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To cite this article: Guendalina Anzolin & Eoin O'Sullivan (2025) Towards a Marshall-based theory of research and technology organisations: the role of regional policy to address the varieties of knowledge, *Regional Studies*, 59:1, 2579625, DOI: [10.1080/00343404.2025.2579625](https://doi.org/10.1080/00343404.2025.2579625)

To link to this article: <https://doi.org/10.1080/00343404.2025.2579625>



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Towards a Marshall-based theory of research and technology organisations: the role of regional policy to address the varieties of knowledge

Guendalina Anzolin^a  and Eoin O'Sullivan^a 

ABSTRACT

The ability to generate knowledge across different technological cycles lies at the core of countries and regions' competitiveness and economic growth. In this paper, we argue that research and technology organisations are public actors best enabled to fill in the capabilities gaps that emerge across the varieties of knowledge. Given the recent policy focus on regional development and the increasing complexity of new knowledge generation, we propose a capability-based theory of research and technology organisations building on the insights of Alfred Marshall, specifically his contributions about the collaborative nature of the knowledge-generation process and the place-based nature of knowledge.

KEYWORDS

regional policy; innovation intermediaries; Alfred Marshall; knowledge transfer

JEL L52, O25

HISTORY Received 29 April 2024; in revised form 13 October 2025

1. INTRODUCTION


Knowledge creation and diffusion are the cornerstones of economic growth and industrial development. In recent decades, and with the advent of the information and communication technology (ICT) revolution and digital technologies, there has been increasing attention to understand how knowledge is created and how it dynamically evolves across different places (Hervas-Oliver et al., 2021; Reveiu et al., 2023). The growing complexity of innovation strengthens the case for national and regional policies to coordinate knowledge transfer and to promote processes through which regions can remain competitive and address structural imbalances and growing inequality (Bailey et al., 2015, 2018). More than a century ago, Alfred Marshall highlighted the role of places in knowledge generation; his well-known analysis of 'industrial districts' emphasised the embeddedness of knowledge in specific places and its path-dependent nature, writing that specialised 'knowledge is in the air', yet at the same time that 'all important knowledge has long deep roots stretching downwards to distant times' (Marshall, 1920, IV, X, 2). Both in the air and with deep roots, Marshall's analysis of knowledge emphasised its embeddedness in specific

places and its path-dependent nature. In his *Industry and Trade* (1919), a neglected aspect is Marshall's analysis of local initiatives that bridge actors across innovation stages to transfer knowledge and realise external economies through collective innovation (Bellandi et al., 2025); Marshall's description of the 'three classes of laboratories' (discussed in section 2.1) provides a first overview of the different organisations required to fill gaps in the knowledge transfer process.

Since Marshall, knowledge, actors and coordination have changed profoundly. Knowledge now involves complex products and interrelated technologies, with each generation building on the last (Andreoni et al., 2021). It also flows across fewer physical boundaries but with a high level of 'stickiness' (Markusen, 2017). Changes in the manufacturing systems have also reshaped different actors' roles: large firms no longer dominate as knowledge gatekeepers, while the role of corporate research and development (R&D) has spurred specialised research and engineering firms (Arora et al., 2018). Production and organisation are more fragmented and dispersed, with clusters of capabilities emerging across regions (Hervas-Oliver & Albers-Garrigós, 2007).¹

CONTACT Guendalina Anzolin  gma39@cam.ac.uk

^aCentre for Science Technology and Innovation Policy, Institute for Manufacturing, Department of Engineering, University of Cambridge, Cambridge, UK

 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/00343404.2025.2579625>

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Against this backdrop, scholars in the Marshall tradition have extensively analysed knowledge generation at the regional level. Regions are complex systems (Lombardi, 2003) where the coordination for knowledge creation sees the emergence of different actors across time, with different roles depending on the failures and gaps characterising knowledge creation. Current disruptive challenges are redefining global and local scales and connections, imposing processes of continuous transformation that require increasing coordination (Bellandi et al., 2025). Recent contributions in the regional innovation systems (RIS) literature, stress the urgency to move from a firm agency analysis (Boschma & Frenken, 2011) to a system-level agency perspective (Hassink et al., 2019). This view calls for a multi-actor approach, where the role of actors (e.g., universities, research institutes) is analysed in their activities to transform and reshape innovation systems and industrial paths through the transformation of knowledge-related capabilities (Isaksen & Trippel, 2016). Existing work in this field focuses mostly on universities, overlooking the role of other innovation intermediary actors in shaping RISs (Benneworth et al., 2017; Kaufeld-Monz & Fritsch, 2013; Pinto, 2024).

Building on Marshall's seminal work on the dynamics and actors involved in knowledge generation, this paper elaborates a comprehensive theory of research and technology organisations (RTOs), which are a specific type of innovation intermediary that promote activities to fill the 'valley of death' gap between university-based research and the commercialisation phase (Conlé et al., 2021; Miller, 2022; Shapira et al., 2015). RTOs are a subset of innovation intermediaries (De Silva et al., 2018) focused on conducting applied research to ensure commercialisation and scale-up activities; they are privileged actors since, through their knowledge and capability repository role, they maintain an organisational memory (Håkanson et al., 2011) that is critical for new knowledge path creation (Albors-Garrigos et al., 2010). Our contribution points to the role that RTOs can increasingly play as publicly funded bodies that coordinate and ensure that value creation translates into value capture across different regions (Bailey et al., 2018, 2023; Pitelis & Runde, 2017). Specifically, we argue that the flexible and adaptable nature of RTOs' activities is key to fostering regional upgrade and diversification, avoiding lock-in traps and promoting regional industrial innovation policy (Oughton et al., 2002). Proposing a renewed role for RTOs as a coordinating body in the ecosystem builds on the Marshallian concept that the benefits arising from firms' co-location (i.e., the external economies) do not materialise automatically and that they require different levels of coordination and intermediation. Our theory is exemplified by RTOs in the US and the UK, where initial efforts to connect RTOs' activities and mandates with regional ecosystems respond to a rising interest in promoting regional upgrade, for example, through programmes such as the Levelling Up Agenda, Strength in Places Fund in the UK, and Regional Technology and Innovation Hubs in the US (Martin et al., 2021; Muro et al., 2023). The evidence presented stems

from a two-year comparative project on RTOs' activities and division of labour with other organisations in the ecosystem; preliminary empirical evidence is discussed by Anzolin and O'Sullivan (2025). As a further contribution, this paper adds a Marshall lens to RTOs, providing a conceptual and theoretical framework to support strategic analysis for regional innovation policy and RTOs' mission, addressing considerations related to the division of activities between intermediaries, varieties of knowledge developed and stages of innovation involved. This paper builds and further extends the work of Anzolin and O'Sullivan (2025), giving an analytical dimension to the multiplicity of activities, and the coordination efforts that are spontaneously emerging through bottom-up experimentation across different RTOs.

The remainder of this paper is structured as follows. Section 2 briefly discusses the theoretical building blocks, revisiting Marshall's ideas in light of more recent contributions. Section 3 presents a framework to conceptualise RTOs as key actors that can strategically 'fill the gaps' within the ecosystem. Section 4 discusses three elements that underpin our theory and exemplifies our argument with reference to recent developments in the UK and the US. Section 5 presents the implications of our theory for regional policy and concludes, indicating opportunities for future research.

2. THEORETICAL BUILDING BLOCKS FOR A PLACE-BASED THEORY OF REGIONAL RTOs

This section illustrates the main Marshallian-inspired theoretical blocks that we use for our theory-building process of RTOs and places our analysis within the RIS literature.

2.1. 'Organisation[s] aids knowledge[s]'²

In the last three decades, the emergence of new technologies and the fast pace of their evolution have reshaped key elements of the economy of production, highlighting new challenges for economic growth. For these reasons, knowledge creation and diffusion have become a priority in policy and economic analyses (Cainelli et al., 2004; Dosi, 2009; Metcalfe, 2002). The classical economist Alfred Marshall had a multifaceted understanding of knowledge, which he believed to be the most powerful engine of production (Marshall, 1919). He thought of innovation not as a disruptive force but rather as a process of continuous practice from which innovation emerges, as 'practice in any kind of thinking develops new connections between different parts of the brain' (Marshall, 1920, IV, IX, 1). He also recognised the path-dependent nature of knowledge and how much its existing stock matters for future advances: 'all important knowledge has long deep roots stretching downwards to distant times' (IV, X, 351).

An interesting, pioneering and overlooked aspect of Marshall's work is his diverse set of actors that contribute to knowledge generation. In *Industry and Trade*, he discussed three classes of national laboratories in charge of

the knowledge-generation process (Marshall, 1919, I, V, 4): the first class seeks to extend knowledge at large (such as university-based laboratories); the second aims at knowledge generation in specific sectors or branches of the economy (such as the big corporate R&D labs³ or associations of firms that collaborate for more applied research); and the third type checks the quality of output of individual works (this is described less of a research laboratory and more a quality and control organisation). Marshall's ecology of laboratories (Metcalf, 2007) already posed that knowledge creation requires a quite heterogeneous set of actors that provide different types of activities beyond the basic R&D, including applied R&D such as demonstration activities, and processes for knowledge adoption and diffusion (e.g., including organisation and standards issues); for example, the third type of laboratory discussed by Marshall 'does not, as a rule, do any considerable research: but it enables the business ... to make sure that each of its products ... is true to its proper standards' (Marshall, 1919, I, V, 4).

The innovation landscape has changed fundamentally since Marshall; the decline of large corporate R&D labs, along with the loss of their embedded technical-scientific capabilities, has reshaped innovation systems. This contributed to widening gaps in commercialisation and scale-up capabilities (the so-called 'valley of death'), leading to the loss of industrial commons (Pisano & Shih, 2009), stagnant productivity in most advanced economies (Haldane, 2017), and concerns over how value creation translates into value capture. Value creation refers to generating new knowledge, often in universities or research labs, and value capture refers to firms' technology adoption and diffusion across supply chains, where large firms and small and medium-sized enterprises (SMEs) face distinct challenges. Addressing these issues requires activities beyond standard R&D; Marshall's three classes of laboratories already anticipated the need for different organisations to support distinct stages of knowledge generation. Framing the innovation process through organisations that promote knowledge development, adoption and diffusion helps to understand (and to address) why processes of value creation and value capture often misalign (Bailey et al., 2018).

2.2. Knowledge generation as a cooperative process

The relevance of multiple actors in the knowledge-generation process points to its collective nature. By using biology as a metaphor in economic thinking, Marshall (1920) also pioneered the concept of knowledge generation as a process where different individuals and organisations need to cooperate to achieve competitiveness and economic growth. He emphasised the importance of bringing together different actors: 'if one man starts a new idea, it is taken up by others and combined with suggestions on their own, and thus it becomes the source of new ideas' (Marshall, 1920, IV, X, 3). Collective innovation is a key aspect of the Marshallian concept of external economies. Specifically, by looking at the 'most

efficient forms of constructive cooperation [they] are seen in a great industrial district where numerous specialized branches of industry have been welded ... into an organic whole' (Marshall, 1919, III, XII, 1), constructive cooperation would, for example, provide smaller firms access to services that could not be available given the low and fragmented demand.

These concepts were first formulated in the 'Localisation of Production' (Marshall, 1919, IV, X), providing a sophisticated analysis of why 'when an industry has chosen a locality for itself it is likely to stay long, so great are the advantages' (Marshall, 1920, IV, X, 3). In describing industrial districts' external economies, what they are and how they develop, a key aspect is local collective initiatives that target the transformation of localised industries requiring an 'organised proximity' of facilities and services for skills upgrading, training and technology transfer (Belandini et al., 2025; Torre, 2008).

Beyond Marshall, cooperation has been largely studied in firm-level analyses as a driver of continuous knowledge creation. Resource-based, evolutionary economics and evolutionary economic geography perspectives stress cooperation as central to building firms' unique advantage to remain competitive (Boschma & Frenken, 2006; Nelson et al., 1985; Penrose, 2009). Similarly, regions and ecosystems endure through 'untraded interdependencies', requiring increasing differentiation and sophisticated coordination (Keeble & Wilkinson, 1999; You & Wilkinson, 1994). In other words, regions develop distinctive competencies, difficult to replicate and reliant on geographical proximity for their renewal (Uyarra, 2010).

The clustering of firms in specific places, producing outcomes greater than the sum of the parts, has been a subject of great interest. Since Marshall, the cluster and agglomeration literature has expanded substantially, offering theoretical and empirical evidence on their importance (Becattini et al., 2009; Brusco, 1986; Dei Ottati, 2018; Piore & Sabel, 1984; Schmitz, 1999). Evolutionary economic geography has contributed to it by examining innovation and firm co-evolution in new path development, with particular focus on micro-foundations of growth (Hassink et al., 2019; Schamp, 2016). In this process, firms and industries are not entirely free to choose their location but are highly influenced by the complementary assets they require for path creation and value generation (Martin & Sunley, 2006).

2.3. Knowledge and regions: a system-level agency analysis

In analysing regional evolution, evolutionary economic geography has been criticised for focusing too heavily on firms at the expense of the institutions (Hassink et al., 2014). Recent studies have addressed this gap, highlighting the institutional dimension of new path developments (Boschma et al., 2018; Boschma & Capone, 2015). They show that technology-driven processes must be coupled with institutional ones, combining external and internal knowledge flows (Trippel et al., 2018). Mainstream approaches take the local firm as the starting point, mostly

neglecting other actors such as universities, research institutes, policy actors and foreign companies; new path development is a combination of a firm-driven process and an institutional-driven process, where the latter is key to fostering and coordinating the recombination of existing and new skills and knowledge (Boschma & Frenken, 2011).

New paths need to be institutionalised and often require changes in the organisational and institutional configurations of innovation systems. Such changes are performed by a heterogeneous multi-actor system, which requires a multi-actor approach (Tripl et al., 2018) to understand how new growth paths are created through activities undertaken by different actors that develop complementary assets (Garud & Karnøe, 2003).

Organisations emerging outside firms play a crucial role in cluster development. Building on Marshall's notion of the tripartite ecology of the laboratories discussed in section 2.1, studies of the Italian industrial districts analysed the emergence of two external (to the firm) actors, who reinforced the cluster formation through collective services: a net of public and private associations that coordinated small firms' activities for the provision of administrative, credit and marketing services (Brusco, 1982; Locke, 2018); and service engineering firms that built problem-solving capabilities across value chains. These actors fostered collective efficiency and knowledge diffusion (Schmitz & Nadvi, 1999), driving competitiveness in product quality, speed and co-innovation, which individual enterprises could not achieve alone.

The nature of linkages between actors determines knowledge-creation effectiveness; the RIS literature supports an institutional and system-level analysis (Hassink et al., 2019), shifting the focus beyond firm-level strategies (Iammarino, 2005; Uyarra, 2010); and RISs encompass two subsystems (Asheim et al., 2016), the knowledge exploration one, involving universities and research institutes generating new knowledge, and the knowledge exploitation one, involving firms in horizontal and vertical networks that apply it. Bridging these subsystems is a core function of innovation systems, ensuring that knowledge is both created and captured locally.

Public sector organisations are key to bridge these subsystems (Howells, 1999). Building on theoretical insights about knowledge types, actor diversity and cooperation, the next section develops a theory of a specific class of public innovation intermediaries: RTOs.

3. THE COORDINATING AND 'GAP-FILLING' ROLE OF RTOs

3.1. Special role of RTOs

Our paper argues that there is a rationale for a specific type of actor that can fill gaps in the knowledge-generation process and act as a coordinating body at the regional level, tackling market and system failures while also leading to market extension and resource creation. For this paper, we consider RTOs that receive part of their funding from public bodies (national and/or regional) (Van

Lente et al., 2003). The provision of government funding for RTOs is justified through the market failure argument: the invisible hand of the market fails to deliver the optimum in the innovation process – with private investors failing to invest enough during pre-commercialisation phases, the so-called 'valley of death'⁴ often indicated with technology readiness levels (TRLs) 4–6⁵ – and thus governments provide funding to favour scaling-up activities (Ellwood et al., 2022). RTOs belong to innovation intermediaries (De Silva et al., 2018), and they provide a set of activities for commercialisation, scaling up and increasingly innovation adoption and diffusion (Anzolin & O'Sullivan, 2025). They have existed for some time; depending on the countries, they emerged after the Second World War (e.g., Fraunhofer in Germany), before the industrialisation period (e.g., Kosetsushi in Japan), or more recently to solve deindustrialisation challenges (e.g., the Catapults network in the UK and Manufacturing USA (M-USA) Institutes in the US). RTOs can be very diverse, depending on their governance, their mission, their funding model and the functions they provide (Leitner, 2005); they are considered 'super intermediaries' because they act at the interfaces of government, industry and academia, promoting the transfer of knowledge (Sheikheldin, 2021). They have also been defined as 'boundary organisations' to emphasise their place at the interfaces where innovation, science and policy actors meet to contribute to technology scaling up (Chataway et al., 2019; Hanlin et al., 2018). Arnold et al. (2010) categorise RTOs into technology-push institutes, industrial development institutes and service-oriented institutes, initially dedicated to measurement and testing activities. While there is a close association between Marshall's third type of laboratory and the initial role of RTOs, activities have expanded to cover applied research for big companies (the first type in Marshall) and, in many cases, quasi-public activities in sector-specific technology applications (which could be closer to the industry-specific organisations in the second Marshallian type).

Understanding knowledge, as Marshall proposed a century ago, as co-produced between different actors and not as a linear model, implies a high level of coordination as well as organisations enabled with different functions. Each ecosystem presents a push and pull dynamic between science, technology and the marketplace; in these ecosystems, the process linking science with the marketplace has additional feedback loops and variations over time (Mowery & Rosenberg, 1979). As recognised by the regional economic literature, the typology of information flow is relevant as it is the quantity and quality of channels through which such information is transmitted. RTOs operate across the horizontal dimension of clusters where learning happens; they have become 'strategic operators functioning as transducers of hidden information' (Lombardi, 2003, p. 1459). This is reflected in their ability to balance both knowledge integration and networking roles (also defined as ambidexterity; De Silva et al., 2018); the former sees RTOs exchanging and integrating the existing stock of skills and knowledge by engaging in

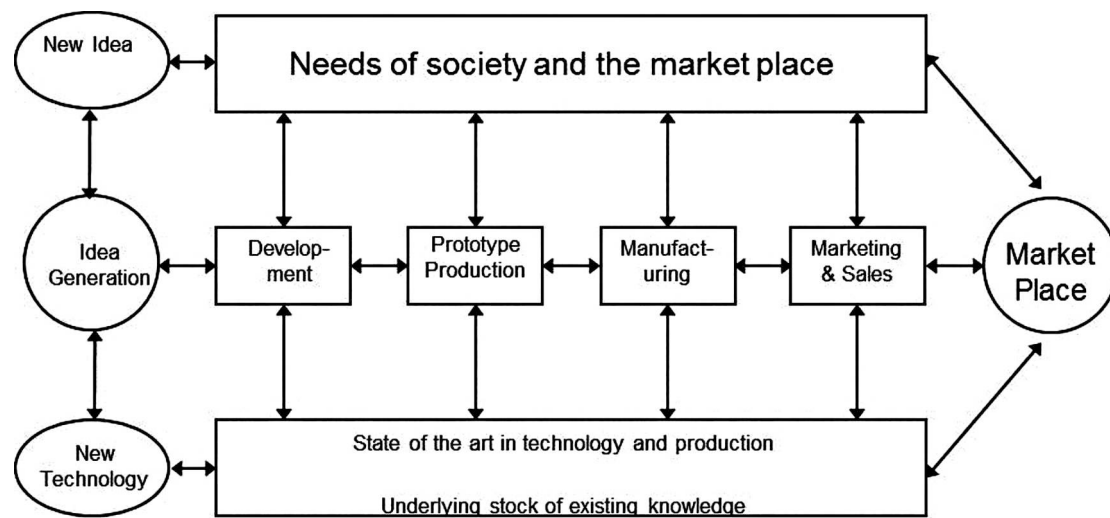


Figure 1. Model of innovation.
Sources: Arnold et al. (2014), adapted from Rothwell (1994).

the transfer and integration of external knowledge (Klerkx & Leeuwis, 2008). The latter role responds to RTOs 'natural' ability to bring together collaborative partners, coordinating and fostering networks.

RTOs' innovation ambidexterity relies on coordinating knowledge flows, from ideas and science to market applications (Figure 1). Central to this process is the stock of existing knowledge, which underpins innovation not only through discoveries but also by reusing and adapting old knowledge. RTOs act as repositories of this knowledge, helping to address multilevel failures (Arnold et al., 2014). First, they mitigate information asymmetries in ecosystems where large multinational corporations often dominate smaller firms, which might remain locked into certain activities. Second, they manage the diversity of knowledge types, which demand tailored and coordinated functions, diffusion channels, and feedback loops. Third, regionally clustered RTOs benefit from knowing and building on local capabilities⁶ while strengthening supply chain connections. The following section further develops the case for the regional role of RTOs.

3.2. Regional industrial policy

The continuous evolution of industrial districts towards value-retaining processes has been seriously challenged (Bailey et al., 2010; Dei Ottati, 2018), with many regions, especially in the West, struggling to quickly shift towards higher value-added segments. These challenges are not only in the industrial structure but also at the socio-economic level since the inability to retain value translated into higher unemployment and an increase in less skilled occupations (Bailey & De Ruyter, 2012). This is evident in high per capita gross domestic product (GDP) countries such as the UK and the US, with exceptional universities that contribute to the research innovation base, but whose value is not fully translated into local manufacturing systems.

In recent years, following the unsuccessful results of policies that treated places on a one-size-fits-all basis,

there has been a renewed interest in regional policies and in how pre-existing capabilities matter for regional transformation. We briefly discuss three examples. First, the Smart Specialisation agenda in Europe (known as RIS3 Research and Innovation Strategies for Smart Specialisation) was a tangible recognition that places matter for economic development. The programme called on regions to promote an 'entrepreneurial discovery process' where opportunities in distinctive innovation domains and across different ecosystems can be identified (Foray, 2014; Morgan, 2017; Vallance et al., 2018). Second, a broader concept of place-based policies has emerged from a focus on clusters as a central unit of analysis to reinvigorating old regional industrial bases (Bailey et al., 2019, 2023), with concepts such as co-creation and cluster-based capabilities that have been adopted by policymakers, for example, in the Levelling Up Agenda and programmes such as the Strength in Places Fund and Innovation Accelerators in the UK (Bailey et al., 2023; Department for Business, Energy & Industrial Strategy (BEIS), 2021; Leyshon, 2021). A third example is the US, where there has been a renewed focus on 'network building industrial policies' (Wade, 2017),⁷ and increasing attention combined with generous funding (Muro et al., 2022) to regional consortia and innovation tech hubs (Audretsch, 2018). One of the most interesting aspects of these place-based policies is the recognition that regional renewal and diversification aim at building a competitive advantage through an entrepreneurial-discovery process that is often coordinated by external actors (Foray, 2014). The following section argues that such a process can be fostered and coordinated by RTOs.

3.3. A framework for RTOs' policy design

The increasing attention to market and system failures that characterise the innovation process, together with the recognition that place-specificities matter for industrial reconfiguration, led to renewed interest in RTOs

and how they can be best designed to increase local value-generating processes (Larrue & Strauka, 2022). In this section, we introduce a framework to further unpack RTOs’ functions along the varieties of knowledge. We argue that there is a specific case for RTOs to promote regional development. Figure 2 indicates two levels of the analysis. First, the top of Figure 2 indicates the varieties of knowledge in the innovation process and how they interact with one another. Knowledge development refers to the process required to move the technology from a lab scale to commercialisation. Knowledge diffusion indicates the diffusion to early adopters, which is followed (not linearly) by knowledge adoption to other sectors and other firms. Finally, production diffusion knowledge refers to the diffusion at the supply chain level, a point where the technology is fully mature, yet it requires activities to spur its use along and across value chains. There are continuous feedback loops and variations over time between the varieties of knowledge, where the interaction of different competencies (e.g., science and engineering) is critical to overcoming scale-up challenges, structural and production bottlenecks. The circle at the centre of the feedback loops refers to how technology diffuses across different levels of the innovation process. The arrow at the top indicates the flow from knowledge creation to the adoption phase, where it becomes integrated at a systemic level; the striped arrow indicates that there is no linear process and that there is often the need to go back to more foundational science to solve issues that may arise in the engineering integration phase. The dotted line indicates the same principle of interrelation between knowledge adoption and knowledge diffusion, which in this case is related to diffusion in the production system. Figure 2 refers then to the TRLs that indicate the maturity

of a specific technology (TRLs 1–9); nowadays, the focus of RTOs is mostly on TRLs 4–6, yet it is evolving to higher TRLs with the evolution of new technologies that require more activities in the knowledge adoption phase, for example, demonstration and deployment (Anzolin & O’Sullivan, 2025).⁸ Higher TRLs, depending on different ecosystems, can be addressed by RTOs or other types of intermediaries; we argue that, given the deep understanding of the ecosystem where they operate and of the technology life cycles, the coordinating role of RTOs is key in organising and orchestrating different actors (and the corresponding activities), also beyond what falls under their mission.

Second, the bottom part of Figure 2 proposes three different types of activities that can form part of RTOs’ action in their ecosystems (Anzolin & O’Sullivan, 2025): technology development, workforce development and supply chain development activities, categories that are both discussed in the recent literature and in policy-related documents⁹ with some activities being core to RTOs’ missions (i.e., technology development) and others that have been emerging. Technology and workforce development point to the importance of building knowledge and human resources, while supply chain development underpins the importance of developing competencies across sectoral and multi-sectoral networks. For each domain, we indicate examples of activities that can be offered to different firms across the ecosystem and that depend on which level of the innovation process (and the TRLs) the RTO, or other intermediary organisation, operates. Figure 2 captures the different ‘varieties of knowledge’ and their respective ‘diffusion channels’ highlighted in Figure 1. Finally, RTOs are nested in specific places, and a clear regional mandate would strengthen RTOs’

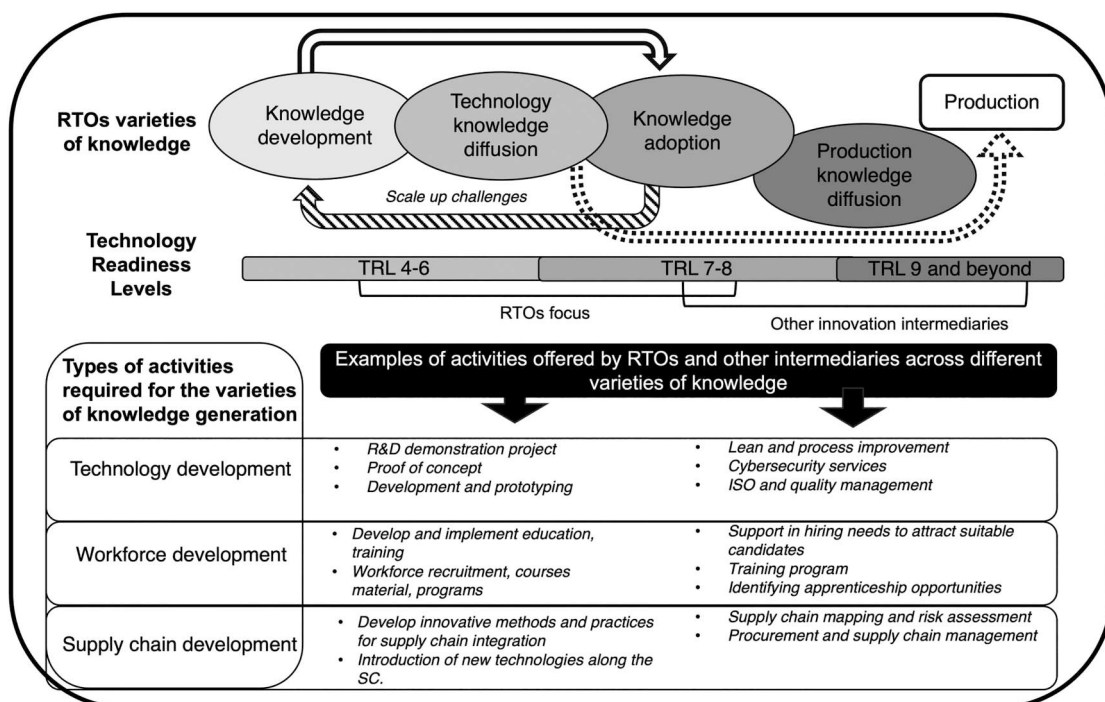


Figure 2. Framework for a multifunctional type of research and technological organisation (RTO). Source: Authors.

role in connecting the innovation exploration and the innovation exploitation subsystems across the varieties of knowledge. There is scope to repropose the concept of regional intermediaries introduced by Clark (2014) with the three roles – that match our domains in Figure 2 – of labour market intermediaries, supply chain intermediaries and innovation intermediaries (Clark, 2014). The next section discusses the four building blocks for a capabilities-based theory of RTOs.

4. TOWARDS A MARSHALLIAN, CAPABILITIES AND REGIONS-BASED THEORY OF RTOs

This section begins by outlining four Marshall-based ideas that build our case for a capability regions-based theory of RTOs that perform different functions within the ecosystem. Although RTOs have existed for decades,¹⁰ we argue that there are some specific conditions, such as deindustrialisation trends, regional inequality and capability loss in many advanced economies, which call for RTOs with a public nature and a regional focus to solve the numerous system failures that characterise the local process of knowledge generation. The concluding part of this section provides examples about the UK and the US, where the recent setting up of RTOs and focus on regional levelling up present an interesting example of the ongoing changes and opportunities discussed in this paper.

4.1. The case for an RTO's capabilities-based theory

4.1.1. A public body for applied R&D

The decline in corporate R&D labs caused an important change in the R&D landscape. Years beyond such decline, there remains a void in addressing early stages research such as the user-inspired basic research and applied research (Stokes, 2011), and the valley of death challenges, which often require firms and other actors to associate in order to bring together their efforts to conduct more applied R&D. However, as already argued by Marshall (1919), in these associations – if left to market forces alone – there may be ‘conspiracy to monopolise’ a particular branch of the industry, and therefore since:

the experience of the ages shows that associations set up for constructive purposes are in danger of being turned to destructive ends ... it may perhaps be to the public interest that some limited contribution should be made from public funds to the support of such associations.

(Marshall, 1919, I, V, 4)

Public intervention in the form of RTOs not only can prevent such ‘destructive ends’ but also can be in a better position to provide and organise a mix of expensive infrastructure, such as testbeds, demonstration facilities and highly specialised training centres that are required for applied R&D and co-innovation, especially in high-technology sectors. These infrastructures have the nature of quasi-public goods, a characteristic that, while raising

transaction costs and thus complicating R&D policy, also justifies/calls for a more coordinated public intervention to fill the gaps with a mixture of public and private funding, distributed over the life cycle of the innovation process (Tassey, 2004).

4.1.2. A public body beyond applied R&D

Although in most countries RTOs were established with the mission to address the valley of death, it has become clear even in well-established RTOs, such as the Fraunhofer centres in Germany and Kosetsushi in Japan, that they have a unique set of technical and organisational capabilities such that their mission can be expanded in terms of both their technology focus (not only concerning the valley of death but also towards knowledge adoption) and their workforce development (i.e., providing specialised training and filling the gaps between university skills supply and firms’ skills demand) and supply chain development (i.e., adopting a perspective where the sector is substituted for a value chain type of analysis that enable to understand the gaps of different value chain segments often nested into and across specific regions) (Anzolin & O’Sullivan, 2025). In other words, RTOs’ understanding of different players and different technical and organisational capabilities in the ecosystem allows them to sit in the interstice with a privileged position to address specific gaps within and across the different varieties of knowledge (knowledge creation, knowledge adoption and knowledge diffusion). Several studies confirm that SMEs are lagging behind in technology adoption (Buonanno et al., 2005; Müller et al., 2018), signalling a problem in the knowledge adoption and knowledge diffusion part of the innovation cycle. In this context, RTOs can act as a public body for dissemination across SMEs, which often lack the retrofitting and organisational capabilities needed to adopt and integrate digital technologies at the firm level and across the supply chain (Raj et al., 2020); in highly successful model of RTOs such as the Fraunhofer institutes in Germany, two-thirds of the research projects are with SMEs, reaching three-quarters in publicly joint research projects.¹¹ Filling this gap by providing public support to SMEs fosters adaptation and learning mechanisms around new technologies. For example, demonstration activities are important to show firms the potential advantage of using more advanced technologies (Anzolin & O’Sullivan, 2025). As Marshall argued, learning by doing is critical, since ‘practice in any kind of thinking develops new connections between different parts of the brain’ and it enables problem-solving, ‘we know for a fact that practice will enable a person to solve quickly, and without any considerable exertion, questions he could have dealt with but very imperfectly a little while before’ (Marshall, 1920, IV, IX, 1).

In countries where RTOs have a long-standing role, they have become accumulators of technical and organisational capabilities due to their problem-solving activities at different levels of the value chain and across sectors, developing a critical set of capabilities to address gaps across the varieties of knowledge. The criticality to address gaps at different levels of the innovation process was part

of Marshall's analysis of the ecology of research laboratories (Marshall, 1919, IV) (Metcalfe, 2007). He argued that in the three types of national laboratories (see section 2.1), their 'division of labour' highly matters because advances are made in cooperation by different men of different capabilities and specialism with different methods (Metcalfe, 2007). Marshall argues that:

his studies [of the academic person searching pure science in laboratories] will lose nothing from keeping in touch with some of those industries, whose methods might be improved by increased knowledge of the properties of the products which he is studying. ... Therefore it is well that laboratories devoted to the advance of pure science should take some account of the work of a second class of laboratories, whose researches are specialized on the attainment of particular ends.

(Marshall, 1919, I, V, 4)

Marshall's approach reflects a wider division of labour in the knowledge creation process, in which competitive advantage depends increasingly on the mastery of abstract science and engineering principles (Metcalfe, 2007). This has straightforward implications for industrial policy, where interventions aimed at influencing the relations between agents should give direction to the specialisation of agents, thus permitting greater articulation and lowering the cost of coordination (Bianchi & Bellini, 1991).

4.1.3. A public body to coordinate external economies

The actors in charge of different bits of the innovation process require coordination to deliver positive spillovers, especially to benefit from co-location dynamics. We discussed these benefits in section 2, referring to Marshall's concept of 'external economies' that do not materialise automatically (Metcalfe, 2007). Actors require coordination to complement their dissimilar and complementary activities, which are better performed between different complementary firms in the ecosystem (Richardson, 1972). Collective learning is a technology-specific process, and the diffusion of innovations depends on incremental adjustments along well-known paths (Bianchi & Bellini, 1991). There is an intrinsic continuity of adaptations in the innovation process, and RTOs are critical actors in coordinating the evolving knowledge while facilitating a particular culture of learning and adaptation (Amin & Wilkinson, 1999); as part of their presence and activities, new parts are developed, connections made and boundaries redrawn (Marshall, 1920; Metcalfe, 2007). Their relational capabilities with other actors of the ecosystem are likely to reinforce their internal capabilities for knowledge generation (De Silva et al., 2018).

Coordination is critical to facilitate positive spillovers; it is likely to reinforce linkages within and across different supply chains and to complement, when not direct, the operations of anchor firms to organise their value chain. In the context of the supply chains, RTOs' role would particularly target vertical linkages (Maskell, 2001) where

they can play an intermediary role between demand and supply, thus providing stable demand for innovations as well as the technical expertise and infrastructure on the supply side (Oughton et al., 2002). Coordinating external economies is a challenging process that requires RTOs to act as 'institutional entrepreneurs' aiming at tying together 'the functioning of disparate sets of institutions together' (Garud et al., 2013; Kitagawa et al., 2025, p. 137). Recent work on RTOs' innovation ambidexterity points to their ability to balance between their knowledge integration role, which is conducive of exploratory innovation (creating new knowledge) and their networking role associated with exploitative innovation (improving existing knowledge and skill set) (De Silva et al., 2018; see also the analysis of Asheim et al., 2016, discussing the concepts of knowledge exploration subsystems and knowledge exploitation subsystems).

4.1.4. An orchestrator of the regional ecosystem

RTOs have a key position to provide an orchestrating role. Again, in line with Marshall's intuition that the 'survival of the fittest' (Marshall, 1920, VI, VII, 597) may not select the best-fitted solutions to benefit the environment/society, RTOs are in an ideal position to be one of the leading actors in policy co-design, both serving policymakers to gather evidence and providing an active role to the policy implementation process. Public funding is already widely deployed to target socially desirable outcomes, and RTOs have the potential to serve such outcomes given their diversified set of dynamic capabilities (Teece, 2017) to address challenges faced by different actors across ecosystems, even more so in times of technology disruptions. Such a privileged position comes from a deep understanding of key actors in the ecosystem based on an organisational memory that is key for their functioning with different actors (Håkanson et al., 2011), from original equipment manufacturers (OEMs) to specialised engineering firms (Castellacci, 2008), SMEs and universities. Finally, and in line with the importance of fostering the evolution and diversification of regions and clusters, RTOs can increasingly be in charge of such transition, building on regional strengths and promoting related or unrelated diversification (Uyarra et al., 2020). Recent evidence finds that when embedded in RISs, that is, when their regional mandate is clear and effective, RTOs can act as an effective regional policy driver, developing a role in the coordination of both policy formulation and implementation (Kitagawa et al., 2025).

4.2. Recent evidence of the debate in the US and the UK

The paper now presents insights coming from two RTOs in the UK and the US to exemplify our proposed theory. In both the UK and the US, challenges in translating knowledge creation into knowledge diffusion became evident in the late 2000s, with deep roots in the deindustrialisation process from the 1980s. In both countries, one of the policy actions was the creation of a network of RTOs to promote higher value capture from innovations: the Catapult

network in the UK (in 2011) and the M-USA institutes in the US in 2013. The evidence presented in this section, to exemplify how our framework can be used in practice, comes from a two-year comparative project on RTOs in the UK and the US, where both primary (20 semi-structured interviews) and secondary (grey literature and available material on different organisations) data were gathered;¹² the main focus of the study was on RTOs' changing roles and activities, and on RTOs' division of labour with other intermediaries (see also Anzolin & O'Sullivan, 2025). We purposefully sampled the organisations to study: two RTOs institutes, the High Value Manufacturing Catapult (HVMC) in the UK and MxD in the US, together with other organisations that aim at filling different gaps in the knowledge-generation process, the manufacturing extension partnerships (MEPs) and in the US, which are long-standing manufacturing organisations that focus more on technology adoption, lean manufacturing and on-demand services for SMEs, and the Made Smarter Adoption programme in the UK.¹³

Figure 3 is an application of our framework. Using examples from the UK and the US, we show different conceptual and strategic layers in RTOs' activities and division of labour across different knowledge domains. Examples of the mix of activities (i.e., technology, workforce) are reported under each organisation (RTOs and non-RTOs), indicating different domains of collaboration (i.e., services) with firms. Figure 3 also indicates that RTOs' range of activities is not limited to TRLs 4–6 anymore (it has been shifting downstream) and that, building on their internal and relational capabilities, they have been able to sense firms' evolving needs and to reconfigure accordingly.

There is recent evidence pointing to a new phase for both networks, where collaboration is taking over

competition dynamics both within the networks (of Catapults and M-USA institutes) and – mostly for the US – with other actors in the ecosystem, for a more efficient division of labour between intermediaries (Anzolin & O'Sullivan, 2025; Simpson, 2022). Complementarity reinforces collaboration; M-USA focus more on the scaling up of both product and process technologies, while MEPs promote the diffusion of production technologies along the supply chain (Figure 3). In the US, such collaboration is both bottom-up, through project collaboration, and top-down, as enforced by the Department of Commerce, which tries to enforce a division of labour and cooperation between M-USA and MEPs (CRS, 2019). In the UK, there is a similar trend of increasing collaboration, yet the emphasis is more on collaboration with universities and businesses rather than with other innovation intermediaries, as discussed in recent reviews of the Catapult network.¹⁴

Collaboration happens across different activities; although these organisations were set up mostly to provide technology support (TRLs 4–6, e.g., providing pilot lines and test beds for technology demonstration), there is evidence of other activities emerging, which are increasingly key for the capability building process. Insights from interviews conducted with all stakeholders, as well as new funding allocated for new strands of activities, confirmed this trend. For example, in the US workforce is a pillar of M-USA,¹⁵ at MxD, where interviews were conducted, examples include services that are part of the MxD Learn portfolio and training centres, as well as services such as hiring guides and digital manufacturing taxonomies available for companies; one of the most important workforce projects is the recently funded CAPITAL programme (US\$6.2 million).¹⁶ In the UK, the HVMC has

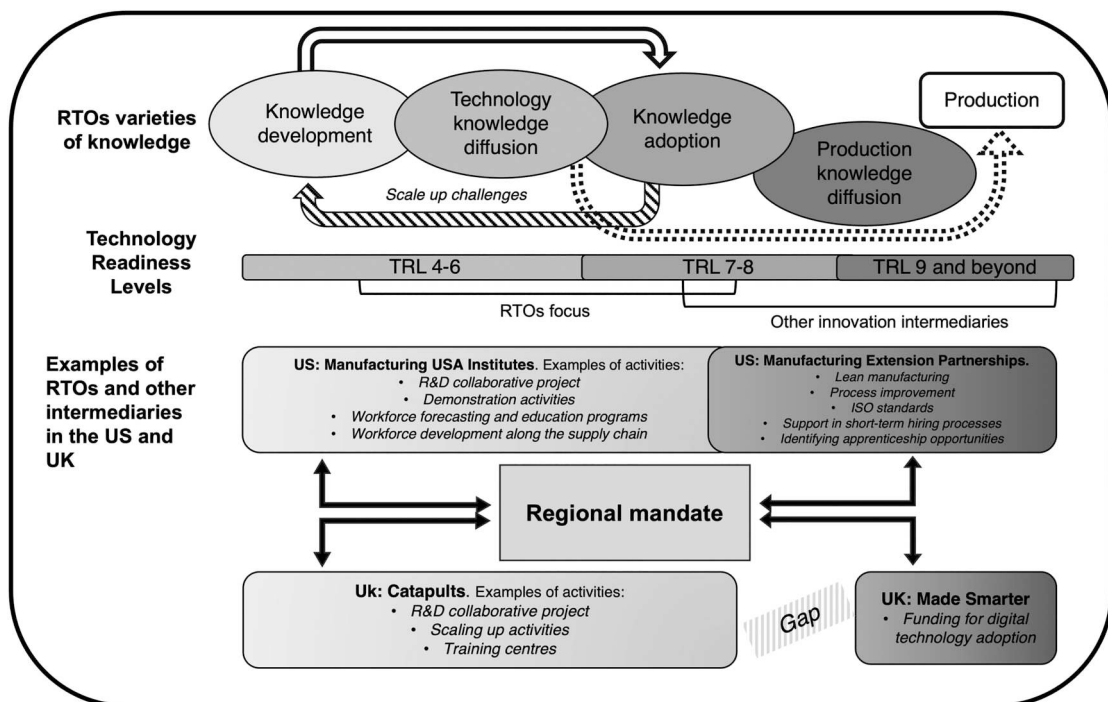


Figure 3. Framework application to the US and UK. Source: Authors.

adopted a skills value chain approach linking workforce development to technology adoption; while skills activities are not a core activity in the Catapults' funding scheme, the UK government signalled interest in funding workforce initiatives through the Catapults.¹⁷

For what concerns regional mandates, M-USA were set up with a regional emphasis, but it was not operationalised since the beginning; Catapults were created just after the abolishment of regional development agencies, so despite not having a formal regional mandate, there seems to be some legacy with some centres that pre-existed the Catapult formation. MEPs have a strong regional mandate; there is one in each US state and Puerto Rico. There is a regional approach also in the Made Smarter Adoption programme, which started in the Northwest region and has been expanding. Our interviews also shed light on the different types of regional mandates; for example, in the US, the regional mandate of RTOs (M-USA institutes) is a strategic one, where they play their technology transition role, ensuring that value capture materialises regionally. Differently, the regional mandate of MEPs responds to the need to ensure that new knowledge diffuses quickly into regional supply chains.

Relatedly, evidence of RTOs' activities at the regional level is mixed. In both countries there has been increasing attention to regional policies; the Levelling Up Agenda (HMG, 2022), the Strength in Places Fund supporting local public-private consortia to develop local R&D capacity (initial budget of £316 million over five years), the Innovation Accelerators supporting city region-led public-private partnership (PPP) cluster development (£100 million in three pilot initiatives) and Innovate UK Launchpads providing regional innovation support and funding for SMEs (£15 million investment in two pilot initiatives), are examples of this effort. In the US, there are around 19 place-based industrial policy programmes for a total amount of US\$77.4 billion across the recent Infrastructure Investment and Jobs Act, the American Rescue Plan, and the Chips and Science Act; this regional-focused investment is complemented by the Tech Hubs programme, which brings attention to cross-sector institutional consortia and regional large-scale transformation. There are some differences between the US and UK experiences. In the US, the M-USAs were originally set up with a regional mandate,¹⁸ which did not materialise until recently into a strong regional activity. Bonvillian argues that the regional mandate became more challenging given the dual national and regional objectives of M-USAs, with, on the one hand, industry and universities that are and remain anchored in regions, and on the other hand, technologies that need to be national (Bonvillian, 2017). Existing research on the effect of M-USA institutes on regions is not optimistic, and points to an increase in regional disparities as a result of their activities, caused by a problematic de-linking between production and technology, where technology policy is unevenly linked to production policy in favour of large incumbent firms (Clark & Doussard, 2019). In the UK, the Catapults were not intended explicitly for regional development;

they were established in places with already existing capabilities and high absorptive capacity. However, there is increasing emphasis on the role they could play for the government's 'levelling up' agenda, given the coordinating role they already play in their ecosystems.¹⁹ For example, Catapults are a common actor in the formation of innovation consortia at the regional level;²⁰ similarly, in the US, they are a common actor in the formation of Tech Hub consortia.²¹ This initial involvement in regional programmes is a sign of the key role that RTOs play, which is recognised by big firms, SMEs and universities. The spontaneous and not coordinated bottom-up emergence of these cases signals the lack of a clear policy direction for these RTOs to engage more directly at the regional level.

Policy support to tie RTOs to regional economies is key to their survival (Bonvillian, 2017). Since RTOs develop a strong role as knowledge repositories of actors and technologies over time, both in terms of technological and actors' knowledge, they have an important coordinating role to play. The initial insights from the UK and US RTOs highlight their dynamism; while RTOs might not have been well placed for a regional mandate as soon as they are set up, their role, as well as their relations with other actors, have been changing over time.

5. IMPLICATIONS FOR REGIONAL POLICY AND CONCLUSIONS

This paper proposes a capability-based theory for RTOs, which are actors that have increasingly become 'accumulators of capabilities' across different phases of the knowledge-generation process. In this theory-building process, we refer to Marshall and his neglected work on the three classes of laboratories (Marshall, 1919), which we would today call innovation (or knowledge transfer) intermediaries. We start from his work to bridge two pieces of literature; specifically, by responding to a recent call from RIS to move from the firm-centric view to a more comprehensive study of different regional organisations and institutions, we provide an analysis of a specific type of actor, which are RTOs. We indicate how RTOs are key to responding to an increased number of challenges related to the nature of knowledge creation in a time of rapid technological change and to fill the gaps in the numerous activities that are required for firms to succeed in the use of innovation technologies.

In doing that, our paper points to the varieties of knowledge in the innovation process and the increased need to understand why certain parts of the innovation process do not materialise in certain regions. A lack of infrastructures that include applied R&D, demonstration facilities, workforce development activities, and increasing collaboration between actors is likely to favour the full development of innovations and attract high-value-adding competitive firms. The recent emergence of policies that address regional capabilities gaps across the varieties of knowledge represents a step in the right direction, despite often suffering a lack of coordination, as our example from the US and the UK indicates. There still is a wide

dispersion of activities between different actors, which impedes a virtuous value-capture process across regions (Bailey et al., 2020). This paper complements and further extends some of the implications from the RTOs' study by Anzolin and O'Sullivan (2025); the latter paper provides evidence on the different types of activities resulting from changes in the technology and innovation space, where such activities are emerging mostly as a result of bottom-up 'experimental' efforts between different organisations to fill gaps. With this paper, we provide a conceptual and analytical framework; the Marshall lens favours a more comprehensive evaluation of why (and how) RTOs should be funded with public resources, by shedding light on the emerging gaps across and within activity domains that were not even part of RTOs' role in the recent past. This framework intends to help policymakers to systematise and strategise around the varieties of knowledge, the actors and activities required to unlock bottlenecks for knowledge generation. The processes related to it have become more complex and somehow more opaque due to the fast-changing features of both technologies and industrial structures; digital production technologies are continuously raising the bar of adoption, adaptation and diffusion (Ciarli et al., 2021; Martinelli et al., 2021), while the economic structure in mature economies has been deteriorating losing high value adding segments of global value chains that have been captured elsewhere. As a result of this, many places in mature economies experienced deindustrialisation and increasing inequality since their innovation ecosystems lost stickiness (Markusen, 1996).

Our study suggests three main implications for regional policy. First, regional actors need closer interaction with RTOs, given their ability to enhance key capabilities within industrial value chain clusters and strengthen linkages between stages and actors in response to evolving opportunities. RTOs act as a de facto anchor for the regional ecosystem, pooling knowledge and resources (Ng et al., 2023). Second, RTOs provide valuable intelligence for regional industrial policy. Their engagement across value chains, including with international and local firms and suppliers, offers evidence on the capabilities, opportunities and emerging industrial trends. Positioned across the triple helix of government, research, and business, they can inform, guide, and complement investments, particularly in lagging regions where absorption capacity is limited (Etzkowitz, 2002; Kitagawa et al., 2025; Morgan, 2017). Third, RTOs could contribute to the regional innovation policy paradox, providing the network, the infrastructure and the organisational and technological capabilities to ensure that higher spending in lagging regions is matched by programmes and resources to increase their absorption capacity (Oughton et al., 2002). The balance between technological and social goals should be a priority in regional policymaking, also considering the evolution of RTOs towards more collaborative and with a stronger focus on value capture.

Our paper intends to contribute to a new field of research on the role that innovation intermediaries play

in fostering regions' diversification patterns. Future studies might collect empirical evidence to substantiate the evidence on innovation intermediaries' functioning in the regional ecosystem, specifically focusing on the multiple roles and activities of different organisations across regional ecosystems. While we exemplify our study by referring to insights on RTOs and regional policy in the UK and the US, evidence from other countries where RTOs have a stronger regional mandate and coordination could provide further support to our theory.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

ETHICS STATEMENT

Good scientific practices were followed in this study. The empirical material was collected thanks to voluntary participations and permission to use the material for academic publications. Interviewees were all anonymised and previously informed about the content and purpose of this study.

FUNDING

This research was supported by the Gatsby Foundation [grant number GAT3816].

NOTES

1. Unless stated otherwise, 'capabilities' here refers to dynamic capabilities (Labory & Bianchi, 2021; Teece, 2017).
2. The title of the subsection recalls the beginning of Book IV of *The Principles of Economics* where Marshall discusses the important intersection between knowledge and organisation, 'organisation aids knowledge' (Marshall, 1920, IV, I, 1). Section 2.1 refers then to the multiple types of organisations that support knowledge analysed in *Industry and Trade* (Book I).
3. 'A single giant business which is pioneering new developments of a subtle industry may reasonably set up a great laboratory for the conception and testing of improvements on current usage' (Marshall, 1919, I, V, 4).
4. The phase of the innovation process where there is not enough private funding to scale up innovations that stem from the basic research process.
5. TRLs are a common measure to assess the level of maturity of a technology. Broadly, TRLs 1–3 indicate basic research and technology concept development; TRLs 4–6 indicate technology development and demonstration phases; and TRLs 7–9 indicate system development and proof in operational environment.
6. Here we refer to technical and organisational capabilities (conventional type of capabilities) that have been

developed over time because of RTOs' dynamic capabilities to sense opportunities and transforming resources.

7. In such policies, government at different levels has attempted to lead low-visibility networks of suppliers, sub-contractors' middlemen, venture capitalists, etc. aiming at scaling up and product commercialisation and at obtaining technological frontier products and services.

8. Figure 2 extends Anzolin and O'Sullivan (2025, fig. 1) and originally introduces the varieties of knowledge building on Marshall, and it unpacks activities along the innovation process, building on the recent work of Anzolin and O'Sullivan. The latter hypothesised the varieties of activities, which we conceptually linked to the varieties of knowledge in this paper.

9. For example, see US RAMI Act (2015), SEC34.

10. For example, the Fraunhofer society was founded in Germany in 1949, and the Kosetsushi centres date back to the 19th century with an initial action in the agriculture, textile and brewery sectors.

11. See <https://publica-rest.fraunhofer.de/server/api/core/bitstreams/3d843c92-06d6-431e-81a7-11cc355a26ce/content>.

12. Semi-structured interviews were conducted with both UK and US stakeholders between 2022 and 2024; see Appendix A in the supplemental data online for a methodological note.

13. In the early 2010s, the UK government abolished the Manufacturing Advisory Services (similar to MEPs in the US), leaving a de facto void in the downstream part of the knowledge-generation process. The smaller, regional-focused programme Made Smarter Adoption was created in 2019.

14. See <https://assets.publishing.service.gov.uk/media/6065a7a9d3bf7f0c8d06b811/catapult-network-review-april-2021.pdf>.

15. See https://www.manufacturingusa.com/key-initiatives/manufacturing-workforce-development?utm_source=chatgpt.com.

16. See https://www.mxdusa.org/2023/04/25/mxd-announces-6-2-million-in-funding-for-workforce-development-training/?utm_source=chatgpt.com.

17. Ibid.; <https://assets.publishing.service.gov.uk/media/6065a7a9d3bf7f0c8d06b811/catapult-network-review-april-2021.pdf>. Recently the Department for Education funded the Emerging Skills Programme to be delivered with the HVMC.

18. See <https://sgp.fas.org/crs/misc/R46703.pdf>.

19. See <https://committees.parliament.uk/publications/4578/documents/46310/default/>.

20. See <https://catapult.org.uk/wp-content/uploads/2023/03/Catapult-Network-2023-Growth-and-Prosperity-Stories-FINAL.pdf>.

21. See https://www.eda.gov/sites/default/files/2023-12/Tech_Hubs_Consortia_Members.pdf.

ORCID

Guendalina Anzolin  <http://orcid.org/0000-0002-8350-3644>

Eoin O'Sullivan  <http://orcid.org/0000-0003-3582-7940>

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