in turn constrains productivity growth.

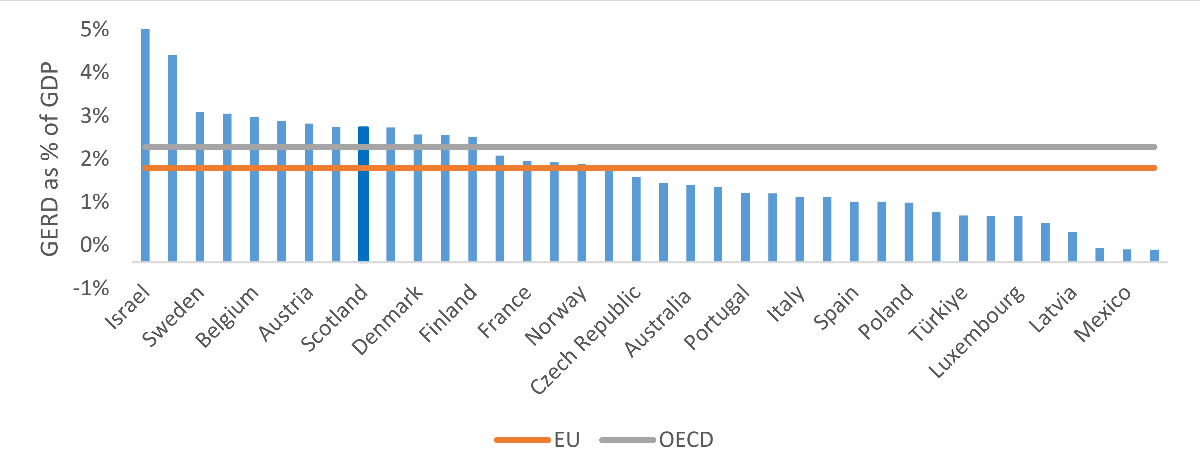

Figure 14 - Scotland's GERD as a Percentage of GDP (Author Representation - Data Adapted from Scottish Government)

Moreover, the low absorptive capacity and low investment in innovation from the private sector, primarily among the large firms, is due to the insufficient interaction between the education and research institutions with the local SMEs. In Scotland, SMEs account for 99.3% of the industrial structure (Brown, 2020). Additionally, there are significant gaps in digital capabilities, digital skills, and entrepreneurial skills among SMEs (Tsoukalas, 2021).

Based on the low stats in R&D expenditure from the industry, in Scotland most innovation and R&D happens in the private sector and in for-profit contract research groups. Innovation in the private sector is mainly responsible for the boost in productivity (The Royal Society, 2021).

To respond to the low investment of the company and increase the spending on R&D to 2.4%, the UK Government had to launch initiatives supported by a long-run investment (SDCI, 2021). Over the last two decades, the Scottish Government has made significant investments in a broad spectrum of programmes designed to improve the collaboration between public and private R&D through research intensive institutions that are able to carry out more applied research and play a more prominent part in enhancing the capacity of the private sector in regions and sectors by fostering the spread of innovation and the development of skills. This will ease and enhance the process of commercialising university research to support enterprises driven by innovation. The following paragraph will show the central policies and programmes the Scottish Government launched to support innovation in the country.

5.1 Policies and Programmes for Collaborative Research

Scotland has made significant progress in innovation and productivity in recent years, but there is still a desire to match the standards of comparable European countries like Denmark, Norway and Finland (Scottish Government, 2023). Such improvements are due to several institutions and assets critical for innovation in Scotland. In fact, it is possible to see how the research landscape in Scotland has undergone a remarkable evolution, driven by a combination of factors including a deep-rooted academic tradition and a strong commitment to excellence. Although universities are still central to the research ecosystem, collaboration and knowledge exchange between academia, industry and public organisations have become crucial to boost R&D activities and enhance the innovation performance of the country. This has led to investment in a range of research, development and innovation programmes from the Government to encourage collaboration between institutions and scale up the level of research activities in Scotland. To this end, several initiatives, such as the establishment of new organisations like translational assets, have been put in place to facilitate the transformation of theoretical concepts and scientific discoveries into practical solutions.

As explained in the literature review, translational assets are entities operating both within and outside university settings that bridge the gap between academia and industry. They drive innovation, foster collaboration and enable seamless knowledge and technology transfer. Scotland has dedicated translational assets within its universities, specialising in various disciplines, from life sciences and engineering to renewable energy and social sciences. These entities provide state-of-the-art research infrastructure, facilitating collaboration among academics and industries. By promoting interdisciplinary research and fostering partnerships, they have become hubs of creativity and innovation, where diverse perspectives and expertise converge to tackle complex challenges. For instance, research centres such as the Edinburgh Centre for Robotics and the James Watt Nanofabrication Centre at the University of Glasgow engage in collaborative research with industries, enabling knowledge transfer and catalysing commercial innovation. Complementing the efforts of university research centres, Scotland has a thriving ecosystem of translational assets outside the university domain, such as the CATAPULT Centres, such as Offshore Renewable Energy (ORE) Catapult and Advanced Forming Research

Centre (AFRC) and independent organisations that aim to tackle social and environmental challenged, such as the Institute of Occupational Medicine in Edinburgh and the James Hutton Institute in Dundee. These organisations can be affiliated with industry or public organisations, focusing on specific domains and providing unique collaboration and knowledge exchange platforms. They serve as catalysts for translating research outcomes into practical applications, addressing industry needs and driving economic growth.

In parallel, to support and nurture the research landscape, Scotland has implemented several initiatives and innovation policies to boost innovation and productivity for sustainable growth (The Royal Society, 2022). Economic agencies like Scottish Enterprise encourage and assist businesses in investing in manufacturing technologies and equipment through multi-strand innovation strategies like the Scottish Co-Investment Fund, the Business Growth Fund, the Proof-of-Concept Fund and the SMART Awards. Grants and critical sector funding programs, such as the Renewable Energy Investment Fund, also support companies in investing in R&D. Additionally, establishing Innovation Centres through the partnership between the Scottish Funding Council (SFC), Scottish Enterprise and Highlands and Islands Enterprise (HIE) has played a crucial role in bridging the gap between academia and industry. These centres aim to form a link between academic expertise and industry, as well as public and third-sector organisations, to produce economic and societal benefits. The Scottish Funding Council (SFC) provides strategic block grants that act as core funding to universities to ensure sustained support for research excellence, infrastructure development and skills enhancement (Mastroeni et al., 2017). Another visible initiative funded by SFC is the Interface programme, a brokerage service created to make connections between SMEs and Scotland's universities.

The UK government offers Research and Development (R&D) Tax Credits to incentivise businesses and research organisations to invest in R&D activities. This provides a financial boost to research initiatives. Furthermore, Scotland also gains from the assistance given by UK-wide organisations like Innovate UK, the organisation that promotes the development and commercialisation of research across the UK and the seven research councils that fund research and are known as UK Research and Innovation (UKRI). Additionally, Scotland sought opportunities in the global market through the Smart Specialisation Strategy. This has the potential to generate significant growth in critical clusters and sub-sectors where Scotland has a distinct competitive edge (Vidmar, 2019).

These opportunities involve adopting new technologies and ways of working that are applicable to a wide range of sectors and regions throughout Scotland.

Scotland is becoming an excellent and competitive innovation centre for the UK and internationally. These policies have yielded significant benefits to Scotland's research and innovation landscape and have enhanced Scotland's reputation as a global leader in various research fields, attracting international collaborations and investments.

In conclusion, the research landscape in Scotland has evolved significantly, driven by a rich academic tradition, translational assets within and outside universities and policies supporting research and innovation. As a result, Scotland has emerged as a global research hub, attracting top talents and fostering collaborative efforts between academia, industry and Government. To maintain its competitive edge, Scotland should continue to invest in research, strengthen industry-academia collaborations, promote interdisciplinary research, engage in international partnerships and support the development of early career researchers to enhance its competitiveness compared to other European countries. By embracing these strategies, Scotland can further consolidate its position as a thriving research destination, driving socioeconomic progress and shaping a brighter future.

5.2 Summary of the Scottish Context

This chapter provided an overview of Scotland's R&D and innovation ecosystem, laying the foundation for understanding the landscape in which TA operate. It highlighted the key actors shaping this ecosystem, including universities, innovation organisations, government bodies and industry.

While Scotland had a strong publicly funded research base and growing innovation infrastructure, the chapter also identified significant challenges, particularly the low level of BERD compared to the UK regions and OECD countries. This issue is not unique in Scotland, as similar trends are observed in Wales and Northern Ireland. Moreover, the chapter addressed Scotland's efforts to enhance collaboration and knowledge exchange through dedicated policies, funding mechanisms and the establishment of translational assets that bridge the gap between academia and industry. These developments are central to addressing the country's innovation and productivity challenges.

The next chapter presents the results of case studies based on interviews with experts from Scotland's translational assets. These insights provide a practical perspective on how TAs function within the STI landscape and their role in translating research into impact.

Chapter 6

6 Empirical Results from Case Studies

6.1 Mapping the TAs – Investigating the Scottish Landscape

6.1.1 Discrepancy between Theory and Real-World Scenario

The process of classifying TAs has always been a crucial aspect of academia and innovation policy. However, classifying these multifaceted entities has proven to be a complex and evolving challenge. While existing literature has provided valuable frameworks for understanding and categorising research organisations, their practical applicability in real-world scenarios remains to be determined. This discrepancy between theoretical constructs and practical realities needed an in-depth exploration and refinement of this framework.

As discussed in the previous chapter, the starting point for this research journey was a comprehensive review of the existing literature on translational assets classification. Extensive efforts have been made over the years to identify and synthesise relevant studies, frameworks, and models proposed by scholars. These literature-driven frameworks, which initially appeared promising in the realm of theoretical research organisation classification, provided a solid foundation for this study. However, as the research would later reveal, the gap between theory and practice in this field is often substantial.

One of the fundamental motivations for refining the classification framework emerged during the process of engaging with experts in the field. Interviews with these experts, who represent diverse experiences and perspectives, uncovered a striking misalignment between the existing literature-based framework and the complex reality of research organisations. The gaps between theory and practice became increasingly apparent as experts shared their insights, experiences and critiques. It became evident that, while the literature review had offered a strong conceptual foundation, it had to encapsulate the complexities of real-world translational assets fully.

There are several reasons why there is a gap between theory and practice. Firstly, the current literature often adopts a one-size-fits-all approach, which tries to fit R&D organisations into neat categories. However, this approach oversimplified the diverse and evolving nature of these organisations, which can encompass universities, independent research institutes, innovation centres and more (Cruz-Castro et al., 2020). Secondly, there are few insights about the multifaceted roles and functions they undertake in the science, technology and innovation ecosystem (OECD, 2022). Moreover, research organisations do not exist in isolation, as they are embedded in a complex web of relationships with Governments, industries and other stakeholders. Every interaction with these entities shapes their identities and operations. The dynamic nature of these relationships further complicates the task of classification, as it requires understanding the ever-shifting sands of collaborative research, industry partnerships and public policy initiatives.

Therefore, in the following section, the researcher shows how the classification framework for translational assets has been refined based on the insights gathered from expert interviews. By bridging the gap between theory and practice, the final outcome aims to provide a more comprehensive and applicable classification framework that can better guide policymakers, academics and practitioners in understanding Scotland's diverse landscape of translational assets.

6.1.2 The Relevance for a Classification – Experts Thoughts

In the ever-evolving landscape of research and innovation, the need for a robust classification framework for translational assets has never been more critical. Such a framework serves as a guide, enabling policymakers, academics and practitioners to make informed decisions that influence academia, industry and society.

The research journey into the realm of translational assets classification began with an extensive literature review that uncovered the foundational elements for defining TAs. However, as the saying goes, "the map is not the territory," and this adage proved true during real-world discussions with experts in the field. These conversations with experts illuminated the need for a classification framework that not only draws from theoretical foundations but also reflects the complexities and practical realities of translational assets.

Discussions with experts underscored the practical value of a well-defined classification framework. As one expert noted, *"A well-defined classification framework is the cornerstone that enables us to understand how a TA actually operates. It makes us aware of each TA's abilities and how they may interact with one another"* (Project Manager of TA_11). The COO of TA_12 further highlights this practical value, stating, "*A precise classification could be a valuable tool for academics to understand how the different translational assets are designed*. *A number of senior people have established many translational assets inside the university but have never written*

down how they designed them. It would be valuable for people to know that there is a tool. Maybe there is a blueprint in the person's head, but it has never been put down on paper". Moreover, the interviewee pointed out that "*Classification is useful for academics if they are in a situation where they want to establish a translational asset and they want to see similarities with the model that one has thought of".*
The COO (TA_12) further noted that a classification system would be valuable beyond academia, particularly for funders: "*They can see what kind of organisation they will have based on specific characterisations*". Indeed, funders, as key players in shaping the research landscape, could significantly benefit from a well-defined classification framework. It could help them direct resources towards programmes that are aligned with their goals. This concept was reinforced by the COO of TA_13, who remarked, "*Through a clear classification, funders can better understand how they can spend their money and avoid duplications".* This demonstrates how a refined framework could not only guide academics but streamline the decision-making process for funders, amplifying the impact of investment on innovation.

For industry stakeholders, the importance of a classification framework is equally compelling. According to the director of TA_6, "*It is important to understand the different translational assets out there, but it is more important for SMEs to know which organisation could be valuable for them for a future collaboration*". This sentiment was echoed by another expert from TA_15, who highlighted how a classification framework could assist companies in identifying the right entities for collaboration and support.

However, not all the experts were equally optimistic about developing a universal classification framework. The manager of TA_6 expressed scepticism about the feasibility of such a system, mainly due to challenges in terminology. "Many *attempts of classification (for TAs) in Scotland were made in the past, but so far, they have never worked because there is always a terminology issue. Industry often misunderstands the language used in the university. The landscape is too wide to capture fully in a single classification",* the interviewee noted. She shared his experience with a similar project, "*We worked on a classification for enabling technologies, which took two years, and still, we did not manage to find the more appropriate terminology. Language is very interesting in the public sector because people use it to give a false sense of knowledge and hierarchy. It should be used simple language so that everybody can understand*".

This scepticism underscores the challenges of creating a one-size-fits-all classification system, especially in diverse and dynamic fields like translational assets. However, despite these concerns, most experts emphasised the importance of a robust and adaptable framework. They saw it as a universal language that could bridge the gap between academia, industry and funding bodies. This framework has the potential to foster collaboration, accelerate technology transfer and ensure that research efforts align with broader societal and economic goals.

In response to these expert insights, the researcher refined the classification framework to account for both the theoretical foundations and the practical realities faced by TAs. By addressing the concerns raised – such as the need for precise terminology and flexibility – the final framework aims to serve as a valuable tool for funders, companies, academics and the wider innovation ecosystem, helping to create more effective collaborations and a more coherent understanding of the landscape.

6.1.3 Translational Assets: A Scotland Case Study

Scotland’s vibrant landscape comprises a diverse range of organisational models, including universities, independent research organisations and standalone research institutes, public sector laboratories, Catapults and other R&D and technology organisations to the most fascinating R&D-intensive startups, scale-up and industrial players (Department for Science, Innovation and Technology, 2023). This diversity reflects Scotland’s historical success in pioneering innovation, such as breakthroughs in medical science, renewable energy technologies and advancements in data science, as well as the challenges faced in scaling promising ideas or meeting market demands. Scotland’s mixed record highlights the complexity of the innovation journey, where remarkable success coexists with notable failures, such as the premature end of the Intermediate Technology Initiative (ITI), an ambitious programme designed to foster innovation but which failed to meet its goal (Parker et al., 2021).

Given this dual reality, there is a growing recognition of the need to understand Scotland's innovation landscape more deeply, particularly in translating research into practical applications for economic and societal benefit. One solution to address these challenges is the establishment of translational assets to bridge the gap between research and industry by facilitating the transfer of knowledge, technologies and innovation into practical use.

However, the landscape of translational assets in Scotland is far from uniform. The diversity among these organisations has been identified as a key challenge, with no comprehensive map of their structure or role within the innovation ecosystem (Campaign for Science and Engineering (CaSE), 2019). Such a framework is critical for understanding, analysing and strategically positioning these organisations within the complex Scottish research ecosystem.

Through an in-depth analysis of 19 case studies of translational assets across Scotland, this study identified factors that distinguish these organisations, including their *creation of organisational genesis, organisational revenue & governance and institutional affiliation*. Based on these findings, five new types of translational assets have emerged:

- *Specialised Independent*: Focuses on addressing specific societal or technological challenges with a strong orientation towards social impact;
- *"Ad-Hoc" Knowledge Gateway*: Serves as a dynamic, flexible gateway for knowledge exchange, developing ad-hoc knowledge to supply the industry and public needs;
- *Advanced Technologies and Innovation*: Primarily geared towards industry engagement and economic growth, driving innovation in strategic sectors or technology;
- *Demand-led*: Catalyses innovation at the national level leveraging Scottish universities' expertise to foster collaborations and initiatives that align with the nation's innovation agenda;
- *Regional Launch*: Focuses on nurturing SMEs through technology-driven initiatives, fostering regional development.

These types reflect the diverse and multifaceted roles that translational assets play in Scotland's innovation ecosystem. Understanding this diversity is crucial for maximising the potential of Scotland's innovation ecosystem and ensuring that promising ideas can be effectively translated into tangible benefits for society, the economy and beyond.

In the following sections, the factors identified from expert interviews and the framework of translational assets mentioned above will be further explained.

6.1.3.1 Factors Shaping Translational Assets

In the dynamic research and innovation landscape, accurately classifying translational assets is important for understanding their roles, enabling better resource allocation and enhancing their contribution to bridging research and industry. To navigate this dynamic terrain effectively, it is imperative to decipher the underlying factors that define these assets' features within the innovation ecosystem. This section sheds light on the essential factors that guide their classification. From the rationale behind their creation to their orientation, funding models, governance structures and institutional affiliations, these factors collectively contribute to a nuanced understanding of the diverse translational assets in Scotland. Therefore, in this section, the researcher embarks on a detailed exploration of the macro categories and subcategories that have emerged through the analysis of interview transcriptions (Tab 5). These categories represent the real-world factors that shape the landscape of TAs, enriching and expanding the classification framework beyond the findings of the literature review.

To complement this narrative, the researcher has developed a structured table akin to the approach used for the literature review, which succinctly encapsulates these new factors and attributes, providing a visual reference for readers. A detailed description of the theoretical significance of factors follows below.

Factors	Attribute	Spectra of Dimensions Criteria		
Organisational Genesis	Legal Status	Non-Profit	↔	For Profit
	Promoters/Supporters	University or Research Org.	↔	Industry Association
	Research Autonomy	Low	↔	High
Organisational Resources & Governance	Funding	Low	↔	High
	Pressure to get External Funding	Low	↔	High
	Infrastructure	Low	↔	High
	Governance	Low	↔	High
Institutional Affiliation	Proximity to the market	Low	↔	High
	Relationship with HEI	Coupled	↔	Loose
	Industry Involvement	Low	↔	High

Table 4 - Update the list of factors for the classification

Organisational Genesis

The first of our macro-categories is "Organizational Genesis". It represents the foundational category in the classification of translational assets, capturing the essential elements that define how these organisations are formed. This category comprises four key subcategories: *legal status*, *promoters/supporters, creation rationale* and *research autonomy*. Understanding these subcategories is important for understanding the diverse ways research organisations are established, governed and positioned within the broader landscape.

The **legal status** of a research organisation plays a pivotal role in determining the character and modus operandi of a TA. This attribute explores the different legal forms TAs can adopt, primarily distinguished between non-profit and for-profit entities. Within the non-profit sphere, organisations can fall into two main legal forms: charitable organisations and companies limited by guarantee. Charitable organisations typically prioritise societal benefits, such as advancing education, research, or addressing social causes, while companies limited by guarantee focus on financial sustainability and limited liability and often engage in collaborative ventures and partnerships.

These diverse legal stati dictate the extent of autonomy, governance and relationships within the innovation ecosystem.

The legal status is associated with the affiliation of TAs, who also play a crucial role in determining their legal status. Some TAs operate as independent entities, detached from any university and governmental oversight, giving them full control over their research agendas and operations. Others are closely tied to universities or governmental bodies, where their legal status is more intertwined with the oversight of these larger institutions, which can limit their autonomy in decision-making. As noted by the Director of TA_3, understanding the legal status of a TA is essential because it dictates its level of independence and how it fits into the broader innovation system.

Another critical attribute in the classification framework is **the promoters/supporters** behind a TA. This subcategory looks at the initiators of these organisations and explores the motivations that drive their creation. TAs can be created by various entities, such as national or regional governments, universities, industry associations, or research associations. Each type of promoter brings a distinct set of objectives and priorities to the creation of the TA, which in turn shapes its mission and operational focus.

For instance, when governments are the primary promoters, TAs are often established to address national or regional strategic priorities, such as fostering innovation in key industrial sectors or supporting economic growth through technological advancement. Universities, on the other hand, may create TAs to enhance their research capabilities, connect academic research to industry or promote translational activities that bridge the gap between academic discoveries and real-world application. Instead, industry associations often establish TAs to meet the specific needs of their sectors.

Understanding who the promoters are behind a TA gives critical insight into the organisation's underlying objectives and its place in the innovation ecosystem. For instance, a TA promoted by a regional government may have different goals and operate in a different capacity than one promoted by a university or industry association.

The **creation rationale** focuses on the fundamental reasons why a TA was established, offering a critical insight into the driving force behind its formation. Initially, this subcategory was tied to the "**Innovation Process**", a factor considered in the literature as an important variable for the classification. However, through the expert interviews, it became apparent that relying on the innovation process to classify a TA oversimplified their activities and overlooked the broader context in which they operate. TAs often engage in a range of activities that span different stages of the innovation process, making this metric too narrow for effective classification.

The creation rationale is a broader and more effective classification attribute because it encompasses the diverse nature behind the TA's establishment. Some TAs are founded to address specific industrial challenges, such as advancing technology in areas like healthcare, biotechnology or renewable energy. Others are established to promote academic research in cutting-edge fields such as artificial intelligence, quantum computing or data science. Still, others may be created to fulfil standardisation and regulatory needs, such as creating frameworks for emerging technologies.

By understanding the rationale behind a TA's creation, it is possible to gain a more comprehensive view of its mission and how it positions itself within the innovation ecosystem. As TAs evolve, their roles may shift, but their creation rationale often remains a core defining feature that informs their ongoing operations.

Research autonomy is the last subcategory of this attribute. This attribute has previously been described in the literature chapter, which refers to the degree of independence a TA has in setting its research agenda. This subcategory examines how TAs balance their autonomy with their affiliations and the influence of their promoters.

Independent TAs, for instance, often have a high degree of autonomy, as they are not bound by the bureaucratic structures of larger organisations like universities and government bodies. This allows them to pivot quickly in response to emerging opportunities, choose their research priorities and engage in partnerships that align with their specific mission. On the other hand, TAs affiliated with universities or government bodies may have less autonomy, as they often need to align their research priorities with the goals of their parent institutions or comply with regulatory frameworks.

While research autonomy is an important factor in understanding the flexibility and independence of a TA, the subcategory of **internal authority**, which was initially considered for inclusion in the literature review analysis, has been ultimately omitted based on feedback from experts. According to the director of TA_12, while "*internal authority is relevant for the day-to-day functioning of a TA, it does not have much significance in the broader context of classification. What truly matters is the legal framework and the driving rationale behind its establishment*". The Director of TA_3 further emphasised that internal authority can vary even within organisations that share the same classification. Therefore, it was decided that the focus should be on attributes that more clearly distinguish TAs in terms of their legal status, promoters, autonomy and creation rationale.

Organisational Resources & Governance

The "Organisational Resources & Governance" category forms a fundamental component of the classification of TAs, as it directly influences their capabilities, sustainability and overarching operational capacity. This factor encompasses two essential attributes: funding (including the pressure to secure external funding) and governance. These attributes offer a comprehensive view of how TAs allocate resources, financial dependencies and make decisions to shape their long-term trajectory.

Funding is central to any research organisation, acting as the essential driver that enables the organisation to fulfil its mission, conduct research and foster innovation. This key attribute has been introduced previously in the results of the literature review.
The sources of funding available to TAs vary significantly, reflecting the diversity of the organisations themselves. These sources range from public grants and government funding to private investments, memberships, industrial contracts and collaborative projects. The degree of reliance on public or private funding often correlates with the organisation's primary mission and strategic goals.

By representing funding on a spectrum scale, at the low end of it, TAs may rely primarily on government grants, public-sector funding and collaborative initiatives with public entities. Such organisations tend to pursue research that is aligned with societal objectives, often focusing on advancing knowledge or addressing broad challenges such as public health, climate change or social inequalities. In contrast, research organisations that derive their financial support from private funding, such as industry partnerships, commercial contracts and proprietary ventures, tend to be more commercially oriented. These entities are often motivated by market-driven imperatives, focusing on generating revenue, fostering innovation in specific industries and driving economic growth. Their financial autonomy allows them to pursue research with immediate or near-term commercial applications.

A critical component of this attribute is the pressure to secure external funding, which varies across research organisations depending on various factors, including organisational objectives, sector-specific demands and the availability of internal resources. Some TAs face intense pressure to gain external financial support to sustain their operations. This high-pressure environment forces organisations to compete for grants, industry partnerships and research contracts, often requiring them to align their research priorities with the interests of potential funders. Organisations facing high pressure for external funding must be agile, adaptable and responsive to emerging trends in their sectors to remain competitive.

Conversely, those with lower pressure to seek external funding, such as the organisations embedded in the university framework, may have greater or more stable financial autonomy. However, these TAs might still actively seek external funding to expand their initiatives or explore new research avenues. This gives them the flexibility to engage in longer-term, high-risk research that may not yield immediate commercial returns but could have significant societal or scientific impact over time.

The second key attribute within this category is governance, which refers to the structure and processes by which research organisations are managed and controlled. Governance plays a pivotal role in shaping how decisions are made, how resources are allocated and how the organisation navigates its relationships with external stakeholders. The spectrum of governance can span from loose to tight structures. TAs with loose governance structures often operate within an academic framework, where decision-making is more flexible, distributed and often decentralised. These organisations allow for a high degree of autonomy among researchers and academic leaders, encouraging creativity and intellectual freedom. The loose governance model is especially common in research organisations closely affiliated with universities, where the primary focus is on advancing knowledge rather than achieving specific commercial outcomes. While this flexibility fosters innovation, it can also make it difficult to maintain the level of accountability and structure required for large-scale industry collaborations or commercialisation efforts. On the other end of the spectrum, those with tight governance structures tend to be more formalised and typically operate within a well-defined management framework. These TAs tend to have clear, industry-focused objectives and are often more directly involved in technology transfer, commercialisation and applied research. Their governance models are characterised by strong oversight, defined roles and responsibilities and systematic approaches to decision-making. The presence of external stakeholders, such as industry partners or government agencies, further tightens governance structures, ensuring that the organisation's activities align with stakeholder expectations and commercial goals.

In sum, the Organisational Resources & Governance category provides valuable insights into the inner workings of research organisations. By examining the diversity of funding sources, the pressure to secure external funding and the range of governance models, it is possible to gain a deeper understanding of how these organisations function within the broader innovation ecosystem. The interplay between financial resources and governance structures influences not only the operational capacity of TAs but also their strategic focus, autonomy and potential for impact. This multifaceted perspective allows for a more nuanced classification of TAs, facilitating informed decision-making and fostering more effective collaboration across the research and innovation landscape.

Institutional Affiliation

The third macro category, “Institutional Affiliation”, offers an understanding of the relational dynamics that shape TAs. This category explores how TAs establish and maintain connections with other entities, including external stakeholders, partners and the broader innovation ecosystem. The pivotal subcategories are Proximity to the market, Dominant Actor/Orientation, Relationship with HEI (Higher Education Institutions) and Industry Involvement.

Proximity to the market, another attribute already present in the initial proposed classification framework, examines where a TA is positioned on the spectrum from academic isolation to market integration. As described in the literature review, this attribute can vary on the spectrum from organisations that may maintain a certain distance from market-oriented activities, prioritising fundamental and applied research. On the other hand, organisations may actively seek close collaboration with industry partners, focusing on applied research and technology transfer to foster innovation.

Relationship with HEI indicates the degree of integration of a TA with a higher education institution to which it may be affiliated. This relationship can range from loose affiliation, where the TA operates at a more arms-length relationship with their parent HEI, operating with a certain degree of independence. Instead, at the coupled end, TAs may be fully integrated into the HEI, sharing resources, faculty and governance structures with the university.

Finally, **Industry Involvement** explores the depth of a TA's engagement with industrial partners or the organisation's industry presence, ranging from low to high involvement. Some organisations focus primarily on academic pursuits, which may have minimal industry engagement. On the other hand, organisations may actively seek industry partnerships, engage in contract research, host industry advisory boards and participate in technology transfer activities.

The combination of various attributes shapes a TA's identity within the broader innovation ecosystem. Real-world TAs often display a mix of these characteristics, and their positioning evolves over time in response to changing leadership, priorities, or external factors. Insights from the interviews highlight how experts navigate these dynamics, emphasising **adaptability** and **flexibility**. For instance, interviewees underscored how translational assets leverage partnership, align with shifting economic or technological priorities, and adopt new funding mechanisms to remain relevant.

Flexibility and adaptability are desirable traits but also essential for translational assets to thrive in dynamic environments and effectively fulfil their missions. This adaptability reassures us of their potential to navigate the complex landscape of research and innovation.

In summary, the interplay of macro-categories provides a comprehensive overview of how translational assets employ diverse strategies and approaches to achieve their objectives and contribute to knowledge creation and dissemination within the research and innovation landscape.

6.1.4 Analysis of Findings from Scottish TAs – Refined Classification

To gain a deeper understanding of translational assets within the Scottish innovation landscape, this study undertook an empirical investigation to classify these organisations and explore their various operational models. Through this approach, the researcher wants to contribute to the field of organisational theory through a classificatory effort and identify new attributes to define the classification of the organisation through an exploratory analysis.

The study rigorously conducted interviews with key stakeholders involved in Scottish TAs to refine and expand the initial classification framework. This process revealed a more nuanced understanding of how these organisations contribute to Scotland's innovation ecosystem. Consequently, the study identified five distinct categories of operational models for translational assets: Regional Launch, 'Ad-Hoc' Knowledge Gateway, Specialised Independent, Advanced Technology and Innovation and Demand-Led. These categories provide a structured understanding of the diverse ways in which TAs operate within the Scottish innovation ecosystem (Fig. 15).

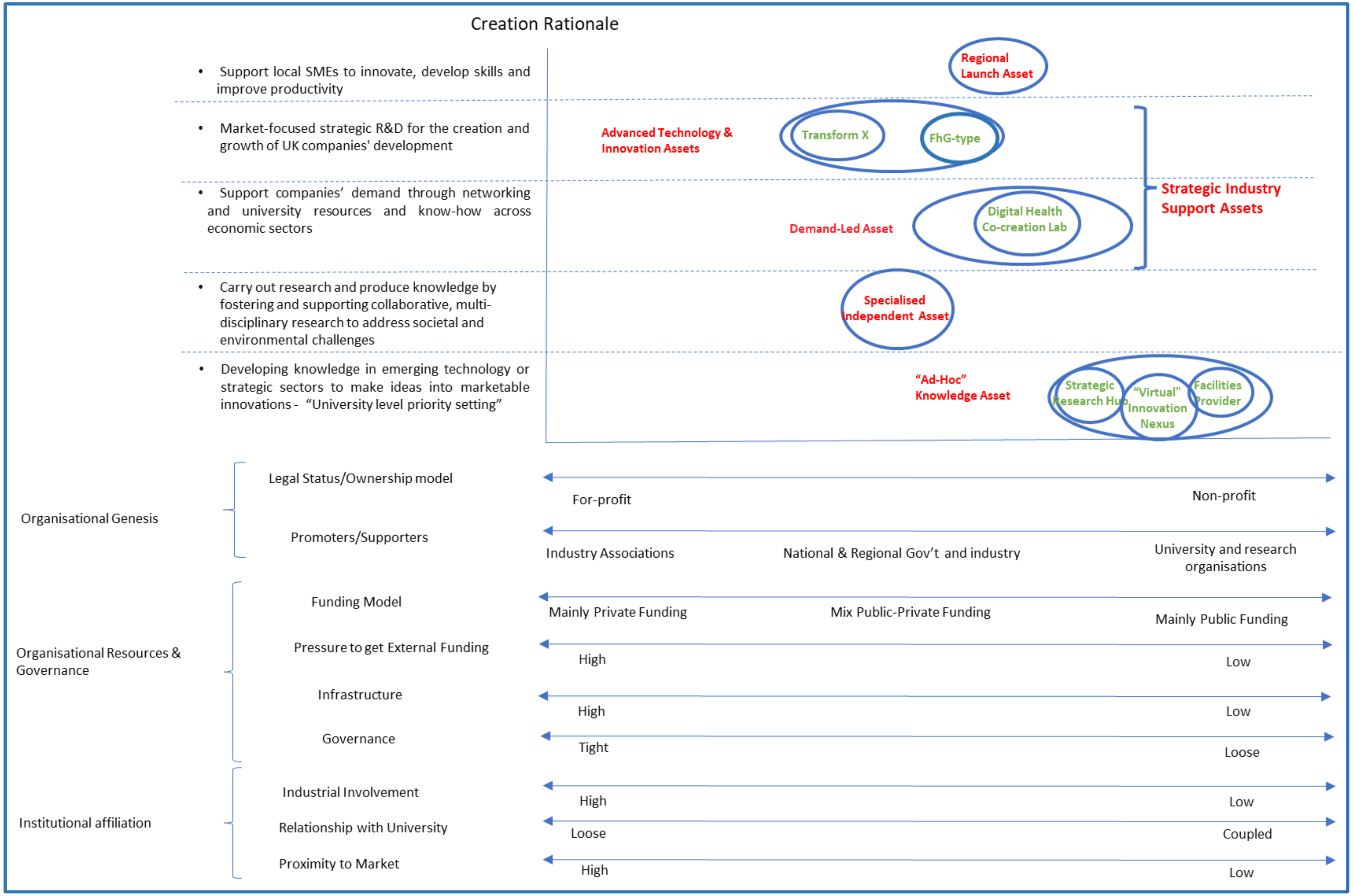

Figure 15 - Landscape of the Interview-Based of TAs in Scotland

6.1.4.1 Regional Launch (RL) Asset

The first prominent category to emerge from the researcher's analysis is the Regional Launch Assets. These assets are vital in facilitating market access for early-stage businesses and small companies by enabling access to necessary resources. Typically, RL Assets are established as legal entities responsible for project oversight and execution. These R&D organisations are characterised as "Launch" assets because they "*do not have all the capabilities available, but [we] have those necessary to support individuals to start a business or help companies to scale up*" (Project Manager at TA_10). They can be public bodies or non-profit organisations responsible for managing the funds, complying with legal requirements and implementing projects. They can be associated with a single university or a partnership between various stakeholders, such as multiple universities, research organisations or public bodies. However, these assets are linked to the university in different capacities, as the Director of TA_18 highlighted: "*We leverage research expertise and resources from Scottish universities and colleges to support industrial advancement in the sector*".

These assets are generally established through a top-down approach driven by industry needs and often reflect specific characteristics of cluster activities. Indeed, these organisations were established by local government and public bodies, such as SE and HEI, to promote the growth of key national sectors, such as manufacturing, and increase the technological capabilities of SMEs (Scottish Government, 2022).

In relation to this subject, the project manager of TA_10 emphasised that the strategic focus of these projects is "*on stimulating and improving the innovative performance of Scotland's SMEs by guaranteeing access to state-of-the-art facilities to test their products before their entrance to the market, as well as providing industry-specific business support and academic/partner agency expertise*". Additionally, the Director at TA_18 added that the SMEs receive "*advice on manufacturing, engineering, regulatory matters and funding and have access to technically supported production facilities*". For example, in the Highlands and Islands, where the initiative helps small companies in the manufacturing sector by providing facilities equipped with Industry 4.0 technologies, which allow businesses to test and demonstrate whole-system techniques on a larger scale than is possible in a laboratory. Therefore, supporting SMEs in remote areas, away from the Central Belt, in this way addresses one of their main challenges - access to a specific technical capability. The initiative's success in this area could boost Scotland's technical offerings and recognise the industry sectors in which the TA operates as leading sectors for the local economy.

Moreover, RL Assets are designed to "*contribute to the improvement of the supply chain by opening new opportunities and improving their competitiveness*" (Director of TA_18). Despite their relatively small scale, these assets can help companies advance to the next stage and complement other national assets to strengthen Scotland's innovation landscape. However, their engagement with industry is limited to supporting SMEs through program activities and they do not have a membership model targeting industry partners or an industry board for direct formal input from industry representatives.

Funding for Regional Launch Assets primarily comes from public sources, including local authorities and the European Union. They operate on a project-based funding structure and are typically limited-term organisations. At the end of the funding period, if the funders see positive performance of the asset by addressing the unmet SME challenges, they may be awarded again to maintain operations. Otherwise, there is the risk that the initiative will be extinguished. Companies are required to match funding through direct cash and/or staff costs when collaborating with these assets.

Finally, Regional Launch assets have different governance structures. Some may be affiliated with a university or multiple universities, but this does not necessarily mean academics are leading the organisation. For instance, an asset such as TA_10 is hosted by a university but is led by experts in the field. In contrast, TA_18 has a governance structure that includes representatives from each participating university and an independent Advisory Group consisting of representatives from the NHS, regulatory and clinical trials experts, medical device companies and clinicians. Therefore, this variation of governance reflects the diverse stakeholders and partners involved across different parties.

6.1.4.2 Ad-Hoc Knowledge Gateway (AKG) Asset

Ad-Hoc Knowledge Gateway assets serve as dynamic connectors between academia and industry, facilitating exploratory translational activities. These organisations are specifically designed to accelerate the development and dissemination of knowledge in emerging technologies in strategic areas and support the UK Government's Innovation Strategy. A key aspect of AKG's assets is its focus on multidisciplinary collaboration, which encourages partnerships between universities and industry to address important national research priorities (Dolan et al., 2019). Examples of these centres can be the Bayes Centre, which focuses on AI, and the Edinburgh Centre for Robotics, which facilitates AI, robotics and autonomous systems research. These centres connect academia with industrial applications in emerging technologies.

They typically operate as non-profit charitable organisations, serving as intermediaries between academic research and the practical needs of industry partners. Ad-Hoc Knowledge Gateway assets are typically university-linked organisations. According to O'Sullivan (2016), some AKGs follow a "hub and spoke" model, such as for quantum technologies, wherein centralised hubs coordinate research efforts and budgets across various institutions.
Universities are often the architects behind the establishment of these R&D organisations to meet Government priorities. They provide cutting-edge facilities, conduct fundamental and applied research and engage with industry to drive the co-development of technologies. As the Principal Investigator of TA_8 explained, AKG assets are deeply "oriented towards fundamental and applied research, carrying out activities using state-of-the-art facilities".

The financial backbone of AKGs is primarily composed of public funding sourced from government agencies, such as the Engineering and Physical Sciences Research Council (EPSRC) and Innovate UK (IUK)). EPSRC funded most of the translational assets focused on graduate education for a length of 5 years through the Centres for Doctoral Training, which aimed to support business-led research that arises from industrial needs (Deputy Director at TA_16). These funding sources allow AKGs to focus on long-term strategic goals, providing relative financial stability and reducing their reliance on external sources. However, to continue receiving this support, AKGs must still demonstrate their alignment with industry challenges. For example, in areas like robotics, automation and big data, there is a strong expectation that research efforts will directly address industry needs. As the Deputy Director at TA_16 pointed out, "*If you want to win research funding in our area (robotics and automation system), you have to address industry challenges. So, there is a benefit for industry from the research we are doing*".

Moreover, while public funding is critical, some translational assets of this type rely on industry partnerships to fund specific projects. These collaborations often blend research and development (R&D) efforts with a focus on delivering practical value to the industry. The Deputy Director at TA_16 emphasised this dual focus: "*Most of our projects fall somewhere in between, and then, they are not purely research but rather a blend of research and development. The goal is not just* *academic insights but delivering practical value to the industry. Our collaborations within the centre are distinctly industry-focused and we are not only looking at the distant horizon through blue-sky projects. We provide something useful to the companies through industrial projects, whose aim is to introduce technologies to market maturity within three or four years*". To maximise impact, some AKGs adopt a portfolio approach, balancing low-risk, industry-near project with high-risk, high reward “moonshot” initiatives. These ambitious projects can be transformative but also carry significant uncertainty. As the COO of TA_8 highlighted, a deliberated mix of projects ensures that the organisation remains innovative while meeting immediate industry needs. Additionally, some of these entities can present a membership model as part of their industrial funding source and the members can help steer the research direction of the organisation. For such organisations, the entire amount of membership fees from each member is spent on projects agreed upon by the TA Board, whose output would "*benefit all the companies involved in the agreement without any depreciation of one and another because they are not competitors*" (Knowledge Exchange Manager TA_12).

AKG assets are characterised by a governance model that prioritises academic leadership in decision-making processes and emphasises the importance of academic freedom. In fact, directors acknowledge the importance of not adopting a top-down, autocratic approach. The Deputy Director at TA_16 remarked, "An organisation *will fail quite simply because the people running them are far too autocratic and dictatorial in what they are trying to do. People tend to go into academia because they do not want to be managed*. *Instead, we promote a consensus-driven culture, where key decisions are made collectively by the steering group*”. It highlights how these assets rely heavily on collaboration with academics and require a culture of respect, consultation and shared decision-making in order to be effective and sustainable. This type of governance style fosters an environment where interdisciplinary collaboration can thrive. By prioritising academic input and aligning their research agendas with academic and industry priorities, AKGs can quickly adapt to emerging challenges and opportunities. This allows the management to identify where the funding needs to be directed to develop a specific technological area. Being part of the setting agenda enables this TA and management to be very comfortable when bidding.

AKG assets maintain close ties with their host university. This integration is not merely symbolic as it manifests in practical ways, such as proximity to academic departments, shared research resources and collaborative initiatives. This integration is essential for attracting talent and ensuring that AKGs remain competitive within the innovation ecosystem (COO of TA_8). Therefore, for these types of TAs, alignment with the host institution is crucial to ensure that the asset and the university grow and thrive together. Moreover, the fact that these assets are embedded within the academic ecosystem plays a crucial role in expressing the university's entrepreneurial spirit. As the Deputy Director of TA_16 pointed out, these assets "*equip the students to think holistically and creatively, setting them on a path to shape the future of both research and industry*", thus positioning universities as key players in national growth. However, according to the Director of TA_2, these TAs do not only unlock the entrepreneurial potential of the university, but they contribute to the overall entrepreneurship ecosystem by "*providing aspiring entrepreneurs with access to critical resources, mentorship and a supportive environment in which to transform ideas into feasible enterprises*".

Although they are part of the university, these TAs have a certain level of industry involvement. Industry engagement is a core element of AKG assets, with many of them involving industry members on their advisory boards or committees. This industry presence ensures that the translational activities are aligned with real-world industry demands, providing valuable insights and guidance. However, it is crucial that the industrial advisors remain focused on strategic input rather than operational decisions, as this could lead to conflicts with academics as they could advocate for a more corporate approach, which is different from the TA's objectives.

Within the broader category of AKG assets, there are three distinct sub-types, each with a unique focus and modus operandi:

- Strategic Research Hub: These centres serve as focal points for research and innovation, tackling critical challenges in targeted domains. They can be presented as joint ventures between two or multiple universities, leveraging academic collaboration from the involved parts to work on an aligned cause. This approach ensures that the research is aligned with national or regional industry strategies (Deputy Director of TA_16).
- Virtual Innovation Nexus: Operating without "physical spaces" because they are not involved in any research activities, these translational assets serve as a platform between universities and industry partners. Their primary role is to increase university research income and enhance the institution's profile in research evaluation like REF (CTO of TA_12). As the manager of TA_12 explained, "*We are a tool to increase the research*

revenue of the university. The more projects we do, the more they contribute to the university's income, and also, we increase the university's profile research in REF". Their unique strength lies in forming the right team through collaborative relationships with academic partners, governments, institutional partners and industry (Document TA_12). For such an asset, the project activities are outsourced to academics, who do a combination of fundamental and translational research. This type of collaboration allows the academics to access the TA's industry partners and the money they provide. Then, overall, these TAs play the role of a network by helping people kick off projects (CTO of TA_12). Then, the Virtual Innovation Nexus relies on the industry partners to guide the organisation's practical focus. They communicate real-world needs and directions, essentially pointing the TA in the right direction for translational research. Conversely, from a research perspective, the academic experts within the TA provide insights into emerging trends and future technologies that need to be explored. It is the leadership's responsibility to harmonise these two different but complementary viewpoints. They aim to bridge the gap between academia and industry without becoming a hindrance.

- Facilities Provider: These assets "*offer access to state-of-the-art infrastructures and resources to any company and researchers. This enables them to develop prototypes, conduct experiments and test new ideas, which in turn drives innovation and competitiveness in the supply chain*" (TA_6). These translational assets facilitate practical experimentation, accelerating the journey from concept to market within a research-driven environment, leveraging academic expertise and state-of-the-art infrastructure to advance knowledge and support early-stage innovation. As noted by the Deputy Director at TA_6, academics working within the TAs "*suggest the technologies and equipment required for scaling up and pool resources for their purchase*". He also added that these assets often offer training support and education programmes to develop the skills of the workforce and support the growth of the sector-specific industry in Scotland. This can lead to the creation of new jobs and businesses in the supply chain.

In summary, AKG assets occupy a critical space in the landscape of translational assets. Their strong university ties, flexible governance and industry engagement, make them dynamic catalysts for research translation and economic growth. As the COO of TA_8 emphasised, "*The university sees us as a jewel. Every time we launch something or every time the university hosts important* *visitors, they always mention our centre and bring them out here. Then, our centre enhances institutional visibility and university reputation*", underscoring the vital contribution these assets make to both academic institutions and the wider economy.

6.1.4.3 Specialised Independent (SI) Asset

The SI assets category includes translational assets designed to address critical social issues, ranging from healthcare to environmental sustainability, through social and technological research.

These assets are structured as independent charitable trusts that operate as a company limited by guarantee. This legal status allows them to pursue their charitable objectives benefiting from transparency, accountability and legal protection associated with a company. This structure, commonly chosen by non-profit organisations, ensures they can define their own purpose while complying with legal requirements. As the CEO at TA_1 highlighted, this independence allows them to maintain autonomy in decision-making.

The Specialised Independent Assets typically combine scientific leadership and operational responsibilities, particularly with Principal Investigators (PIs), who make strategic decisions such as income generation and staff and resource development. In these organisations, PIs operate more within a service-oriented framework as decisions have to be aligned with organisational objectives rather than enjoy more autonomy over their research trajectories (Cruz-Castro and Sanz-Menendez, 2018).

Two particular aspects of these assets are: 1) their adoption of an "*open science*" model, which promotes the sharing of data, models, methods and results to maximise the social impact of their research (Document TA_13); and 2) their in-house capacity, which enables them to set their priorities without being overly influenced by external entities. Following the open science model, these assets act as "*independent, open and trusted sources of information to help translate emerging information and commercialisation for the benefit of industry, Government, academia and the public* " (CEO at TA_1). Furthermore, their independence allows them to publish non-commercial findings, even when the results may be uncomfortable for certain stakeholders (CEO at TA_1).

These assets maintain a stable workforce with diverse skill sets, which enables them to take on various projects and work with different types of funders. This internal stability is crucial in

ensuring that research programmes can continue even when external funding sources fluctuate (CEO at TA_1 and the Director at TA_13).
However, these entities secure funding from multiple sources, including government departments, European research programmes, industry associations and companies, without receiving core funding. According to the Director of TA_13, "*A particular Government department provides 60% of the income. Then, the deliverables are aligned with the department's research needs and strategic priorities.*"

The challenge for these independent organisations is not receiving core funding. As the CEO of TA_1 explained, this represents a challenge because they "*will always be in a situation where there is insufficient funding to do everything they want. There is always uncertainty. We may have work for the next month and some business areas would work for the next two years, but in other areas, we have work for the next two weeks*". This instability is compounded by a reduction of UK Government funding over the years, although it has been somewhat offset by the increasing amount of funding won from the European Commission's Framework Programmes and Horizon Europe programmes. Therefore, for these assets, European funding is essential to expand their research capabilities. For example, the Director of TA_1 mentioned that they "*had to expand the organisation's vision of what we could do and get more of a business approach, which included different subject areas in different industrial scenarios and a wider range of clients. Seeing research on its own is not going to pay the bills and we will have to do something else. Then we started a consultancy business for supplement research income*". Then, the "wholly owned subsidiary" company is set up to operate profitably within the charity framework of the parent translational asset.

Although these TAs work closely with Governments from a technical and financial point of view, they also build relationships with universities, especially with those in their local area. For instance, the Director of TA_13's translational assets hosts a department of one of the local universities, and they share staff members. Regarding this, she pointed out that "*this collaboration has significantly advanced the translation of fundamental research into applied solutions across our research fields and this has generated millions in joint funding*".

In conclusion, the interviewees highlighted how being agile is crucial for independent translational assets to maintain a sustainable funding model to support their mission-driven research. Given that research priorities can shift over time, having a diverse funding stream allows these assets to scale their efforts. For example, investment from city regional deals can lead to the development of capability for supporting the translational pipeline, from fundamental research to commercial and policy application.

6.1.4.4 Strategic Industry Support (SIS) Assets

SIS assets are pivotal in the constantly evolving research, development and innovation (RDI) landscape. They are based in a specific location to connect business with research to provide a link from research output to commercialisation (Arthur et al., 2022). These assets are part of policies to address systematic failures, such as infrastructure deficiencies, capabilities and institutional failures (Russo et al., 2018).

SIS assets are broadly classified into two groups. The first category, *Advanced Technology & Innovation (AT&I) Assets,* aims to enhance science and technology through business-led partnerships. Organisations such as Fraunhofer institutes or Catapult Centres can be associated with this category. The second group, called *Demand-Led Assets*, acts as a national catalyst for innovation, driving transformative change on a broader scale by leveraging the Scottish university infrastructure and human resources. An example of this type of organisations is the Scottish Innovation Centres. These strategic assets are essential to propel industries forward, especially SMEs, and foster innovation on regional and national fronts.

6.1.4.4.1 Advanced Technology & Innovation Asset (AT&I) Assets

The AT&I assets encompass TAs that foster seamless collaboration between research organisations and private sector entities. They are often not-for-profit organisations, acting as a "risk-pooling platform" (Moradlou et al., 2023), improving technical capabilities to support business innovation. Their financial model is not related to the orientation or type of leading partners, but, for some of them, this could depend on the type of institution linked to, such as a university, but they are not pressured to look for several income streams because of the commitment of the public bodies to recognise their role in supporting business innovation and addressing national challenges.

These entries exhibit varying degrees of governance. Some have a moderate-tight level of governance. For instance, on one side, there are AT&I assets that, although they have established partnerships with industry and Government, focus primarily on use-oriented research, development and knowledge exchange. This implies that the organisation maintains moderate autonomy in its research activities, balancing relationships with its funding and industry partners. In some instances, like the translational assets involved in the energy sector, they are likely subjected to specific industry standards and regulations. Therefore, their governance structure ensures that research activities align closely with industry demands. On the other side, some operate under tighter governance, where research activities are closely controlled and directed towards the needs of their customers.

Industry involvement in these organisations is high, with mechanisms such as contracts research and industry partners on management boards. This involvement ensures that the strategic direction and research priorities of these assets are in line with industry needs. Industry experts can provide valuable insights, guide decision-making and contribute to setting research priorities that are directly relevant to the sectors they represent. Moreover, maintaining a strong connection with universities is also a key feature. This collaborative relationship extends beyond research, as it facilitates the science and technology transfer and access to state-of-the-art research facilities and ensures a broader impact is made by opening up research to society through national initiatives.

In this category, two subcategories have been identified as follows:

> **Fraunhofer Gesellschaft (FhG) Type**: As the label suggests, it is a model organisation inspired by independent Fraunhofer institutes that are renowned for driving innovation in Germany. In the UK, this asset operates as a non-profit company limited by guarantee with the British-German Trade of Commerce and Fraunhofer-Gesellschaft as its two members. The structure is designed to balance operational independence with close ties to the German Fraunhofer system, ensuring innovation and applied R&D for industry.
>
> The leading promoters of these assets include the Scottish Government and the German Fraunhofer, both of which play a critical role in funding and governance. The Scottish Government provide core funding, which is tied to performance indicators. "*If the centre does not meet the KPIs, the funding will be cut*", explained the Executive Director at TA_3. The German Fraunhofer offer oversight to ensure compliance with its brand and

reputation, though its influence is indirect, primarily exercised through funding and guidance on maintaining standards (Executive Director at TA_3).

What sets this translational asset apart is its "recipe for success". This recipe includes a clear governance structure, a mission dedicated to addressing practical industry and societal challenges and a blended funding model. As the Executive Director of TA_3 explained, "*The main challenge is that many organisations do not fully understand what we do. We provide professional applied R&D services for industry, either directly or in collaboration with industry*". Understanding how all these elements intertwine is crucial to appreciating the asset's design. Many organisations struggle with this, and this is why it is hard to replicate this model correctly.

Central to Fraunhofer's success is its dedication to professional applied R&D services, which align with the needs of the industry. The TA_3's Executive Director ensures that the "work's maturity" reflects the centre's remit: "*If a company comes along and they want some work done, we assess the research maturity. If it is at an early stage, the university can do that. If it is more developed, for instance, like a prototype, that is more our type of competency. We aim to ensure that both organisations succeed. If the university proves the principle and advances a few TRLs, then we are positioned to take over from TRL 3 to 6, sometimes 7*". Despite being very market-oriented, these assets engage with industries primarily through research contracts, allowing them to remain focused on high-quality R&D.

The organisation is structured so that researchers are encouraged to work at the forefront of their respective fields, driven by a clear mission of solving real-world challenges (Intarakumnerd and Goto, 2018). TA_3's Director noted, "*Everyone can write a proposal, have an idea and be encouraged to contribute. They are entitled to make suggestions to companies*". In addition, the TA_3's human resources policy further extends beyond developing business-relevant skills. It prepares suitable employees for the entire national innovation system, ensuring they are equipped for roles in research organisations, businesses and politics.

Fraunhofer asset types promote "*transfer through skilled minds*", embedding researchers directly into companies instead of simply delivering technical reports. “The most successful way to impart expertise to a corporation is to integrate a well-trained researcher within their workforce”, said the Executive Director of TA_3. This approach builds lasting relationships between the organisation and the industry, as former employees often become future clients.

Students also play a critical role in these assets, particularly in projects linked to engineering doctorates. These students receive hands-on laboratory experience, working with strict budgets on real projects. The Executive Director of TA_3 explained, "*Some of them will work directly on projects that may be in the early stages, while others are more focused on an "ideal world" project. […] We want to pull the research through the gate almost 100 per cent, especially with engineering doctorate projects. These students have an experience that is much more applied, working in our laboratories, attending meetings with companies and operating within the budget*”. This approach differs from traditional PhD programmes, with most students eventually working in industry rather than academia.

The relationship with the university is another cornerstone of the FhG type of asset. Directors, who are often professors at the partner university (joint appointment), manage both the technical offering and business focus. “*The professor has one foot in each organisation and has to make both succeed*”, explained the Executive Director of TA_3. This connection grants the asset access to basic research and junior talent, while universities benefit from industry-focused project and hands-on learning opportunity for students.

Another aspect that often needs to be clarified is the financial model, known as the 1/3 model. Although this could be an "oversimplification of the reality", Fraunhofer-type assets receive funding from three sources: 30% of the budget from grants gained through “in-house” research, which are projects financed by the government, 40% from contract research, projects contracted directly with the industrial partner and 30% from collaborative research, where projects are funded by public agencies and industrial partners. This is a rigorous criterion for assessing the performance of its R&D institutes and represents a reasonably well-balanced financial status. Institutional money enables FhG to perform future-oriented research, while industry profits allow the organisation to demonstrate its ability to transfer research findings to the market (Klingner and Behlau, 2012). To address the question, "*Why is this funding model ideal?*" Executive Director at TA_3 explained, "*There is no such thing as a perfect project. The perfect project for us bridges university research and industry needs. Those projects do not exist. If you only did industrial projects, you would think and behave like a consultancy or a job shop. If you only did collaborative work or were awarded funding by H2020, you would behave like an academic department. The balance comes from having a balanced portfolio of both types of projects, keeping you close to industry and research. So, you are on a narrow path not to do too much cash, not too much collaborative*".

A unique characteristic of the 1/3 model is the feedback loop. As the Executive Director of TA_3 described, "*The third of funding from the Government matches what the industry gave you last year. Headquarters distributes government funding based on an algorithm that considers your staff, European work and industry engagement. You will not get the right reward if you do too little or too much industry work. I have to find the sweet spot to find the right balance. So, there is that tension in the feedback. For this reason, the institute directors are motivated to find that balance to ensure they are doing some farsighted and some near-sighted work to optimise their funding*".

The FhG operating model is considered a model to follow for many R&D organisations, not only in the UK but also around the world. However, UK organisations face different challenges in implementing this model. One of the main issues is the core funding. It is not guaranteed in the UK, with the government handling finances for three or five years before encouraging the translational asset to be self-sustained. By omitting this type of income, many translational assets cannot operate similarly to the FhG model. Without such funding, UK assets risk becoming overly reliant on short-term, low-risk projects, turning them into consultancies rather than innovation drivers. Continuous core funding is vital for maintaining the relevance of the research capabilities that define the FhG model.

Transform X (TX): The Transform X assets are one of the backbones of the national industry strategy. They have been established to drive radical transformation within a specific sector or technology that has transversal employment. These assets play a crucial role in sectors with broad applications by bridging the gap between innovative research and commercial solutions. TA_4, for instance, operates within the offshore wind sector, with emphasis on the application of Robotics and Autonomous Systems (RAS) to provide advanced solutions to maintain and repair the offshore structure already installed. As highlighted by the CEO of TA_4, one of their goals is to replace human-led maintenance to ensure safety and efficiency. "*We are responsible for developing functional technology for the entire offshore wind energy chain*". The CEO of TA_4 emphasised the tangible impact of these assets in de-risking cutting-edge technology and easing the path to acting as an engine of economic growth by offering technical expertise and crucial mass to businesses.

Although based in a single location, these organisations may have multiple sites across the UK to facilitate industry-university collaboration and develop new innovative technology to better support the industry sectors within which they operate. This geographical spread enhances their ability to drive national and local benefits. CEO at TA_4 has given a striking example of local contribution, mentioning how their organisation transformed a demonstration turbine in Scotland as "*the most technically advanced open-access offshore wind turbine in the world*". This facility now serves as a unique test and demonstration platform for research and development. In addition, the CEO of TA_3 mentioned their organisation's strategic effort in collaboration with regional stakeholders "*to develop a cohesive plan and developed a talent and skill pipeline*" for green energy initiatives in the North East of England and Scotland (STI, 2023). The ability to engage with local communities while having a national impact exemplifies how Transform X assets operate as key innovation hubs.

These organisations typically operate as non-profit entities, often registered as charities due to their close affiliation with the university, which holds a charitable status. They are also registered as independent organisations limited by guarantee. COO at TA_7 pointed out the advantages of such a relationship with the university: "*Being closely connected with the university is not only a legal necessity, but also a strategic advantage - the university assumes legal responsibility for our actions, not us*". Moreover, the CTO at TA_7 explained that operating under the university's umbrella brings additional benefits, such as access to academic resources, infrastructures and collaborative opportunities. " I see more benefits of being part of the university than being independent", the CTO at TA_7 explained, underscoring the strategic alignment between the translational asset and its university partner.

Despite their connection with the university, these translational assets maintain operational independence, with key roles such as budget controller, finance controller, business developer, project manager and industry director functioning autonomously. As the CEO at TA_9 noted, "*Although we have operational autonomy, the final signature for collaboration must still come from the university*", illustrating the balance between autonomy and institutional oversight. Therefore, there is a dual reality where the translational asset has operational independence and operates within the university's overarching legal and regulatory framework. However, this operational independence could represent an initial step towards full independence for some translational assets (Director at TA_9).

An important feature of Transform X is their governance model. Although these translational assets represent a public programme, their daily management does not involve political profiles. Since the main idea behind the establishment of these organisations is to work side-by-side with industries, they must be managed with business acumen, not to maximise profit, but to achieve their objectives. Because of their market-driven nature, they necessitate a business-led management board, including business users and technology experts. "*Our board helps identify critical areas where innovation and technological development can reduce risks and costs*", Innovation Manager at TA_4 said, emphasising the role of industry-focused leadership in shaping strategic priorities. In university-affiliated assets, the Research Advisory Group also play a vital role by "providing a filter to prioritise the best academic ideas for commercialisation", as explained by the Innovation Manager at TA_4. This dual structure ensures that both industry and academia collaborate effectively to deliver impactful innovation.

The financial model for Transform X assets is inspired by the "one-third model" similar to the FhG asset type, which relies on a diversified income stream. The first pillar of funding comes from core government subsidies, awarded for five-year periods based on pre-established objectives. The second pillar corresponds to the funds secured through application to various R&D programmes, including non-governmental organisations, the UK Government and international bodies. The third pillar includes income generated by offering technological services to companies and other institutions. Additionally, some organisations adopt a membership model, where companies pay a fee to collaborate over an extended period, providing both financial and in-kind contributions.

As the CEO of TA_4 highlighted, "*We are not only reliant on core government funding but also on the income we generate through our technological services and collaboration*". This diversified funding strategy allows these assets to maintain financial sustainability while pursuing their innovation goals. Public funding can also come from the UK research council, such as the Engineering & Physical Sciences Research Council (EPSRC), further reinforcing their role in addressing long-term challenges in the UK's industrial landscape (O'Sullivan, 2016)

In conclusion, Transform X assets are central to driving innovation and supporting the UK's industrial strategy. Their unique operation models, strong industry ties and diversified funding streams position them as critical players in de-risking technology, fostering economic growth and addressing national challenges in key sectors like offshore wing and manufacturing. Their ability to navigate between academic research and commercialisation ensure that the UK's industries remain competitive on the global stage.

6.1.4.4.2 Demand-Led Assets

The final asset category is the Demand-Led asset. They catalyse the innovation level of Scotland's key economic sectors, including digital data and AI, healthcare, construction and biotechnology (Scottish Government, 2023). The term "Demand-led" reflects the central principle of these assets: they respond directly to the industry's needs. If there is no demand from the industry, these assets do not support the research. As the Project Manager at TA_11 explained, "*the industry is the primary customer*", meaning that the focus of these assets is on demand-led innovation rather than a technology push, aligning their research to industry requirements to contribute to national growth.

The initiators that designed this initiative involved multiple Scottish entities, including the national education and research authority, the Scottish Funding Council (SFC) (part of the Scottish Government), Scottish Enterprise (SE) and Highlands and Islands Enterprise (HIE). These bodies sought to enhance Scotland's economy and society by fostering collaboration between university-industry, industry-industry and university-university (Project Manager of TA_14). A lot of these collaborations are fostered through extensive networking. As the CEO_TA2 emphasised, "*Networking is critical for these assets as they must be aware of people working in the field, understanding what the demands are and what the drivers are for the companies, what type of support they need, or maybe linking them into other value chains*".

For such a reason, these assets will act as dynamic platforms, supporting national industries by leveraging educational infrastructures, skilled human resources and research excellence that characterises Scottish education institutions. Through this innovation initiative, universities can showcase their strengths while playing a crucial role in addressing industry demand (The Royal Society, 2014). Additionally, the assets aim to foster a culture transformation, placing business at the heart of academia and integrating academic innovation into business practices. As part of this mission, they facilitate collaborative knowledge exchange from academia to industry and vice versa, helping both sectors understand each other's needs and how research can provide support. This exchange, as noted by Ekos (2016), extracts the commercial value from an idea within the university while presenting industry challenges to academics.
A distinctive feature of these assets is their lack of legal entity. Instead, they are embedded within a "host" university and managed as a "*project within the university*" (COO of TA_11). Therefore, the "host" university is the legal entity that provides essential functions like finance, safety and human resources, offering stability and accountability. However, despite being administratively part of the university part of the university, these assets operate independently. The Director of TA_2: "We are an arm-length from the university and do not favour our host in terms of funding or projects *over other universities*". He also pointed out that while being part of the university has advantages, having a separate legal entity would allow access to additional funding streams, particularly for intellectual property (IP) development. "*If you are interested in creating or owning IP correctly*", he said, "*a legal entity would overcome some drawbacks that the university might impose*".

The project manager at TA_14 pointed out that these assets do not take so much guidance from the university and that "*the organisation's role is to keep an eye on what we are researching and to ensure that what we are researching is applied to industry. The research direction is most of the* *time led by funding that the UK Government and EU set*". Therefore, these organisations are overseen mainly by the founder rather than the hosting university (CEO of TA_2).

Demand-led assets are guided by industry rather than academia, with management teams often coming from industry backgrounds. In addition, they may have different types of advisory boards for recommendations, such as a scientific advisory board, which oversees scientific content to ensure the centre advances in its thematic areas and a commercial advisory board and/or NHS for some, which aims to ensure that the centre maximises the commercial impact and the industrial reputation of the translational asset and education advisory board, whose aim is to understand the skill and education gap within a specific industry sector. Usually, both scientific and commercial advisory boards play a crucial role in selecting R&D themes and projects as they have members from the university and industry. Based on that, the founder's oversight is flexible enough to avoid interfering with the industry board in delivering its strategy. According to the COO of TA_11, the connection with government entities is also significant, enabling these assets to "*identify areas for investment and opportunities for business*". He cited an example where the asset advocated for increased attention to cybersecurity for Internet of Things (IoT) devices, leading to government funding for a programme to increase awareness of the security of IoT. Thus, this engagement with the government highlights how Demand-led assets influence national funding strategies while maintaining that companies are the most influential stakeholders, driving the assets' innovation strategy. "*Companies want to use the technology pull rather than the academic push*", mentioned the CEO_TA2.

These assets also exhibit a growing concern for societal challenges beyond economic development. For example, the Director of TA_2 stated, "*We are becoming more like a mission-oriented organisation because of the focus on how biotech can help to reduce carbon emissions*". Furthermore, they improve the collaborative abilities of the parties in the innovation ecosystem by strategically focusing on "community building" activities through workshops, conferences and technical summits (Director of TA_2; Project Manager at TA_14 and COO at TA_11).

The financial model for Demand-led assets has evolved over time. Initially, these were fully funded through public funding from the Scottish Government, with a five-year cycle. However, funding from SE and HIE has gradually decreased, encouraging assets to generate up to 30% of their own income (Project Manager of TA_11). "*The Government wants to see the establishment of new* *companies, the generation of new jobs and the acquisition of new skills, so they reduce funding after each cycle*", explained the Project Manager of TA_11. This reduction pushes the assets to seek alternative funding mechanisms, such as consultancy and membership models, to maintain financial sustainability. For example, the Director of TA_2 highlighted how they leveraged collective industry representation to secure BBSRC (Biotechnology and Biological Sciences Research Council) funding despite the initial eligibility constraints for industry-led requirements. This brings some pressure to the organisations, especially if they are young and then being more proactive. Moreover, the reduction of funding brings to be less flexible in funding research projects to benefit companies. They have to be more selective in what projects are worth funding to achieve the necessary disruptive innovation.

A subgroup of Demand-Led assets is represented by the **Digital Health Co-creation Lab**, which differs from the broader category by focusing on a citizen-oriented approach to digitising services and social care. This is possible because these assets gather input and innovative product ideas from scientists, engineers, and end users to co-produce tailored healthcare products for patients (The Royal Society, 2014). Therefore, it serves as a mechanism and infrastructure for developing new technologies and services in healthcare. The Director of TA_15 explained how Scotland's geographical position, with its compact size and extensive rural areas, makes it an ideal "*test-best for future research*". She noted that "*challenges we face in Scotland are shared worldwide*", citing a successful collaboration with a Danish company to develop and implement a camera pill technology that now has international applications. This is also facilitated by providing access to a "*virtual sandbox environment, where experience laboratories provide various users, businesses and researchers collaborate and prototype healthcare solutions replicating a real-world scenario can be useful to address the needs of citizens*".

In summary, Demand-Led assets are critical in driving Scotland's innovation by directly addressing the needs of economic sectors. The defining feature of these assets is their industry-centric approach, whereby they respond to the demands of businesses instead of pushing technology from academic research. This demand-driven model ensures that the assets are aligned with market needs, contributing directly to national economic growth and social benefit

6.1.5 Charting Translational Assets

Chapter 4 introduced a radar diagram to represent an idealised framework of types of translational assets, including **internal authority, external autonomy, funding, dedicated human resources, infrastructure scales, proximity to the market** and **SME support**. These variables were assessed qualitatively across three levels: low, medium and high, to reflect the asset's positioning on each characteristic. Figure 13 shows how translational assets score uniformly high across all the dimensions.

Figure 16 (Pag. 112) provides a comprehensive comparison of five TA types identified in Figure 15, evaluating them on nine attributes, including orientation, legal status, promoters/supporters, public funding, governance, and industry involvement. Unlike Figure 13, Figure 16 reveals the nuanced realities of translational assets, illustrating a granular perspective on the practical challenges of balancing academic priorities and marker-driven goals. The diagram underscores a non-linear progression, where assets must prioritise specific dimensions over others depending on their stage maturity and strategic focus. For example, the "Launch Assets" demonstrate a high reliance on Public Funding and reasonable Proximity to the Market due to their strategic focus on engaging with local SMEs. Despite their moderate score in Infrastructure, they are able to provide practical support for businesses to translate ideas into prototypes, enhance assembly processes or refine operations. By contrast, the "Competing Industry-Centric Assets" prioritise strong Industry Involvement, Governance and a robust Infrastructure, positioning themselves as highly capable entities designed to meet the needs of the industry. Their advanced technological capabilities and tailored infrastructure make them pivotal for market-oriented solutions, providing the industry with ready access to applied R&D and commercialisation pathways. "Demand-led Co-Creation Assets" score high across Governance and Promoters/Supporters but display moderate Infrastructure. These assets rely on their collaborative model, where industry partners engage with them to solve specific challenges, leveraging university expertise and research networks to deliver solutions. This framework, while effective in addressing demand-driven needs, underscores their reliance on academic partnerships rather than independent infrastructure. In contrast, the "Ad-Hoc Technology Knowledge Gateway" types demonstrate good Infrastructure, though not as advanced as "Competing Industry-Centric Assets". Their infrastructure tends to remain more localised within university settings, limiting their capacity to address large-scale industry needs independently. However, their low Proximity to the market

The Specialised Independent Assets show strength in legal status and infrastructure with lower scores in industry involvement and proximity to the market, indicating the autonomy of the asset in pursuing its vision and its targeted operations tailored to societal and environmental priorities. Moreover, they score high in Pressure for external funding, highlighting the sustained efforts to secure competitive funding streams and maintain relevance within their niche.

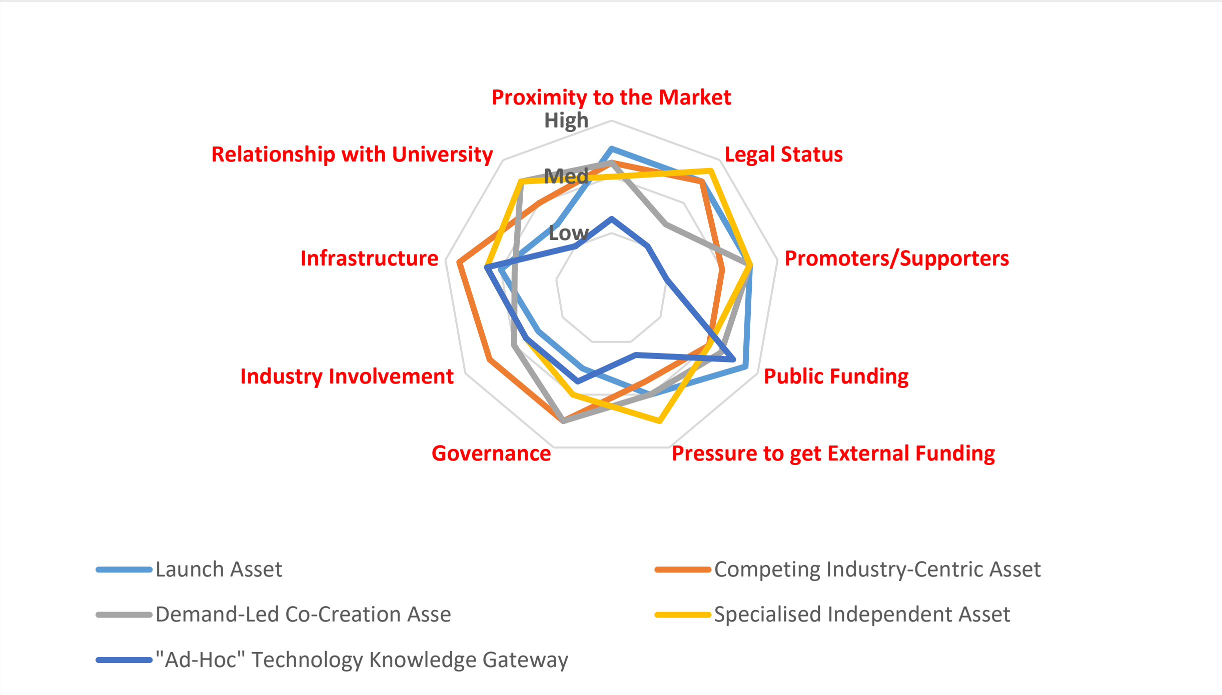

Figure 16 - A Comprehensive Spider Diagram Exposing the Various Factors of TAs

It is important to understand that evaluating an organisation on these nine characteristics, as shown in the radar diagram, is inherently subjective and cannot be precisely quantified. The primary purpose of these charts is not to measure an organisation's hybridity or performance in an absolute sense. Instead, they serve as a **comparative tool** that allows for the evaluation of different organisations or the same organisation at different points in time.

Furthermore, beyond a descriptive visualisation, this spider diagram also plays an **indicative-diagnostic role**, highlighting areas where an organisation's operating model may be advantageous or where improvement could be made. For example, the researcher used this tool to facilitate discussions about the translational assets' strategic operating model within the Scottish landscape. By asking employees within the investigated organisations to provide their own scores, the researcher stimulated an internal assessment of the organisation's current state. The diagram effectively captured these differences in perspective, offering a valuable platform for discussion and revealing how members of the organisation perceive its operation.

The visual tool not only prompted a deeper examination of the organisation's present state but also encouraged reflection on its potential future trajectory, paving the way for strategic dialogue and planning.

6.2 Summary of the Finding

In this chapter, the research analyses the factors of a sample of translational assets within the Scottish STI landscape. In analysing the Scottish landscape, this research initially utilised Hauser's (2010) definition of TAs. However, as the study progressed, it became evident that a broader definition was required to capture the diversity of assets observed. Hauser's definition of TAs primarily focuses on organisations with a mission to drive commercialisation through collaborative R&D and shared technology infrastructure to reduce risk and accelerate market access. However, the translational assets identified in this study operate across a broader mission spectrum, advancing technology from fundamental research to application (TRL 3 to 7) while addressing both commercial and societal and sector-specific goals. To reflect this range, the author proposed a refined definition:

"*TAs are independent or semi-autonomous organisations that enable the transfer of knowledge, technology, and innovation into practical applications. They exist on a continuum of capabilities and roles, shaped by their functions, strategic focus, and stakeholders' needs.*"

This broadened definition allows for the classification of translational assets that address a spectrum of needs, aligning more closely with the five categories of Scottish translational assets identified, each characterised by its unique model, stakeholders and strategic drivers. By shifting to this inclusive definition, the study accommodates the multifaceted roles these assets play beyond the narrower scope of TAs to reflect their integral position in the innovation ecosystem.

The translational assets investigated varied in size, scope, operating model and specific research area. Each asset operates according to different operational models, considering organisational structures, financial arrangements, and managerial procedures, as well as its mission and the particular needs driving its establishment.

To help with this analysis, it is helpful to list the benefits and drawbacks of each of the five translational asset operating models, which can be seen in Table 6.

Operating model	Pros	Cons
Regional Launch Asset	• Free access for SMEs to several cutting-edge technologies such as 3D printing, robotics and automation. • Designed to deliver a specific and focused initiative. • Access to regulatory and testing facilities. • Industry-led knowledge exchange and supporting collaboration amongst businesses.	• The cycle of funding is not long enough (circa 3 years) and it is hard to see the results in such a short time – the risk that the asset can be closed. • Focus on a specific technology or challenge.
Advanced Technology and Innovation Asset	• Multidisciplinary focus • Can present a "hub and spoke" model by collaborating with other universities or research organisations. • Flexibility with the structure to accommodate different partners between industry and university. • Membership model to gain access to real-world challenges and opportunities for technology transfer. • Offers a range of business support services to help companies grow. • Solving practical problems for industry, making it a good option for companies seeking immediate solutions. • Industry-ready talent programs.	• Financial sustainability could be a concern for "Transform X" - To support a better funding decision they should be asset with a proper evaluation process as FhG type. • Being affiliated with the university could affect the flexibility of the asset. • Assets that operate in sustainable energy and pharmaceutical sectors could be affected by regulation changes. • Keeping up with the ever-changing technological landscape while also adjusting to shifts in the research environment. Sustaining leadership in innovation necessitates constant observation and adjustment. • Challenges related to industry engagement may include concerns about intellectual property, varying expectations and different timelines between academic and industrial partners.
	• Effective use of university resources by having access to university services such as academic committee structures,	• Reduced funding support after every cycle – they could struggle to be self-sustained.

Demand-Led Asset	contracts, human resources and research administration. • Boosting innovation and economic growth by bringing together researchers, businesses and investors. • Focuses on specific areas of strategic importance for Scotland. • Facilitates collaboration between academia and industry, allowing each to benefit from the other's strengths and expertise. This can lead to more commercially relevant research and faster technology transfer.	• The lack of a legal entity could impact the asset's flexibility – the university is their legal entity. • Despite being embedded in the university framework, they could find it difficult to apply to certain funding calls (e.g., EPSRC).
Specialised Independent Assets	• Higher levels of autonomy in comparison to alternative operating models. • Broad research scope. • Provides a solid foundation for the development of policies, guidelines and interventions aimed at improving social and environmental conditions. • Actively engages with communities and the public, promoting awareness and understanding of social and environmental issues. • They share findings, collaborate with international organisations and contribute to global initiatives addressing global challenges.	• Lack of core funding. • Assets collaborating with industries might face challenges in maintaining a balance between industry partnerships and maintaining impartiality in research. • Regulations may impact the focus and direction of research activities. • Difficulties in fostering interdisciplinary collaboration. • Communicating technical scientific findings to the general public can be difficult. It could take dedicated work to translate scientific terminology into understandable information for a broad audience and clarify misunderstandings.
"Ad-Hoc" Technology Knowledge Gateway	• Aimed to carry out a targeted and concentrated research and teaching program. • Access to state-of-the-art facilities and expertise. • Benefit the university's reputation.	• Being part of a university might involve a bureaucratic process that could impact the agility of decision-making and resource allocation. • Equipment may become outdated due to the rapid pace of technological

		advancement, necessitating constant updates and replacements.

Table 5 - Pros and Cons of Translational Asset Operating Models

Through a review of 19 translational assets, the classification exercises five distinct operational models, each with unique features that help achieve organisational goals. Some translational assets were established to meet specific industrial, societal or academic needs, while others evolved through sustained research funding and programmatic objectives.

These assets differ not only in their research scope but also in their activities – ranging from outreach and training to translation, commercialisation and academic research. The strategic motivations behind their creation typically involve addressing unmet demands (related to industrial, societal or academic needs) within the STI sector. These translational assets are often established with significant financial and require a strong strategic driver to justify the resources involved. For industrial partners, the benefits include preferential access to emerging research, technological development and the ability to influence industry-based research through open innovation strategies.

In terms of funding, all five operational models depend on public money streams with varying levels of industrial income. While some assets are fully publicly funded, others rely on a combination of government grants, contracts and public money. This financial dependence raises challenges related to sustainability, as securing ongoing grants is essential for long-term stability. Although this study did not delve deeply into financial allocation, further research could explore the relationship between funding models and translational assets' operational and research performance.

Table 7 provides a blueprint for designing a translational asset, outlining the main components that distinguish one TA from another. This can guide practitioners in addressing key challenges such as securing funding, building infrastructure and establishing strategic collaborations.

<u>Market Needs and Opportunities</u> • Identify the strategic needs that the establishment of the institute will answer in terms of societal, emerging subject or industrial benefits. • Understand the needs of key stakeholders (e.g., researchers, industry, funders, policymakers). • Evaluate existing assets and identify distinctive value offerings. • Identify the organisation's value proposition that will attract funding. • Choose a suitable translational asset operating model considering the pros and cons.
<u>Governance and Operations</u> • Provide a practical governance framework outlining roles, duties and decision-making procedures to guarantee transparent and effective management. • Consider the level of integration with university/healthcare organisations. • Create a communication plan to interact with the public and build a reputation. • Develop a strategy for IP management processes. • Consider the level of independence.
<u>Organisational Resources</u> • Consider sources of funding and develop a sustainable financial plan. • Invest in state-of-the-art equipment to aim for translational research. • Consider the type of skills and expertise needed to operate the translational asset.
<u>Flexibility and Adaptability</u> • Maintaining flexibility to adapt to shifting societal demands, financing environments and research agendas. • Establish long-term financial and revenue-generating plans. • Create plans to increase impact, services and skills in order to meet emerging challenges.

Table 6 -Blueprint to support Translational Asset Design

Chapter 7

7 Discussion and Concluding Remarks

The first chapter highlights the importance of university-industry collaboration as a strategic response to the growth of the regional economy, where SMEs are located and how it is a source of innovation (Alexandre et al., 2022). As a result, technology and knowledge transfer have become priorities for many Governments (Cunningham et al., 2019). One effective strategy to support the linkage between universities and companies is through translational asset-type organisations (Santos et al., 2023). However, these organisations present heterogeneity, which makes it more challenging to discern the different types of organisations while identifying their common traits and differences (Caloffi et al., 2023).

Facing this challenge, there is the need to advance our understanding and organise how these organisations differ from each other. This research set out to address this gap in the understanding and classifying of translational assets within the innovation ecosystem, particularly in the Scottish context. While TAs play a pivotal role in bridging the gap between academia, industry and government, they are diverse and operate on complex models, posing a challenge to developing a unified classification framework. Through this study, the researcher aimed to create a flexible and comprehensive classification system that can accommodate the heterogeneous nature of TAs, offering insights for both academic research and practical application in the development and management of innovation ecosystems.

Throughout this thesis, the researcher has developed and refined a conceptual framework that classifies TAs based on their operational models, including resources, funding structures, and strategic orientations. The literature review synthesised existing research on translational assets, highlighting the gaps in discrete classification methods and advocating for a more nuanced approach to represent the complexity of these entities (Cruz-Casto et al., 2020; Whitman, 2023).

By conducting a qualitative study involving in-depth interviews with stakeholders from Scottish TAs, the research identified new operational variables—such as Promoters/Supports, Industry Involvement, Creation Rationale and Pressure to Get External Funding—that shape the ways in which TAs function. The empirical findings revealed that traditional classification methods failed to capture the hybrid and evolving nature of TAs, leading to the refinement of the framework to include new dimensions, such as the rationale behind their creation and degree of integration with external partners.

In addition, the research identified five different operational models for TAs in Scotland: Regional Launch, Demand-Led, Advanced Technology and Innovation, Ad-Hoc Knowledge Gateways and Specialised Independent Assets. Each model demonstrates how different TAs function within the broader STI (science, technology and innovation) landscape, providing practical insights into their intermediary roles in innovation and economic development.

7.1 Revisiting Research Objective

This thesis set out to solve two main research questions:

RQ 1: **What are the defining factors for classifying translational assets and how can they be represented along a continuum to enhance understanding?**

RQ 2: **What key factors should be considered in developing a comprehensive classification framework for translational assets in Scotland, and how can these factors be adapted or enhanced to create a context-specific system?**

The thesis tackled these research questions by linking them back to the findings and ensuring the contributions to theory and practice are highlighted. The following section discusses how each research objective has been addressed.

7.1.1 Research Objective 1: Define the main factors for classifying TAs

Chapter 4 addressed the first research question by synthesising research from the fields of innovation systems, triple helix theory, and translational assets international programmes. Therefore, it laid the foundation by consolidating multiple strands of research into a cohesive conceptual framework. The need to develop a conceptual framework comes from the heterogeneous population in Scotland of distinct translational assets operating in the overlapping areas of the Triple Helix. Additionally, there is a need for a more granular representation of diverse characteristics exhibited by translational assets.

To develop the conceptual framework, key factors were identified through an in-depth analysis of relevant literature. Foundational studies in innovation systems emphasise the importance of inter-organisational networks, knowledge flows, and system dynamics that shape innovation processes (Granstrand and Holgersson, 2020). Similarly, the Triple Helix theory (Etzkowitz and Leudesdorff,

2000) highlights the interaction between universities, industry, and government, providing a structural lens through which translational assets can be examined. More recent studies, such as those by Perkmann et al. (2013) and Tijssen et al. (2018), expand on these frameworks by exploring how research organisations facilitate knowledge transfer and the ways in which research collaboration models adapt to dynamic innovation ecosystems. R&D international programmes such as Horizon Europe and global case studies of translational assets (OECD, 2021) further stress the diversity and dynamism inherent in these organisations. These works collectively underscore the challenge of imposing rigid, discrete classifications on complex organisational entities.

In the literature, the struggle of misclassifying organisations through a discrete classification has been widely acknowledged. Discrete often fails to capture the continuum of organisational attributes and interactions. Scholars such as Cruz-Castro et al. (2020) and Yung Ng (2023) highlight that organisations involved in knowledge transfer and translational activities often operate along a spectrum of research and innovation functions. These insights align with a OECD (2022) study, which argues that research organisations evolve dynamically over time, and rigid classification approaches fail to accommodate their changing roles, objectives, and external conditions. Furthermore, Cruz-Castro et al. (2020) and Caloffi et al. (2023) emphasise the need for developing a more flexible framework that accounts for the misclassified or non-classified organisation, and the contextual evolution of organisations, enabling a more accurate representation of their operational model.

This objective was met by using a continuum approach rather than discrete classification, which allowed a more comprehensible differentiation of TAs based on multiple factors, such as organisational structure, resources, and collaboration. Moreover, this approach allowed multiple factors to be plotted, demonstrating that no single TA could be boxed into a specific category. This flexibility is critical in capturing the heterogeneous nature of TAs in the real world. The radar diagram used to represent the operational models provided a visual tool to identify the three ideal types of TAs - exploratory, plug, and development – further enhancing the clarity of the classification scheme.

In conclusion, the conceptual framework leveraged the literature review to address the heterogeneity of translational assets. By adopting a continuum approach and utilising a spider diagram, the framework provides a flexible and comprehensive representation of TAs. This methodology overcomes the limitation of discrete classifications, offering a tool to analyse and visualise the dynamic nature of TAs within innovation ecosystems.

7.1.2 Research Objective 2: Defining a context-specific classification framework for Scottish translational assets

The second objective aimed to refine the conceptual framework through an empirical investigation of Scottish TAs. The empirical findings, which are discussed in Chapter 5, provided new insights and led to the refinement of the original framework.

In particular, interviews with the heads or key people of TAs revealed a range of perspectives on the framework's applicability, highlighting the need for adjustments. One such adjustment was the reconsideration of certain variables, with some being deemed less influential for classification purposes. For instance, variables such as the authority structure, initially thought to be a key factor, was identified as less significant than originally anticipated. In contrast, the underlying rationale for the existence of TAs emerged as a more critical and foundational variable. This shift in focus led to the incorporation of new variables and the revaluation of others, resulting in the development of a more robust and context-specific classification system tailored for the Scottish landscape.

This empirical refinement contributed to answering the second research question, demonstrating that the framework could be adapted to reflect the specific context of Scotland's TAs. The refined framework consists of five categories of TAs. Moreover, the findings suggest that this refined framework holds potential applicability beyond Scotland, offering insights that could inform the development of similar systems in other nations. By incorporating real-world data, the framework has become more flexible and relevant to the practical challenges faced by TAs.

Furthermore, the process of empirical refinement involved direct engagement with exerts from TAs in Scotland, who shared their experiences and insights on the existing TAs. This dialogue provided invaluable context, offering a deeper understanding of Scotland's innovation ecosystem. These expert perspectives not only helped shape the evidence-gathering process from the literature review but also served as a way to validate and sense-check the findings from a broader analysis of evidence. Ultimately, the refined classification system has both theoretical and practical significance, laying the groundwork for future decision-making in the Scottish innovation ecosystem and potentially offering a framework for other regions to adapt and apply to their own translational asset landscape.

7.2 Contribution to Knowledge

This dissertation makes significant contributions to both **theoretical knowledge** and **practical application** in the field of translational assets. It addresses key gaps in the existing literature while offering a useful framework and tools to study TAs for policymakers, managers and other stakeholders involved in research and innovation ecosystems. The contribution of this study is multifaceted, providing insights into how translational assets can be classified, how these classifications can be adapted to specific contexts and how they can inform decision-making processes within the Scottish innovation landscape and beyond.

7.2.1 Theoretical Contribution

One of the primary contributions of this study is the development of a novel classification framework for translational assets (Strazzullo et al., 2021). While previous research has explored various aspects of R&D organisations, the classification of TAs has remained underdeveloped and fragmented, with existing frameworks often relying on rigid, discrete categories that fail to capture the complex, hybrid nature of these organisations. This dissertation addresses this gap by proposing a more dynamic, continuum-based classification model that accounts for the diverse and evolving characteristics of translational assets.

The theoretical contribution can be broken down into several key areas:

1. **Bridging the gap in TA literature**: Previous studies on translational assets have been limited in scope, often focusing on specific case studies, sectors, or functions, leading to the need "for further study" to examine a more comprehensive theoretical framework (Santos et al., 2023). Although there are several contributions to the literature about TAs, the literature is still very fragmented. This study contributes to a new understanding of TAs by identifying the translational assets type of organisation described in the existing literature from fields such as innovation systems, research policy and organisational theory, creating a more holistic and unified framework, highlighting the several definitions used to describe this type of R&D organisation and to identify the main factors used to describe these organisations, and ultimately creating a classification framework. It offers an improved conceptual foundation for future studies on translational organisations, addressing the need for a deeper understanding of their roles, structures and functions within innovation ecosystems.

An important advancement in this research is the proposed definition of translational assets (Pag. 115). Initially, Hauser's (2014) definition was employed, which focuses primarily on organisations that facilitate commercialisation through collaborative R&D and shared technology infrastructure. However, a thorough investigation of Scottish translational assets revealed that Hauser's definition was too narrow to adequately capture the complexity and heterogeneity observed in practice.

This study introduces a broader and more subtle definition that reflects the diversity of translational assets, recognising their various functions across the continuum. The revised definition of TAs reflects the diverse roles, stakeholder engagement, and continuum-based capabilities of TAs, making it more relevant for understanding modern innovation ecosystems. By acknowledging these hybrid roles, the proposed definition wants to enhance the conceptualisation of translational assets, offering a more accurate portrayal of their structure, functions, and impact within evolving innovation landscape.

2. **Introduction of a continuum-based model**: The use of a continuum to classify TAs is a major theoretical advancement. From a theoretical perspective, the continuum approach enhances the conceptual clarity of TAs by offering a more integrative and inclusive classification system. Traditional classification systems often impose rigid, static categories that may fail to capture the complexity and hybridity of TAs, particularly as they evolve in response to shifting research priorities, stakeholders' needs, and funding landscapes. By introducing a continuum-based approach, this study moves beyond such limitations, offering a flexible, dynamic, and multidimensional framework for understanding TAs by emphasising their differences based on degree, rather than kind, enabling to maintain a more precise and meaningful distinction (Master et al., 2012)

   The continuum model reflects the fluidity of translational assets, recognising that these organisations do not operate within fixed boundaries but instead exhibit varying degrees of emphasis across key dimensions, such as funding sources, governance structures, research orientation and collaborative engagement.

3. By positioning TAs along a continuum, the framework reflects their **dynamic operational models**, which can shift over time based on external pressures, policy changes, or strategic objectives (Gulbrandsen and Thune, 2020). This approach moves away from the limitations of discrete classification methods, which often fail to account for the complexity of these entities and may lead to the misclassification or oversimplification of certain organisations.

4. **Contextual adaptation to Scotland**: While the framework has general applicability, this study's focus on the Scottish innovation landscape adds an important context-specific dimension to the theoretical contribution. By examining a sample of Scottish translational assets and refining the classification framework based on empirical data, this research demonstrates how global frameworks can be adapted to suit local contexts. This contextualisation provides a valuable template for applying the classification model to other regions, offering insights into how local policies, industrial needs and academic strengths shape the operational models of TAs.

5. **Identification of key classification factors**: This study identifies a set of key factors that define TAs and influence their classification, such as organisational structure, legal status, research orientation, funding sources, industry involvement and industry collaboration. (Strazzullo et al., 2021). These factors were derived from both the literature and empirical investigation and they provide a comprehensive lens through which TAs can be understood and classified. The framework incorporates these factors into a multidimensional approach, recognising the complex interplay between them in shaping the operational models of translational assets.

By offering this continuum-based, flexible framework, the study opens up new avenues for theoretical exploration of R&D organisations and translational entities, laying a foundation for future research in this area. The framework can also be expanded and tested in other contexts, providing a starting point for cross-national comparisons and further refinement of TA classifications.

7.2.2 Contribution to Practice

In addition to its theoretical advancements, this dissertation has important **practical implications** for a range of stakeholders involved in research and innovation, including policymakers, funding bodies, universities and industry partners. The development of a refined classification framework for TAs offers a practical tool that can enhance decision-making, strategic planning and policy development within innovation ecosystems.

Key practical contributions include:

1. **A decision-making tool**: The refined classification framework offers policymakers and funders tasked with designing, evaluating or investing in translational assets. This would also support which model of TA would support the gaps in university-industry collaboration at the regional, national or local level and the need to formulate better or modify innovation policies (Santos et al., 2023).

Moreover, it enhances adaptability by recognising that translational assets can shift along the continuum over time, responding to changing societal, technological, or industrial needs.
By clearly defining different types of TAs and their operational models, the framework enables the design of more effective innovation programmes by targeting specific dimensions, such as infrastructure, skills development, or collaborative partnerships that align with the asset's priorities (Jibril et al., 2023, Lepore 2023). This is aligned with the study made by the OECD (2022), which highlights that public authorities have to support the process of ongoing change of these R&D organisations at the internal and external levels.

2. **Guidance for universities and research managers**: Universities and research managers can use the classification framework to better understand the strategic positioning of their translational assets. The framework helps identify the core strengths and weaknesses of individual TAs, enabling research managers to make informed decisions about resource allocation, partnership development and organisational strategy. For example, if a TA is positioned closer to the academic end of the continuum, with limited industry engagement, university leaders may decide to pursue partnerships with industry stakeholders to balance the organisation's focus.

3. Furthermore, the framework can guide the **design and development of new TAs**, offering universities a blueprint for creating assets that meet the demands of specific sectors or regions. By understanding the operational models of existing TAs, universities can build new organisations that are strategically aligned with both academic priorities and market needs. For instance, universities can conduct foresight analysis to assess so societal and industrial demands to define the TA's mission. Scotland's National Innovation Strategy emphasises focussing on sectors like Health and Life Science, Data and Digital Technologies, and Energy Transition. (The Scottish Government, 2023). From a policy perspective, Government initiatives encourage regions to identify and build on their unique strengths. Policymakers aim to identify gaps in regional manufacturing capabilities and fund infrastructure to support SMEs and industries, ensuring alignment with regional economic priorities. Another example can be to develop programs to ensure TAs can respond to shifting societal demands and technological advancement (UKRI, 2022). Another example is investing in state-of-the-art equipment and facilities to support translational research, such as the quantum economy underscores the need for infrastructure in emerging tech sectors (DSIT, 2023).

4. **A tool for enhancing collaboration and innovation**: For businesses and industry partners, the framework provides a means of navigating the innovation ecosystem and identifying TAs that align with their needs. By classifying TAs based on their operational models, businesses can more easily

locate potential partners for collaborative R&D, technology transfer or commercialisation efforts (Lepore, 2023).

5. **Contribution to policy development in Scotland**: The focus on Scotland offers a direct contribution to regional policy development. A better understanding of the RDI landscape would be facilitated by mapping TAs in the country (DSIT, 2023). The framework highlights how translational assets can be leveraged to address Scotland's unique industrial and societal needs, such as the development of sustainable technologies, advancements in health and life sciences and the growth of the digital economy. By identifying the strengths and weaknesses of existing TAs, the framework can inform future investment strategies and support the creation of new policies that promote innovation-driven economic growth in Scotland (The Scottish Government, 2023).

7.3 Research Limitations and Further Research

Although this study offers a robust classification framework for TAs, several limitations present opportunities for future research:

Firstly, the complexity of the research topic poses challenges. TAs are unique and multifaced entities and limited prior studies, particularly in Scotland and the UK, have made it difficult to rely on existing literature. The Science Direct database showed a very low volume of publications. The multidisciplinary nature of this field, blending aspects of innovation, technology transfer and organisational theory, adds to its complexity. Future research could narrow its focus by applying specific theoretical frameworks. For instance, resource dependency theory could explore the financial and knowledge resources TAs rely on and how this creates dependencies between TAs and external stakeholders. Similarly, process theory could examine how TAs facilitate technology transfer and their role in creating market-related dependencies (Borsi, 2021). Another avenue of exploration could be the role of TAs in developing strategies to collaborate with local firms, particularly with SMEs and their contribution to the local supply chain, especially in sectors like manufacturing.

An important area for further development is the integration of framework elements that explicitly address impact assessment. This could involve the introduction of typology of impacts that categorises the types of value that translational assets generate. Such a typology could include:

- **Economic impact**: Job creation, start-ups, supply chain development, increased productivity in supported firms.

- **Societal and political impact**: Contribution to public policy, social innovation, addressing grant challenges, and enhancing community resilience.

- **Capability-building impact**: Skill development, workforce training, SMEs engagement, and enhancing absorptive capacity of local forms.

- **Environmental impact**: Support for clean technology deployment, reduced emission through innovation, and circular economy interventions.

This typology could be linked to the intent or mission of each TA, allowing researchers and practitioners to assess performance against intended outcomes rather than applying a one-size-fits-all metric. Developing and testing such a typology would help build a more nuanced, outcome-based evaluation model.

Secondly, the lack of a unified definition (Cruz-Casto, 2020; Yuen Ng, 2023; Jibril et al., 2023); for translational assets presented a significant challenge throughout the research. The term "translational assets" is still relatively new and evolving, leading to inconsistencies in interpretation and application. Compounding this issue was the lack of a comprehensive overview of the Scottish RDI landscape, which made it difficult to compare different types of TAs, such as public research organisations (PROs), university research centres, government-owned research organisations, innovation centres and research and technology organisations. This also limited direct comparisons with other countries. Future research should focus on proposing a standardised definition of TAs, not only in Scotland but across the UK and internationally. Establishing a clearer, widely accepted definition would facilitate comparative studies and allow for further refinement of the classification framework. An option to address this would be to initiate a pilot study with some willing countries that would provide a list of TAs that match the agreed definition.

Thirdly, the study was hampered by data limitations. The absence of a comprehensive directory for TAs in Scotland and limited access to up-to-date secondary data sources restricted the scope of the research. The qualitative data used in this study was largely drawn from government reports and other public bodies, which were sometimes outdated due to the fairly low number of academic publications. Additionally, during interviews with key individuals in TAs, it became clear that some had gaps in their understanding of their own organisation's operational model and how to classify it. Future research could focus on developing a comprehensive directory of TAs in

Scotland and the wider UK, which would provide a clearer picture of the RDI ecosystem and enable more robust empirical studies.
Extending the framework for ecosystem-level applications would help identify geographical or sectoral gaps in the provision of TAs, revealing underserved regions or emerging sectors that lack institutional support.

Fourthly, future research should demonstrate the practical application of the framework by using it to assess a real-world issue, such as examining how a particular TA supports SME digitalisation or the decarbonisation of regional supply chains. Case-based demonstration would test the framework's utility and allow for its iterative refinement based on empirical evidence.

Finally, the use of a qualitative approach posed challenges in representing the diverse characteristics of TAs along a continuum. Converting qualitative insights into measurable points on a continuum is inherently difficult. While this method provided valuable flexibility, future research might consider incorporating quantitative techniques to complement the qualitative findings. By doing so, researchers could achieve a more comprehensive understanding of TAs' attributes. Quantitative measurement would allow for more precise data collection and statistical analysis, enhancing the reliability of comparison among different TAs. However, the number of translational assets in Scotland could not be strong enough for robust statistical analysis.

Though the investigator tried to be as reflexive as possible in analysing data, it is likely that some of the findings presented in this thesis express some degree of his thoughts. However, it is very hard to think that any research study is not affected by personal preferences or biases.

7.4 Final Remark

In conclusion, this thesis makes a novel contribution to both the theory and practice of translational assets. The continuum-based classification framework (Fig.15) developed in this study advances our understanding of the heterogeneous nature of TAs, particularly within the Scottish innovation ecosystem. By continuously linking back to the research questions, the study highlights the importance of a flexible and adaptable framework that can be applied to various contexts. This framework offers valuable insights for future research and practical decision-making in the innovation ecosystems.

Future research should build on these findings by refining the framework further, adapting it to different innovation systems and exploring its applicability in other regional or national contexts. However, it is important to note that there may be challenges in applying the framework to vastly different contexts, such as cultural and regulatory differences. The potential to compare Scotland's innovation landscape with other countries could deepen our understanding of best practices in translational asset management. For instance, some comparison approach could be to choose countries with innovation systems comparable to Scotland's, such as those with similar economic structures, industrial sectors, or policy environments. Countries like Denmark and Finland or regions with the UK, such as England, may be suitable comparators. Moreover, it is possible to establish criteria to evaluate and compare the innovation landscape, focusing on assessing indicators like R&D expenditure, number of patent filings, or capacities (Budden et al., 2019) or identify and categorise the types of TAs present in each country, such as public research organisations, university research centres, and research and technology organisations.

Moreover, the practical implications of this research are equally important. The framework developed here will support how policymakers, managers and stakeholders approach the development and support of translational assets. By providing a comprehensive tool for understanding TAs, this research ensures that these critical entities will continue to drive innovation, economic growth and social impact, instilling confidence in the future of translational assets.

To maintain the momentum of innovation and ensure translational assets remain at the forefront of technological advancement, policymakers and industry leaders should embrace the flexibility of this framework. A continued effort is needed to support and adapt TAs in response to evolving market needs, technological advancements, and societal challenges in the dynamic landscape of innovation ecosystems. By fostering this ongoing commitment is crucial in the dynamic landscape of innovation ecosystems. In doing so, we can enhance the ability of TAs to transform knowledge into real-world impact.

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Annex I

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An Investigation of the Translational Asset: A Proposed Classification

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Abstract
Translational assets (TAs) are considered one of the actors that play a critical role within the national innovation system (NIS) of every country that embraces university, government, and industry collaboration. Moreover, these organisations have been established to support industries, companies, and particularly SMEs, filling the university-industry gap. Although the establishment of translational assets creates many benefits, this organisational ecosystem has been a controversial topic. It is hampered by a lack of consensus on how to define and classify translational assets. The problem arises because of their heterogeneity. This study identifies the critical factors for presenting a general classification from the analysis of academic papers and technical reports. The proposed classification is built, showing the factors of organisational structure, resources, and motivation for collaboration on a bidirectional continuum. Therefore, this paper's findings provide a proposed classification of three main types of TAs, which are as follows: exploratory, plug, and developer/solver. This is a heuristic classification that provides enrichment to the literature and a better understanding for practitioners of these organisations' behaviour.

Keywords Translational asset · Applied research · Classification · Theoretical typology

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Introduction

In a knowledge economy, there is a consensus that innovation represents, for almost all organisations, one of the keys for surviving and increasing competitiveness and knowledge is the driver for it.
Therefore, companies started to look beyond their boundaries and engage withother organisations to absorb knowledge as input to satisfy their scarce resources or capabilities, know-how, and reduce the risk of new product/service development. This strategical approach is known as open innovation, and opening their R&D boundaries for collaboration is the core of this paradigm (Arrigo, 2018; Chesbrough et al., 2006; Subtil de Oliveira et al., 2019). There are different levels of "openness" based on the firms' operating environment and the organisations with which the industries established new collaborations such as universities, intermediate institutions, and government bodies.

Despite the different perspective between university and industry, they often work in partnership. As enterprises have begun to establish new collaborations with several stakeholders, universities shifted their logic taking on entrepreneurial tasks (Leydesdorff & Etzkowitz, 1995) through the translation of knowledge (Etzkowitz et al., 2019). Universities, industries, and government are the main institutional R&D components in the knowledge economy model defined by Leydesdorff and Etzkowitz, known as Triple Helix. These national infrastructures that facilitate R&D and its contribution to technological innovation work on the macro- and micro-level. The macro-level is made from university, industry, and government, aiming to provide research activities. The micro-level consists of business that transforms service/product that embody the new technologies, which brings to an economic value (Betz et al., 2016; Sarpong et al., 2017).

The intersection between the helixes is the key to innovation. Indeed, the collaboration between university-industry has been encouraged by governments and funding agencies in developed and developing countries. The different supports provided by the government for innovation comprise research, technology and innovation policies, and other policy measures such as financial instruments (i.e. R&D innovation grants, tax incentives with a focus on collaboration) and regulatory mechanisms (i.e. (IP) right regime, incentives to different parties involved in the university-industry cooperation), and many else (Morrison & Pattinson, 2020; OECD, 2019). One of the policy strategies supporting research and sustaining the relationship between university and industry is establishing bridging organisations that facilitate the linkage between two entities. These organisations operate in the middle level of the technology readiness level (TRL) to resolve the translation gap. TRL is a 9-level scale used to assess innovation project eligibility based on their maturity (Figs. 1 and 2).

The translational problem is very prominent in the pharmaceutical industry but is found in other sectors such as manufacturing (Haeussler & Assmus, 2021). The term "translation" is meant the process of transforming basic research knowledge into use in the real-world promoting innovation of both products and process(Garegano, 2019).

Fig. 1 Technology readiness level (EARTO, 2014)

TRL Scale	Description
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technological validity in a lab
TRL 5	Technology validated in relevant environment
TRL 6	Technology demonstrated in relevant environment
TRL 7	System prototype demonstration in an operational environment.
TRL 8	System completed and qualified
TRL 9	Actual system proven in operational environment

The model of this type of organisation has been widely diffused during the last four decades, initially in western and more developed countries such as the USA, Australia, and Canada, and then has been set up in Europe in Italy, the UK, Netherland, Germany, Finland, France, Spain, and others. Thus, these bodies occupy a unique place within the innovation ecosystem by playing a crucial role in the country's economic growth through the creation, employment, and diffusion of knowledge (OECD, 2011a, b). The role played by these entities fits the state of the innovation system of the nation as they change based upon their strategies, structures, and economic orientation (Arnold et al., 1998). However, their worldwide presence brings some confusion proving their definition and classification (Ciappetti & Perulli, 2018). However, we are aware that not a publication has addressed this terminology inconsistency yet. These organisations have been labelled using several terms over time (Youtie et al., 2006) in the policy arena such as translational infrastructures (Hauser, 2010), R&D laboratories (Crow & Bozeman, 1987a, b), research centre (Boardman & Corley, 2008), or research institute (Stahler & Tash, 1994).

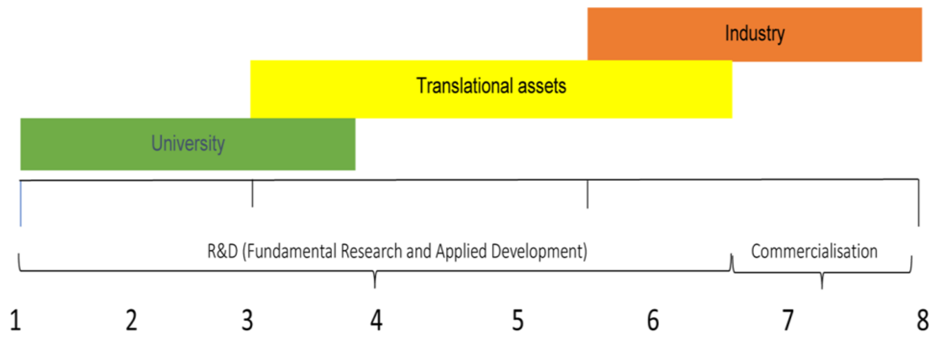


Fig. 2 Technology readiness level (TRL) (own elaboration)

To simplify this issue, in this paper, these institutions will be labelled under the umbrella term of "translational asset (TA)," used first by Hauser (2010) in his report where he highlighted the need for the UK to fill the gap between industry and university.

With the term asset, we want to include tangible (i.e. equipment) and intangible (people) resources. Commonly, the term asset identifies only the tangible resources, then to only the infrastructure. However, we adopt the new term of translational asset for two reasons: the first is because it is becoming popular in the UK in both the academic and practitioner environment, and second, which is the more important reason, the organisations, especially those involved in R&D, are recognising the value of the talent, skills, and knowledge as drivers for a successful organisation. Therefore, in this analysis, it is essential to link the concept of asset to tangible and intangible resources to have a clear idea of what the TAs are. Moreover, the concept of assets can be linked to that of infrastructure. Therefore, we have used these two terms interchangeably.

Ultimately, the need for classification is manifold. This research particularly wants to assess the different primary factors that distinguish the different R&D organisations' boundaries. To achieve this objective, the investigators conducted a qualitative study based on the triple-helix theory and the general literature at the international level about the TAs. This research is the starting point for studying this broad field of organisational theory and R&D and innovation management. Its contribution has impacts on theory and practice. The proposed general classification aims to fill the literature gap by clarifying the different types of TAs from a holistic perspective. This initial piece of research could enrich the theory through a framework and provide suggestions to practitioners in this field to examine and improve their organisations and policymakers needing a better understanding of the nature of the typologies of these organisations.

The paper is structured as follows: first, the authors introduce how the universities and the research organisations are changing their role within their ecosystem; the second section presents the existing classifications used in the literature of the different research organisations; the third section shows the typology and the variable considered to build it up; in the end, in the fourth section presents the conclusion and discussion in which includes further studies.

Approach to the Study

For this investigation, our main objective is to establish the diverse factors that define the translational assets to identify the main typologies that operate within a national innovation system (NIS). This objective was influenced by the relatively novelty of this issue and from the fact that such a phenomenon is still a grey concept from practitioners and academics. From here, the challenge is to categorise the Tas according to the existing literature. The authors aimed to analyse this phenomenon and to so they address the research question, "what does the literature says about the main factors that have been used to characterise the TAs?" The question has been answered by reviewing the literature on the characteristics of a variety of translational assets.

The purpose of the literature review was to have a background of information in the field and understand the main characteristics to classify these organisations according to the most influential scholars. The sources analysed distinguish various translational infrastructures with different reasons to be established for public and private support. The authors think that the difficulty in exploring this field does not come from the limited data but from the blurry concepts that shape this topic's boundaries, especially regarding the translational assets covering the mid and high TRL.

To gather information for the literature review has been used an electronic database (Science Direct) considering publication from the past three decades and considering different reports issued by governmental bodies and other translational assets within various OECD (Organization for Economic Cooperation and Development) countries and in the USA involved in science, technology, and engineering domains. Within the database, we searched using the combination of key terms as "research university" OR "research and technology" OR "research centre" OR laboratories AND "organisation design" AND classification OR typology. Research Policy, Technovation, and

Technology Forecasting and Social Change as the principal journals in research and innovation were considered to identify the relevant articles. The papers considered have mainly empirical findings gained from case studies. The authors read the first set of papers, and a snowball approach has been applied to gather further documents. Therefore, the literature analysis was useful to distinguish these organisations at a high level to classify and naming them according to relevant factors.

There is a call to a few a priori studies (notable Bozeman & Crow, 1990; Bozeman & Moulton, 2011; Crow & Bozeman, 1987a, b; Sanz-Menéndez & Cruz-Castro, 2003; McNie et al., 2016) about how these types of R&D organisations have been classified based on different dimensions. Nevertheless, as a result, these studies seem to be insufficient for recognising TA types failing to present a general classification scheme as they lack heterogeneity and sharp demarcations (McKelvey, 1982). Moreover, these past studies did not use an extensive list of factors to identify different types. For this reason, with the existing classifications, some organisation could not be collocated within the right group. This issue has been addressed in this paper by considering key factors and representing them on a continuum. The representation on a continuum eases the inclusion of hybrid organisations and better segmentation of the TA types. Only the necessary information has been collected from the literature sources to fill the variables that build the theoretical framework. In the following section, the analysis of the sources of literature on the translational assets and their past classifications.

Theoretical Background

Changing of Roles

In a context where the production of knowledge and its diffusion drives the growth of every national economy, research and development, in all its forms, and innovation induce changes of organisational and institutional nature. These changes caused by R&D costs, concurrency, or the risk of launching new technologies have seen the industries to require the support of the implementation of research and innovation initiatives within the industry boundaries to boost their growth. These initiatives do not bring only industrial development but also impact a social point of view.

In this wave of change, the knowledge-based economy context brought about a substantial revolution in the research landscape (Bazan, 2019). Mainly, the university has made a significant change: it shifted from its traditional academic activities of teaching and research activities to a third one. This third mission sees the university cover a substantial role in innovation, for example, by the commercialisation of the research outputs through the transfer of knowledge and the change of its funding sources. This transition brought about the birth of a university's new model: a university of entrepreneurial nature (Muizniece, 2020). In this way, the old linear model of innovation (from basic research to commercialisation) has been replaced as the industries try to resolve their challenges through science.

Another aspect due to these changes is about the freedom acquired from the investigators and how they started to set their research agenda with activities beyond the fundamental science's scope. By showing its innovation outputs, the university eases its connection with potential investors. The industry also found the university a valuable partner for its R&D objectives by having access to tangible and intangible resources (Bazan, 2019). These developments are described in the Triple Helix model, which represents the synergy between university, industry, and government that drives innovation and economic growth (Etzkowitz, 2000).

Moreover, a further change has been the need for a multidisciplinary approach to overcome industrial challenges. An example of this change can be seen in the translational asset that gathers researchers with different expertise to address complex problems in a specific context to create and transfer knowledge to the stakeholders involved in the collaboration.

These types of entities can be identified at the meso-level of the Triple Helix model, and according to Etzkowitz and Leydesdorff (2000), there are three different types of institutions:

- Hybrid innovation agents (responsible for the production and use of knowledge);
- Innovation interfaces between firms and public research;
- Hybrid innovation coordinators that provide coordination between the traditional research actors.

The concept of hybrid organisations covers various meanings based on the context in which the organisations fit. For this investigation, an intermediary organisation is conceived as an organisation (that carry out research activities) with a sequence of different characteristics and operating models (De Waele et al., 2015) based on their remit, stakeholders, organisational structure, and funding stream. Despite their relevance, the evolution of the translational asset has not had the same attention as the universities' transformation (Cruz-Castro et al., 2015). We may attribute this lack of consideration towards the translational assets because of the low expenditure in R&D by governments. Scholars could

also give more attention to the university because of the shift of the fundamental research beyond what were its boundaries through a multidisciplinary approach, new research activities, and their higher impact.
Nevertheless, introducing this new actor within the innovation ecosystem brought to the development of new collaborations. For instance, the partnership between university, industry, and the translational asset is strongly encouraged by the governments of each country, and it has brought both technologies and services to the firms, especially to the small and medium enterprises (SMEs) (Adams et al., 2001; D'Este & Patel, 2007). There are several mechanisms to establish a university-industry collaboration, both formal and informal such as collaborative research, research contracts, consulting, spin-off, IP transfer, licensing (D'Este & Perkmann, 2011; Etzkowitz et al., 2019), creation of physical facilities, postgraduate training in the company, training company employees, and joint research agreements (D'Este & Patel, 2007).
Therefore, these changes have entirely turned the R&D landscape and emphasised the role of these meso-level organisations. Since our principal objective is to classify these organisations, the following section reviews the effort made by the previous scholars to develop a classification of the TAs.

Typologies of Translational Assets in Literature

General Definition of Translational Assets

Although these organisations are not a new phenomenon in the innovation landscape, there is still a limited understanding of this complex type of organisations. An argument could be the hybrid nature of the organisations. Therefore, it is appropriate to attempt to analyse the variety of innovation organisations encompassing those most frequently known in literature and practice such as the research centre, research institutes, government laboratories, technology centres, and research and technology organisations (Cruz-Castro et al., 2020).
One of the causes of the lack of understanding is the birth of new types of innovation organisations to which have been associated with a variety of definitions that have created confusions between the scholars (Gray et al., 2013). Over the years and in every NIS, the definition of "translational asset" has evolved. Several definitions have been attempted, trying to expand the concept of innovation organisation from what was initially conceived as a traditional academic department. Table 1 proposes a selection of several definitions of the translational asset from literature sources and reports from different countries.

Table 1 Selection of definition of innovation organisations

Sources	Definitions
Gray et al. (2013)	A Cooperative Research Center (CRC) is an organisation or unit within a larger organisation that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and technology transfer, and ultimately innovation
Hauser (2010)	ICs (Innovation Center) are defined as organisations focused on the exploitation of new technologies, through an infrastructure which bridges the spectrum of activities between research and technology commercialisation
Adams et al. (2001)	IUCRCs (Industry-University Research Center) […] are designed to foster technology transfer between universities and firms. Since IUCRCs are small academic centres that depend mostly on industry support, we expect them to advance the research of member companies
Bozeman and Boardman (2003)	Academic departments are discipline-based units charged with teaching, research, and service missions
Bozeman and Boardman (2003)	URC as a formal organisational entity within a university that exists chiefly to serve a research mission is set apart from the departmental organisation and includes researchers from more than one department (or line management unit)
BIS (2015)	RIOs in the UK are defined as non-profit organisations that perform research and innovation support as their main activity, whose existence depends on a significant degree of public funding, and whose work serves some public policy purpose
OECD (2011a, b)	PRO is used to refer to a heterogeneous group of research performing centres and institutes with varying degrees of "publicness". [..]can distinguish four ideal types: mission-oriented centres, public research centres and council (PRCs), Research and

	Technology Organization (RTOs), Independent Research Institutes (IRIs)
Ikenberry and Friedman (1972)	Fully funded by Government and the funds were provided only for specific purposes. The main reason (frequently cited) for the creation of institute is the increased demand for multidisciplinary or interdisciplinary collaboration
House of Commons (2011)	Research and Technology Organisations (RTOs) is the term given to specialised knowledge organisations dedicated to the development and transfer of science and technology to the benefit of the economy and society. RTOs […] operate on both a commercial and not-for-profit basis with a focus on more routine and commercially lucrative laboratory and technical consultancy services

While various definitions of the term "translational asset" have been suggested, this paper will use the definition first proposed by Hauser (2010). We opted to choose Hauser's description because the other definitions in the table highlighted translational assets' characteristics like university-based, public-funded or industry-driven. In contrast, Hauser has a broader perspective as he sees TAs as organisations that collaborate with both private and public entities to adding value to the R&D process through the employment of technologies to attempt to fill the gap of the Valley of Death, that is, the gap between the research economy and the commercial economy (Jucevicius et al., 2016). Therefore, this definition is closer to our idea of a translational asset.

Other than struggling to find a clear-cut definition, there is a problem identifying a classification for the TAs. It is then appropriate to understand what distinguishes these entities by identifying several dimensions. This drives to build a framework that proposes a classification of how these organisations can be described.

Theoretical Typologies

This state-of-the-art classification is mainly due to the lack of conceptual clarity and conformity of the terminology adopted (Cruz-Castro et al., 2020). The different types of R&D based on the users have brought to the establishment of a varying kind of translational assets. The word classification has a different meaning in literature and often has been identified as typology or taxonomy. According to many authors (see Carper & Snizek, 1980; Hambrick, 1983), there is not a substantial difference between the two terms. Rich (1992) affirmed that a typology classifies data into types based on a priori theory.

In contrast, the taxonomy is a classification scheme aiming to represent empirical data in similar groups in a hierarchical fashion. In this analysis, the classification is identified with the term typology. According to Collier et al. (2008), typologies are understood as "organised system of types" and "is useful only if it reduces the redundancy and complexity of many variables" and "to reduce the redundancy and the complexity of the competing typologies" (Kilmann, 1983). The introduced typologies have been built considering data from deductive theories present in the literature. Moreover, being a theoretical typology, this investigation represents only the first step toward a system of classification and not the final one (Carper & Snizek, 1980). Its scope is to provide a framework for describing the nature of the different innovation organisations.

Typologies A Priori

We have stated above that the field of translation assets is a "grey" topic in literature. Thus, there are not many classifications of such organisations, and those existing do not present any homogeneity. Most of the literature aims to classify the industry-university cooperative research centre (Boardman & Gray, 2010). Thus, there is a lack of knowledge regarding other forms of R&D organisations. Mainly, the past classifications involve the changing environment due to the influence of the government and market (Crow & Bozeman, 1987a, b), stakeholders (Hagedoorn et al., 2000; Adams et al., 2001), type of technology transfer (Hameri, 1996), type of research (Geiger, 1990).

The main factors that several authors have considered will be analysed to design the existing classifications.

Environment: R&D organisations face various environments that impact the organisation overall (Aldrich & Herker, 1977). Crow and Bozeman (1987a, b) have investigated the context of the American R&D laboratories considering their legal status or ownership (public, private, or non-profit). AIRTO (2018) has provided a clear definition of the different legal status in one of its report. This variable shows the logic that prevails in the organisational environment. Several variables affect the organisational environment but what we think is the most appropriate variables to describe it are the "publicness" that identifies the degree of government influence on the organisation and the market influence. Indeed, laboratories can be owned by a public or private organisation like government and university or industry.

Simultaneously, the products can be identified as generic products with low market influence, balanced products with a moderate influence and property products having a heavy market influence (Crow & Bozeman, 1987a, b).

Collaboration: The collaboration between university, industry, and government has strategic importance and brings advantages to all the parties involved. Several scholars such as Feller et al. (2002) have investigated the perspective of the university on innovation organisation to emphasise the new face of the university as an entrepreneur (Etzkowitz et al., 2019), while other studies considered the collaboration between the innovation organisation and industry partner (Boardman & Corley, 2008). Collaboration goals are critical for the success of a partnership because they are related to the structure of collaboration. These goals target knowledge generation, basic research, sharing of resources, interaction with the community, and career development. This collaboration can start through a bottom-up process, top-down process, or mixed process (Corley et al., 2006). Hagedoorn et al. (2000) and Bonaccorsi and Piccalunga (1994) classified the motivations that drive members within the ecosystem to engage in this collaboration. The private sector involves this collaboration for several reasons such as having access to resources like highly qualified personnel and valuable knowledge (Bonaccorsi & Piccalunga, 1994); exploiting their resources and developing sustained competitive advantages; increasing the efficiency, synergy, and power through the networks; learning to build up new skills and capabilities; and internalising core competencies and enhancing competitiveness (Hagedoorn et al., 2000). Moreover, policymakers encouraged university-industry partnerships to correct market failure, accelerate technological innovation, and increase technological innovation exchange among firms, universities, and public research institutes (Cohen & Levinthal, 1989; Hagedoorn et al., 2000).

Organisational Structure: The structure is one of the key variables used to classify organisations. Among the organisational structure advocates, Burns and Stalker (1961) describe the organisation's structure as either mechanistic or organic, considering the hierarchy levels. Their classification is questionable because it could be obsolete or inconsistent, even if many scholars still use Burn and Stalker's classification to analyse the organisational structures. Nowadays, many R&D organisations attempt to increase their flexibility level independently of their size and hierarchical levels. Other factors that influence the structures are the research projects' scale and research autonomy (Jordan, 2006). Instead, it would be more relevant if scholars would analyse an organisational structure under collaboration format lenses. The study of Champalov et al. (2002) and Bonaccorsi and Piccalunga (1994) on the typology of organisation and management of the partnership by considering the different dimensions of bureaucratisation (leadership, formalisation, hierarchy, and division labour) is a notable example.

Resources: Generally, for the translational assets, the primary organisational variables considered for classification are the financial model, the human capital, and research infrastructures (equipment). Those variables can be seen as input for an R&D organisation. The last two elements can represent a set of capabilities for the TAs. Funding is one of the critical factors that distinguish the different form of organisations because it has a remarkable influence on the research's orientation and how organisations set priorities (Etzkowitz & Kemelgor, 1998; Lal et al., 2007). The funding is available from the R&D programs, government, and industries (Balthasar et al., 2000) to support new ideas and the initial demonstration that they work (Auerswald & Branscomb, 2003; Youtie et al., 2006). Moreover, the funders outline the geographical scale of the organisation's operations. The organisations established and funded by the regional government limit their activities to their home region. At the same time, those who receive national government funds address national needs (e.g. Fraunhofer Institutes) (Charles & Ciampi, 2014). The sources and the amount of funding received from translational assets show where they fit within the technology readiness level spectrum. However, they do not drive the research agenda of the TAs. If an organisation receives a majority of funding from a single stakeholder, the management and the researchers pursue their research objectives without neglecting the stakeholder interests (Lal et al., 2007). This could be partially true as, for instance, for a Tas that has industrial members that bring a considerable percentage of funding to the organisation force the research to satisfy the member's needs firstly.

In contrast, if the funding stream comes from different players, the organisation may cover different directions (Gulbransden 2011; Crow & Bozeman, 1987a, b). Therefore, various sources allocate funding to the TAs. Thus, the management of a TAs have to establish a clear mission and vision to avoid inefficiency and loss of funding in the future.

Human capital is an essential component in the TAs and consists mainly of scientists, researchers, technicians, and researcher students (Adams et al., 2001). This resource presents a certain autonomy level based upon funding and management (Jordan, 2006). It can be diversified based upon the size and the functions of the personnel. Jordan (2006) classifies individuals and a group's competencies, considering the specialisation level with specific expertise and the complexity and diversity of the research teams. Lal et al. (2007) classified the personnel as academic faculty, research faculty, and research staff. Research infrastructures are also relevant, but not all innovation organisations have the same equipment and space. For instance, ample laboratory space, workshop and up-to-date instrumentation, and other resources are not available for innovation organisation based within the university. Therefore, not all TAs can have stability in tasks and resources (Ikenberrry & Friedman, 1972). The TA facilities' capability depends mainly on the level of support they receive (Stahler & Tash, 1994). Another variable of input linked to the funding stream is the research projects. The projects are classified based upon their “size” and technical and organisational complexity (Corley et al., 2006). The innovation organisations attempt to develop a long-term alliance to have sustained support from their stakeholders (Gray et al., 1986

Stakeholders: Stakeholder is a recurring factor in many classifications because the type of stakeholder is linked to the organisation’s themes (e.g. Health, digital economy, energy) and because there are different groups based on the kind of innovation organisation and its objectives. For instance, Hagedoorn et al. (2000) classified the stakeholders into public and private. The public stakeholders embrace university and public research centres, while the firms represent private stakeholders. Bonaccorsi and Piccalunga (1994) share the same perspective, considering only the university and the industries. Differently, Adams et al. (2001), Gray (2000), and Leydesdorff and Etzkowitz (1995) stated that the stakeholders for the innovation organisation are represented from the Triple Helix’s actors, that is, the university, government, and industry. Gray et al. (2001) and Adams et al. (2001) affirm that the industries support the research programs run from the innovation organisation through membership and usually contribute with more funds (Lal et al., 2007). The spheres represented by the stakeholders influence the culture of the organisations (Gulbrandsen, 2011).

Building a Proposed Classification of TAs

In this work, the investigators attempt to classify the translational assets through a systemic approach. That is, the translational assets are a complex system, then “it is analysed as a whole entity to describe and understand differences and their origins, to explain the relationship with the surrounding environment, and to arrange types of phenomena into a meaningful order” (McKelvery, 1982). Previous authors suggested different factors for the classifications of organizations (see Table 2). However, these fail as they do not present an approach to a general classification scheme for knowledge economy impact in this organisational context.

Table 2 Classification based on the literatur

Sources	Classification	Characteristics
Crow and Bozeman (1987a, b)	Environment	• Legal status or ownership • Government influence • Market influence
Hagedoorn et al. (2000); Corley et al. (2006)	Collaboration	• Motivation for collaboration • Organisational structure • Bottom-up/Top-down process/mixed model
Chompalov et al. (2002); Bonaccorsi and Piccalunga (1994)	Organisational Structure	• Bureaucratisation • Size • Research autonomy • Scale of project
Gray (2000); Jordan (2006); Stahler and Tash (1994); Corley et al. (2006); Lal et al. (2007); Balthasar et al. (2000)	Input	• Funding schemes • Human capital • Research infrastructures • Research project
Hagedoorn et al. (2000); Bonaccorsi and Piccalunga (1994)	Stakeholders	Public, private, and public/private

This issue happens for different reasons. For instance, Burnes and Stalker (1961) analyzed the organizational structure, either mechanistic or organic. These are two arbitrary groups that cannot represent those organizations that fell between the two extremes of a dimension. This discrete way to classify the organizations brings to a lack of stability of the classification because organizations can change over the years because of the instability of their environment due, for example, to the change of stakeholders, globalization, technological convergence, market focus and policy (Arnold et al., 2010). After all, they may be misclassified or left out (McKelvey, 1982). Therefore, it is relevant to identify the organizations that are “mixed” in characteristics considering characteristics. A classification has been proposed to address this issue. The classification is built considering, according to the investigators, the more relevant factors listed in Table 2 that can be relevant for the design and evolution of a TA and can capture the role played within its innovation. These factors involve attributes that authors did not represent through a bidirectional continuum in the previous studies. Identifying an organisation using a continuum is a useful tool to grasp such phenomena, especially if the organisations operate in a “landscape of tension” as the TAs, which it referees to the need of this organisation to change and be able to create change within their boundaries (Gustafsson & Lidskog, 2018). Therefore, the dimensions selected to build the classification of TAs are the organisational structure, the resources, and the collaboration (Table 3). Table 3 shows in the left column the factors considered for the classification, in the central column the attributes associated with each factor, and in the right column describes the variable considered for each attribute, following the description of the factors with the related characteristics that will help to identify the different types of R&D organisations.

Organisational Structure

The organisational structure is an essential factor for designing an organisation because it is necessary to choose the appropriate configuration to achieve their goals and be high-performance in their environment. Its importance is that it describes the hierarchical lines of authority, information flow between the different levels, responsibilities, and duties (Pugh, 1990). Two dimensions to illustrate this factor are identified : external autonomy and internal authority of a TA (Cruz-Castro & Menédez, 2018; Boardman, 2012).

Table 3 Theoretical typology of innovation organisations (own representation)

Factors	Attribute	Spectra of dimensions criteria
Organisational Structure	Internal Authority	Low ←——→ High
	External Autonomy	Low ←——→ High
Resources	Funding	Low. ←——→ High
	Dedicated Human Capital	Low ←——→ High
	Infrastructure scale	Low ←——→ High
Collaboration	Proximity to the market	Low ←——→ High
	SMEs Support	Low ←——→ High

These characteristics emphasises the hybridity of the TAs since they have to engage in strategies to account the different expectations of the stakeholders involved (Gustafsson & Lidskog, 2018).
Considering the autonomy of a TA, this can vary in a range between semi-autonomous and autonomous. The former type is based at the lower extreme of the continuum. It identifies the R&D organisations part of the university organisational structure (e.g. industry-university research centre or organised research unit (ORU)) (Gray et al., 2001) that are more dependent on the state and lack of own budget, infrastructure, and employment (Arnold et al., 2012; Sanz-Menéndez et al., 2011). While at the other end of the spectrum are the organisation with a solid structure, strategy, facilities, and stable relationship between the individuals and stakeholders (Gray & Rivers, 2013).
Instead, the variable authority depends on the nature of the organisation's management model (Corley et al., 2006) and from the changes in the system funding (Cruz-Castro & Sanz-Menéndez, 2018). Such a variable aims to measure individuals' autonomy in the decision-making process to pursue their research agenda or curiosity. Corley et al. (2006), in their study about multi-institutional collaboration, identify two levels of authority and autonomy through the bottom-up and top-down approaches. The former describes an informal approach in which the principal investigators have significant freedom to pursue and shape their research agendas (Philbin, 2011) and translating their research to address technical problems and market needs (O'Kane et al., 2020). On the other hand, the second approach where the decisions about the research priorities are taken from the director(s) and filtered down to the working unit (Cruz-Castro et al., 2012). This variety of decision-making approach implies that the innovation organisations can be structured either with a flexible management (decentralised) style or a more formal style (centralised). However, some innovation organisations are structured through intermediate authority mechanisms like the director's strong leadership within the TAs, committee, and advisory board. An example of the mid authority organisations can be identified from a government innovation organisation led by a director appointed by the president of the organisation. Although it is a formal structure, the director has a degree of autonomy to set up the research agenda (Cruz-Castro et al., 2011).

Resources

TAs need different resources to run their operations. In particular, among the main assets, there are financial resources and human capital and infrastructures. Moreover, the type of resources shows the kind of output of the TAs. For instance, the Tas that are very close to the university could focus on publishing in a scientific journal or carry out more fundamental research. Vice versa, the TAs more industry-oriented are more willing to provide activities as consulting, knowledge and technology transfer, and commercialisation. Innovation organisations are very different between them by design, and the mode of how they are funded is an explanatory factor to see their difference. Financial resources are critical factors because, for example, nonprofit TAs cannot produce internal income, and they cannot be used to buy other types of resources (Hoppmann, 2021). The usual sources of funding in TAs are as follows:

– Public Non-competitive Funding: They are long-term government "core" funds which are employed to support the capability building.
– Public and Private Competitive: The organisations have access to this funding through competitive bid or grant from public or private agencies. This funding can be national or European.
– Private or Market Funding: This represents an income from industry through research contracts, annual membership fee, and services with the aim to the dissemination of knowledge for a specific scope.

These funding sources are distributed in different percentages in the organisation based on the organisational strategy. Moreover, this variable impacts the nature of the ownership's organisation. Illustrating this factor on a spectrum, the TAs focused on a faculty member's or department's R&D interest are shown at the low end. These types of organisations have a high level of institutional core funding. Moving towards the top end of the spectrum, the R&D organisations have a lower level of core funding and receive external funding from industries and other authorities. Government is the primary funder for the public sector research to guarantee public outputs from the R&D activities. These types of TAs are mission-oriented (Cruz-Castro et al., 2011). By using these funds, the TAs can move "a little ahead of market needs." However, in many countries, government funding is decreasing, and this issue drives the TAs to pursue new financing sources by establishing new strategic collaboration with industries. However, to engage with new stakeholders, the organisations have to offer broader capabilities (Arnold et al., 1998). The other funding source is the private sector through collaborative research contracts, patents, licensing, and consultant. The TAs needs to have industry as a stakeholder as these collaboration programmes sustain funds (Bozeman & Boardman, 2003).
Human capital is one of the pillars for the R&D organisations as they rely on researchers and technicians' different expertise in different areas. This resource varies based on the type of organisation. According to Tijssen (2018), skilled human capital is a fundamental to entrepreneurial success because of the ability to recognise future opportunities and exploitation and commercialisation of their research. Scientists and researchers need to have formal training and required education to have the right skills for undertaking research and other science and technology activities. They also need to have soft skills like leadership and management (McNie et al., 2016). Based on the skills, the human capital can be classified as researcher, crossover collaboration, inventor, and entrepreneur (Tijssen, 2018). For those organisations towards the market side, it is relevant to have dedicated personnel with industrial experience and technical knowledge to recognise the industrial pressures and priorities that could not be obvious to people whose experience is limited in the academic field (Arnold et al., 1998).
Moreover, some TAs do not have dedicated personnel, such as university- based TA, consisting of academic and research staff. Zaichenko (2018), in his article, describe the academic and non-academic research workers in a TA. Some university-based organisations dedicate only a part of their time to the research activities because they have to carry out other academic activities such as teaching, tutoring, etc.
The infrastructure for a TA is essential for its performance. Many TAs do not have the equipment for specific activities, and then they are dependent on other organisations. Moreover, the funding scheme change is an issue for scaling up and upgrading the organisation facility. For example, the UK government set up programmes to contribute to infrastructures investment and establish extensive research facilities to address this issue. Moreover, some types of TAs provide access to the industries to use their scientific capabilities and expertise (Hoppmann, 2021). This aspect is crucial because it may be another form of income for the organisations as firms are often willing to pay for access and, if the TAs is campus-based, this makes firms closer to the university (BIS, 2015).

Collaboration

The Industry-university relationship has been widely studied in the past and is one of the priorities for innovation development and a priority for policymakers because it is considered one element of the technology strategy (Bayona Sáez et al., 2002; Meissner, 2019). Recently, additional programmes and initiatives in R&D have been launched to strengthen university and industry collaboration (Meissner, 2019). Through this collaboration, both parties obtain advantages. For instance, firms with a strong capability can access trained personnel (students, professors) and facilities with leading-edge technologies. By doing so, firms can engage in open innovation activities (Fernández-Zubieta et al., 2016) and achieve revolutionary technology development. Besides, establishing a collaboration with the university over the years allows the academics to have a deep understanding of the industry's needs and identify new research opportunities to support the business (Dowling, 2015). At the same time, the universities collaborate with the industries to be exposed to practical problems. University and industry collaborate employing different mechanisms such as research support, cooperative project, knowledge transfer, and technology transfer (Bonaccorsi & Piccaluga, 1994; Hagedoorn et al., 2000; Carayol, 2003). However, this collaboration seems to involve only the university and industry. However, the translational asset is an important "public–private research actor" (Fernández-Zubieta et al., 2016) and interacts with the university and industry encompassing the same means. Cooperation with the private sector allows this actor to undertake more applies research.
It is possible to enhance this aspect of the collaboration by analysing two variables: its proximity to the market and

Its collaboration with the SMEs. Understanding how far the TAs are from the market helps to perceive the university's level integra- tion. These organisations can be characterised by no direct association with HEIs or strong institutional ties with the university (Zaichenko, 2018). Therefore, this vari- able aims to identify the legal status embedded by such organisation (BIS, 2015).

Considering the other dimension of the collaboration, TAs are involved in col- laboration with businesses of every size but supporting SMEs' innovation pro- cess is essential for many countries, as they often lack knowledge and resources (Garengo, 2019). TAs often show interest in supporting the SMEs to encourage them to absorb new and external knowledge to accelerate innovation and then raise the knowledge transfer from TA to industry (Hoppmann, 2021). However, working with SMEs is costly and require specific competencies; then, these industries can be supported technologically by TAs with more commercial.

Types of Translational Assets

Based on the description of the factors used to describe the TAs from a review of literature is possible to map the different nature of these organisations. It is essential to remind the reader that this analysis focuses only on the translational asset that car- ries out translational research as a primary activity. Those organisations are based between the 3–6 TRL levels and are critical to support the innovation.

Following are highlighted the features for the typologies of translational assets considering the factors in Table 3 and some general details that shape the TAs. The authors acknowledged the lack of standard terminology for these organisations, the absence of a precise organisational mapping, and trying to account for the classifi- cation of the "mixed" translational assets. For such reason, we labelled the transla- tional assets based on the characteristics that could identify them rather than using the standard terms in the literature (e.g. PRI, UIRC, R&D). Such R&D organisations have been labelled as exploratory organisation, plug organisation, and development organisation (Fig. 3).

Figure 3 shows three coloured circles, which identify how the ideal TAs are dis- tributed along the critical factors' developmental continuum versus the innovation process. These organisations are labelled as exploratory, plug, and development. The graph below describes the different innovation processes on the vertical axis, which vary from basic research to manufacturing and sales. For instance, the TAs who embrace a university logic carry out processes toward the fundamental research and vice versa if they have a more commercial philosophy. In contrast, the hori- zontal axis identifies all the variables considered by the investigators to classify the TAs.

To classify the ideal typology of TAs, the variables on the horizontal axis have to fall on the same side of the spectrum. However, we are aware that not "one size fits all," and then there are trade-offs for each type of organisation because there could be a few cases of TA that could not match entirely the descriptions that we proposed and then fall outside the circle boundary. For instance, a university TA could be an independent entity within the university. It could better fit a different typology like, for example, the centre of excellence and cooperative research (see the red intersec- tion between exploratory and plug organisation).

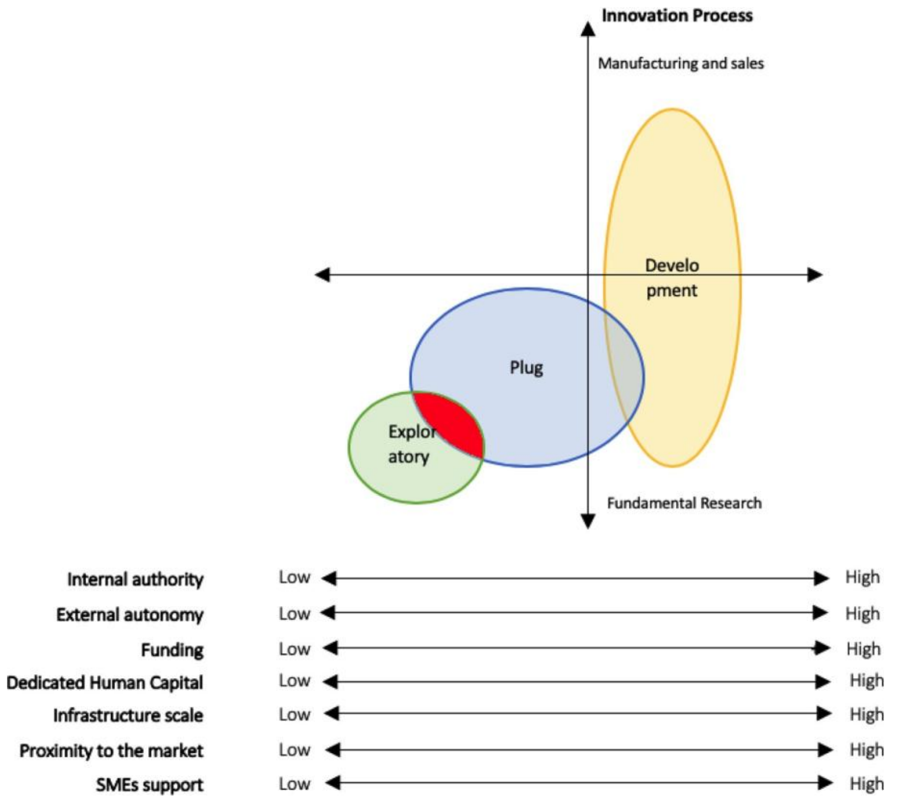


Fig. 3 Classification of the translational assets (own representation)

Exploratory Asset

This type of TA is typically university-based but can also be an off-campus facility owned by the university. It is usually supported and commonly owned by the univer- sity's department. Therefore, inside these organisations prevail the university logic, although they could run projects working closely with the end-users. However, the exploration organisations (EA) can vary their autonomy based on the added value brought to the university. Some cases of this typology can be associated with organi- sations as Max-Plank (Germany), CSIC (Spain), and CNR (Italy).

The name EA comes from their primary research focus that is the use-inspired basic research (a type of research that lies in between purely basic and purely applied research). Therefore, they ideate new solutions through new or existing knowledge, focusing on social and economic good. They also carry out other activities as teach- ing/education functions, tutoring to MSc and PhD students, and the technology transfer.

The main features identified for the explorer organisation are as follows:

- They are sustained from stable government block funding (institutional funds and/or from basic/applied research programs) and individual grants. They per- ceive a small proportion from collaboration with the industries.
- Hierarchical structure with a variable degree of authority by the director(s) that report(s) to the Head of the Department, Dean, Chair, or Vice President. Explore director (initially) does have little management experience.
- EA is typically monitored by traditional academic line management and have formal hierarchy decision-making but weak;
- In the case of a strong relationship with industry, explorer organisations have an industrial advisory board or an industrial program;
- Researchers' autonomy can vary because they have to ask the directors to follow their research agenda due to the possible constraints of lack of equipment, R&D expenses, and the type of research funding. Their autonomy increases in case they obtain personal external funding.
- EA has academic and research trained staff from various disciplines that focus their research on areas relevant

to the industry. Some staff members dedicate only limited hours to the research activities because of their conflict role as they have to support other educational activities.

- The majority of these R&D organisations have a low scale facility (e.g. laborato- ries or workshop) exiting within the university, but they might have a large-scale facility off the campus.
- Their proximity to the market is very far as they are a part of the university structure framework.
- The industries engage with this TA to establish a relationship with professors to have the opportunity to absorb new knowledge and have access to highly qualified students and public funds.

Plug Asset

Plug assets (PAs) are so called because they have been set up with the specific goal to satisfy the industry needs in a particular sector or technology. Their research activities are mission-oriented with a societal or technological target, yet they could carry out some research in the TRL 2–3 with the university sup- port. Mainly, in these organisations, the phase of development prevails on the research one. PAs have the university and the industry logic involved, and this logic depends on the relation that the R&D organisation has with the univer- sity. Although most of the funding comes from the government, this does not affect the organisation's management. Some examples of these organisations are CSIRO (Australia) and Netherland Cancer Institute (Netherland).The main features identified for the explorer organisation are the following:

- The majority of the financial sources is public, and only a small percentage from private investments through short/ medium applied research contracts and consultancy. However, the "arms lengths" from the government could evolve over the years, bringing a gradual reduction of their core funding.
- TA with either own space like offices and laboratories or a university/other institution host them. In case they are hosted, they use the administration function of their host.
- The staff involved in the research activities hold mainly technical and scien- tific skills with different backgrounds.
- Usually, someone with industrial experience leads the organisation.
- This TA is set according to a top-down strategy under the ministerial con- trol, but they never used a high level of authority on the management of the organisation.
- The decision-making process in some organisations could be influenced by external players such as advisory board made up of government and private firms as well as the stakeholder members.
- The individuals, led by a group leader or principal investigator (PI), have an intermediate level of autonomy due to the right level of decentralisation con- trol.
- A good relationship with the university is established, and this limits the TA's operational flexibility because of its market logic.
- Firms engage with plug organisations to be assisted by accessing their know- how and expertise and can help create a research network helping to find the right collaborators for the projects.

Development Asset

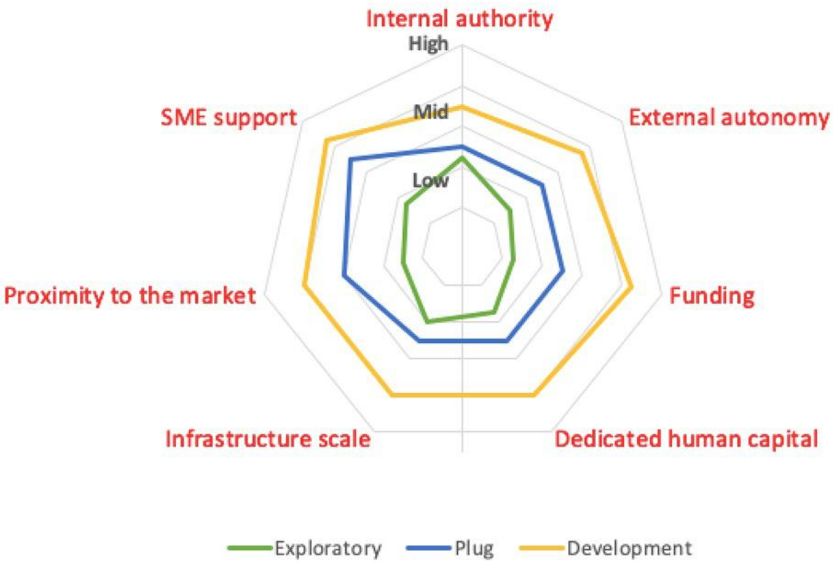
The development organisation (DA) aims to carry out applied R&D and tech- nology services with and for the industry to improve its competitiveness. How- ever, they also carry out public support activity, and they are supported by around 30–50% from the government. These industry-oriented organisations can cover a wide TRL area, from 2 to 8 (e.g. Fraunhofer Society), because they do not pro- vide only innovation service to the industry. They also offer service not neces- sarily commercial. They include this wide range of TRL activities because it depends on their research objective and their relationship with the university. These R&D organisations have outstanding interaction with the university. They can have public, semi-public, and private non-for-profit governance. A few exam- ples of DAs are the Fraunhofer Society (Germany), TNO (Netherland), Catapult (UK), and VTT (Finland).
The main features identified for the development organisation are as follows:

- Target to achieve the one-third model funding like Fraunhofer institutes: one- third core funding, one-third competitive funding, and one-third private financing. This flexible funding scheme varies based on the organisation's research objective and how much the TA aims to be financially self-sustainable over the years.

- The organisational structure is hierarchical, but this is not a driver for a bureaucratic type. It comprises independent management established by the director(s) with an academic and industrial background with previous man- agement experience.
- In this type of organisations, the research staff have a reasonable degree of autonomy.
- DAs have capabilities that consist of the expertise of people and the equip- ment that they own. They have extensive facilities with workshops and labora- tories with leading-edge technology.
- Human capital plays a crucial role in these organisations. There are experts from academia and industry with a broader focus (scientific and management skills) and mostly held a PhD. They work alongside PhD and MSc student. Moreover, a part of the staff has also management expertise. In some cases, these organisations share human capital with universities.
- DAs are very close to the market, and to some extent, they have a close inter- action with the university. They keep a high level of flexibility and operational autonomy to adapt to changing need of their customers and market.
- Mainly they support SMEs as they lack innovation capabilities through tech- nology transfer, training, consultancy, and different R&D services.

Figure 4 illustrates the key differences between the three types of TA. The fig- ure is illustrative, not quantitative. It uses a scale, from low to high, to represent the characteristic reported in the description of the TAs. Thus, through the shift from "low" to "high," we want to show how the factors impact the TAs.

Fig. 4 Comparative typologies of TAs (own representation)



Conclusion and Implications

The past academic research in this area has focused on what TAs do and classify- ing them through a discrete representation employing a specific factor. We argued that before understanding the activities that these R&D organisations develop, more attention is needed for the boundaries of such organisations considering multiple factors and illustrating them along a continuum.

This article fills this knowledge gap by outlining the TA in the literature's pre- vious classification and addressing the investigators' research question. We sug- gested that the proposed classification of the translational assets aims to address this question by identifying three ideal types of TA through a bi-directional and multi-dimensional continuum. The three TA ideal types are labelled as exploratory, plug, and development. Also, this investigation offers novel theoretical insights and practical implications regarding a preliminary assessment of the existing dominant R&D organisations classifications. However, such an analysis is a heuristic approach to an initial step in a broad research project on understanding the establishment of translational assets. Moreover, such a study provides a theoretical and practical contribution.

Theoretical Implication

This study provides an initial cognitive contribution of the translational assets that are still poorly studied but very relevant for the industry innovation and policy for the local innovation systems.

The paper enriches the body of literature on the translational asset by fostering a deep understanding of the heterogeneity of the TAs and discussing the main charac- teristics. However, the literature in this field is still fragmented. The authors pulled together perspectives from previous studies to classify the TAs and propose a new classification by improving the relevant dimensions to describe each type of transla- tional infrastructure's boundaries. Previous investigations are characterised by their quantitative nature and the limited number of factors. Besides, this study contrib- utes to the past research limitations through the factors' representation and consider- ing a more comprehensive range of factors. The characteristics that we selected for the classification are shown on a continuum rather than discrete value. Such factors allowed us to identify three ideal groups of translational assets: exploratory, plug and development.

The ex-ante classifications were limited only to a discrete categorisation of organ- isations. The discrete classifications could be inadequate because they have brought to the exclusion or misclassification of all those with a hybrid nature. The authors fixed this downside by improving the selection of relevant factors to build a new classification for the ideal type of TAs.

Practical Implication

Although this article is a review of the literature, it has a practical contribution. The proposed classification provides a better understanding for managers of the organi- sational heterogeneity of the TAs, implying an accurate description of the bounda- ries that shape these bodies. Thus, even if it is an early stage, such typology gives insights to facilitate the practitioners to design new assets within a particular con- text. On the other hand, it can be used repeatedly to observe the changes of the different characteristics that influence the overall alignment of the organisational environment. Therefore, the classification can be used as a tool to support the TAs design.

Research Limitations and Further Research

Considering this evidence, the authors attempted to shed light on the topic and contribute to the translational infrastructures' literature. However, as with every research, this analysis presents some limitations that could be as input for future research. The first limitation and that more obvious is the lack of substantial litera- ture inherent to the topic. The literature is significantly fragmented due to the lack of clear understanding because of the complex and challenging concepts. Moreo- ver, most of the sources are not up to date, and this, in some way, could impact the research and its flexibility. The second limitation is that the classification may need a trade-off to embed all the type or TAs and refine the description of these ideal types. However, the context of TAs is vast, and our results suggest some direction for future research. For instance, further studies could address other configurations of TA and consider different factors. With our initial study, we provide an outline of the TA, and then it would be interesting to see in future research the application of the framework to classify TA in a specific sector, within a particular country or benchmark different national innovation systems. There are differences across the various countries in terms of management systems, funding schemes, actors, and different administrations. All these factors are contingent on policies, funding struc- ture, sector, management, and stakeholders. Thus, we need to know more about how these factors may influence the TAs to have a more unified understanding of these organisations. This suggests another way to grow our knowledge in the TA field by investigating additional factors or extend the work carrying on empirical analysis.

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Annex II

Interview Protocol

Understanding Translational Asset Classification

Introduction

1. Introduction of myself and explain the purpose of the interview.
2. Can you describe your role and responsibilities within the organisation?
3. What kind of activities the organisations engages in?

Overview

4. How would you describe your organisation? (ex. Rationale and aim, staff, stakeholders, ownership, funding, etc.)
5. Based on your description, how would you define the organisation where you work and why?

Understanding Translational Assets

6. Are you familiar within any existing classification or framework for translational assets?
7. What are your thoughts on developing classification of translational assets?
8. In your opinion, what improvements or enhancements would you suggest for this classification? What dimensions or factors do you consider important in a distinguishing different type of translational assets?

Utility

9. What are the potential benefits and challenges of a classification of translational assets?
10. Could this classification be used to inform-decision -making in research , funding allocation or more?

Closing

11. Is there any additional information or insights you would like to share regarding the classification of translational assets

Annex III

Explanation of Scottish Translational Assets Classification Framework

Figure 15 represents a new framework developed from qualitative interviews with representatives from a range of translational assets in Scotland. The purpose of the figure is to visualise how TAs can be positioned in relation to one another based on their strategic intent and operational characteristics. It offers a tool for comparison and reflection, showing how TAs may evolve, overlap, or complement each other.

The x-axis (horizontal axis) of the framework represents a qualitative continuum, constructed from multiple interrelated factors consistently identified across interviews. Importantly, each organisation included in the framework was placed along the x-axis continuum based on the alignment with all the factors associated with that area of the x-axis. This means that organisations are only plotted if they exhibit a coherent and internally consistent model, as perceived and described by practitioners. The positioning is interpretative and representative, reflecting the average or ideal-typical characteristics described by interviewees regarding each organisation's function, purpose, and operational model.

Because the positioning is based on qualitative data and thematic interpretation, it is indicative rather than a precise measurement. The continuum is not based on numerical scoring or formal indicators. Instead, it reflects the researcher's interpretative judgment derived from participants' views of their organisation. A more quantitative approach might have enabled precise measurement, but it would have required a different dataset and potentially imposed constraints on capturing the hybrid nature of many TAs, layered roles, and the emergent nature of many translational assets. This interpretative-positioning method was chosen to reflect the complex realities described by participants and to accommodate the diverse forms that TAs can take.

The y-axis captures the strategic rationale or founding intent behind the establishment of each TA. This includes motivations such as regional economic development, industry support, and national policy. Including this vertical dimension helps to reduce ambiguity that might arise if placement were based on x-axis factors alone.

Overall, the figure should be read as a conceptual tool, helping to stimulate discussion, inform strategic planning, and support more structured reflection on the structure and diversity of TAs within innovation ecosystems.