Responsible Innovation and the Commercialisation of Quantum Technologies

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Statement of originality

This is to certify that the content of this thesis is my own work. This thesis has not been submitted for any other degree or purpose.

I certify that the intellectual content of this thesis is the product of my own work, and that all assistance received in preparing this thesis and all sources have been acknowledged.

Gabriella Rose Skoff
02/03/2026

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Authorship Attribution Statements

Paper One (Chapter Three)

Risk and the Discursive Construction of Quantum Technologies in Australia: How Geopolitical and Economic Threats are used in Hyping Emerging Technologies – Accepted and presented at EGOS 2023 Conference. This paper is currently being revised and resubmitted at a journal. I designed the study, collected the data, analyzed the data, and drafted and revised this manuscript with feedback and support from my supervisors.

Paper Two (Chapter Four)

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Paper Three (Chapter Five)

Orchestrating Responsible Innovation in Knowledge Ecosystems – Accepted and presented at AoM 2025 Conference. I designed the study, and drafted and revised this manuscript with feedback and support from supervisors. My supervisor, Stefan Meisiek, presented the paper at the conference.

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As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

Stefan Meisiek
02/03/2026

Generative AI & Government Support Statements

Generative AI Statement

During the revision of the thesis the author used Claude AI for the purposes of re-structuring the existing argument. The use of this generative AI tool includes suggestions for structuring the literature review and theory section using existing text written by the author of this thesis. The author confirms that where text was modified by generative AI, the content was reviewed for possible errors, inaccuracies, and bias. The author takes full responsibility for the submitted thesis and ensures the work is their own and has used generative AI in accordance with the University of Sydney generative AI guidelines and policies for researchers.

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Abstract

As governments worldwide seek to encourage innovation, there is a growing concern for doing so in a way that both fosters competitive technological advancement and generates societal benefits. Responsible innovation (RI) is one approach to addressing this challenge by integrating ethical, social, and inclusive values into the development and governance of emerging technologies from the earliest stages of innovation. While the limitations to RI adoption in commercial organizations are well understood, it remains unclear how or why RI may be systematically adopted and adapted in a commercialization, rather than research policy, context. This thesis argues that this challenge cannot be resolved without first grappling with a foundational problem: the meaning of RI is not fixed but continuously (re)produced through the interactions of diverse actors whose values and normative commitments are shaped by competing institutional logics and socio-political contexts. It advances a systematic social constructionist analysis of RI in a commercialization context, reframing the challenge of RI from an implementation problem to a meaning-making problem across competing normative worlds.

Using data from interviews, media, public announcements, and strategic documents, this thesis presents a longitudinal case study of Australia's developing quantum innovation field. Paper One explores the role of hyping in the discursive construction of quantum technologies in Australia, demonstrating how emerging technologies are positioned as a risk management solution to security and economic threats while novel social risks are marginalized, with important consequences for the meanings and actions considered responsible. Paper Two investigates how RI entered Australia's quantum innovation landscape not as a fixed framework but as an interpretively flexible lens used to reconcile a tension between competing stakeholder visions, shaping the National Quantum Strategy and becoming reshaped through this process. Paper Three responds to calls for a systemic turn in RI by theorizing how RI can be orchestrated within knowledge ecosystems, treating orchestration itself as a socially constructed and negotiated process and offering three propositions for how ecosystem orchestrators can construct the conditions under which RI becomes a shared and sustained commitment.

Taken as a whole, this thesis addresses a critical gap in RI research by demonstrating empirically how RI's meaning is contested and stabilized through the discursive and institutional dynamics of a specific innovation system, and by advancing a theoretical account of how those dynamics can inform the orchestration of RI in practice. In doing so, it directs attention to what is ultimately at stake in the governance of emerging technologies – not just how innovation is managed, but whose values shape it and whose futures it serves.

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Prologue

My journey to this point has been a winding one. My interest in my subject area came together over the past decade; the puzzle pieces of my professional life began to coalesce into something that resembled a cohesive pathway forward as I followed my interests and honed my skills in research. I was first introduced to the field of Science, Technology, and Society (STS) in a role as a researcher on the Human Perspectives on the Nanoscale program, an effort to foster multidisciplinary thinking between Sydney Nano and the Faculty of Arts and Social Sciences. The project I worked on provoked a motivating realization that oftentimes, science and technology are treated as if they operate in a world enclosed in a sterile bubble, despite the fact that technologies are constructed through a range of socio-political processes and influences to be used by society, on society, and for society (Pinch & Bijker, 1984). Since then, my mission has been to bring the social and the technical closer together.

My subsequent work in this space led me to Project Q, a research group looking at the geopolitical implications of emerging quantum technologies. I had the freedom to explore my research interests of the geopolitical, societal, and environmental impacts of emerging technologies within this space and there discovered the literature on responsible innovation (RI). What struck me about this outlook, as opposed to other approaches to developing technologies that cause less harm and promote greater good for a larger segment of society, was the inclusion of a diversity of perspectives from across disciplines and sectors of society (Da Silva et al., 2019). As an inter-disciplinary scholar, this concept appealed greatly. In RI's deliberative and inclusive mandates, I saw an important business angle in what can otherwise be eschewed as solely a normative ethical pursuit – offering both a way to both produce more responsible technologies, but also the hope of producing, in that process, *better* technologies. I wondered how the inclusion of diverse perspectives could inform a more resonant technological output.

Likewise, the opportunity to learn more about the development of quantum technologies led me to believe this emerging suite of technologies presents a unique case study for the implementation of RI. In an applied sense, both RI and quantum technologies are at a similar stage of maturity – both are the focus of efforts to figure out how they can be applied as they are transitioned from a research setting to a commercial context. In undertaking this PhD, I endeavored to explore how this could be done. My intention was to devote a few years of my life to figuring it out, and my hope was that after all of this, I would be best placed to apply this knowledge to the problem and solve it. Through the process, I gained an in-depth understanding of Australia's quantum sector, developed meaningful connections with incredible people working in this space, took advantage of a multitude of opportunities for my own professional development – spoke a quantum conferences, on panels, and ran workshops based on an approach to RI developed through my research.

I've also gained, particularly through these later stages of my research, an appreciation for the fact that there is no role for me to be 'the quantum RI person' in Australia that I hoped for. Rather, what I uncovered through my research is that RI is simply not being approached as a standalone activity in Australia's quantum space. So, while the irony is not lost on me that all this effort to establish myself in a position to apply my research is not as straightforward as I hoped it would be, I feel that my findings affirm the quality of my research. If you discover something different from what you thought you would through the research process, it's likely a sign that you have done something right.

Despite the struggles inherent to undertaking an ambitious and long-term intellectual pursuit spanning years of my life and the struggle to bridge the (superficially) disparate worlds of the social and the technical, I'm proud of the output of this body of research. This thesis contextualizes RI in the process of the social shaping of innovation through the case study of emerging quantum technologies as they are ushered from research labs to industry applications, revealing the fundamental role of socio-political process in shaping responsible technological futures.

1. Chapter One: Introduction

1.1 Research Purpose

Technological innovation has previously been understood as a deterministic and linear process exclusively directed by a specialized technological elite (Godin, 2006; Pinch & Bijker, 1984; Winner, 1980). Upon the backdrop of increasing awareness of both the risks and opportunities presented by emerging technologies, recent interventionist perspectives, such as responsible innovation (RI) from the field of Science and Technology Studies (STS), have sought to disrupt this assumption (Pinch & Bijker, 1984; Jasanoff, 2004; Jasanoff, 2015). Responsible innovation is broadly defined as an approach to innovation governance that focuses on "…taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013, p.1570). RI initiatives and approaches aim to promote 'collective co-responsibility' (von Schomberg, 2007; von Schomberg, 2013) for innovation outcomes amongst diverse actors contributing to innovation, including academic researchers, commercial organizations, and policymakers (Owen et al., 2013). Critically, this outlook is implicitly underpinned by a philosophy of the social construction of technological futures. However, this thesis argues that without explicitly addressing the socio-political contexts that shape innovation perspectives and processes, the application of RI will have limited success as a governance mechanism.

RI is firmly rooted in scholarly debates in STS that view "scientific knowledge as a social construct rather than an epistemic given" (van Oudheusden, 2014, pg.82). Positioned within this philosophy of social constructionism, RI aims to proactively engage diverse actors contributing to innovation in a conscious, consistent, and collaborative process of societally acceptable, technological future-making. As such, RI treats innovation as "…a complex, future-creating phenomenon with the potential to co-produce risks and ethical, social, environmental and political entanglements in uncertain and unpredictable ways" (Owen et al., 2021, p.1). The future orientation inherent in RI raises a key question: what kinds of futures do innovation actors envision, desire, or seek to avoid? Answering this question requires interrogating how certain meanings become attached to technologies and influence their developmental trajectories.

This thesis applies a social constructionist perspective to analyze RI as an approach to innovation governance. Drawing on the Social Construction of Technology (SCOT) tradition (Pinch & Bijker, 1984; Bijker, 1995), this social constructionist perspective understands innovation governance as an open and contested process wherein diverse actors influence the trajectories of technological futures based on their distinct values, normative commitments, and institutional positions. It holds that innovation governance is co-produced (Jasanoff, 2004) alongside the technologies it seeks to develop. As such, governance arrangements both reflect and constitute social order, embedding particular values and political arrangements. From this perspective, RI is not conceptualized as a neutral technical framework. Rather, its formulation is contingent on the social circumstances of its development (Klein & Kleinman, 2002).

Socio-technical imaginaries offer an analytical framework for interrogating how the social circumstances of innovation systems shape technology development trajectories, revealing which values are embedded in governance, and which actors are empowered (Jasanoff & Kim, 2009). Jasanoff & Kim (2015) define socio-technical imaginaries as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff, 2015, p. 4). By engaging with this construct, this thesis examines RI as co-produced alongside quantum innovation strategy in Australia. This thesis takes a discursive analytical approach to identify hype as constructive of socio-technical imaginaries through the mobilization of "a collective vision and promise of a possible future, around which attention, excitement, and expectations increase over time" (Logue & Grimes, 2022, p.1055). As a mode of discourse, hype produces a state of increasingly exaggerated expectations (Caulfield and Condit, 2012; Funk, 2019; Logue and Grimes, 2022; Pontikes and Barnett, 2017) that drives the innovation process by shaping perceptions and directing resources (Logue and Grimes, 2022).

Establishing how hype animates socio-technical imaginaries reveals how RI is 'made sense of' and orchestrated accordingly. Importantly, orchestration itself is socially constructed. Who orchestrates what activities, when, and why are all social constructions that signal how a given society imagines innovation governance can and should function. Orchestration here refers to the purposeful facilitation of RI practices and processes within a system of innovation, understood as a socially constructed and negotiated process through which diverse actors are supported to develop shared meaning and collective responsibility for responsible innovation outcomes. In RI, orchestration is required to facilitate interventions such as creating forums for integrating stakeholder perspectives, engaging innovators in reflexive practices to help anticipate social and ethical issues, developing capacity to respond to these issues as they surface, and channelling innovation toward areas of public good (Owen et al., 2013; Nazarko & Melnikas, 2019; Owen & Goldberg, 2010). The orchestration of RI becomes necessary when responsibility in innovation is constructed as a collective pursuit requiring the management of the competing values and normative commitments held by diverse innovation actors.

The orchestration of RI addresses an important question: how can innovation actors collectively act and respond to societal demands on innovation (Owen & Pansera, 2019)? In particular, RI focuses on innovation practices within commercial organizations. Industry participation in RI is critical, as commercial organizations are increasingly important actors in innovation (Ivanova et al., 2021; Ivanova et al., 2023). However, research has established that RI has limited transferability to commercial domains due to the conflicting interests between society and corporations (Martinuzzi et al., 2018; Lubberink et al., 2019). Studies reveal entrenched tensions at the organization level between commercial priorities and values, such as intellectual property rights and information asymmetry, and the collaborative and open innovation demands of RI. This disjunction has rendered the uptake of RI in commercial organizations largely ineffective (Auer & Jarmai, 2017; Pfotenhauer et al., 2021; Gurzawska et al., 2017; Ko & Kim, 2020). Examining RI through a social constructionist lens leads to a context-specific understanding of how it can be adapted to govern commercial innovation.

This thesis understands the orchestration of RI as a systemic, rather than organization-level challenge. The application of a systems lens has become a recent focus in RI literature (Stahl et al., 2017; Jakobsen et al., 2019; Stahl, 2022; Foley & Wiek, 2017; Dreyer et al., 2020; Smolka & Böschen, 2023). This 'systemic turn' in RI (Smolka & Böschen, 2023) highlights the importance of attending to system-level dynamics in applied contexts and offers an avenue for positioning organizations within the broader socio-political and economic structures in which they operate. The logic of a systemic approach to RI is likewise anchored in the core principle of co-responsibility, where the processes of research and innovation "should be established as a collective, inclusive and system-wide approach" (van Oudheusden, 2014, p.70). Smolka & Böschen (2023) introduced the concept of responsible innovation ecosystem governance to direct attention to developing system-level capacities for socioethical reflection so that it becomes a shared task for all actors within an ecosystem to collectively govern innovation. This thesis locates this systemic challenge in the context of knowledge ecosystems, specifically, where the coexistence of academic and commercial actors creates both the conditions for and the obstacles to collective RI. Elevating the conduct of RI to an ecosystem-level approach surfaces the challenge of managing competing stakeholder values and norms.

Within a given system of innovation, the diverse and often competing values and norms of stakeholders become socially, politically, and economically entangled. This poses a challenge to the expectation that these actors will work together to produce innovation outcomes. This is particularly true in RI, where collective co-responsibility for societally acceptable innovation outcomes is the goal. As Blok and Lemmens (2015) explain: "The fundamental differences among stakeholders with regard to their vision, goal, sector and motive, can be seen as bottlenecks in responsible innovation" (p.22). The divergent values of innovation actors present a challenge to stakeholder collaboration regarding their capacity to agree on critical issues throughout the innovation pipeline, from problem definition to co-creating solutions to address a collective goal. This directly challenges a core strategic objective of RI for stakeholders to develop co-responsibility for innovation outcomes and become mutually responsive to one another (von Schomberg, 2013). Therefore, rather than treating them as secondary considerations in innovation processes, stakeholder values and normative commitments require explicit attention in RI research.

Despite this perspective on the importance of situating RI within systemic socio-political dynamics, the mutual shaping of RI and socio-political systems is a largely overlooked aspect of RI research (van Oudheusden, 2014; Macnaghten et al., 2014; Owen & Pansera, 2019). As Lubberink et al. (2017) argue:

> On the one hand, new knowledge and technology embeds and enacts value-laden and politically significant judgments of what the world should look like and will look like. A similar assertion can be said for the concept of responsible innovation, because its proponents have a normative-political orientation as they aim to change the governance of science and innovation, and ultimately change the current political and socioeconomic system. (p. 22)

Understanding the specific socially and culturally constructed meanings, visions, expectations and institutional arrangements that shape a given innovation landscape is fundamental to understanding how RI might be applied in commercialization contexts. Yet few studies on RI have taken the social shaping of innovation processes as their starting point. This oversight is fundamentally problematic, since RI attempts to organize innovation by re-configuring how scientists, innovators, markets, and governments understand and respond to their responsibilities in the innovation process (Owen et al., 2021).

This thesis addresses this gap by explicitly foregrounding a social constructionist perspective that has remained largely undertheorized in RI research. While RI scholarship implicitly acknowledges that science and technology are socially and politically constituted (Stilgoe et al., 2013), it has not systematically interrogated how RI itself is socially constructed through the competing values and visions of diverse innovation actors operating in specific socio-political contexts. This oversight is consequential in theorizing how RI might find resonance in the transition to a commercialization context. If RI is to effectively govern innovation, it must be understood as co-evolving with the sociotechnical systems it seeks to shape (Jasanoff, 2004). This philosophical outlook guides a methodology and provides a framework for examining how innovation processes unfold in specific socio-political contexts through negotiation and contestation among actors (Pinch & Bijker, 1984; Bijker 1995). By critically engaging with stakeholder values within their broader social, cultural, economic, and political contexts, this thesis positions the meaning and orchestration of RI within the dynamics of the construction of technological futures.

This thesis is motivated by an overarching question: *how does the social construction of RI shape its orchestration in commercialization contexts?* It seeks to answer this questions across three papers, which examine three distinct sites in which the process of the social construction of RI and emerging technologies can be studied: hype, sociotechnical imaginaries, and orchestration in knowledge ecosystems.

Paper One employs a discourse analytic approach to interrogate the ways in which language is used to construct emerging quantum technologies in relation to notions of risk and responsibility. While much RI research leaves these normative concepts unquestioned, this paper interrogates how such notions become socially constructed in the socio-political context the underpins Australia's quantum innovation. It asks: *how does hyping, understood as a discursive process involving contestation through discursive struggle, influence the meaning of an emerging technology?*

Paper Two uses interviews and policy documents to trace how Australia's RI policy formulation is shaped through the quantum socio-technical imaginary to mediate contested visions of quantum futures. As a result, this paper advances an understanding of applied RI beyond a templated approach to guidelines or principles, instead positioning it as uniquely constituted by the process of the social construction of emerging technologies. It locates RI within this process by asking: *how and why does RI enter and shape socio-technical imaginaries of emerging technologies?*

Paper Three responds to calls for a systemic turn in RI by theorizing how it could be orchestrated in knowledge ecosystems to facilitate its uptake and management, particularly within participating commercial organizations. By treating orchestration itself as socially constructed, this paper theorizes how it could function as a critical vehicle to induce RI practices in commercial actors on an ecosystem-wide scale. To examine this, Paper Three asks: *how does orchestration in knowledge ecosystems ameliorate tensions between enacting the requirements of RI and addressing the market-led priorities that drive innovation?*

1.2 Thesis Structure

This thesis is comprised of six chapters formed around three core papers. The first chapter serves as an introduction to the thesis. It outlines the purpose of the research, the context of Australia's emergent quantum technologies sector, and discusses the relevant literature RI literature to establish the research gap in relation to this thesis, which informs the motivating questions of the three papers. It then introduces the theoretical framework as applied to the constructs this thesis examines. The second chapter presents a high-level overview of the longitudinal case study research methodology undertaken for the empirical component of this thesis. The following three chapters comprise the core focus of this thesis.

Briefly, Chapter Three (Paper One) interrogates the social construction of emerging quantum technologies through the lens of hyped discourse. It identifies hype as a field-level phenomenon where concepts of risk and responsibility are contested in the social construction of quantum technologies. These findings suggest that hype is a symptom of the presence of a socio-technical imaginary establishing itself, which is the focus of Chapter Four (Paper Two). Chapter Four interrogates how RI interacts with socio-technical imaginaries, finding that it is employed as a mediating outlook to address tension between competing stakeholder visions. The strategic integration of RI both shapes a collective socio-technical imaginary and produces a practical re-shaping of the concept as it is selectively applied through this process. Chapter Five (Paper Three) extends and applies the findings surfaced through the lenses of hype and socio-technical imaginaries in the preceding chapters of the importance and utility of RI in the context of emerging technologies as they transition from research to industry contexts. Chapter Five offers a thought experiment for orchestrating RI in knowledge ecosystems, presenting it not as a static set of principles or a framework, but as a dynamic, negotiated process on a system-level.

Finally, this thesis' conclusions are presented in Chapter Six. The final chapter ties all three papers together with a summary of their discreet contributions, followed by a discussion of the overarching contribution of this thesis. The limitations to this also research are discussed and avenues for future research that would further enrich the project on RI are likewise presented in this chapter.

1.3 Research Context

Quantum technologies are a class of emerging technologies that rely on the principles of quantum mechanics, a branch of physics that describes how the universe works on a subatomic level. While previous work in quantum theory helped to create first-generation quantum technologies such as lasers and transistors, the next generation of quantum technologies, including quantum computing, communications, and sensing, have the potential to disrupt a broad diversity of industries, including those vital for national security.

Quantum technologies present an exemplar or "revelatory case" (Eisenhardt & Graebner, 2007) to explore RI for several reasons. First, this thesis understands RI as a concept that has been institutionalised predominantly within an emerging science and innovation research context (Owen et al., 2021). In its focus of understanding how the concept can be transitioned to a commercial innovation context, it is useful to study a technology that bridges this divide. While different quantum technologies (for example, quantum sensing versus quantum computing) are at varying stages of market maturity, quantum broadly represents a unique case of a suite of emerging technologies currently undergoing the research-to-industry transition. As such, the innovation actors involved also bridge these two worlds; academic researchers critically contribute to commercial technological development. University spin-offs with academic founders are ubiquitous in the quantum world, and much of the funding for these companies has either initially or continues to come from public organizations.

At the time of writing, government, which tends to have a more vested interest in societal benefit and public acceptance of emerging technologies than venture capital funders, is the leading funder of quantum technological development worldwide (Erixon et al., 2025). The need to garner public acceptance of novel and complex science and technology contributed to motivating the development and application of RI (Coenen et al., 2022; Coenen & Grunwald, 2017). As quantum is a highly specialized and culturally mystified domain of science, the risk of public non-acceptance and barrier in industry to technological adoption are legitimate concerns. Likewise, the revolutionary potential of quantum technologies has not yet delivered the transformational impacts that are regularly promised by companies and governments (Derian & Rollo, 2024). Today, many of the potential risks and opportunities associated with the development of quantum technologies remain a subject of speculation and hype, as organizations, researchers, governments, and non-governmental organizations around the world begin exploring approaches to managing the responsible development and governance of these technologies (World Economic Forum, 2022; Perrier, 2022; Sydney Quantum Academy, 2021; Kop et al., 2023).

Finally, the literature on RI prescribes that diverse stakeholders be engaged in the research and innovation process from the initial stages of research and development (Owen et al., 2013; Silva et al., 2019). Taking a systemic perspective on RI brings ecosystems that are developed around emerging technologies into focus. Governments around the world, including in Australia, are heavily invested in fostering the development of such ecosystems by bringing public and private stakeholders together to co-create quantum ecosystems. In Australia and abroad, new centers dedicated to facilitating quantum ecosystem development are being established (Quereca, 2025), making quantum an exemplary site for studying how RI may or may not play a role in this process of collaboration between innovation actors with diverse values and priorities. These factors make quantum an ideal site of inquiry for this research.

Australia has an extensive history in quantum science and technology research. Australian quantum physics researchers are world renowned for producing significant advancements in quantum optics and experimental and condensed matter physics during the 1980s and 1990s (Roberson & White, 2019). Over two-decades of sustained government investment in academic quantum science research across various domains has expanded and strengthened Australia's quantum expertise and research capabilities, laying the groundwork for a quantum technology sector. Early domestic quantum commercialization efforts were predominantly university spinouts; most of these startups received either direct or indirect early-stage funding from defence and are beneficiaries of corporate funding from critical infrastructure industries, including telecommunications and banking (Roberson & White, 2019; CSIRO, 2020). Likewise, multinational technology corporations, including IBM, Microsoft, Intel, and Google, initiated major collaborations with quantum researchers from several Australian Universities. By 2017, a native commercial quantum industry began to take seed.

In 2020, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, released the Growing Australia's Quantum Technology Industry roadmap, forecasting a four-billion-dollar opportunity to be harnessed by cultivating a strong domestic quantum industry (CSIRO, 2020). In 2021, the Australian Army published a Quantum Technology Roadmap, offering a strategy to develop and retain a strategic security advantage through the exploitation of emerging quantum technologies (Army, 2021). That same year, the Australian Government Department of Industry, Science and Resources (DISR) designated quantum as a critical technology in the national interest (DISR, 2023b). Australia's quantum industry witnessed a rapid acceleration during this period of documentary inertia and public positioning, more than doubling the number of domestic quantum companies in the industry landscape, which includes ongoing partnerships between international technology companies and Australian universities, as well as several international quantum technology firms that have established offices in major Australian cities (CSIRO, 2020).

The launch of Australia's National Quantum Strategy in May 2023, alongside the commencement of a diversity of funding and industry networking programs, underscore this shift from a focus on academic research to one on industry activation and commercialisation efforts

(DISR, 2023a; Australia's Chief Scientist, 2024). In April 2024, Quantum Australia – a consortium of industry, research and government partners with nodes across the country – was awarded $18.4 million AUD as part of a national effort to "catalyse industry growth, support collaborative research and strengthen Australia's position as a global quantum leader" (DISR, 2024). The institutionalization of a national, strategic approach to commercializing quantum technologies notably includes a RI element associated with one of the National Quantum Strategy's five themes. Theme Five – building a trusted, ethical and inclusive quantum ecosystem – is supported by the claim that the Australian government will "champion responsible innovation" (DISR, 2023a, p.41). At the time of writing, more than 30 countries around the world have established national quantum strategies or plans (Qureca, 2025); Australia's National Quantum Strategy is one of, if not the only, framework to explicitly mention RI.

These strategic initiatives demonstrate a concerted, top-down interest and effort to transition Australia's quantum science and technology expertise to a thriving, responsible, and impactful domestic industry. At the time of writing, this transition is still underway. The majority of quantum knowledge capital remains tethered to academia, and public research organizations and universities remain central actors in the innovation landscape – fostering critical research efforts to advance quantum technological development, providing a skills and talent pipeline, coordinating and collaborating on innovation projects with government and industry actors, and commercializing quantum technology IP developed by academic researchers. The development of a quantum innovation ecosystem is a work in progress and can be understood as the goal of innovation policy related to quantum in Australia. These factors speak to the centrality of knowledge-producing institutions in Australia's current quantum field and justify its characterization as a knowledge ecosystem.

Table 1: Event History

Year	Event
2003	The Australian Research Council (ARC) establishes the first quantum Centres of Excellence (CoEs), bringing researchers from universities across the country together to collaborate around the achievement of fundamental quantum physics problems
2008	QuintessenceLabs, Australia's first quantum company is founded. The company offers quantum-enhanced cybersecurity solutions based on research conducted at the Australian National University's Quantum Optics Group
2012	Establishment of the Australian Research Council (ARC) Centre of Excellence for Engineered Quantum Systems (EQUS)
2015	Formation of Silicon Quantum Computing (SQC) as a spin-off from UNSW to develop a silicon-based quantum computer
2016	Launch of the Australian Quantum Computing Program, a collaboration between UNSW, the University of Melbourne, and other institutions
2017	Investment by Commonwealth Bank of Australia and Telstra in SQC, marking significant commercial interest

2017	Q-CTRL, a quantum start-up specializing in quantum control solutions is formed as a spin-off from The University of Sydney
2017	Formation of Main Sequence Ventures by CSIRO to bridge research and commercialization with a focus on deep tech
2017	Microsoft and University of Sydney forge multi-year quantum computing partnership
2017	The University of Melbourne and IBM establish the IBM Quantum Hub, providing university researchers with cloud access to IBM's quantum computing systems and resources
2018	Quantum physicist and founder of SQC, Michelle Simmons, is awarded as the Australian of the Year
2018	Australian Government invests A$25 million in quantum research through the National Innovation and Science Agenda
2019	Archer Materials begin developing quantum computing chips domestically
2019	Formation of Quantum Brilliance, a spin-off from the Australian National University focused on room-temperature diamond-based quantum computing
2019	Sydney Quantum Academy (SQA) is formed through state funding and in collaboration between Sydney-based universities to develop quantum talent and foster a recognized ecosystem
2019	Formation of the Tech Council of Australia, including a focus on supporting the quantum technology sector
2020	CSIRO releases 'Growing Australia's Quantum Technology Industry' report, outlining a roadmap for quantum technology development and commercialization in Australia
2020	The Australian Quantum Alliance (AQA) is formed through Tech Council Australia (TCA), with both local and global quantum company members
2021	Australian Government allocates A$70 million for quantum technology development as part of the Modern Manufacturing Strategy
2021	The Army publishes their Quantum Technology Roadmap, offering a strategy to develop and retain a strategic security advantage through the exploitation of emerging quantum technologies
2021	The Department of Industry, Science and Resources (DISR) designates quantum as a critical technology in the national interest
2022	Establishment of the National Quantum & Information Science Research Network (NQISRN) to foster university-industry collaboration
2022	Formation of the Quantum Industry Consortium (QuIC) to support commercialization of quantum technologies
2022	The first Quantum Australia conference is hosted by SQA, bringing global and national leaders from research, industry, and government together
2022	The National Quantum Advisory Committee (NQAC) is established to provide strategic advice to the government on growing Australia's quantum sector and help guide the development of the National Quantum Strategy. It is comprised of representatives from industry, academia, public research organizations, and venture capital organizations
2022	The National Quantum Strategy Issues Paper is released, and responses are solicited from the quantum community to create and support a sustainable and thriving quantum ecosystem
2023	The National Quantum Strategy, the federal plan to grow the quantum industry in Australia, is published
2024	Australia's Chief Scientist hosts Quantum Meets workshop series – events that bring producers and potential end-users of quantum technologies together to ideate and discuss sector-specific opportunities for collaboration
2025	The Federal and Queensland governments invest a total of $1B in quantum company PsiQuantum to build the world's first utility-scale quantum computer in Australia
2025	Quantum Australia, a national center supporting growth of the quantum ecosystem, is established through the University of Sydney

While Australia's quantum sector is globally competitive, it is relatively small. The Australian quantum community includes a rich diversity of startups and more established multi-national companies working across quantum computing and sensing hardware, cryptography, software, professional associations, consultancies, venture capital funders, public research organizations, universities, and governmental organizations. Familiarity with this diverse and closeknit community makes for easier access to data. I have several years of experience in Australia as a researcher focused on quantum technologies and their societal impacts. This has provided opportunities to attend and participate in quantum sector events over the years, including annual Quantum Australia conferences, ecosystem-building and responsible innovation workshops.

Attending the national Quantum Australia conferences since the event's inception provided me with a unique insider's perspective into the developing quantum sector in Australia, enabling me to observe how aspects such as national priorities, the focus on academic quantum research versus industry applications, discussions around risk and responsibility, as well as the diversity of participants in attendance (e.g. academia, industry, government) changed over time. Being involved in these spaces has provided a useful knowledge base of quantum technologies and RI and access to information and networks, such as who the relevant actors are and what role(s) they play in the burgeoning quantum technology sector. As such, my experiences with members of Australia's quantum community influenced my subsequent data collection approach.

I was also a panelist and participant at two Quantum Meets workshops, hosted by Australia's Chief Scientists. These workshops bring stakeholders across the ecosystem together, presenting an opportunity for producers and potential end-users of quantum technologies to ideate and discuss sector-specific opportunities for collaboration. In 2021 I presented at a roundtable on RI and quantum in Australia, co-hosted by the Sydney Quantum Academy (SQA) and consulting firm, KPMG. In 2025 I convened a series of four workshops on RI for quantum physics PhD students and professional staff. Participating in these events provided critical insights that shaped my research interests and questions. These experiences, as well as the informal conversations I had with participants, contributed critical insights into the ways in which RI and concepts of risk and responsibility are perceived by actors contributing to Australia's quantum sector across different demographics, which inherently shaped my line of inquiry in this thesis.

1.4 Responsible Innovation: Literature Review and Research Gap

This thesis makes its primary contribution to the field of RI. This section provides context for this contribution by establishing the current state of academic research and identifying the gap this thesis aims to build upon. It argues that where RI seeks to engage commercial innovation actors, it meets the fundamental challenge of managing divergent values and normative commitments amongst stakeholders whose visions of the purpose and meaning of innovation are shaped by competing logics. Though commonly identified, this problem is critically undertheorized in existing literature.

Innovation is an inherently collective endeavour. Bringing a technology from conception to market requires the participation of a diverse range of actors including researchers, entrepreneurs, investors, policymakers, and publics. RI holds that the inclusion of this broader spectrum of actors enables innovation to be steered toward outcomes that are ethically acceptable, societally desirable, and sustainable (Stilgoe et al., 2013). Yet this ambition contains a tension that the literature has not yet adequately resolved: the very diversity of actors RI seeks to engage is also a source of divergent, and often competing, normative commitments (Garst et al., 2017; Blok & Lemmens, 2015). These commitments are not simply given or fixed but are shaped by the distinct institutional and socio-political contexts the actors inhabit, which in turn shapes the lens through which they interpret and engage with the innovation process (Van de Poel et al., 2020; Jakobsen et al., 2019). As such, the technological futures envisioned by diverse innovation actors are variable, contestable, and open to negotiation – a point this thesis develops theoretically in the section that follows. If RI is itself shaped by the actors who enact it, then the challenge of orchestrating RI across a diverse actor landscape is not merely one of coordination. It is a problem of how meaning is negotiated, settled, and potentially transformed across competing normative worlds. It is this problem that this section traces through the existing literature and that this thesis sets out to address.

1.4.1 From RRI to RI: A Contested Conceptual History

By way of introduction to this subject matter, it is fundamentally important to distinguish two entangled discourses in this field that have emerged in parallel since the beginning of the decade – RRI (responsible research and innovation) and RI (responsible innovation). While these terms are sometimes used interchangeably and indeed share much in common conceptually, they have distinct roots and divergent paths. Differentiating these concepts has important implications for the purpose of this research, which focuses on RI rather than RRI. Crucially, the history of the development and divergence of these entangled concepts is itself instructive, as it reveals that what RI means has never been settled; it is continuously produced, contested, and rearticulated through the interactions of the researchers, commercial organizations, policymakers, and practitioners who engage with it (Owen et al., 2021; Owen & Pansera, 2019).

The concept of RRI was developed in the policy-driven environment of the European Commission as an approach to research and innovation governance. Von Schomberg's oft cited definition reveals a broad and transformational ambition: "RRI is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the ethical acceptability, sustainability and societal desirability of the innovation process and its marketable products" (von Schomberg, 2013, p. 63). Proponents of RRI sought to disrupt the dominant macro-economic conceptualization of innovation as "steerless but inherently good", meaning that funding research and innovation will implicitly lead to job creation and economic growth (von Schomberg, 2013, p.12). It was developed to address this by guiding anticipatory practices to enhance reflexivity amongst innovation actors. As such, it aims to position stakeholders as "mutually responsive to each other" (von Schomberg, 2013, p.1) and collectively responsible for innovation outcomes (Owen et al., 2021).

RRI was developed within a specific normative context that gave it coherence. Its development was driven by societal concern for the implications of nanotechnology research in the early 2000s, which revealed frayed public trust in institutional science and a demand for policy action to better address societal concerns in research and innovation agendas (Owen et al., 2021; Schuijff & Dijkstra, 2020; Coenen & Grunwald, 2017). Leaning on the traditions of technology assessment and ethics, RRI emphasizes co-production with and for society through the governance of scientific research. It became linked to the achievement of grand societal challenges and the Sustainable Development Goals – innovation for public good to be addressed through scientific research through its adoption. As such, it critically engages with a motivating question: how can research and innovation contribute to "the right outcomes and impacts" and how should it be channelled toward these objectives (von Schomberg, 2013, p.8)? This perspective highlights the normative dimensions of RRI, which centers democratic, European values as constructive of what is 'right' in the context of innovation. These values are neither neutral nor universal, but the product of a particular institutional and socio-political context in which actors who constructed the RRI agenda were embedded (Blok et al., 2015). They provided a shared normative foundation that gave coherence to the actors working within it and justified the articulation of a collective goal.

RRI was adopted as a central theme in Europe's major research and innovation funding program, Horizon 2020 (Lund Declaration, 2009; Italian Presidency of the Council of the European Union, 2014), which provided more than 300 million Euros to fund several hundred RRI-related projects between 2014 and 2020 (Ivanova et al., 2023). As the concept was filtered through this applied policy lens, six main action lines or 'RRI keys' were developed to guide the concept's implementation. The keys provided a framework for the orchestration of RRI mandates in research projects as well as a standard by which adherence to these could be measured. However, in providing a templated framework for orchestrating RRI mandates, the keys included metrics and concepts that were not previously part of the RRI discourse, such as gender equality, open access, and science education, alongside more resonant concepts such as ethics, public engagement, and governance (Owen et al., 2021). The additional metrics allude to the shaping force of RRI's socio-political context, where these dimensions held pre-existing value. While the adoption and adaptation of RRI into Horizon 2020 imbued the concept with normative cohesion, the keys produced a dominant framing that interpreted RRI as a universal, project-based, and templated approach that was disconnected from its transformational ambition.

As Owen and Pansera (2019) argue, the RRI keys "represented isolated themes rather than a coherent discourse", failing to "substantively engage with innovation, or innovation systems" or offer significant prospects for systemic change (p.27). The normative coherence that gave RRI its distinctive character became less applicable as the concept was applied in new socio-political contexts with differing institutional actors and policy processes (Owen et al., 2021; Ivanova et al., 2023). While the discourse of RRI has spread internationally to some extent – for example, making its way into China's five-year plan on science and technology and the US National Nanotechnology Initiative (Owen et al., 2021) – there is little evidence of the concept being adapted to suit these new environments. Researchers have problematized the transferability of an RRI framework laden with context-specific values and assumptions, noting that conceptualizations of responsibility and innovation tend to vary across geographic locations (Macnaghten et al., 2014). In this sense, the institutionalization of RRI through Horizon 2020 illustrates how the meaning of a concept becomes actively reshaped as it moves across different actor contexts and institutional settings.

As the meaning of RRI became contested, it produced offshoots and rearticulations as researchers sought to recover von Schomberg's influential vision and apply their interpretations in new contexts. (Owen et al., 2021). The fragmented scholarly domain on RRI demonstrates that no single, authoritative account has prevailed. Rather, diverse actors (including the author of this thesis) continue to construct and reconstruct its meaning in line with their own normative commitments, intellectual traditions, and institutional positions (Owen & Pansera, 2019; Blok & Lemmens, 2015). RI can be understood as one such rearticulation, formulated in parallel during this period by researchers from the field of STS (Stilgoe et al., 2013). Compared to the policy backdrop of RRI, the origins of RI are decidedly academic, built on research foundations drawing from the social responsibility of science (Genus & Stirling, 2018), anticipatory governance (Guston, 2014; Urueña, 2021; 2022), ELSA/ELSI frameworks, technology assessment (Grunwald, 2011; Genus & Coles, 2005), and social innovation (Lubberink et al., 2017).

Stilgoe et al. (2013) presented a framework for RI developed around four dimensions — anticipation, inclusivity, reflexivity, and responsiveness (see **Table 2** below for a summary of these dimensions). The researchers emphasize a prospective notion of responsibility by defining the objective of RI as "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013, p.1570). In contrast to RRI, which has been implemented predominantly in a pre-commercial, publicly funded research context (Jakobsen et al., 2019), RI engages more deliberately with the fundamental challenge of shaping market-led innovation. It seeks to expand the spectrum of participation beyond academic research and development actors, extending the scope of legitimate actors to include entrepreneurs, businesses, policymakers, public institutions, and research funding agencies (Jakobsen et al., 2019). In doing so, RI ambitiously aims to extend RRI to the commercial domain.

Table 2: Dimensions of RI (Stilgoe et al., 2013)

Dimension	Application
Anticipation	Explore alternative futures and plausible outcomes of science research and technologies through their intended and unintended consequences.
Inclusivity	Create forums for deliberation for diverse stakeholders to bring their experiential and empirical knowledge to bear on the directions of innovation activities.
Reflexivity	Innovation actors consider their underlying motives, assumptions, biases, and perspectives that motivate innovation activities.
Responsiveness	The capacity of innovation actors to decide on a different approach after acquiring new knowledge (for example, after learning from other actors included in the innovation process).

However, to achieve this ambition, RI must reckon with a persistent question: how should the differing values and normative commitments that shape the perspectives and practices of a broader range of innovation actors be managed to advance RI as a collective pursuit? Where RRI operated within a shared normative framework anchored in European democratic values, however contested that framework became, RI reaches toward a far more diverse actor landscape. As opposed to the research policy environment, a commercial innovation context does not have an equivalent normative scaffolding to hold its participants in alignment (Blok & Lemmens, 2015; Van de Poel et al., 2020). The challenge of stabilizing the meaning of RI across the competing institutional logics of commercial innovation presents a considerable challenge that requires scholarly attention.

A further, less explored stream in RI research deals directly with these normative dimensions and their context-dependence. Stilgoe et al. (2013) acknowledge that their framework reflects "second-order normative commitments to democratisation" (p.1577), noting that most RI activities take place in Western Europe, stemming from European Union and public institutional funding. As the history of RRI's institutionalization demonstrates, the values it was anchored in were specific to driving European Union research policy – relevant to the context of the existing societal concerns and policy motivations of that time and place. As discussed, these values and norms are neither neutral nor universal. The researchers comment, almost as an aside, that "in different areas of innovation, and in different cultural contexts, different values will be more or less pertinent, and they may be conflicted" (Stilgoe et al., 2013, p.1577). As Macnaghten et al. (2014) argue more directly, "RI is interpretively flexible, culturally framed and politically entangled" (p.193). This view leads to the logic that for approaches to operationalizing RI to be effective, its normative dimensions must be re-articulated in the context of the politics, culture, and practices of its intended site of application. This challenge becomes considerably more acute when that site is a commercialization context shaped by market logics rather than European research policy. It is in this context that the existing literature on RI in commercial settings must be examined.

1.4.2 RI in Commercialization Contexts: The Orchestration Problem

The case for applying RI in commercial contexts is well founded in the literature. Recent research confirms organization-level interest in RI, citing existing incentives for its uptake. These include the personal values of CEOs (Ko & Kim, 2020; Auer & Jarmai, 2018), the normative expectations of employees (Gurzawska et al., 2017), and the shifting discourse around the role of commercial organizations in society (Dreyer et al., 2020; Scherer & Voegtlin, 2020). Garst et al. (2017) explore firms' motivations for targeting socially responsible innovation outcomes, finding that commercial actors are motivated both by instrumental motives such as profit, regulatory compliance, and maintaining legitimacy, as well as by moral motives relating to business purpose and employee expectations. Logics such as corporate social responsibility (CSR), and social and sustainable innovation have been identified as providing a business case for advancing RI in commercial settings (Jarmai et al., 2020; Lubberink et al., 2017). Van de Poel et al. (2020) further argue that the non-linear nature of innovation and the uncertainty of technological outcomes demand RI methods that target the inclusion of a broader diversity of stakeholders.

Critically, researchers argue that understanding context, including values and norms at a national, industry, and firm level, plays an important role in incentivising the uptake of RI (Gurzawska et al., 2017; Garst et al., 2017; Van de Poel et al., 2020). While the concept of RI rarely surfaces explicitly in the discourse of responsibility in organisational studies, studies identify that practices and processes related to RI occur regularly across a diversity of organisational practices, including stakeholder engagement and anticipating innovation outcomes (Auer & Jarmai, 2018; Martinuzzi et al., 2018). These findings suggest that while the framework of RI has not holistically penetrated the industry sector, the concept's logic, practices, and processes are at least partially resonant in a commercial context. Yet these ground-level motivations do not resolve a more fundamental problem: the logic and structure of research ethics that provides coherence for actors working in pre-commercial innovation contexts is not transferable to commercial settings. Further, the values that enable coherence in academic settings are precisely the values that commercial logics are most hostile to.

Empirical studies reveal that RI has had limited penetration in private companies and entrepreneurial ventures due to competing values and normative commitments (Gurzawska et al., 2017; Blok et al., 2015). This is not simply a matter of implementation but reveals a structural misfit between the normative architecture of RI and the institutional logics of commercial innovation. While RI establishes that "innovations should be steered toward (ethical) acceptability, societal desirability and sustainability" (Lubberink et al., 2019, p.182), a firm's responsibility is tethered predominantly to profit-making and shareholder interests (Scherer & Voegtlin, 2020). Likewise, the inclusion of diverse stakeholders through meaningful deliberation is a central tenet of RI aimed at 'opening up' the innovation process to enable reflexivity and collective responsibility over outcomes (von Schomberg, 2013; Stilgoe et al., 2013; Blok et al., 2015). This is not common practice in commercial settings, where it can lead to a loss of competitive advantage produced by information asymmetries (Flipse, 2013) and conflicts that critically hamper efficiency in fast-paced emerging technology markets (Scherer & Voegtlin, 2020).

What this body of literature reveals, when read together, is far deeper than an implementation challenge. It poses a deeper theoretical problem related to the normative commitments that different actors bring to the innovation process, which are shaped by their distinct institutional contexts. In commercial settings, these competing values, norms, and priorities actively inhibit the enactment of collective stewardship demanded by RI. Further, the challenge is not simply that commercial actors lack awareness of RI or the tools to enact it, it is that their values, incentives, and understandings of responsibility are constructed differently, in ways that challenge alignment, particularly with other societal actors. As researchers argue, "concrete guidance for the business sector or individual corporations acting within [the RI] paradigm is still missing" (Ivanova et al., 2023, p.4). This thesis argues that the reason this guidance has proven so elusive, despite the fragmented approaches offered by RI researchers, is that it cannot be developed without first grappling with the divergent normative commitments of the actors it seeks to coordinate.

This leads directly to what this thesis identifies as the central undertheorized problem in the RI literature: the orchestration of RI across actors with divergent values and normative commitments. While the coordination of stakeholders around RI activities is implicit in the framework offered by Stilgoe et al. (2013), the literature has not adequately resolved how this coordination can be achieved when the actors involved hold fundamentally different orientations toward innovation. The implementation-focused research provides some guidance as to how this can be facilitated. Van de Poel et al. (2017; 2020) highlight how existing corporate practices such as CSR can provide tools for integrating societal values in innovation processes; Da Silva et al. (2019) find that stakeholder engagement is most often initiated by academic researchers and tends to occur in later phases of innovation; Bacq and Aguilera (2022) propose frameworks for stakeholder governance centred on value allocation through deliberation amongst actors with differing levels of power. Yet as Scherer and Voegtlin (2020) argue, "responsible governance requires governance structures at various levels that facilitate an inclusive process of collective will formation on the goals and means and the societal acceptability of innovations" (p.6). These structures remain underspecified.

Lacking the centralized, top-down policy mechanism of Horizon 2020 and the templated framework of the RRI keys, mechanisms for the application of RI in commercialization contexts tend to be decentralized and dispersed. As a result, the body of literature in this domain is comprised largely of fragmented empirical studies that take the dimensions offered by Stilgoe et al. (2013) as a starting point, without resolving the question of how divergent actor values can be brought into productive alignment. In short, the orchestration problem is not merely one of coordination or implementation, but a problem of how meaning is negotiated across competing institutional logics and normative worlds, and a question of who bears responsibility for facilitating that negotiation.

1.4.3 Knowledge Ecosystems: A Site for RI Orchestration

As mentioned in the introduction, ecosystem-level approaches to RI have begun to gain traction in the literature. The findings from this small body of literature sharpen the orchestration problem this thesis sets out to address. Advocates of an ecosystemic approach argue that RI "cannot be implemented in isolation" but must be "anchored in an ecosystem of stakeholders comprising government, citizens, academia and business, each playing its role and assuming its responsibility" (Dreyer et al., 2020, p.2). Foley and Wiek (2017) find that while traditional triple helix stakeholders (academia, industry, and government) are well connected within innovation ecosystems, actors representing societal interests remain weakly connected. They argue that enacting RI demands on an ecosystem level requires coordinating efforts to build bridges between core and peripheral stakeholders. Smolka and Böschen (2023) likewise identify the critical need for the coordination of engagement activities for RI to be activated on an ecosystem level, advocating for consideration of "power dynamics within the system and the real-world political contexts in which the system is embedded" (p.19). Dreyer et al. (2020) emphasize the need for RI managers to support and guide stakeholders with differing values to steer the innovation process toward sustainable and societally acceptable outcomes. Taken together, these studies confirm that the orchestration of RI on a system level is both necessary and an unresolved challenge, and that the divergent values of innovation actors within ecosystems are central to why this remains so difficult.

In contrast to the innovation ecosystem lens widely adopted to interrogate ecosystem-level RI (see for example Stahl, 2022; Foley & Wiek, 2017; Dreyer et al., 2020; Smolka & Böschen, 2023), this thesis argues that knowledge ecosystems represent an important and underexplored site for theorizing how RI might be orchestrated as scientific knowledge, capabilities, and academic actors become involved in the commercialization of emerging technologies. Knowledge ecosystems are collectives "in which actors such as universities, public research institutions, and for-profit firms collaborate to create new knowledge in a pre-competitive setting" (Järvi et al., 2018, p.1523). They include a notably diverse actor configuration of universities and public and private research institutions alongside established firms, small technology firms, incubators and makerspaces, governments, and policymakers (Rådberg & Löfsten, 2023; Shi & Chen, 2022). These actors are linked through relationships of knowledge exchange, resource interdependence, and shared orientation toward complex, often grand challenge-style problems (Clarysse et al., 2014; Dougherty & Dunne, 2011; Järvi et al., 2018). The specific actor configuration of knowledge ecosystems makes them a particularly productive site for studying how RI can be transitioned from academic to commercial settings. The central role of universities and research institutions provides a critical link between RRI's research policy context and the commercial environment RI targets, introducing in-built requirements for the inclusion of diverse stakeholder perspectives and reflexivity in the pursuit of co-creating new knowledge (Järvi et al., 2018; Shi & Chen, 2022; Carayannis & Campbell, 2009).

Knowledge ecosystems are pre-competitive and pre-commercialization, meaning they are further upstream in the innovation process than innovation and business ecosystems, which are specifically concerned with commercialization activities (Järvi et al., 2018; Perkmann & Schildt, 2015; Valkokari, 2015). As such, knowledge ecosystems are not governed exclusively by market logics. Further, the presence of academic actors, public institutions, and intermediaries introduces a plurality of normative orientations that more closely approximates the diverse actor landscape RI envisions (van der Borgh et al., 2012; Cobbens et al., 2022). Crucially, their orientation around mobilizing a diversity of research and commercial innovation actors to address complex, societally significant issues that resist resolution by any single actor or sector alone provides a degree of shared normative purpose that purely commercial contexts lack (Dougherty & Dunne, 2011; Fiandrino et al., 2025). This is a useful lens for the study of RI, as it calls for diverse innovation actors to coalesce around a shared objective (Pandza & Ellwood, 2013).

The shared orientation offered by the construct of knowledge ecosystems does not dissolve the divergence of actor values. It does, however, create the conditions through which those values may be brought into conversation with one another, providing a vehicle for the meaning of RI itself to be collectively negotiated rather than unilaterally imposed. Knowledge ecosystems therefore offer not a solution to the orchestration problem but a productive site within which it can be examined. In knowledge ecosystems, the tensions between academic and commercial logics and between collective stewardship and market imperatives are present and observable. As such, knowledge ecosystems, with their pre-commercial positioning, their inclusion of both academic and commercial actors, and their orientation around complex societal challenges, provide an important site for theorizing how the dynamics of normative alignment can be orchestrated in line with the collective pursuit of RI.

This thesis pursues two related avenues that emerge from this body of literature. The first concerns the socio-political expectations and contested visions that drive innovation processes within knowledge ecosystems. This thesis traces this thread through the concept of hyped discourse and socio-technical imaginaries, introduced in the theoretical section that follows. The second is the more practical question of ecosystem orchestration, which is variously referred to as governance, management, and coordination in the literature. Specifically, this thesis takes orchestration as a socially constructed process itself and interrogates how RI can be positioned and orchestrated as a dynamic, negotiated process amongst actors with divergent values. Applying these constructs to RI requires a theoretical perspective that can account for the ways in which meaning, values, and normative commitments are formed, contested, and negotiated through social interaction. It is to this theoretical gap that this thesis now turns.

1.5 Theory

This thesis is grounded in a social constructionist theoretical perspective. Broadly, social constructionism is the view that "all knowledge and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (Crotty, 1998, p.42). As the term suggests, this perspective holds that human beings construct meanings rather than discover or create them. The 'social' dimension emphasizes that humans are embedded in cultures and institutions that shape the ways in which they interpret the world around them. Where constructivism tends to focus on the individual's cognitive construction of knowledge through experience, social constructionism extends this by arguing that humans are born into a world of meaning that precedes them. These provide a "publicly available system of intelligibility" (Fish, 1990, p.186) produced collectively through language, interaction, and social practice.

This distinction is consequential for the study of innovation, as it shifts the analytical focus from individual actors and their cognitive orientations toward the intersubjective, institutionally embedded processes through which meaning is collectively produced, contested, and stabilized. As Berger and Luckmann (1966) argue in their foundational account, reality is socially constructed through the ongoing interactions of human actors whose shared understandings, categories, and institutional practices solidify over time into structures that appear objective and given, yet remain, in principle, open to transformation through social action. This thesis operationalizes this perspective through three interconnected theoretical concepts: the social construction of technology, socio-technical imaginaries, and hyped discourse. Each of these illuminates a different dimension of how the meaning of RI is constructed, contested, and negotiated.

The social constructionist epistemological position also has direct implications for how this thesis conceptualizes RI. It considers that the meaning of RI is not fixed or given but continuously (re)produced through the interactions of the diverse actors who engage with it. It follows that to understand how RI operates in a given context requires attending to the social processes through which its meaning is constructed, contested, and potentially stabilized. This foundational perspective reframes the challenge of orchestrating RI not as an implementation problem, as much of the research has theorized by taking RI as a pre-defined framework, but as a problem of meaning-making across competing normative worlds.

1.5.1 Social Constructionism and RI

The relationship between social constructionism and RI is more formative than the existing literature has explicitly acknowledged. As van Oudheusden (2014) observes, "the RI conception of technological change builds on social constructivist studies of science and technology, such as anticipatory governance, upstream public engagement, and technology assessment" (p.71).[1] Social constructionism, as van Oudheusden argues, is constitutive of RI's intellectual foundations. RI shares with STS "a critical stance regarding the relationships and dynamics between science, innovation, politics and society", and it is "RI's second order reflections on not just science and

[1] Van Oudheusden (2014) employs the term "social constructivist" rather than "social constructionist". As discussed above, this thesis draws a deliberate distinction between these positions, adopting social constructionism with its emphasis on the intersubjective, institutionally embedded, and collectively produced nature of meaning as the more appropriate epistemological foundation for studying how the meaning of RI is constructed across diverse actor landscapes. Still, van Oudheusden's observations about RI's intellectual roots are directly pertinent, as they confirm that the constructionist tradition this thesis makes explicit has always been implicit in RI's theoretical foundations.

technology but innovation and innovation systems that prompt and invite a more critical discussion on the notion of innovation itself" (Owen & Pansera, 2019, p.42). However, while RI may be "steeped in the philosophy of deliberative democracy and in social constructivist approaches of science" (p.80), it has not been explicitly theorized as such.

Despite these constructionist roots, a systematic social constructionist analysis of RI has not been undertaken. Van Oudheusden (2014) notes that RI views "scientific knowledge as a social construct rather than as a historical or epistemic given" but does not develop this insight into an explicit theoretical framework. Owen and Pansera (2019) identify that "socio-political contexts cannot be assumed, vary geographically, and are often nuanced" (p.41), recognizing that the meaning of RI is context-dependent and shaped by the institutional and political environments in which it is enacted, but stop short of theorizing the mechanisms through which this context-dependence operates. The closest existing work in this direction is Randles (2017), who draws attention to the literature on legitimacy construction and the dynamics of organisational change, examining how value systems move from articulation through visions to routine performance in practice. This work opens an important avenue but remains at the level of institutional analysis rather than developing a fully social constructionist theoretical framework for RI.

This gap is particularly relevant in relation to a systemic perspective on RI. As Owen and Pansera (2019) note: "to date, there has been very little research or scholarship at the intersection of RI and innovation systems" (p.42). They argue that "any consideration of the transition to a responsible innovation system cannot be divorced from a consideration of its political and ideological imaginaries, visions and assumptions" and offer a call to action: "these [considerations] need to be opened up for scrutiny and explored in far greater detail" (Owen and Pansera, 2019, p.43). Macnaghten et al. (2014) similarly position RI as "...interpretively flexible, culturally framed and politically entangled" (p.193). This claim is fundamentally a social constructionist perspective yet has not been developed into an analytical framework for examining how RI's meaning is constructed and negotiated in practice. Finally, Pandza and Ellwood (2013) gesture toward this gap most directly, arguing that understanding how RI can be operationalized requires a focus on "agents and their embeddedness into social interactions" (p.1113), which motivates the social constructionist analysis this thesis undertakes.

This thesis responds to these calls by bringing social constructionism to RI explicitly and systematically, developing a theoretical framework that can account for how the meaning of RI is constructed, contested, and negotiated across the diverse actor landscapes. It does so through the three interconnected theoretical concepts of the social construction of technology, socio-technical imaginaries, and hyped discourse – each of which operationalizes a different dimension of the social constructionist perspective in relation to RI. Together, these concepts form a layered analytical framework that moves from the broadest epistemological foundation to the specific discursive mechanisms through which RI's meaning is enacted in practice. This framework underpins the three papers of this thesis. Paper One examines how hyped discourse constructs and mobilizes competing visions of responsible technological futures in Australia's quantum knowledge ecosystem; Paper Two analyzes identifies how the contested stakeholder visions produced through discursive constructions are moved to a state of co-production to stabilize a collective socio-technical imaginary of responsible quantum innovation; and Paper Three develops a thought experiment for how ecosystem orchestrators can work with the dynamics of divergent normative commitments to foster shared meaning and collective responsibility for RI. The theoretical basis for each of these papers is developed in the sections that follow.

1.5.2 The Social Construction of Technology

The social construction of technology (SCOT) approach stemming from the field of STS connects social constructionism to the study of technology and innovation. It forms the theoretical backbone of this thesis' positioning of RI as a sociotechnical phenomenon itself. SCOT emerged in the late 1970s as a response to the limitations of conceptualizing technological innovation as a neutral, linear process of development and diffusion (Godin, 2006). It maintains that technologies are not objective, pre-determined objects, but rather, artifacts shaped by social, political, and cultural forces. As Pinch and Bijker (1984) argue, the development of a technology cannot be understood by examining the artifact itself in isolation. It must be understood as constructed through the social processes by which its meaning and form are negotiated amongst the diverse actors involved in its development. This ontological position directly extends the social constructionist perspective established above. Just as social reality is produced through human interaction and institutionalized over time, so too are technologies. Their meanings, uses, and developmental trajectories are outcomes of particular social processes rather than properties inherent to the artifacts themselves.

SCOT conceptualizes technological development through three core concepts. The first is that of relevant social groups. These are the diverse actors and collectives who share distinct interpretations of a technology and innovation, and whose interactions shape its development (Pinch & Bijker, 1984). Relevant social groups do not just respond to a technology as a fixed object, but actively participate in constructing its meaning, function, and purpose. Different social groups may hold entirely different understandings of the purpose of innovation, what a technology should be for, and what problems it should solve. These understandings reflect the distinct institutional contexts and normative commitments those groups inhabit (Klein & Kleinman, 2002). Winner (1980) critically identifies that different groups also wield differing levels of power, and these dynamics become embedded in the outcomes of technological design. The composition of relevant social groups is therefore never neutral, and always a reflection of broader social and political relations.

The second concept is interpretive flexibility. This holds that technological artifacts are open to multiple, competing interpretations by different social groups (Pinch & Bijker, 1984, p.409). Specifically, interpretive flexibility is relevant to the condition of a technology in the early stages of its development, when its meaning and form have not yet been settled. It describes how different relevant social groups may understand it in fundamentally different ways, attribute different problems to it, and envision different solutions. This multiplicity of interpretations reveals the "broad range of demands and desires that are packed into technical developments of various kinds" (Winner, 1993, p.372). The concept of interpretive flexibility is particularly generative for this thesis. It provides a theoretical basis for understanding how the meaning of RI remains open to multiple, competing interpretations across the diverse actor landscape of a knowledge ecosystem.

The third concept is stabilization and closure. This describes the process by which interpretive flexibility is collapsed, and a dominant interpretation of a technology becomes established (Pinch & Bijker, 1984; Prell, 2009). Closure occurs when contestation between relevant social groups resolves into a settled configuration and a particular interpretation of a technology comes to be accepted as natural or given. This process is not purely technical but fundamentally social. Closure is achieved through negotiation, power dynamics, rhetoric, and the mobilization of institutional resources, rather than through the inherent properties of the technology itself (Klein & Kleinman, 2002). Importantly, stabilization is always provisional. A settled configuration can be destabilized when new relevant social groups enter the field, when socio-political contexts shift, or when the assumptions underpinning a dominant interpretation are challenged. The underlying assumption of SCOT is therefore that the technology design process is non-deterministic. It can produce any number of different outcomes depending on the social circumstances of a technology's development (Klein & Kleinman, 2022).

Together, these three concepts provide a powerful analytical framework for examining how RI undergoes processes of interpretive flexibility, negotiation, and provisional stabilization across different institutional and socio-political contexts. Yet SCOT, in its original formulation, operates primarily at the level of discrete technological artifacts by studying the social dynamics of the actors directly involved in their development. Understanding how the broader visions and normative commitments that animate innovation at a collective level shape the construction of RI requires an analytical concept that operates at a higher level of abstraction. It must be capable of capturing the collectively held imaginaries of desirable technological futures within which specific acts of construction and contestation are embedded.

1.5.3 Socio-Technical Imaginaries

The concept of socio-technical imaginaries offers an analytical framework for examining the relationship between science and innovation policy and culture, as well as the normative dimensions surrounding technological design (Jasanoff et al., 2007). Socio-technical imaginaries are defined as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff, 2015, p.4). The concept stems from the anthropology of science and technology, originating in Marcus' (1995) notion of technoscientific imaginaries. Marcus draws attention to how the imaginaries of scientists are tied to their current positionings, practices, and institutional locations. Jasanoff and Kim (2009) expand this concept to include other societal groups beyond scientists, coining the term socio-technical imaginaries and developing the analytical approach of cross-national comparison. Their work emphasizes how national endeavours in science and technology align with specific conceptions of nationhood (Hendriks et al., 2025), offering a tool for interrogating the socio-political dynamics that contribute to the production of innovation processes.

Socio-technical imaginaries are both normative and performative. They are "at once descriptive of attainable futures and prescriptive of the kinds of futures that ought to be attained" (Jasanoff & Kim, 2013, p.1). As Mager and Katzenbach (2020) explain, "by guiding the making of things and services to come, imaginations of the future are co-producing the very future they envision" (p.1). Imaginaries are not simply abstract or speculative visions. They are materially and discursively enacted through policies, scientific agendas, and public discourse from a range of state and non-state actors (Mager & Katzenbach, 2020). As Jasanoff and Kim (2009) highlight, science and technology policies provide unique sites for exploring how political culture and practices stabilize particular imaginaries, and how technological trajectories come to be represented as being in the national interest.

The process of future-making through imaginaries is neither linear nor straightforward. Multiple stakeholder groups can hold competing visions of socio-technical futures that embody differing values, priorities, and pathways for technological development (Jasanoff, 2015; Higham, 2019; Augustine et al., 2019). These tensions are not necessarily obstacles, as they can be productive and generative, revealing the power dynamics, implicit assumptions, and normative commitments of different stakeholder groups (Mager, 2017; Jasanoff, 2015). Jasanoff (2015) suggests that such tensions can lead to co-productive relationships. Co-production refers to "the constant interplay of the cognitive, the material, the social and the normative" (Jasanoff, 2004, p.38). Through co-production, competing imaginaries can move from a state of contestation toward communal adoption and institutional embedding. The ways in which different imaginaries compete or coexist therefore influence the direction, governance, and legitimacy of emerging innovation fields (Jasanoff, 2015; Jasanoff & Kim, 2013).

The performativity of socio-technical imaginaries is particularly significant for the governance of innovation. As Konrad and Böhle (2019) argue, "the performativity of socio-technical imaginaries needs to be considered when studying the governance of innovation and transformation processes" (p.105). Imaginaries are embedded in specific practices and contexts that manifest collectively held expectations and promises as they unfold over time. They influence the developmental trajectories of emerging technologies as they circulate amongst policy actors and others contributing to the shaping of innovation (Konrad & Böhle, 2019).

Despite this relevance, the concept of socio-technical imaginaries does not feature prominently in the RI literature. While there is conceptual recognition that RI is situated within specific socio-technical imaginaries (Stilgoe et al., 2013; Genus & Iskandarova, 2018), little empirical work has examined how RI interacts with them. This is a notable gap given the centrality of future-making to RI itself. The definition of RI offered by Stilgoe et al. (2013) is illustrative of this future-oriented notion: "taking care of the future through collective stewardship of science and innovation in the present" (p.1570). Likewise, the anticipation dimension of RI is explicitly associated with prospective tools and practices aimed at improving technological foresight (Guston, 2014; Genus & Iskandarova, 2018; Urueña, 2021). As Owen and Pansera (2019) argue, any consideration of responsible innovation systems cannot be divorced from their political and ideological imaginaries. This thesis responds to that call directly by analyzing RI in the context of socio-technical imaginaries.

Bringing socio-technical imaginaries into conversation with RI addresses two related challenges surfaced in the literature. First, it sheds light on the ways in which ethical, social, and political commitments contribute to unique formulations of innovation systems across different contexts (Jasanoff et al., 2007). This is pertinent to understanding the normative dimensions of RI as a barrier to its transfer across differing innovation contexts. Second, the theory of socio-technical imaginaries provides a vehicle for exploring how individual identities shape and are shaped by participation in collectives (Hendriks et al., 2025). This is directly relevant to questions of stakeholder coordination and collective responsibility in RI. Examining the values and priorities that define the identities of diverse innovation actors is critical to developing collective co-responsibility in RI. This section now turns to hype as a discursive analytic mechanism for understanding how imaginaries become mobilized in practice.

1.5.4 Hyped Discourse as an Analytical Mechanism

Discourse plays a central role in the social shaping how a technological artifact's meaning is contested and eventually settled by relevant social groups (Frohman, 1994). Discourses produce the ideas, categories, and connections through which actors relate to one another and to the wider context in which they operate (Grant & Hardy, 2004). The narratives constructed around an emerging technology tend to favour certain social groups over others, creating and constraining specific possibilities and outcomes (Maguire & Hardy, 2006; Deetz & Mumby, 1990). Different social groups engage in discursive struggle to bring about a normative meaning of a technological artifact that provides a strategic advantage for that group. The social construction of technology is thus acted out on "discursive terrain" (Frohman, 1994, p.5). As such, discursive practices provide a tool for understanding how certain meanings become attached to technologies and influence their developmental trajectories.

The concept of hype provides a particularly productive entry point into understanding how visions of technological futures are discursively enacted. As Groves (2013) posits, "future narratives are always constructed around promises connected to particular technological capabilities" (p.191). Discourses of emerging technologies tend to include an element of hype (Petersen et al., 2017). Hype has been defined as "a collective vision and promise of a possible future, around which attention, excitement, and expectations increase over time" (Logue & Grimes, 2022, p.1055). It can be employed at a range of scales, from the individual entrepreneur to a national or global level. Constructivist perspectives on hype emphasize the performative manner in which hyped expectations "influence the momentum of the technology development" (Kriechbaum et al., 2021, p.3). As a mode of discourse, it also reveals the socio-political expectations about innovation and guides material scientific and technological activity (Borup et al., 2006). In this sense, hyping shapes both the pace and path of emerging technology development.

Drawing on the sociology of expectations (Borup et al., 2006; Brown & Michael, 2003; van Lente et al., 2013), hype can be understood as a key expectation-building mechanism. In this tradition, imagined futures are performed through the mobilization of resources, the orientation of action, and the legitimization of innovation's purpose and meaning. Hyping imbues specific values to emerging technologies through the work of powerful coalitions (Kriechbaum et al., 2021). It links the meaning of technologies to societal imperatives to attract capital, talent, and attention (Berube, 2006; Ometto et al., 2023; Van Lente et al., 2013). These linkages can have lasting impacts on innovation trajectories, even as hype diminishes (Bakker, 2010; Ruef & Markard, 2010). In this way, hyping contributes to forming a collective vision for the future and constructing a scientific imaginary that has material impacts on the developmental trajectories of technological innovation (Fujimura, 2003; Coenen & Grunwald, 2017; Olson, 2019).

The ways in which hype is discursively employed to shape concepts such as risk and responsibility can be understood as a symptom of socio-technical imaginaries at play. This thesis takes hyping as a mode of discourse that produces a state of increasingly exaggerated expectations (Caulfield & Condit, 2012; Funk, 2019; Logue & Grimes, 2022; Pontikes & Barnett, 2017). This perspective enables an interrogation into how hype drives the process of technological innovation and development (Roberson, 2020; Yakura, 2002) by shaping perceptions and directing resources (Logue & Grimes, 2022).

This thesis employs hyped discourse as the primary analytical mechanism for Paper One. Drawing on interviews with ecosystem actors, media coverage, public funding announcements, and strategic documents from Australia's quantum ecosystem, Paper One examines how hyped discourse constructs competing visions of technological futures. Specifically, it attends to how different relevant social groups within the ecosystem deploy hyped narratives to advance particular understandings of the meaning of quantum innovation, who it serves, and what counts as responsible development. In tracing these discursive constructions across multiple data sources, Paper One reveals the normative commitments and socio-political expectations embedded in Australia's quantum innovation discourse and surfaces how these shape the conditions under which RI must be negotiated. The findings of Paper One provide the empirical foundation for Paper Two's analysis of how competing visions can enter a state of co-production to form a collective socio-technical imaginary of responsible quantum innovation.

1.5.5 The Social Construction of Knowledge Ecosystems and Orchestration

Knowledge ecosystems present a particularly productive site for a social constructionist analysis of RI. The coexistence of academic and commercial actors within a shared but normatively pluralistic environment means that the processes of interpretive flexibility, contestation, and provisional stabilization that SCOT describes are not only present but observable. Likewise, the orientation of knowledge ecosystems around grand challenge-style problems provides a degree of shared normative purpose that creates the conditions for collective negotiation of meaning, surfacing the divergence of actor values that make such negotiation necessary.

The concept of orchestration in knowledge ecosystems has stabilized around a particular meaning in the existing literature. Because the complex challenges that define knowledge ecosystems as a system-level goal tend to be abstract and ill-defined, orchestration is understood as a facilitative rather than directive function. It aligns the incentives and cognitions of diverse actors to enable joint knowledge creation without restricting the exploratory search that knowledge ecosystems depend on (Järvi et al., 2018; Valkokari, 2015; Garud et al., 2008). Formalized, centralized, and hierarchical orchestration is understandably resisted in this context, as it is interpreted as a control mechanism that limits the fluidity and flexibility required for inter-organizational exploration (Cobbens et al., 2022; Shi & Chen, 2022). Applying a SCOT perspective to orchestration in knowledge ecosystems positions it as stabilized interpretation rather than an inherent property of orchestration itself. As such, this interpretation reflects a specific set of values such as openness, distributed agency, exploratory freedom that have become dominant in the knowledge ecosystem literature. Like any stabilized construction, it forecloses certain possibilities. In particular, it offers little purchase on the question of how ecosystem actors can be guided toward shared normative commitments around a goal such as RI, where the the pursuit of knowledge creation requires alignment between divergent values.

This thesis argues that orchestration itself must be understood as a socially constructed process. In the existing literature, orchestration tends to be treated as a functional coordinating role, denoting a set of activities and responsibilities to be assigned and measured. This framing takes the meaning of orchestration as a given. A social constructionist perspective challenges this assumption. It enables questions around what counts as legitimate orchestration, who has the authority to orchestrate, what methods are appropriate, and toward what ends. In this sense, orchestration is constructed through the same processes of interpretive flexibility, contestation, and provisional stabilization that shape the meaning of RI itself. The values, institutional positions, and socio-technical imaginaries that ecosystem actors bring to the innovation process actively shape what orchestration looks like in practice, and whose vision of responsible innovation it serves. Treating orchestration as socially constructed therefore opens up questions about power, legitimacy, normative alignment, and the conditions under which shared commitment to RI can be collectively produced rather than hierarchically imposed.

This reframing has direct implications for Paper Three. Rather than treating orchestration as a pre-defined construct, Paper Three treats orchestration as an emergent, negotiated process. It theorizes how ecosystem orchestrators can work with the divergent values and normative commitments of knowledge ecosystem actors to construct the conditions under which RI becomes a shared and sustained commitment. Based on this interpretation, it develops propositions grounded in the RI and knowledge ecosystem literatures through a thought experiment that takes actor divergence as its starting point.

1.5.6 An Integrated Theoretical Framework

Together, the theoretical concepts developed in this chapter form a layered analytical framework for the thesis as a whole. Social constructionism establishes the epistemological foundation: the meaning of RI is not fixed but produced through human interaction and shaped by institutional and socio-political contexts. SCOT connects this foundation to the study of technology and innovation, offering the concepts of relevant social groups, interpretive flexibility, and stabilization that make the constructionist perspective empirically tractable. Socio-technical imaginaries extend this to the collective level, providing a lens for examining how shared visions of responsible technological futures are constructed, contested, and stabilized across actor groups. Hyped discourse provides the specific discursive mechanism through which those imaginaries are established in emerging technology contexts. Finally, the knowledge ecosystem provides the unit of analysis through which these concepts are applied, as a site where the tensions between academic and commercial logics and between collective stewardship and market imperatives are open to theoretical interrogation. Crucially, this framework does not treat orchestration as a fixed or neutral function. It positions orchestration itself as a social construction whose meaning is open to reinterpretation. As such, it proposes that orchestrating RI within a knowledge ecosystem, rather than orchestrating the ecosystem itself, is both theoretically defensible and practically necessary.

Paper One examines hyped discourse in Australia's quantum ecosystem. Paper Two examines the socio-technical imaginaries that animate and contest responsible quantum innovation within it. Paper Three develops a novel conceptual framework for the orchestration of RI as an emergent, negotiated process within knowledge ecosystems. Read together, these three papers advance a systematic social constructionist analysis of RI, responding directly to the calls made in the existing literature and opening new ground for both theory and practice.

1.6 Summary of Papers

Paper One: Risk and the discursive construction of quantum technologies in Australia: How geopolitical and economic threats are used in hyping emerging technologies

Taking SCOT as a starting point for understanding the social construction of emerging technologies, Paper One uses a discourse analytical approach to interrogate how concepts of risk and responsibility are employed in the hyping of quantum technologies in Australia's quantum sector. This paper analyzes historical textual data from Australian business- and finance-focused media, as well as documents generated by ecosystem actors generated between 2012-2024. It also analyzes data from 37 interviews with a range of participants in Australia's quantum ecosystem, collected in late 2023 and early 2024, just before and after the release of Australia's National Quantum Strategy. This paper presents a longitudinal case history of Australia's emerging quantum ecosystem. It finds a prominent contestation between concepts of risk and responsibility that unfolds over time through the hyped construction of quantum technologies, which are positioned as either as a risk management solution to prevent security and economic risks or as a risk object capable of producing social risks. It also finds the concept of responsibility is constructed as a negotiation between government, civil, and the quantum technology industry to balance the risks and benefits of quantum innovation.

This paper was accepted and presented at EGOS 2023 (Cagliari, Italy) for Sub-Theme 58: *Organizing Risk for Better Futures*.

Paper Two: Responsible Innovation in Australia's Quantum Socio-Technical Imaginary: From Tension to Co-production

Paper Two extends the findings from Paper One by considering the prominent role of hyping as indicative of the formation of a quantum socio-technical imaginary. Likewise, it follows from the finding that the notion of responsibility was discursively constructed as a means of negotiation between tensions related to the transition of quantum technologies from research to industry. As such, this paper analyzes the dynamics of contestation within a socio-technical imaginary that emerged in relation to Australia's quantum innovation efforts as they developed over time. It engages with the question of how RI is used to reconcile a tension between two competing stakeholder visions: one centered on quantum science as a public good and another on quantum technology as a strategic commercial and security asset. Taking a longitudinal case study approach, it analyzes data from 37 interviews and 45 strategic documents, including state and federal roadmaps, strategies, funding announcements, and other policy documents, which highlight activities and programs aimed at developing Australia's quantum technology field from 2020 to 2025. The findings foreground the role of government in facilitating a process of co-production through the introduction of RI, as a new perspective, to align competing stakeholder visions. In doing so, it advances the study of socio-technical imaginaries by tracing how competing visions enter a state of co-production. It provides a novel account of how this perspective functions as both a shaping and shaped element of a socio-technical imaginary. I show how RI was introduced into national innovation policy to shape a collective, future-oriented imaginary and practically reshaped through use, as its meaning became filtered through the imaginary.

This paper was accepted to and presented at 85th Annual Meeting of the Academy of Management 2025 (Copenhagen, Denmark) in the Technology and Innovation Management (TIM) division.

Paper Three: Orchestrating Responsible Innovation in Knowledge Ecosystems

Paper Three builds on the findings from Paper One and Paper Two, which present a new perspective on the ways in which specific socially constructed notions of responsibility and risk bring RI to the fore as an approach for negotiating both material and perceived tensions between the diverse actors involved in innovation activities. Drawing on these findings and responding to calls for an ecosystem-level approach to RI, Paper Three offers a thought experiment for the orchestration of RI in knowledge ecosystems as a means of ameliorating organization-level tensions to develop robust and responsible knowledge ecosystems for emerging technologies. It first argues for the utility of implementing RI in knowledge ecosystems, providing insights into the specific features of knowledge ecosystems amenable to a RI overlay across logics, policies, and practices. It then presents a review of extant literature identifying the tensions organizations encounter between enacting the requirements of RI and addressing the market-led priorities that drive innovation. Finally, it advocates for the establishment of a role for RI orchestrators in knowledge ecosystems, offering three propositions for policymakers to encourage and facilitate RI orchestration in knowledge ecosystems by providing pathways for exposure to and participation in RI practices for both public and private actors through their collective interest in the technological outcomes generated through a knowledge ecosystem.

This paper was accepted and presented at EGOS 2025 (Athens, Greece) for Sub-Theme 46: *Responsible Innovation of Digitalization and the Digitalization of Responsible Innovation.*

2. Chapter Two: Methodology

This chapter outlines the research philosophy and methodological approaches undertaken to address this thesis' research questions. First, I describe the ontological and epistemological position underpinning the theoretical perspective of this research body as a whole. As Papers One and Paper Two both employ a similar methodological approach, I then turn my attention to justifying the use of a longitudinal case study as the appropriate form of inquiry for these papers. The collection and analysis approaches used in each paper are then briefly outlined, as well as my rationale for the 'thought experiment' (Weick, 1989) approach undertaken in Paper Three. Finally, I discuss the challenges and limitations inherent to the chosen methodological approaches.

2.1 Research Philosophy

This thesis is grounded in a social constructionist ontology and epistemology. As established in the theoretical framework, social constructionism holds that meaningful reality is contingent upon human practices, constructed through interaction between human beings and their world, and developed and transmitted within an essentially social context (Crotty, 1998). This position differs from constructivism, which tends to locate knowledge construction in the cognitive processes of individual actors. Social constructionism insists instead that meaning is produced collectively, through the intersubjective and institutionally embedded processes through which actors engage with and make sense of the world around them (Berger & Luckmann, 1966). This distinction is consequential for the methodological approach of this thesis. It directs analytical attention not toward individual cognition or perception but toward the social processes through which shared meanings are produced, contested, and provisionally stabilized across diverse actor landscapes.

The social construction of technology (SCOT) approach operationalizes this ontological position in the study of technology and innovation. Emerging in the late 1970s as a response to the limitations of conceptualizing technological innovation as a neutral, linear process (Godin, 2006), SCOT maintains that technologies are not objective, pre-determined objects but artifacts shaped by social, political, and cultural forces. It challenges technological determinism by foregrounding the role of multiple, diverse, and at times competing social groups in shaping technological outcomes (Prell, 2009). Crucially, SCOT conceptualizes innovation as a multi-directional process whose outcomes depend on which actors and groups are involved, when, and how (Pinch & Bijker, 1984). As Winner (1980) identifies, different groups wield differing levels of power and authority, and these dynamics become embedded in the outcomes of technological design. The technology design process is therefore non-deterministic. It can produce any number of different outcomes depending on the social circumstances of a technology's development (Klein & Kleinman, 2022).

SCOT is rooted in a relativist epistemology. Pinch and Bijker (1984) identify three stages of its explanatory program. The first is interpretive flexibility, which holds that technological artifacts are open to more than one interpretation by different social groups. This flexibility gives rise to the second stage, scientific controversies, in which multiple, contested interpretations sit in tension with one another. A relativist epistemology does not adjudicate between these interpretations as true or false. It attends instead to how varying interpretations "reveal the broad range of demands and desires that are packed into technical developments of various kinds" (Winner, 1993, p.372). The third stage is closure, whereby interpretive flexibility collapses or stabilizes into a settled configuration (Prell, 2009). Together, these three stages provide the epistemological basis for this thesis' focus on the socio-political forces that shape innovation, understanding these forces as fundamentally constitutive of the ways in which systems of innovation are organized and emerging technologies are developed.

This ontological and epistemological position has direct methodological implications. If the meaning of RI is not fixed but continuously produced through social interaction, then studying how RI operates in a given context requires methods that can surface the processes of construction, contestation, and stabilization through which its meaning is negotiated. It requires attending to the discourses, imaginaries, and institutional practices through which diverse actors construct their understandings of RI, and to the power dynamics and normative commitments that shape those constructions. This is the methodological orientation that informs Papers One and Two, which employ a longitudinal case study approach to examine these processes empirically within Australia's quantum knowledge ecosystem. It also informs Paper Three, which takes the social constructionist insight that orchestration is itself a negotiated and contingent process as the theoretical basis for a thought experiment that theorizes how RI can be purposefully embedded within knowledge ecosystem contexts. The methodological choices for each paper are developed in the sections that follow.

2.2 Qualitative Case Study Approach

Qualitative research methods were used to conduct this research, enabling a deep understanding of the ideas, experiences, and meanings that actors ascribe to actions. While quantitative methods are suitable for uncovering generalizations and predictions, qualitative methods are appropriate when the study's objective is to explain, explore, describe, or understand a social phenomenon (Coviello, 2005). Qualitative methods enable the exploration and description of patterns in various social contexts. Further, qualitative research is well-suited to examining the interrelationships within complex and dynamic social phenomena (Denzin & Lincoln, 2008), making it an appropriate method for a study on RI in the context of innovation systems. As Leavy (1994) argues, qualitative research is appropriate for complex and dynamic environments where "The focus for study tends to be on processes rather than structures, and on dynamic rather than static phenomena. The emphasis tends to be on description and explanation rather than on prescription and prediction" (1994, p. 107). The focus on analyzing dynamic processes is well suited to understanding complex and changing phenomena such as the social construction of emerging technologies.

A case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used" (Yin, 1984, p. 23). Case studies are an appropriate method of inquiry when answering "how" or "why" questions about empirical phenomena where there exist important contextual conditions shaping them (Yin, 2013). While case studies can confirm or disconfirm existing theory, this approach is well-suited to generating new ideas (Morland et al., 1992). A case study approach uses multiple data sources to elucidate participants' viewpoints and create a holistic, in-depth description. As such, a case study can be considered "a multi-perspectival analysis", in which "the researcher considers not just the voice and perspective of the actors, but also of the relevant group of actors and the interaction between them" (Tellis, 1997, p. 2). As such, a case study approach is suitable for studying perspectives, actions, and meanings associated with the development of quantum technologies, which this thesis frames as a process of co-creation by diverse actors. While many studies on socio-technical imaginaries use a cross-national comparison approach, this research employs a single case study design in order to offer an in-depth exploration of a "revelatory case" (Yin, 2013; Eisenhardt & Graebner, 2007). Furthermore, a longitudinal case study design was chosen to "address questions about how and why things emerge, develop, grow, or terminate over time" (Langley et al. 2013, p. 1). This is critical to a study design that aims to capture a period of transition for emerging technologies as they move from research to commercialization, as was observed in the context specific to this thesis.

2.3 Case Study Data Collection

2.3.1 Boundary Conditions

To establish the scope of the case study, historical data from mainstream Australian business- and finance-focused media outlets was reviewed alongside strategic documents related to the development of Australia's quantum capabilities. As a result of this scoping process, Paper One considers 2012 as pivotal year in the strategic coordination of Australia's applied quantum innovation activities. Paper Two takes a broader view to consider the earlier history of Australia's quantum research environment and the establishment of the first quantum-focused CoEs in 2003. The historical narratives offered by interviewee participants helped to establish the initial boundary condition for strategic document collection as 2020, as this was determined this to be the start of publicly documented national strategic positioning in relation to developing Australia's quantum sector. However, several texts published before 2020 were also collected to corroborate and supplement interviewee's historical narratives as required. Data collection began in 2021 and was concluded in February 2025 to include the release of Australia's National Quantum Strategy in 2023, a series of federal announcements around the establishment of a national hub for quantum industry development, major funding announcements, and the Quantum Australia 2025 conference.

2.3.2 Interviews

A total of 37 semi-structured interviews were conducted utilizing purposive sampling to select individuals with substantial knowledge or experience concerning quantum technologies and the formation of Australia's quantum sector. Purposive sampling was used to select interviewees who were particularly knowledgeable about or have experience with the phenomenon under consideration (Cresswell & Plano Clark, 2011). Following Palinkas et al. (2015): "Purposeful sampling is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources" (p.534). Specifically, interview invitations were targeted at actors working in organizations contributing or adjacent to Australia's quantum technology sector. These individuals were identified through Australia's national science agency's – the Commonwealth Scientific and Industrial Research Organisation (CSIRO) – a Roadmap for Growing Australia's Quantum Technology (CSIRO, 2020) list of domestic quantum companies and supplemented with actors participating in the annual Quantum Australia conference, the Australian Quantum Industry Alliance (AQA), and government officials known to be working on quantum ecosystem development efforts.

A primary set of 19 interviews were conducted in 2023, just before and just after the release of Australia's national quantum strategy, and one year later, in 2024, 18 interviews conducted in 2024, with four participants interviewed in both phases. In total, 37 interviews were conducted over this period. Interview participants were purposively selected to reflect a range of positions and perspectives on the development of Australia's quantum technology sector. These included actors from a diversity of organizations with the public, private, and civil society sectors. The sampling strategy was designed to capture a comprehensive and varied set of insights on the discursive construction of quantum technologies in Australia. One-hour interviews were recorded and transcribed with informed consent via Zoom, with notes taken during or immediately afterward. The interviews used open-ended questions to understand Australia's history in quantum research and technology, individual and organizational roles in the quantum sector as it developed over time, perceptions of its development, and potential benefits and drawbacks of developing new quantum technologies. I continued to conduct interviews until theoretical saturation was reached, when, "...in collecting fresh data, no new properties, dimensions, or relationships emerge, and the category has been fully accounted for in terms of variation and process" (Glaser and Strauss, 1967, p.111). Upon arriving at the saturation point, the data collected is sufficiently dense for theory to be developed.

Table 3: Interviews

Interviewee	**Description of interviewees' roles**	**Sector**	**Duration**
1	Quantum technology firm - founder	Private	69 mins
2	Quantum technology firm - founder	Private	37 mins
3	Quantum technology firm - founder	Private	49 & 43 mins
4	Government - data scientist	Public	39 mins
5	Venture capital firm - investor	Private	49 mins
6	Technology association - director	Civil society	53 & 55 mins
7	Technology association - partnership manager	Civil society	38 mins
8	Quantum technology firm - founder	Private	48 mins
9	Venture capital firm - investor	Private	56 mins
10	Technology firm - manager	Private	26 mins
11	Venture capital firm - investor	Private	53 mins
12	Consulting firm - employee	Private	46 mins
13	Quantum technology firm - founder	Private	40 mins
14	Quantum technology firm - founder	Private	58 mins
15	Consulting firm - employee	Private	44 mins
16	Research center - director	Public	40 & 46 mins
17	Government - technology director	Public	30 mins
18	Quantum technology firm - researcher and director	Private	50 mins
19	Government - technology director	Public	47 & 65 mins
20	Research center - director	Public	50 mins
21	Research center - director	Public	83 mins
22	Quantum technology firm - manager	Private	47 mins
23	Government - research director	Public	61 mins

24	Technology association - director	Private	52 mins
25	Technology association - director	Private	47 mins
26	Research center - director	Public	61 mins
27	Government - research advisor	Public	53 mins
28	Research center - director	Public	43 mins
29	Quantum technology firm - researcher and director	Private	67 mins
30	Venture capital firm - technology director	Private	57 mins
31	Quantum technology firm - business development director	Private	48 mins
32	Government - technology director	Public	44 mins
33	Industry association - researcher	Civil society	55 mins

2.3.3 Texts

Textual data collection began in 2021. Following research on ecosystems and emerging technologies (Ansari et al., 2016; Autio and Thomas, 2018; Dattée et al., 2018), archival and qualitative data about the formation of Australia's ecosystem around quantum technologies were collected. The documents collected included textual data from Australian business- and finance-focused media, and strategic documents generated by ecosystem actors. Media texts were identified using Factiva to search for articles from The Australian, The Australian Financial Review, and The Sydney Morning Herald, and the technology policy-focused InnovationAus. The search query included "quantum comput*", "quantum technolog*", "quantum industr*", and results were filtered for relevance by excluding documents that only referenced "quantum" in the context of technological developments. This approach ensured the collection of texts relating specifically to Australia's quantum innovation sector. Following the search and review process, 266 media articles spanning the period of 2012 to 2024 were retained for analysis (see **Table 4**).

Media texts were supplemented with publicly available strategic documents. A total of 45 strategic documents published across the boundary period were collected, including state and federal roadmaps, strategies, funding announcements, and other policy documents, which highlight activities and programs aimed at developing Australia's quantum technology field (See **Table 5**). As I was well-acquainted with the case study prior to beginning my PhD research, some documents were already known to me as critical texts in the development of Australia's quantum sector. The inclusion of these texts agrees with Stake's (1995) perspective on data collection: "A considerable proportion of all data is impressionistic, picked up informally as the researcher first becomes acquainted with the case" (p.49).

Table 4: Media texts

Source	Total retained
The Australian	71
The Australian Financial Review	81
The Sydney Morning Herald	19
InnovationAus	95

Table 5: Strategic texts

Title	Publisher/Source	Pub. Date	Pages	Category
CSIRO Quantum Technology Roadmap	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	2020-05	56	Strategic Roadmap
Army Quantum Technologies Roadmap	Australian Army	2021-04	48	Strategic Roadmap
National Quantum Strategy Consultation Paper	DISR	2021-11	36	National Quantum Strategy
Blueprint for Critical Technologies	Dept. of Prime Minister and Cabinet (CTPCO)	2021-11	20	Strategic Framework
Action Plan for Critical Technologies	CTPCO	2021-11	30	Implementation Plan
Joint Leaders' Statement on AUKUS (Quantum-related sections)	Governments of Australia, UK, US	2021-11	8	Joint Statement
National Quantum Strategy Consultation Paper	Department of Industry Science and Resources (DISR)	2021-11	36	National Quantum Strategy
Responsible Quantum: Starting the Conversation	KPMG Australia & Sydney Quantum Academy	2022-01	21	Discussion Paper
Quantum Computing Governance Principles	World Economic Forum (contributions from Aus)	2022-01	35	Insight Report
National Quantum Strategy Issues Paper	DISR	2022-04	16	National Quantum Strategy
National Quantum Strategy Issues Paper	DISR	2022-04	16	National Quantum Strategy
Australian Quantum Alliance (AQA)	Tech Council of Australia (TCA)	2022-08	2	Industry Alliance
Growing Australia's STEM Industries: Lessons from Quantum	Office of the Chief Scientist	2022-09	12	Strategic Insight
Growing Australia's STEM Industries: Lessons from Quantum	Office of the Chief Scientist	2022-09	12	Strategic Insight
CSIRO Updated Economic Analysis	CSIRO	2022-10	6	Economic Forecast
National Quantum Advisory Committee	Minister Husic	2022-11	1	Advisory Committee
An Australian Strategy for the Quantum Revolution	Australian Strategic Policy Institute (ASPI)	2023-04	40	Policy Analysis

Impact Assessment of ARC-Funded Research	Australian Research Council/ACIL Allen	2023-04	70	Research Impact
National Quantum Strategy	DISR	2023-05	52	National Quantum Strategy
Investments to Grow Australia's Critical Technologies	DISR	2023-05	1	Funding Announcement
National Quantum Strategy	DISR	2023-05	52	National Quantum Strategy
Quantum Communication Networks and Standardisation	Standards Australia	2023-07	28	Research Report
Quantum Meets Sports: Workshop Summary	Office of the Chief Scientist	2023-08	14	Workshop Summary
Queensland Quantum and Advanced Technologies Strategy	Queensland Government	2023-10	34	State Strategy
AUKUS Factsheet: Quantum Arrangement (AQuA)	House of Commons Library	2023-11	14	Research Briefing
AUKUS Defense Ministers' Joint Statement (Quantum focus)	Australia, UK, US Defense Ministries	2023-12	5	Joint Statement
Quantum Australia Initiative Announcement	DISR	2024-01	1	Program Announcement
Quantum Meets Resources: Workshop Summary	Office of the Chief Scientist	2024-02	28	Workshop Summary
Quantum Algorithms and Applications Study (NSW)	Office of the Chief Scientist	2024-03	64	State Strategy
PsiQuantum Partnership Announcement	Prime Minister's Office	2024-04	1	Funding Announcement
University of Sydney Awarded $18.4 Million for Quantum Centre	University of Sydney	2024-04	1	Funding Announcement
Delivering a Future Made in Australia – PsiQuantum	Prime Minister's Office	2024-04	1	Media Release
Solving national challenges using quantum technologies	Minister for Industry	2024-05	1	Media Release
Tech Council Welcomes opening of Critical Technologies Challenges Program	TCA	2024-05	1	Media Release
Quantum Meets Space: Workshop Summary	Office of the Chief Scientist	2024-05	23	Workshop Summary
Quantum Meets Energy: Workshop Summary	Office of the Chief Scientist	2024-05	20	Workshop Summary
Quantum Meets Public Service: Workshop Summary	Office of the Chief Scientist	2024-07	20	Workshop Summary
Quantum Meets Finance: Workshop Summary	Office of the Chief Scientist	2024-08	23	Workshop Summary
Australia's National Science Statement: A Future Made in Australia	Australian Government	2024-08	14	Strategic Framework
Quantum Meets Health: Workshop Summary	Office of the Chief Scientist	2024-09	19	Workshop Summary
State of Australian Quantum Report	DISR	2024-11	40	Progress Report
Albanese Government invests in Defence Tech	Department of Defence	2024-11	1	Media Release
Quantum Thesis	Main Sequence Ventures	2025-03	5	Blog/Commentary

Standards Australia Draft Standard AS 5405 – Quantum Computing Reference Guide	Standards Australia	2025-04	45	Draft Standard
Quantum Technologies and Standardisation Globally and in Australia	Standards Australia	2025-04	32	Research Report
Critical Technologies Challenge Program (CTCP)	DISR	n.d.	2	Funding Program
Quantum Meets Workshop Series	Office of the Chief Scientist	n.d.	1	Workshop Series

Table 6: Data Summary

Data Source	**Total**
Media	266
Strategic texts	45
Interviews	37

2.4 Case Study Data Analysis

The researcher is ever-present in the process of conducting inductive, qualitative research –from the assumptions present in the development of research questions, to the interviewing itself, to the data analysis, where "the researcher becomes the instrument for analysis, making judgments about coding, theming, decontextualizing, and recontextualizing the data" (Nowell et al., 2017, p.2). While the researcher can acknowledge and bring consciousness to this through reflexivity in the data collection, analysis, and writing-up steps (Gabriel, 2015), rigorous data analysis is required for qualitative research to yield reliable and deep insights, especially to elicit this quality from a context the researcher is deeply embedded in (Lincoln & Guba, 1985). For both Paper One and Two, I used an iterative and inductive theory-building approach (Van Maanen et al., 2007). This approach entailed moving back and forth between analyzing data, consulting existing literature, and applying theoretical lenses to develop insights specific to the case. This method is effective for exploring phenomena that remain under-theorized (Gehman et al., 2018; Langley, 1999), aligning with the objective of theory building. The sections below briefly outline the data analysis approaches used for each paper, as well as a justification for the thought experiment approach to Paper Three, which is not included in the paper itself. The extended version of these summaries can be found in the relative data analysis sections of the papers that comprise Chapter Three to Four.

2.4.1 Paper One

For Paper One, I began by organizing both the media texts and strategic documents separately into an event history database (Van De Ven & Poole, 1995) to provide a chronological record of events and discourse, detailing who said what, when, and how (Maguire, 2004). I then used the temporal bracketing technique (Langley, 1999; Langley et al., 2013) to identify three distinct periods in the discourse pertaining to quantum technologies in Australia. I used open coding to analyze the transcripts, paying particular attention to the ways in which the concepts of risk and responsibility were employed across both texts and interviews to discursively contribute to a positive collective vision and escalated expectations around quantum technologies. I likewise looked for dissenting reactions to this framing to identify specific ethical and societal concerns linked to the potential adverse effects of the technology. The first order codes identified were then examined across the entire dataset to develop second-order themes. This examination was guided by the interaction between the collected data and the conceptual patterns forming through our analysis (Eisenhardt, 1989). An iterative approach entailed repeated analysis of texts and interviews, transitioning between first-order codes and the emerging second-order themes. This approach enabled me to refine my analysis, aggregating codes to uncover patterns (Langley, 1999; Strauss & Corbin, 1990) in how actors harnessed the discourses of risk and responsibility when hyping quantum technologies. Finally, I mapped the codes chronologically to trace patterns in the discourse over time to identify three temporal periods outlined in the second part of the findings for Paper One.

2.4.2 Paper Two

Given the research question for Paper Two, I coded my data for traces of socio-technical imaginaries. I looked for elements of imaginaries as expressed through rhetorical devices, metaphors, repeated narratives or 'myths', as well as future-forward language that conveys expectations about desirable (and undesirable) visions of the future (Bareis & Katzenbach, 2022; Jasanoff & Kim, 2015). My approach to this was informed by Jasanoff (2015), who writes of social meaning making: "the languages, metaphors, and symbols…can be mined for framings of risk and benefit, attitudes toward regulation and the market, and visions of technologically mediated progress or failure and backsliding" (p.25). For example, tropes and analogies (e.g. "Australia punches above its weight in quantum") can be used to identify elements of the imaginary (Jasanoff, 2015). Across both the interview data and strategic documents, I looked for future-forward language expressing the perceived role of quantum in Australia, metaphors, assumptions, or mention of things taken for granted as true, as well as the identification of national strategic priorities, and expressions of expectations for the development and impact of quantum technologies. Throughout this process, I moved iteratively and inductively between the data from texts, observations, and interviews and extant theory to refine my analysis (Patton, 2015). I aggregated codes to uncover patterns and create second order themes for actors, policy, funding, activities, and narratives – categories chosen to reflect how imaginaries are conceptualized in the literature as enacted through configurations of institutions, discourses, and practices.

During analysis, it became clear that these themes carried different emphases across stakeholders and time: in some cases, prominent stakeholders were primarily academic researchers while in others industry and defense figures were foregrounded; some policies emphasized science as a public good while others stressed competitiveness and security; funding was framed at times as long-term capacity-building and at other times as short-term and commercially driven; activities ranged from celebrating scientific prestige to institutionalizing industry consultation; and narratives shifted between portraying quantum as safe in the lab and framing it as a race not to be missed. These patterned differences provided the basis for the analytical move to aggregate dimensions. My analysis revealed two distinct visions: one was long-term and scientific, and another was near-term, commercialization and security driven, which circulated at the same time. However, my second-order themes suggested significant shifts in how they became embedded and enacted as the quantum sector matured. As such, my data analysis revealed how a tension between these visions was reflected in concerns for the sustained development of the quantum sector expressed by stakeholders from academia and industry. By tracing how RI was discursively introduced as a perspective that addressed this tension, my analysis showed how the concept shaped the development of a collective quantum socio-technical imaginary as it was, in turn, reshaped through its application in this process.

2.4.3 Paper Three

For Paper Three, I began by reviewing the literature on the application of RI in commercial organizations to identify the major tensions between commercial demands and the enactment of RI that repeatedly surfaced across case studies (Auer & Jarmai, 2017; Pfotenhauer et al., 2021; Gurzawska et al., 2017; Lubberink et al., 2019; Ko & Kim, 2020; Martinuzzi et al., 2018). These were identified as (1) fiduciary responsibility versus collective societal responsibility, (2) organizational efficiency versus stakeholder inclusion and reflexivity, and (3) protecting competitive advantage versus transparency and knowledge sharing. I developed three propositions for knowledge ecosystem orchestrators to weave RI into their existing responsibilities by fostering a shared understanding, organizing inclusive deliberative activities, and providing incentives for and monitoring progress toward continuous alignment with RI expectations at the ecosystem level. These propositions were arrived at through iterative analysis of the literature on RI ecosystems (Smolka & Böschen, 2023; Jakobsen et al., 2019; Stahl, 2022; Stahl, 2017; Foley & Wiek, 2017;

Dreyer et al., 2020) and knowledge ecosystems (Clarysse et al., 2014; van der Borgh et al. 2012; Dougherty & Dunne, 2011; Cobbens et al., 2022; Fiandrino et al., 2025).

This theory-driven paper is presented in the form of a thought experiment. From Plato's famous cave to the eponymous Schrödinger's cat, thought experiments have a rich history as a tool that transcend disciplines. Drawing on Gendler (1998; 2010), Kornberger and Mantere (2020) define thought experiments as "judgements about what would be the case if what is being played out in an imagined scenario were real" (p.3). Thought experiments do not aim to discover new information about an empirical reality; as such, this approach does not entail new data collection. While grounded in existing data and knowledge, thought experiments are a creative function for generating new ideas through open-ended scenarios aimed at encouraging reflection on something that may have been neglected or overlooked (Kornberger & Mantere, 2020). They can also be understood as "devices of framing and persuasion" (Gendler, 2010, p.128) that help to communicate new ideas in often complex scientific debates. In organizational studies where "theory construction is hemmed in by methodological strictures that favor validation rather than usefulness" (Weick, 1989, p.516), thought experiments provide a useful, yet underutilized, avenue for conceptual development.

Weick (1989) argues that theory development in organizational studies can transcend the artificial bounds of the methodological expectations around validation and verification through the application of what he terms "disciplined imagination". Weick's elaborates on this concept:

> The discipline comes from systematic variation of concepts and problems, from adherence to the requirements of logic and consistency, and from evaluation by a community of peers. The imagination comes from conjecture, from willingness to try out new combinations, and from seeing familiar things in unfamiliar ways (1989, p.516).

This concept justifies the construction of a thought experiment as an approach to theory development in Paper Three. By beginning with a "what if" scenario (responding to Weick's call for the researcher's use of imagination) and applying discipline through decisions around unit of analysis and boundary conditions, the integration of diverse perspectives and theoretical lenses, and offering propositions, Paper Three aims to communicate a novel perspective through rigorous and systematic speculation.

2.5 Methodological Limitations and Challenges

The methodological limitations of a case study approach have been discussed with regard to generalizability (Yin, 2003; Stake, 2000; Flyvbjerg, 2006). According to a positivist research perspective, which emphasizes the use of statistical interpretations to express external validity, case studies are limited in their ability to produce generalizable findings, particularly in a single case study approach (Yin, 2009). In response to this critique, proponents of a single case study approach offer research strategies to increase rigor in case study research. A notable approach to addressing this limitation relates the researcher's ability to bring the reader along on the journey of their methodological approach to data collection and analysis to "...establish a clear chain of evidence to allow the readers of the case to reconstruct how the researcher departed from the initial research questions and reached the final conclusions" (Mariotto et al., 2014, p.360). Methodological transparency (Eisenhardt & Graebner, 2007) should aim to address the issue of rigor up-front by reporting a detailed strategy with a focus on constructing internal, rather than external validity. In line with this advice, this thesis aims to present a thorough and detailed narrative of the research procedures undertaken in the case study approach presented in Papers 1 and 2.

The use of a single, rather than comparative, case study approach is also a contested method of theory building. As Eisenhardt and Graebner (2007) contend:

> Somewhat surprisingly, single cases can enable the creation of more complicated theories than multiple cases, because single-case researchers can fit their theory exactly to the many details of a particular case. In contrast, multiple-case researchers retain only the relationships that are replicated across most or all of the cases (p. 30).

The limitation identified here is linked to the generation of generalizable laws, which dominates scientific thinking. However, a single case study approach does not intend to reveal universal laws. Rather, this approach offers an inroad to understanding a phenomenon in a specific context and aims to produce a rich description of a revelatory or exemplar case (Eisenhardt & Graebner, 2007). This is particularly useful when generating theory, as an in-depth case can produce a novel perspective and provide an explanation for the connections between various constructs at play (Tsoukas, 2009).

Another challenge in the methodological approach of this paper is related to identifying socio-technical imaginaries. In undertaking this aspect of the study, the question arose – How does one reveal something that is imaginary? To address this challenge, I spent time in the literature on socio-technical imaginaries to better understand analytical approaches aimed at interpreting imaginaries. As previously mentioned, there are several identifying mechanisms that allude to the construction or presence of socio-technical imaginaries. These can include rhetorical devices, metaphors, repeated narratives or 'myths' (e.g. Australia is good at innovation but bad at commercializing), as well as future-forward language that expresses expectations about or desirable (and undesirable) visions of the future (Bareis & Katzenbach, 2022; Jasanoff & Kim, 2015). These elements hint at the shape of imaginaries at play.

Surfacing these elements in the data required an analytical approach focused on reading in between the lines to draw out and compare the "visions of what is attainable through science and technology but also of how life ought, or ought not, to be lived" (Jasanoff & Kim, 2015, p.4) expressed by diverse interviewee participants across the time brackets. Here, interpretive social theory was critical to coding the transcripts for tacitly held beliefs about...

> ...the ways people imagine their social existence, how they fit together with others, how things go on between them and their fellows, the expectations that are normally met, and the deeper normative notions and images that underlie these expectations. (Taylor, 2004, p.23)

Identifying visionary, metaphoric, and symbolic language was more straightforward for the strategic texts. As Jasanoff and Kim (2015) write, "It often falls to legislatures, courts, the media, or other institutions of power to elevate some imagined futures above others, according them a dominant position for policy purposes" (p.4). As a result, future-forward visions tend to be more prominent and clearly articulated in these texts.

Every methodological choice entails certain limitations and challenges. Those inherent to the selected methodological approaches were duly considered in the design of the research presented in this thesis. I have addressed these through taking care to be reflexive in my role as a researcher, presenting ample evidence for the specific methodological choices made that led me to my results, and ensuring my data collection and analysis procedures were transparent, rigorous, and appropriate in relation to addressing my research questions.

3. Chapter Three: Paper One

Risk and the Discursive Construction of Quantum Technologies in Australia: How Geopolitical and Economic Threats are Used in Hyping Emerging Technologies

Abstract

In this paper, we examine the role of hype in the discursive construction of emerging quantum technologies. As these technologies transition from academia to industry, they have been the object of hyping in which, as our findings show, concepts of risk and responsibility figure prominently. We find that hype does not just describe a state of escalating excitement and positive expectations around quantum technologies; additionally, and more specifically, 'hyping,' understood as a discursive process, constructs these technologies as risk management solutions to highly salient geopolitical and economic risks to state actors while acknowledging the possibility that they may pose less salient, novel social risks to citizens and social groups within a state. We also find that the former construction overwhelms the latter, with important consequences for meanings as well as actions considered responsible. We develop a discursive model of how the hyping of emerging technologies, through contestation invoking discourses of risk and responsibility, shapes the meanings that get attached to them and hence the expectations around them. Building on the sociology of expectations, we contribute a discursive perspective on technological hype by showing how risk and responsibility are mobilized in struggles over emerging technologies, and we show how these discourses expand coalitions and link issues, shaping the nature, direction, and pace of technological development.

1. Introduction

Emerging technologies have historically driven geopolitical developments by reshaping military and economic power balances and redefining global competition (Der Derian & Waters, 2024; Grumbling and Horowitz, 2019). Nothing is better illustrative of this claim than the emergence of quantum physics, which facilitated nuclear weapon development during the first quantum revolution and the establishment of a bipolar world order (Derian & Rollo, 2024; Witt, 2022). The second quantum era underpinned the digital economy and accelerated global interconnectivity (Grumbling & Horowitz, 2019; Der Derian & Rollo, 2024). Today, advances in computing, communications, and sensing promise a third wave of new quantum technologies that appear likely to function as both strategic assets and drivers of existential questions about national security, economic resilience, and global influence (Der Derian, 2013; Zhong et al., 2020). Prophesied in this third quantum era are unbreakable encryption, unparalleled computing power, and advanced sensing capabilities that are expected to disrupt traditional power dynamics and intensify technological competition among global actors ("China Realizes Secure, Stable Quantum Communication Network Spanning 4,600 Km," 2021; Langston, 2022). Claims about the transformative potential of "Quantum 3.0" technologies (Der Derian & Rollo, 2024, p.1) therefore carry significant weight and make it difficult to scrutinize these technologies' possible adverse impacts, even if deliberating and balancing the benefits and risks of emerging technologies is a crucial matter of public interest (Jasanoff, 2007; Stilgoe & Guston, 2017)

How has this situation arisen and with what implications for scientific and technological development in a multipolar world? To explore these questions, we adopt a social constructionist view: technologies are constructed as objects of knowledge through discursive activity undertaken by actors and in conditions made possible by existing discourses (Maguire & Hardy, 2009). Further, we draw on the sociology of expectations (Borup et al., 2006; Brown & Michael, 2003; van Lente et al., 2013) – where imagined futures performatively mobilize resources, orient action, and legitimate innovation – and treat hype as a key expectation-building mechanism that valorizes emerging technologies via coalition expansion (Kriechbaum et al., 2021) and links to societal imperatives that help attract capital, talent, and attention (Berube, 2006; Ometto et al., 2023; Van Lente et al., 2013) – linkages that help generate momentum that often lasts even when hype diminishes (Bakker, 2010; Ruef & Markard, 2010).

Yet hype is not merely investor exuberance or a predetermined "cycle"; it is political and performative, simultaneously enabling and constraining sociotechnical trajectories through a promise-requirement dynamic (Borup et al., 2006) that routinely sidelines debate about risks, ethics, and alternatives, even as ongoing concerns about technologies persist (Irwin, 2001; Mokyr et al., 2015; Petersen et al., 2017). Consequently, contestation is endemic in hype: advocates and detractors advance competing futures, prompting regulatory scrutiny and, in some cases, slowed commercialization (Brown & Michael, 2003; Ometto et al., 2023). Examining this contestation is important because hype surrounding emerging technologies with yet-to-be-defined applications and uncertain potential for benefits raises legitimate concerns that novel risks they pose may be inadvertently downplayed or concealed (Caulfield & Condit, 2012). In such instances, there is "uncertainty or unfamiliarity concerning the harm that a [risk] object may cause, the likelihood the harm will occur, or the causal processes connecting the object and the harm" (Hardy & Maguire, 2020, p. 688).

Building on discourse studies, we adopt a discursive, processual view of 'hyping' and connect with and extend studies that focus on hype as a *state* of increasingly exaggerated expectations (Caulfield & Condit, 2012; Funk, 2019; Logue & Grimes, 2022; Pontikes & Barnett, 2017) and studies that track its evolution via 'hype cycles' (Anderson & Smith, 2007; Dedehayir & Steinert, 2016; Momtaz, 2021; Rutherford et al., 2009). Rather than focusing solely on hype as an outcome state, we examine hyp*ing* as a contested process shaped by coalitional struggles between proponents and skeptics of an emerging technology (see also Kriechbaum et al., 2021). In a multipolar geopolitical context, this struggle increasingly pivots on discourses of risk and responsibility that position emerging technologies as solutions to salient threats (e.g., security, economic resilience), while displacing their construction as risk objects. As a result, in this paper, we focus on the relationship between emerging technologies, expectations and the contested discourses harnessed when hype is used to construct emerging technologies.

Our study focuses specifically on quantum technologies in Australia. These technologies exemplify what Rotolo et al. (2015) define as *emerging* as they display radical novelty, coherence, relatively fast growth, uncertainty and ambiguity, as well as prominent expected socioeconomic impacts – features that make analyzes of their discursive construction well suited to exploring and theorizing the hyping of an emerging technology as a contested process of discursive struggle. The advent of any emerging technology poses known and unknown risks to societies, as well as to different social groups within them, and what they value. As society becomes ever-more technologically dependent, the risks generated by developing and deploying emerging technologies with unfettered enthusiasm multiply and increasingly draw attention as well as resources to manage them in a contemporary 'risk society' (Beck, 1992). Risks associated with hyped quantum technologies are only beginning to be recognized (Kop et al., 2024; Roberson, 2023), and responsible governance of these technologies is in its initial stages (Perrier, 2022; Quantum Computing Governance Principles: Insight Report, 2022; "Responsible Quantum: Starting the conversation," 2021). In Australia, the anticipation surrounding quantum technologies has been driven by hyping (Roberson, 2020), with quantum technologies—including quantum computing, sensing, and communication—transitioning from academic research to a range of industrial and defense-related applications with much fanfare and excitement, leading some policy experts to claim the global quantum sector represents a multi-billion-dollar market opportunity and promises hundreds of thousands of jobs (Bartholomeusz, 2021; Department of Industry, 2023b; Roberson & White, 2019; Watts, 2021). Consequently, we examine the discourse around quantum technologies in Australia as we explore how hyping influences the meaning of an emerging technology.

We make two primary contributions from this study. First, we advance a discursive perspective on technological hype (Bakker, 2010; Ruef & Markard, 2010) by showing that hyping is a contested process in which advocates and dissidents both mobilize discourses of risk and responsibility, and that this process shapes the construction of an emerging technology. Specifically, advocates of emerging technologies strategically reposition potential benefits as nationally and geopolitically important by discursively constructing emerging technologies not just as routes to prosperity but as important ballasts against decline. Second, we extend work on the sociology of expectations (Borup et al., 2006; van Lente, 2012) by demonstrating how these discourses expand coalitions and link issues – often through geopolitical issues of technological sovereignty and international competitiveness – thereby giving momentum to particular trajectories and tempos of development. In doing so, we broaden the moral lens on hype beyond investor losses and hype cycles (Momtaz, 2021; Kriechbaum et al., 2021) to translating imagined opportunities into risks of inaction and reshaping what counts as "responsible" action in a risk society.

Our paper proceeds as follows. To motivate our research question, we begin by engaging with the literatures on sociology of expectations, technological hype and the discursive struggle over emerging technologies. Next, we explain our research setting, data collection, and analysis. We then present our findings in two parts. The first part describes and illustrates how actors harness the discourses of risk and responsibility in hyping quantum technologies, and the second part examines how these discursive dynamics played out over three time periods. After discussing these findings in relation to extant literature, we conclude with a summary, limitations of our study, and recommendations for future research.

2. Theoretical Background

2.1 The Sociology of Expectations and Technological Hype

The sociology of expectations examines and theorizes how imagined futures shape present scientific and technological practices by mobilizing resources, influencing social action, and legitimizing innovation through performative visions (Borup et al., 2006; Brown & Michael, 2003; Van Lente et al., 2013). In shedding light on how understandings of the future are implicated in practices that give rise to outcomes, it connects expectations to enduring sociological concerns about power relations and their role in innovation as well as social continuity and change (Konrad et al., 2016; Suckert, 2022; van Lente, 2012). Within this body of work on expectations and their effects on innovation processes, hype has received much attention (Borup et al., 2006; Kriechbaum et al., 2021; Ruef & Markard, 2010; Van Lente et al., 2013). Hype, despite being recognized as "simplified and sensationalized science" (Roberson, 2020, p.545) that is characterized by bold claims that exaggerate the benefits of emerging technologies while minimizing their potential risks (Caulfield and Condit, 2012), nonetheless markedly influences the pace, path, and process of emerging technology development (Kriechbaum et al., 2021; Coenen & Grunwald, 2017; Fujimura, 2019; Olson, 2019).

One reason for these effects is that hype brings the expectations of actors brought together around an emerging technology in ways that lead the technology to become valorized, eliciting collective efforts to position development of the technology as a hotbed of innovation and entrepreneurship (Gurses & Ozcan, 2015; Weber et al., 2008). The expansion of this set of actors with positive expectations, investments at stake, and anticipations of returns results from the mobilization of narratives, endorsements, and identities (Kumaraswamy et al., 2018; Navis and Glynn, 2010; Wodak et al., 2011). Another reason for these effects is that technological hype is fueled not only by innovation and entrepreneurship narratives but also by linking technologies to broader societal issues, such as climate change or healthcare efficiency (van Lente et al., 2013). These 'issue linkages' provide legitimacy and urgency, which align the promise of emerging technologies with political and moral imperatives. By aggressively promoting an emerging technology's potential for addressing critical issues and driving economic growth, hype attracts investments, talent, and public attention that combine to facilitate commercial activity (Berube, 2006; Ometto et al., 2023). As powerful actors become entangled in an emerging constellation of constructed interests, the constellation develops momentum.

This alignment of emerging technologies with significant societal concerns not only boosts legitimacy and mobilizes support in the short term but can also shield technologies from the consequences of disillusionment if expectations are not met in the long term (Bakker, 2010; Ruef and Markard, 2010). For example, Ruef and Markard's (2010) study of stationary fuel cells showed that when hype around the technology collapsed, only near-term expectations were scaled back.

Broader societal views remained intact, and newly established institutional structures generated positive externalities, allowing innovation around this technology to continue, even as some actors strategically withdrew and the industry grew more fragmented. This cyclical pattern of intense build-up and partial collapse is consistent with Bakker's (2010) account of the "blow-out" of the hydrogen car hype, in which strong societal issue-linkages amplified expectations but also heightened vulnerability to sharp downturns when performance lagged. Yet, as Bakker notes, such downturns rarely erase all momentum; the institutional and discursive infrastructures built during hype phases often persist, creating conditions for future rounds of expectation-building. In other words, hype is a means through which advocates of an emerging technology generate escalated positive expectations that then performatively generate momentum for innovation processes – momentum that often endures despite later disappointment and frustrated expectations (Ruef & Markard, 2010).

But it is important to recognize that hype cycles and possible sustained momentum following a downturn in expectations are not inevitable. While societal issue linkages can amplify attention and excitement in some social groups, they also expose emerging technologies to intensified scrutiny and competing claims about promised futures from other social groups. As a result, hype typically elicits skepticism, dissent, resistance, counter narratives and contestation (Brown & Michael, 2003). Whereas advocates of new, emerging technologies tout their potential to solve salient societal problems and drive wealth creation, detractors often highlight ethical/moral, health/safety and environmental concerns (even if these concerns, arguably, cover self-interested ones) about potential negative impacts from emerging technologies, to counter hype; and these societal concerns can lead to increased regulatory scrutiny and skepticism, slowing technological development and commercialization (Brown & Michael, 2003; Ometto et al., 2023).

As a result, hype often plays dual roles: on the one hand, it emphasizes the transformative potential and benefits of a technology, while on the other, it sidelines critical conversations about risks, ethical implications, and alternative pathways (Irwin, 2001; Petersen et al., 2017). This duality reflects the "promise and requirement" dynamic (see Borup et al. 2006) that, once articulated, expectations create obligations and lock-in trajectories which both enable and constrain subsequent innovation despite critiques of its nature, direction or pace. Placing this within a historical and cultural frame, it is clear that this duality is deeply rooted in recurring societal responses to technological change and thus unlikely to disappear even as specific technologies evolve; throughout history, periods of rapid innovation have been accompanied by recurring "technological anxieties" concerning economic displacement, social disruption, and moral decay (Mokyr et al., 2015).

Research in the sociology of expectations has therefore cautioned against viewing hype merely as transient exuberance or investor-centric disappointment due to so-called 'irrational' expectations, instead foregrounding its deeply political, material, and performative yet, ultimately, indeterminate, open-ended, and unfolding nature (Borup et al., 2006). Indeed, contestation and negotiation feature prominently in sociological perspectives on expectations (Borup et al., 2006; Van Lente, 2012), reflecting competing visions of desirable futures, power asymmetries between actors, and socio-spatial differences in risk perception and in actors' confidence in the ability of institutions to manage risks (Ometto et al., 2023; Roberson, 2023, 2020).

We are interested deepening our understanding of the contestation that hype elicits, which will benefit – in addition to scholars – regulators, policymakers, innovators, investors, and the public more broadly as they seek to make informed, responsible decisions about technology development, investment, and regulation (Brown & Michael, 2003; Markard et al., 2016). To do so, we adopt a Foucauldian approach to discourse and discursive struggle.

2.2 Discursive struggle over emerging technologies

The performative role of expectations provides a conceptual foundation for understanding hype – defined as "a collective vision and promise of a potential future, escalating attention, excitement, and expectations over time" (Logue & Grimes, 2022, p.1055) – a specific discursive process through which meanings get attached to an emerging technology in ways that generate such a collective vision and promise of a potential future. Discursive approaches are particularly well suited to constructivist, non-deterministic studies of phenomena (Hardy & Maguire, 2016; Hardy & Phillips, 2004). A discourse is a collection of interrelated texts and practices "that systematically form[s] the objects of which they speak" (Foucault, 1979, p.49) by cohering in some way to produce both meanings and effects in the world. The discursive perspective presumes that language does not reflect a pre-existing reality but, rather, constructs and constitutes what actors experience as reality. In other words, discourses "do not just describe things; they do things" in the world; the attachment of concepts and meanings to objects is consequential because it creates conditions of possibility for subsequent discursive formations and actions (Potter & Wetherell, 1987, p.6).

Following Maguire & Hardy's (2009) and Hardy & Maguire's (2013) approach to interrogating the discursive construction of technological artifacts, i.e. the shifting meanings of the molecules DDT and BPA in their empirical studies, we adopt a discursive, processual view of 'hyping'. We define hyp*ing* as discursive work, i.e. the purposeful production, distribution, and consumption of texts (Maguire & Hardy, 2013), undertaken to create, maintain, or defend a sensationalized, positive meaning of an emerging technology and, hence, escalated, positive expectations for futures built around it (cf. Logue & Grimes, 2022). In doing so, we extend studies of hype that treat hype as a state of escalating expectations (Caulfield & Condit, 2012; Funk, 2019; Logue & Grimes, 2022; Pontikes & Barnett, 2017), a moral problem centered on the financial deception of investors (Momtaz, 2021), or as a predetermined ascent and descent of expectations through a 'hype cycle' (Dedehayir & Steinert, 2016; Kriechbaum et al., 2021; Van Lente et al., 2013) . Rather than focusing on hype as an elevated state or predetermined up-and-down trajectory of states, we examine hyp*ing* as a contested, indeterminate process shaped by discursive struggle between proponents and skeptics over the meaning of an emerging technology (cf. Kriechbaum et al., 2021). As Chalaby (1996, p.694) notes, "texts are weapons that agents in struggle use in their discursive strategies".

While research on the sociology of expectations and hype acknowledges contestation, more empirical work is needed to identify and theorize the discursive work undertaken by advocates and dissenters as they seek to attach positive and negative meanings, respectively, to an emerging technology. As a result, we ask: How does hyping, understood as a discursive process involving contestation through discursive struggle, influence the meaning of an emerging technology?

3. Methods

3.1 Research setting

To answer our research question, we explore the "revelatory case" (Eisenhardt & Graebner, 2007) of the hyping of emerging quantum technologies in Australia. Quantum technologies are a class of new technologies that rely on the principles of quantum mechanics, a branch of physics that describes how the universe works on a subatomic level. There was much evidence of hype in relation to quantum technologies when we began our research, which drove our site selection. Hyping continues, with recent media headlines such as "Will quantum computing ever live up to its hype?" (Horgan, 2021), "Quantum computing has a hype problem" (Das Sarma, 2022), and "Quantum computing: The next frontier or a hype-filled bubble?" (Randieri, n.d.). In addition, social studies of science and technology document hype and escalated positive expectations about quantum technologies (Roberson et al., 2021; Roberson, 2020; Smith, 2020). As a result, Australia is an excellent site for studying the hyping of quantum technologies.

3.2 Data Collection

For our case study, we gathered three primary types of data: textual data from Australian business- and finance-focused media, documents generated by key actors brought together around quantum technologies, and interview data from a diverse subset of these actors. To establish the scope of our study, we reviewed historical data from mainstream Australian business- and finance-focused media outlets, using Factiva to search for articles from *The Australian, The Australian Financial Review*, and *The Sydney Morning Herald*, and the technology policy-focused *InnovationAus*. We searched for "quantum comput*", "quantum technolog*", "quantum industr*", and filtered the results for relevance by excluding documents that only referenced "quantum" in the context of technological developments. Based on analysis of search results, we identified 2012 as a pivotal year and chose to use the establishment of the Australian Research Council (ARC) Centre of Excellence for Engineered Quantum Systems (EQUS) as the starting point of our retrospective case study because of the Centre's role in shifting Australia from foundational quantum science toward purposeful engineering of quantum devices. We concluded our data collection in March 2024, which came after the release of Australia's National Quantum Strategy in 2023 and just before the Australian government entered a nearly A$1 billion agreement with a private company to develop the world's first commercially viable quantum computer – another significant milestone marking a new era in Australia's quantum journey and hence a good ending point for our retrospective case study. Following our search and review process, we retained 266 media articles for analysis collected from 2012 to 2024. We supplemented media texts with 45 additional strategic documents from this same period that were authored by actors brought together around quantum technologies. We searched for publicly available documents authored by actors identified in our media texts from various sources, assembling document from organization and business websites, government media releases, industry roadmaps, and other strategic documents.

We also carried out semi-structured interviews with 33 key actors (four actors were interviewed twice due to their evolving role in the time period under our consideration, for a total of 37 interviews), utilizing purposive sampling to select actors with substantial knowledge or experience concerning quantum technologies and their development toward commercialization. Specifically, we focused on actors appearing frequently in our media texts as well as authors of, and actors appearing frequently in, documents we had collected, such as quantum technology ventures listed in the national science agency's – the Commonwealth Scientific and Industrial Research Organisation (CSIRO) – roadmap for 'Growing Australia's quantum technology industry' (CSIRO, 2020), along with actors participating in the annual Quantum Australia conference. Interviewees offered a wide range of perspectives on quantum technology, from eight public sector actors (government and regulatory), fifteen private sector actors (technology firms, venture capitalists, consultants), and eleven civil society actors (researchers and industry/technology associations), reflecting diverse viewpoints on both the commercial and societal dimensions of quantum technology – and its meanings for different actors. Our interviews averaged 50 minutes and were recorded and transcribed with informed consent, with notes taken during or immediately afterward. Our open-ended questions elicited interviewees' understanding of their relation to quantum technologies and their perceptions of the opportunities, risks, and societal implications of these technologies. As interviews were the last type of data we collected and continued into data analysis, we continued interviews until we reached theoretical saturation (Glaser & Strauss, 1967).

Our data collection was designed to capture a comprehensive and varied set of discursive constructions of quantum technologies in Australia, over time. We summarize our data in **Table 6** and provide details of our interviewees in **Table 3**.

3.3 Data Analysis

We analyzed our data using an iterative and inductive theory-building approach (Van Maanen et al., 2007), moving back and forth between analyzing data, consulting existing literature, and applying theoretical frameworks to develop insights from our case. This method is effective for exploring phenomena that remain under-theorized (Gehman et al., 2018; Langley, 1999), aligning with our objective of theory building. Initially, we organized our media texts and publicly available documents chronologically from which we could build an event history database (refer to **Table 1**) (Van De Ven & Poole, 1995) to capture what happened, involving whom, and when; as well as the shifting discourse that brought quantum technologies into existence and made them meaningful in different ways over time, documenting who said what, when, and how (Maguire, 2004).

To learn more about hyping, the contested process underpinning hype understood as an outcome state of escalated, positive expectations, we applied open coding to our media texts and documents, and this coding led us to distinguish discursive work that contributed to a positive collective vision and escalated expectations around quantum technologies from dissenting reactions to this advocacy-focused discursive work and the escalated, positive expectations it generated. The former related to the technology's potential to avoid dystopian scenarios from eventuating while delivering societal benefits, whereas the latter emphasized ethical and societal concerns linked to the potential adverse effects of the emerging technology. Ironically, given hype is usually associated with escalated, positive expectations, our analysis revealed an underlying predominantly gloomy or pessimistic tone in the hyping of quantum technologies in Australia, with advocates' hyping of the technology anchored on the technology's capacity to preclude or mitigate highly or even existentially undesirable possible outcomes. While opportunities and benefits of quantum technologies were mentioned, we were struck in our interpretive analysis by how much emphasis was placed on the opportunity cost of *not* pursuing them, meaning downside risks – including some existential ones – were prominent. For example, first-order codes relating to positive discursive work included 'quantum described as a transformative tool for national defense' and 'economic potential of quantum technologies highlighted through industry value and job creation.' But some first-order codes were also related more explicitly to risks, such as 'quantum positioned within broader US-China rivalry' where, if under control of China, it represented a serious threat to Australian military security. In contrast, codes pertaining to dissenting discursive work included 'risks of mass surveillance enabled by quantum technologies' and 'ethical concerns about quantum misuse and potential societal harms.' Related to dissent that countered advocates' discursive work, we also identified actions intended to address proactively potential ethical and social harms arising from quantum technologies. Such codes included 'discussions on balancing the opportunities and risks of quantum innovation' and 'calls for an ethical inclusive quantum ecosystem.'

These codes were then examined across our entire dataset, including interviews, to develop second-order themes. This examination was guided by the interaction between collected data and conceptual patterns forming from our analysis (Eisenhardt, 1989). Our iterative method involved repeated analysis of media texts and documents, transitioning between first-order codes and the emerging second-order themes. This approach enabled us to refine our analysis and uncover patterns (Langley, 1999; Strauss & Corbin, 1990) in how actors harnessed the discourses of risk and responsibility when hyping quantum technologies. As second order themes began to emerge from media texts and documents, we also immersed ourselves in our interview data through repeated readings of transcripts. Points raised by interviewees were compared to media accounts, allowing us to corroborate events and perspectives, as well as to revise in minor or major ways our themes to ensure they aligned with and honored all our different types of data. Our interviews therefore provided complementary, contextual insights and alternative perspectives that clarified media accounts and served as a robustness check on patterns initially identified in the analysis of media texts and documents, into helping us to nuance and interpret the contrasting meanings that advocates and dissenters sought to attach to quantum technologies. As a result, our second-order themes included contrasting ideas such as 'quantum as a tool for addressing national security threats,' and the 'potential misuse of quantum for societal control,' for example.

Aggregating these themes, we found that quantum technologies were hypefully constructed either as a risk management solution to prevent significant security and economic risks from materializing or as a risk object capable of producing novel social risks. We also found the concept of responsibility to play a role in the hypeful construction of quantum technologies. Responsibility in practice was constructed as the outcome of a negotiation between government, civil, and the emerging quantum technology sector – one aimed at balancing the risks and benefits of quantum technologies. **Figure 1** outlines our data structure, showing our first-order codes, second-order themes, and aggregate dimensions; and our first set of findings details how these meanings were attached to emerging quantum technologies.

With our conceptual building blocks in terms of meanings attached to quantum technologies now relatively stable, we revisited our chronologically arrayed data to explore whether we could identify patterns in time and, if so, how might we reasonably interpret them. We used temporal bracketing (Langley et al., 2013) to identify three distinct periods in the development of quantum technologies in Australia, as follows. As per Langley (1999), we identified key inflection points in time by looking for events which appeared to mark notable shifts in the constellation of actors brought together around quantum technologies and/or the nature and scale of activities they were undertaking. The resulting brackets (2012-2016, 2017-2020, and 2021-2024) each capture a coherent period with distinct dynamics, as elaborated in the second set of findings.

Our final step involved mapping discursive shifts in the media texts and documents we had assembled to the temporal periods we identified, mapping our codes chronologically to trace patterns in the discourse about quantum technologies in Australia over time. Our initial interpretive analysis of the relative importance of different meanings was triangulated with counts from our media texts, confirming the following pattern: initially, advocacy dominated, which was followed by a period of increased contestation as dissent countered advocacy, and ending with a period of advocacy overwhelming the dissent. By the final period, a prevailing meaning was that responsible action involved accelerating the development and commercialization of quantum technologies not only for their security and economic benefits but, importantly, as risk management solutions to significant, almost existential, threats, despite possible novel social risks posed by these technologies, as elaborated in the second set of findings.

Figure 1: Data Structure

First-Order Codes	Second-Order Themes	Aggregate Dimensions
Quantum technology development framed as a geopolitical competition Quantum positioned within broader US-China technological rivalry	Geopolitical competition framing quantum as a critical technology	Quantum as a risk management solution to geopolitical and national security risks
Quantum described as a transformative tool for national defense Quantum positioned as a threat to military security	Quantum as a tool for addressing national security threats	
Quantum descriptions aligned with Cold War-style tensions Quantum described using arms race and space race metaphors	Cold War-era parallels in geopolitical discourse	
Importance of maintaining leadership in quantum technologies Warnings about falling behind global leaders in critical technologies	Maintaining global leadership in critical technologies	
Economic potential of quantum technologies highlighted through industry value and job creation Quantum development linked to transformative economic opportunities for industries	Economic benefits and job creation linked to quantum development	Quantum as a risk management solution to economic risks
Talent migration framed as a risk to Australia's quantum sector 'Brain drain' and missed opportunities highlighted as economic risks	Framing of talent retention as critical to economic competitiveness	
Quantum portrayed as a driver of transformative applications Quantum linked to solving complex societal challenges	Technological innovation for economic and social applications	
Quantum technologies associated with access inequality due to high costs Concerns about unequal distribution of benefits from quantum development	Social risks related to inequality and accessibility	Quantum as a risk object posing social risks
Risks of mass surveillance enabled by quantum technologies Quantum integration with AI raising societal risks	Potential misuse of quantum for societal control	
Threats to encryption and privacy highlighted Ethical concerns about quantum misuse and potential societal harms	Ethical and privacy challenges posed by quantum technologies	
Advocacy for ethical, inclusive development of quantum technologies Calls for an ethical and inclusive quantum ecosystem	Emphasizing ethics and inclusion in quantum development	Responsibility as a notion balancing the risks and benefits of quantum innovation
Discussions on balancing the opportunities and risks of quantum innovation Need for responsible governance to address societal implications of quantum	Balancing innovation with ethical and societal considerations	
Calls to embed responsibility principles within quantum innovation processes Responsibility framed as important in the development of quantum technologies	Responsibility as a key consideration	

4. Findings

Our first set of empirical findings sheds light on the dynamics of how actors harnessed discourses of risk and responsibility in hyping new quantum technologies. Our second set of empirical findings presents how these discursive dynamics played out over three periods between 2012 and late 2024. Here, we outline how risk and responsibility were harnessed in hyping quantum technologies, before presenting how this hyping evolved over the course of our study.

4.1 Harnessing 'risk' and 'responsibility' in hyping quantum technologies

4.1.1 Quantum technology as risk management solution to geopolitical and national security risks

We found abundant evidence in our data that the concept of risk connects quantum technologies to geopolitical and national security threats, with the development of quantum technologies constructed as a risk management solution to prevent these threats from materializing. Headlines such as "Race on for quantum tech" (The Australian Financial Review, 10 September 2015), "Epic struggle between the US and China for control of big tech" (The Sydney Morning Herald, 30 November 2018), and "The dangers of a tech cold war" (Waters, Hille and Lucas, 2019) exemplified this discourse and positioned quantum technologies as objects that adversarial actors will weaponize given their transformative potential. For example, texts warned that quantum computers would be "a game-changer for defence" and "able to crack encryption, which safeguards everything from our banking transactions to spy and military networks" (The Sydney Morning Herald, 27 September 2021). Texts even openly claimed that the development of quantum technologies had "geopolitical implications…including whether Australia should have sovereignty in manufacturing semiconductors (The Australian Financial Review, 18 May 2021).

Further, in our data, the development of quantum technologies was regularly referred to in the media as a geopolitical "race", with parallels drawn from Cold War language of an arms race (The Sydney Morning Herald, 27 September 2021), and the space race (The Australian, 6 May 2021; The Australian Financial Review, 11 May 2021). Reinforcing the arms race discourse, texts positioned quantum technologies as a risk management solution to geopolitical and national security risks by identifying quantum as a critical technology needed to "protect the nation against technologies that can significantly enhance or pose risks to Australia's national interests" (The Australian, 22 April 2021). Similarly, texts warned:

> "The US once led the world in wireless cellular technology, only to drop the ball and allow China to surge ahead. It must rectify this mistake and ensure that the same thing does not happen in associated strategic technologies such as quantum computing and artificial intelligence. Australia can play a leading role in both fields through our world class research and expertise." (The Australian, 8 June 2019)

Finally, shared technological capabilities were a centerpiece of the joint security agreement signed in 2021 between Australia, the UK and the USA, known as AUKUS, which also positioned quantum technologies as a "critical technology":

> "The Australian Government also recognises the risks critical technologies can present – whether through: unwanted knowledge transfer and intellectual property theft; undermining our sovereign decision-making; increasing our cyber threat surface compromising critical functions, systems or supply chains." (Department of Industry, 2023a)

This discursive construction was confirmed in our interviews, with the founder of a quantum technology firm explaining it as such:

> "… if there was going to be quantum computing developed, you would want to make sure that your country had one. And so in a sense, the issue was one of ensuring that the country didn't fall behind nation states that may not use that they can potentially use that capability in a harmful way. Okay, so I think that it's been the case that one of the one of the motivating triggers that unlocked funding in Australia, and certainly, I would say, in the United States, and probably in other countries as well, was the concern of governments to keep ahead of the game because of the risk. So in a way, it was kind of a protection mechanism." (Interviewee 8 – Quantum technology firm founder)

To summarize, hyping entailed discursively constructing quantum technologies as a solution for managing highly salient geopolitical and national security risks.

4.1.2 Quantum technology as risk management solution to economic risks

In our data, we also found that actors constructed quantum as a risk management solution to economic risks by framing the prospect of slow or non-development of quantum technologies as a national economic risk. They emphasized the "danger of inaction" (The Sydney Morning Herald, 20 April 2016) and urged embracing the financial risks tied to uncertain returns on quantum investments (The Australian, 14 December 2015) to avoid squandering economic opportunities afforded by quantum technologies – "a A$4 billion industry for Australia, with 16,000 new jobs by 2040" (The Australian Financial Review, 18 May 2021) – losing Australia's comparative advantage, and falling behind in on economically important technology (Tillett, 2022). They compared this risk to previous missed opportunities, asserting, "We don't want this to be like solar technology, where we were pioneers until it went offshore and we lost much of the environmental and economic benefits" (Sier, 2022). Although this discourse emphasizes potential economic benefits such as job creation, industry growth, and technological leadership, in our data, they were consistently juxtaposed with and overshadowed by the counterfactual risk of missing out on these benefits, whether through talent outflow, missed investment, or loss of comparative advantage. In this sense, economic themes were articulated not simply as opportunities, but as risk management imperatives aimed at averting economic decline relative to global competitors.

Public debates highlighted fears of this risk materializing, particularly through domestic inaction on preventing the "brain drain" of quantum talent overseas: "We are in grave risk of all the technology we have developed and the trained human capital being transferred overseas with little long-term benefit to Australia" (The Australian, 10 September 2015). Other actors expressed similar sentiments:

> "Australia has already begun to feel the effects of not keeping pace with the rest of the world. We are now seeing more and more of our talent whom we initially developed and nurtured whisked overseas. The founders of some of the largest and most heavily funded quantum start-ups in the world are Australian, yet are based elsewhere - photonics companies PsiQuantum and Xanadu (which have raised more than A$500 million and A$100 million respectively) are headquartered in Palo Alto and Toronto instead of Sydney or Melbourne." (Devitt, 2021)

Actors portrayed the economic risk as extending beyond missed venture capital investments lured overseas, emphasizing a range of other benefits offered by emerging quantum technologies. They highlighted specific industries and potential applications, asserting that "Australia benefits when the quantum era arrives. The exponential increase in computer processing speeds will bring benefits in areas such as health, finance, IT, transport and security, creating opportunity, jobs and economic return" (The Australian Financial Review, 19 March 2018) Even though quantum technologies had not yet reached a stage of significant commercial impact, media articles boldly claimed future applications, suggesting, "In the future, quantum computers will help us grow crops without expensive fertilizers, discover new drugs and treat disease with therapies matched to our DNA" (Chapman, 2017). Again, this discursive construction was present in our interview data, with one interviewee referencing quantum as a risk management solution to both economic risks and geopolitical risks:

> "I mean, what has been discussed is the risk of doing nothing. Right? Yes, which is the risk of not understanding and having these technologies, and that's particularly in the security and defense sector. And then the economic loss of opportunity that would happen more broadly. So that's the risk." (Interviewee 3 – Quantum technology firm founder)

In summary, actors hyped quantum technologies by constructing them as solutions for managing highly salient risks involving serious threats to national security and damage to the economy. These risks are also relatively familiar ones, with citizens understanding the consequences of losing critical 'races' tied to collective self-defense and economic well-being. As a result, hyping also involved actors stressing the need to embrace these technologies to prevent a 'brain drain', capture economic benefits, and mitigate potential security and economic risks.

4.1.3 Quantum technology as risk object posing social risks

Our analysis revealed, albeit less, emphasis on social risks associated with quantum technologies in the empirical textual data. Some texts even lamented the lack of attention to possible risks: "The only people likely to think about and plan for the consequences — those in government — are not talking about it, but celebrating it — for example, by appointing Michelle Simmons as Australian of the Year" (The Australian Financial Review, 27 January 2018). This relative lack of attention was despite scholars identifying such risks in research on "responsible innovation" of quantum technologies (Coenen & Grunwald, 2017; Inglesant et al., 2021; Ten Holter et al., 2023) . These risks included harms such as inequality of access due to the substantial resources required to build and maintain quantum computing devices, possible jobs losses, threats to non-quantum-safe encryption protocols, and jeopardized citizen privacy initial stages (Quantum Computing Governance Principles: Insight Report, 2022; "Responsible Quantum: Starting the conversation," 2021).

The lack of focus on the social risks posed by quantum technologies was connected to understandings of the technologies and their capabilities. One interviewee expressed alarm over society's minimal awareness of quantum technologies: "As we become more reliant on advanced technologies, very few people—even a small percentage of society—are even vaguely aware [of quantum]" (Interviewee 7 – Technology association partnership manager). As a result, these risks were seemingly less salient than the security and economic risks surfaced in our data.

In the few instances when social risks associated with quantum technologies where discussed, these focused on data and privacy concerns:

> "It's not all upside [in regards to quantum technologies], though — quantum computing could also pose risks to the security of customer data and the stability of the financial services industry. To gain access to customer data, a hacker currently has to use trial and error to crack a code that could be hundreds of digits long. Quantum computers could perform the same task much more efficiently, and at much greater risk to the customer." (The Australian, 11 April 2017)

Another interviewee expressed similar concerns about the risks of quantum computing in relation to decryption, which would pose a "personal security risk for everyone's information" (Interviewee 8 – Quantum technology firm founder). Similarly, an interviewee flagged risks stemming from quantum's integration with existing technologies like artificial intelligence, stating:

> "It's about what happens if [quantum pushes] an existing technology forward? What are the associated risks? For example, [quantum] sensing could suddenly enable surveillance at a level of detail we couldn't previously achieve, raising risks associated with mass

> surveillance and its implications for society." (Interviewee 3 – Quantum technology firm founder)

However, broadly, many risks associated with quantum technologies mirrored those of other Fourth Industrial Revolution technologies, including unclear accountability structures, lack of transparency in technological outcomes, and insufficient public engagement (World Economic Forum, 2022).

In summary, actors paid far less attention to the social and ethical risks of quantum technologies compared to their economic and security risks. These overlooked risks included potential harms such as inequality of access, compromised encryption protocols, loss of citizen privacy, unclear accountability, and minimal public engagement. When it is constructed as a risk object, some notable harms of quantum technology stem from their potential misuse in conjunction with existing technologies such as artificial intelligence, resulting in risks from mass surveillance and its societal implications.

4.1.4 Responsibility as a notion balancing the risks and benefits of quantum technology

Finally, actors positioned the responsible development of quantum technologies as a critical condition for balancing the risks and benefits of quantum innovation. The Australian Federal government explicitly acknowledged this relationship in its consultation with the quantum technology sector, stating:

> "Australia should be a leader in responsible quantum development. We need to carefully consider the social, ethical and security challenges that quantum technologies will present. Quantum technologies will be transformative and present tremendous opportunities for all aspects of Australian life. But it will be important to ensure that quantum technologies are developed responsibly, ethically and with the broader national interest in mind." (Department of Industry, 2022)

Actors echoed this construction of responsibility as a commitment to ethical development and governance. For instance, an actor argued that "[w]ith every digital advance, we have a responsibility to ensure that everyone is empowered and that it creates the opportunity for equitable growth" (Courtois, 2020). Similarly, a leading academic entrepreneur aware of the potential of quantum technology stated they "felt a tremendous responsibility to make sure the Australian government knew where it could go … Part of my job has been making absolutely clear the potentials of this technology and bringing [government and industry] in to our research, so they are at the ground level and see the technology as it develops." (The Australian Financial Review, 20 March 2018).

Texts also attributed the responsible development of quantum technologies to specific groups. Australia's National Quantum Strategy identified "A trusted, ethical, and inclusive quantum ecosystem" as one of its five themes. The government committed to 'champion responsible innovation and introduce new standards and regulatory mechanisms where national well-being is at risk" (Department of Industry, 2023b). However, the strategy left the form of responsible action largely undefined, highlighting a gap between rhetoric and clear implementation plans. Founders of quantum technology firms similarly acknowledged the importance of responsibility. As one such actor explained:

> "[T]he main risk at the moment is that the key principles of responsible innovation—the awareness of thinking about your technology, where the componentry comes from, the implications of that supply chain, and the application of your technology—are pretty much non-existent in the industry. Addressing that awareness and encoding it in industry practices will go a long way toward mitigating big risks…the unknown unknowns we currently face." (Interviewee 13 – Quantum technology firm founder)

Others pointed to more concrete practices of responsibility in investment decision-making. As one investor described,

> "We do a thorough ESG screen on all of our investments - the social and governance aspects. Right, in particular, for quantum [our question to founders is] how do you ensure that this is not being used for an improper purpose? How are we comfortable that, you know, the risks can be mitigated or have been addressed already… [And] from a security standpoint, how do we get comfortable that structures exist, or will exist, to minimize the risk of improper use? It is very much an important part of the screening of every investment, but more specifically was an important part of recent investments that we've made in quantum technologies." (Interviewee 11 – Venture capital firm investor)

At the same time, responsibility was also framed through skepticism toward exaggerated promises of near-term breakthroughs. As another actor cautioned, "most of these companies out there, [their] proposals are worded so that it almost sounds like they can solve some problems in the next three years' time. It's not true" (Interviewee 18 – Quantum technology firm researcher and director).

In summary, our first set of findings sheds light on how actors harnessed discourses of risk and responsibility to construct quantum technologies as both a solution to and a source of risk, balancing between geopolitical, security, economic, social, and ethical concerns. Overall, while actors acknowledged a loosely defined need for responsible development, this acknowledgment was overshadowed by a prevailing sense that slow or non-development of quantum technologies would be irresponsible. Within this discourse, actors positioned truly responsible action as accelerating quantum technology development to address critical threats to national security and economic growth. In our second set of findings, we now trace these dynamics across three periods covered in the study.

4.2 Discursive dynamics constructing quantum technologies over time

4.2.1 Period 1 (2012–2016): Quantum advocacy is dominant, with the technology constructed primarily as a risk management solution to economic and geopolitical/security risks

During the period from 2012 to 2016, quantum technologies were primarily constructed as solutions to economic challenges and as strategic assets for enhancing Australia's global standing, particularly in the context of growing interest in advanced computation and security applications. This construction was catalyzed by landmark scientific breakthroughs in 2012, when researchers in Australia achieved two critical milestones: Michelle Simmons' team demonstrated the world's smallest transistor made from a single phosphorus atom in silicon, which was a key step towards donor-based qubits, while Andrew Dzurak's group demonstrated the feasibility of building silicon-based quantum processors at the atomic level (The Sydney Morning Herald, 21 Feb 2012). These results drew international attention from industry and defense sectors, validating years of Australian investment in quantum research and positioning the country at the forefront of global efforts in the field. Media texts from the period emphasized the transformative potential of quantum technologies for industries such as finance and energy, celebrating their substantial benefits and portraying them as national assets with the capacity to enhance Australia's international reputation. For example, quantum computing, along with solar photovoltaics and cancer research, was described as an area where "Australia has an enviable research record" (The Sydney Morning Herald, 10 November 2012). By linking these technological advancements to geopolitical significance, the quantum technologies were presented as both a source of national pride and a symbol of Australia's scientific and strategic capability.

By 2015, discussions increasingly emphasized Australia's globally competitive position in the development of quantum technologies. High-profile figures, such as Professor Michelle Simmons, highlighted this leadership, stating that "the US government had said her team was 'two to three years ahead in silicon quantum computing' of their competitors" (The Australian Financial Review, 10 September 2015). Such statements reinforced the construction of quantum technologies as strategic assets essential to maintaining Australia's leadership in scientific innovation. Similarly, texts declared that "Sydney is establishing itself as one of the principal centres for quantum computing—a technology that, once realised, will impact on everyone's life in a multitude of ways" (The Sydney Morning Herald, 20 April 2016). These narratives connected Australia's advancements in quantum research to global competition, positioning quantum technologies as a driver of national progress. However, they also stressed the risk of missing out on the opportunity:

> "Australia holds an unparalleled lead in one of the hottest, most competitive frontiers of innovation today: quantum computing. It's the next big computer revolution and could reap the country enormous benefits. But we could let it slip from our grasp … We may well be two years ahead of the rest of the world in a range of areas of quantum computing but this lead could quickly be overtaken … We've been given a second chance to lead the computer revolution. The question is, will we take it, or again let it slip from our grasp?" (The Australian Financial Review, 24 November 2015)

The technological potential of quantum technologies, particularly in industries reliant on advanced computation, was a recurring theme during this period. For example, it was noted that quantum computers could solve "calculations that would now require a machine larger than the size of the known universe" (The Sydney Morning Herald, 30 November 2012). These accounts portrayed quantum as a transformational tool capable of solving complex problems with significant financial implications. Additionally, Australian companies were reportedly exploring applications such as using quantum computers to "speed up risk analysis for insurance and capital asset management" (The Australian Financial Review, 20 May 2014). This positioning emphasized the practical economic benefits of quantum technologies for various industries.

Policymakers and industry leaders advocated for investments in the sector, underscoring its economic importance. In 2015, Industry, Innovation, and Science Minister Christopher Pyne stated that "quantum computing could be worth billions of dollars to Australia" (The Australian Financial Review, 11 December 2015). These comments highlighted quantum technologies' strategic value and their role in securing Australia's competitive position in the global economy.

While there were early indications of quantum's potential to disrupt existing systems, such concerns were generally minimal and contextualized as part of the broader progress of technological development. For instance, texts observed that "[t]he arrival of practical large quantum computers, possibly in another decade or so, with their immense computing power and consequent ability to break current encryption codes, will change the whole game dramatically" (The Australian, 28 May 2016). However, these concerns were limited and did not detract from the largely positive positioning of quantum technologies.

In summary, from 2012–2016, quantum technologies were primarily constructed as solutions to economic (46%) and geopolitical/national security risks (35%), with texts emphasizing their potential benefits in addressing threats to national security and economic growth, with occasional and minor references to potential social risks associated with the technologies (12%) or the need for responsibility to balance the risks and benefits of quantum innovation (8%). During the period, early breakthroughs in single-atom transistors and silicon-qubits were heralded as symbols of Australia's scientific leadership and economic opportunity, attracting major defense and corporate actors (e.g., Telstra, Commonwealth Bank, IBM, Hewlett-Packard, Lockheed

Martin). Government policy reinforced this momentum, with the 2015 National Innovation and Science Agenda committing funding to the national quantum program. Small but growing coalitions signaled both commercial and security stakes. Overall, quantum technologies were constructed as risk management tools for national security and economic growth, with only limited references to potential social risks.

4.2.2 Period 2 (2017–2020): Quantum contestation increases, as dissent counters advocacy through growing attention to social risks and responsibility

2017 marked a significant shift in the discourse, moving from a focus on celebrating Australia's scientific leadership in quantum research to positioning quantum technologies as strategic national priorities with immediate economic, security, and competitive implications. The creation of Silicon Quantum Computing Pty Ltd in 2017, funded by universities, governments and large corporates (The Australian Financial Review, 23 August 2017), exemplified this turn toward institutionalized commercialization, while initiatives such as CBA's quantum simulator with UNSW and QxBranch (The Australian Financial Review, 10 April 2017), Microsoft's Station Q Sydney partnership (The Sydney Morning Herald, 25 July 2017), and the NSW Government's A$26 million Quantum Computing Fund reinforced broader public–private engagement. By 2019 the Sydney Quantum Academy extended state-level investment into workforce development, and in 2020 CSIRO's quantum technology roadmap (CSIRO, 2020) projected A$4 billion in revenue and 16,000 jobs by 2040, warning that Australia must "act now" or fall behind in a global race dominated by billion-dollar U.S., EU, and Chinese programs. These developments contributed to the discursive construction of quantum technologies becoming increasingly contested between 2017 and 2020. While earlier narratives that positioned quantum as a solution to geopolitical, national security, and economic risks remained central, texts increasingly included references to quantum as a potential risk object, raising concerns about social risks, disruption, and the need for responsible innovation (Australian Strategic Policy Institute, 2021).

The geopolitical focus in texts continued to intensify during this period, with quantum computing, in particular, increasingly described in terms of global competition and urgency. The technology was framed as a "21st-century space race" (The Australian Financial Review, 1 December 2017), drawing on Cold War-era imagery to underscore its strategic importance. One actor commented in an op-ed piece:

> "Right now, the government, reacting to international propaganda and heightened geopolitical tensions, is proposing restrictions that will put a damper on the brightest light within the Australian technology sector. All in the name of national security against what is seen as a rising threat from China in quantum technology." (Biercuk, 2019)

This comment highlights a tension in the construction of quantum as a solution to national security and geopolitical risks connected to a perceived skills shortage in Australia's quantum technology sector.

Other texts further emphasized the geopolitical significance of quantum computing. Telstra Chief Scientist Hugh Bradlow described it as a "21st-century space race" (The Australian Financial Review, 1 December 2017), reflecting global competition. Reports frequently referred to China's advancements, noting that it "has the fastest supercomputer... and is building the world's most lavish quantum-computing research centre" (The Australian, 17 March 2018). Quantum was presented as highly political, with one text stating, "The race to build the first quantum computer is not merely a scientific one, but highly political" (The Australian Financial Review, 5 March 2019). The Australian Defence Force was described as "becoming increasingly receptive to game-changing capabilities, including quantum computing and hypersonics" (The Australian, 25 May 2019). Broader geopolitical concerns also surfaced, with texts stating, "Cold War 2.0 is heating up as Washington continues to push back against predatory Chinese behaviour widely perceived in the US as an existential threat to the country's technological pre-eminence and national security" (The Australian, 8 June 2019). Finally, the US Bureau of Industry and Security was reported to have proposed export controls for emerging technologies such as quantum computing "because losing control of them could threaten the country's national security" (The Sydney Morning Herald, 30 November 2018). These texts positioned quantum technologies as essential for addressing pressing security challenges and maintaining global leadership.

Economic considerations continued to feature in texts, emphasizing the transformative potential of quantum technologies for businesses and industries. Quantum technologies were described as having the ability to "take data gathering to new dimensions" (The Australian, 23 May 2017). Another text noted, "Quantum technology presents a once-in-a-generation opportunity for Australia to lead the development of a world-changing technology" (The Australian, 9 May 2018).

Echoing optimism, some researchers admitted uncertainty about how their work might be used but maintained that the "possible benefits for mankind and society mean that we can't ignore these technological advances" (The Sydney Morning Herald, 19 October 2019). Policymakers also anticipated significant economic opportunities, anticipating "Australia's economic opportunity from quantum technologies, which we think could be a multibillion-dollar opportunity for Australia and create thousands of jobs" (The Australian Financial Review, 28 January 2020). These portrayals reinforced quantum's role as a driver of economic growth and a solution to challenges such as stagnation and falling behind international competitors.

By 2017, the discourse began to include societal risks associated with quantum technologies. These texts linked quantum's efficiency to potential vulnerabilities, cautioning that quantum computing "could also pose risks to the security of customer data and the stability of the financial services industry" (The Australian, 11 April 2017). In another example, an industry actor stated:

> "Quantum computing probably will be used to defeat encryption algorithms, with all sorts of potentially chaotic implications, so we need to be thinking about that [as] hype about the benefits of new technologies [should be] accompanied with a proper consideration of risks." (The Australian Financial Review, 20 March 2018)

Concerns extended to labor market disruptions, with actors warning that advancements in quantum technologies could significantly alter workforce dynamics. Broader concerns about surveillance and ethical governance also emerged, with one commentator stating that "[i]t ultimately boils down not so much to the technology itself, but human beings, the institutions, the law, governance and the people who use the technology, to ultimately determine whether the human race uses [it], on balance, for its advancement or its detriment" (The Australian Financial Review, 20 March 2018). Texts also highlighted quantum computing's ability to redefine repetitive tasks and improve efficiencies across sectors. For instance, "[t]he definition of what is a repetitive and mundane task, better done by a machine, is expanding and will probably expand enormously once quantum computing becomes a reality" (The Australian Financial Review, 27 January 2018).

The notion of responsibility as a balancing framework for the risks and benefits of quantum innovation also gained attention during this period. Policymakers and commentators emphasized the importance of responsible governance to ensure the equitable and ethical development of quantum technologies. One policymaker noted that discussions of governance "need to ensure hype about the benefits of new technologies is accompanied with a proper consideration of risks" (The Australian Financial Review, 20 March 2018).

In summary, from 2017–2020, discourse on quantum technologies became more contested. While discourse constructing quantum as a solution to geopolitical/national security (36%) and economic risks (31%) remained dominant, references to social risks (20%) and calls for responsibility (13%) grew in prominence. This period marked a shift from research breakthroughs to institutionalized commercialization and urgency around global competition, symbolized by the 2017 launch of Silicon Quantum Computing Pty Ltd, backed by UNSW, governments, CBA, and Telstra. CSIRO's 2020 Quantum Roadmap reinforced this momentum, projecting A$4 billion in revenues and 16,000 jobs by 2040 while warning that Australia must "act now or fall behind." New coalitions, including the Sydney Quantum Academy (2019), broadened the ecosystem, while think tanks such as ASPI increasingly cast quantum as a security risk, emphasizing threats to encryption and great-power rivalry. Overall, quantum technologies were still constructed as both economic and security risks, but also as emerging risk objects demanding responsible innovation.

4.2.3 Period 3 (2021–2024): Quantum advocacy dominates dissent, with the economic and geopolitical/security risks for which the technology serves as a risk management solution overwhelming the social risks of quantum technology

Between 2021 and 2024, contestation in the discursive construction of quantum technologies diminished, with texts increasingly dominated by the positioning of quantum as a solution to geopolitical, national security, and economic risks. Media coverage portrayed quantum as central to Australia's competitive positioning in the global technology race, linking it directly to defense alliances such as AUKUS and to safeguarding national sovereignty (The Australian, 17 Sept 2021). Government strategies, such as the Federal Government's explicit inclusion of quantum in the Digital Economy Strategy (Australian Government, 2021), reinforced its status as a strategically sensitive domain demanding policy leadership and sustained investment. Although notions of quantum as a risk object and calls for responsible innovation persisted, including concerns over its potential to break existing encryption standards (The Sydney Morning Herald, 27 September 2021), these were largely overshadowed by narratives emphasizing the urgency of building domestic capabilities to counter foreign technological dominance (The Australian Financial Review, 4 August 2021).

Geopolitical urgency remained a central narrative, with texts frequently invoking quantum's strategic importance in global power dynamics. Reports underscored the risks of Australia falling behind in the global quantum race, emphasizing the critical need for increased investment and policy action. For instance, the Australian Strategic Policy Institute warned that "Australia is falling behind in the global quantum technology race despite its history of leadership in the field," calling for a "step change" in policy settings and investment (InnovationAus, 13 May 2021). Similarly, government figures emphasized quantum's role in securing national sovereignty, with discussions highlighting the "geopolitical implications" of semiconductor manufacturing and other quantum technologies (The Australian Financial Review, 18 May 2021).

The narrative of quantum as a security imperative also gained traction. Quantum technologies were increasingly portrayed as essential for mitigating cybersecurity and national defense vulnerabilities. Industry and government actors warned of the risks associated with "harvest now, decrypt later" attacks and the potential for quantum computers to disrupt cryptographic systems, emphasizing the urgency of developing secure quantum readiness plans (The Australian, 12 March 2024). These texts positioned quantum technologies as important for maintaining national security and navigating a highly competitive international landscape.

Economic imperatives also remained prominent during this period. Forecasts from CSIRO projected significant economic opportunities, with quantum technologies expected to generate A$4.6 billion by 2040 and A$6 billion by 2045, along with thousands of new jobs (InnovationAus, 14 October 2022). Government and industry leaders repeatedly stressed the need to scale quantum technologies from academic research into commercial applications. The Australian government's National Quantum Strategy and investments through initiatives like the A$15 billion National Reconstruction Fund were framed as critical steps in maintaining Australia's economic competitiveness and leadership in high-tech manufacturing (InnovationAus, 28 September 2023).

While discussions of quantum as a risk object persisted, they were increasingly peripheral. Concerns about societal risks, such as inequality of access, data breaches, and ethical challenges, appeared sporadically. For example, texts acknowledged the potential for "negative outcomes" if quantum technologies were not handled responsibly, cautioning that quantum's transformative potential could lead to challenges in governance, workforce inclusion, and emissions management (InnovationAus, 28 September 2023). However, such concerns were framed as secondary to the broader strategic and economic imperatives.

Discussions of societal risks occasionally intersected with concerns about geopolitical tensions. For example, Australia's Chief Defence Scientist noted that growing restrictions on international collaboration, particularly with countries like China, were necessary to safeguard quantum technologies with national security implications (InnovationAus, 23 February 2022). While these restrictions highlighted the potential social and academic impacts of geopolitical competition, the discourse largely prioritized national security concerns.

The notion of responsibility remained part of the discourse but was largely subsumed by calls for accelerated quantum development. Key institutional texts, such as CSIRO's Roadmap for Growing Australia's Quantum Technology, emphasized the need for a "trusted, ethical, and inclusive quantum ecosystem" (InnovationAus, 28 September 2023). Similarly, leaders in the sector stressed that responsible action involved balancing the acceleration of quantum innovation with considerations of broader societal and environmental implications. However, discussions of responsibility often reinforced the dominant narratives of security and economic competitiveness. Responsibility was framed as a means to achieve these goals, with texts urging stakeholders to "think big" and collaborate across sectors to realize quantum's potential while addressing risks (InnovationAus, 28 September 2023). The emphasis on responsibility was thus closely tied to maintaining geopolitical and economic leadership.

In Period 3, major policy actions – including Australia's inclusion of quantum in AUKUS (2021), Morrison's A$100M Critical Technologies Blueprint (2021), and the A$1B National Quantum Strategy (2023) – reinforced the construction of quantum technologies as risk management solution both security (40% of codes) and economic (43% of codes) risks, with the social risks posed by quantum technologies (10%) and the need for responsibility to balance the risks and benefits of quantum (7%) acknowledged but largely sidelined.. Actor coalitions expanded further during the period: federal leaders and defense agencies institutionalized quantum in security planning (e.g., Army's Quantum Roadmap), and emerging quantum technology firms like Q-CTRL and SQC showcased world-first commercial and technical milestones (e.g., SQC's 2022 integrated silicon quantum circuit). Although actors appeared to be conscious of potential social risks posed by new quantum technologies during Period 3, their engagement with these risks was broadly limited to acknowledging that they might occur and that action should eventually be taken to minimize their impacts. Consequently, it appears that the construction of quantum technologies as a risk management solution to highly salient security and economic risks – along with the associated entrepreneurial opportunities that this situation presents – overwhelms quantum's construction as a risk object. There is little evidence that the latter construction is driving action in the quantum sector.

5. Discussion

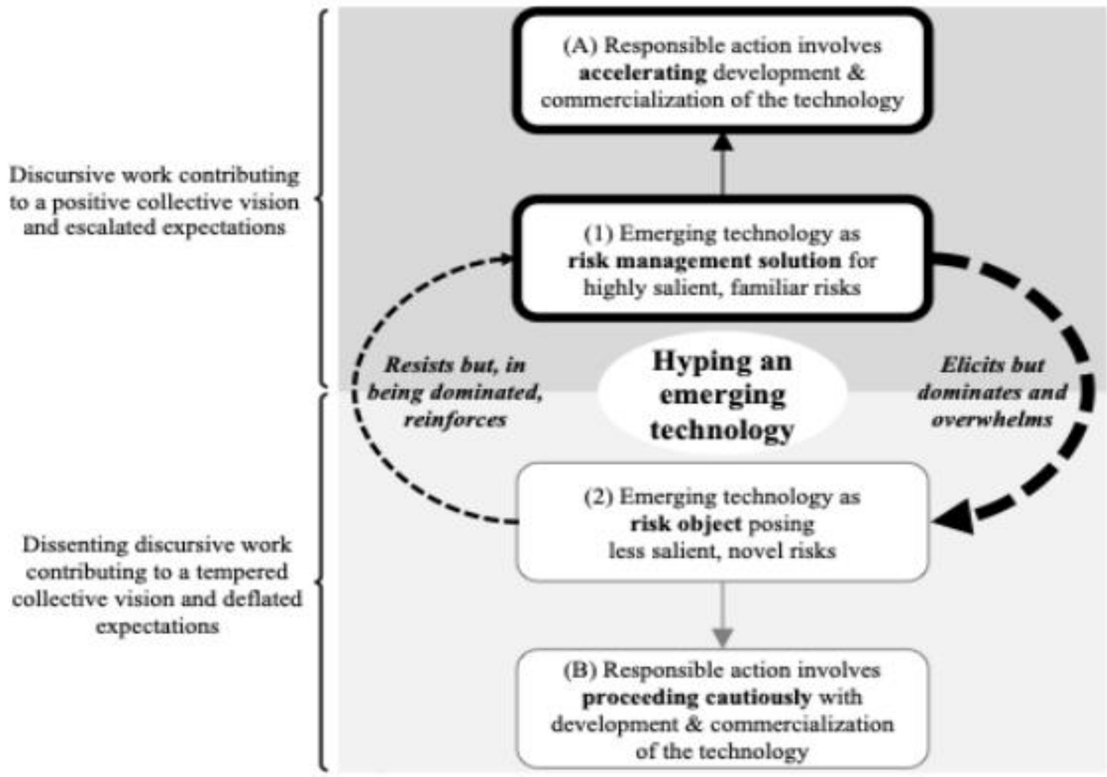
Our research question asked: How does hyping, understood as a discursive process involving contestation through discursive struggle, influence the meaning of an emerging technology? We found that hyping an emerging technology involves positioning the technology in relation to multiple risks for which it plays very different roles – as a risk management solution on one hand versus as an object posing risk on the other hand. Our findings are consistent with sociological accounts of risks and risk objects (Hardy & Maguire, 2016; Hilgartner, 1992): in the first positioning, the "risk object" is specifically the uncontrolled, adversarial deployment of quantum capabilities by geopolitical security and economic rivals, for which the "risk management solution" is the speedy sovereign, domestic development of quantum technologies to neutralize such threats; in the second positioning, quantum technologies are the risk object. In our case study of quantum technologies, the former risks were salient, familiar economic and security ones; and the latter risks were less salient, unfamiliar social ones. In the case of other new technologies, the specific risks in question will vary. For example, in the hyping of agricultural biotechnologies (e.g., GMOs), these technologies were enthusiastically championed and constructed as solutions for preventing or mitigating the materialization of risks of crop loss and, by extension, malnutrition and hunger;

while possible novel health and environmental risks were downplayed (Mehta & Vanderschuren, 2021; Varshney et al., 2011).

These competing focal risks not only have different levels of salience for actors, but also divergent implications for what constitutes responsible action. Building on the sociology of expectations, our findings illustrate how these competing visions of responsibility reflect not only present disagreements but also deep-seated cultural repertoires for imagining technological futures (Mokyr et al., 2015). When hyping an emerging technology, its construction as a risk management solution to highly salient, familiar risks overwhelms its construction as a risk object posing less salient, novel risks. This asymmetry aligns with observations that elite coalitions, including the likes of policy actors, corporate strategists, and scientific leaders, play a pivotal role in stabilizing certain future visions over others (Guice, 1999), filtering contestation in ways that privilege acceleration over caution. As a result, an understanding of responsible action in which the development and commercialization of the emerging technology should be accelerated overwhelms a competing understanding of responsible action in which actors should proceed more cautiously.

Drawing on the findings of our case study, we propose a generalized theoretical model of how the hyping of emerging technologies, through contestation invoking discourses of risk and responsibility, shapes technological trajectories (see **Figure 2**).

Figure 2: The role of hyping and expectations in shaping emerging technologies



Our model highlights key dynamics in the discursive process of hyping an emerging technology, presented as the recursive loops between (1) and (2). The discursive work of advocates of an emerging technology entails constructing it as an innovative risk management solution for preventing highly salient, familiar threats from materializing and/or mitigating them should they materialize (depicted as (1) in Figure 2). Because the technology is innovative and still new, its impacts cannot be confidently known or assessed and are likely to be novel and unfamiliar to actors; and because some of these impacts may be undesirable, dissent to advocates' discursive work and the hype it generates constructs the technology as a risk object posing uncertain risks (depicted as (2) in the Figure 2), those risks where "uncertainty or unfamiliarity concerning the harm that an object may cause, the likelihood the harm will occur, or the causal processes connecting the object and the harm" (Hardy & Maguire, 2020, p. 688).

With the discourse of risk, once risks are constructed, managing them is what responsible actors are expected to do. As a result, our model also highlights what constitutes responsible action in light of the competing risks. When emerging technologies are constructed as risk management solutions, and especially for highly salient, familiar risks, responsible action involves accelerating technological development and commercialization (depicted as (A) in the model). In contrast, responsible action when emerging technologies are constructed as risk objects involves adopting a more cautious approach to the technology's development and commercialization (depicted as (B) in the model).

Further, because advocates' discursive work in hyping the emerging technology involves exaggerating its benefits and discounting its risks (Caulfield & Condit, 2012), the highly salient, familiar risk for which the technology is constructed as a risk management solution and its associated responsible action of accelerating development and commercialization of the technology overwhelms calls for more cautious approaches to developing and commercializing the emerging technology, thus prevailing in the discursive process of hyping, which includes contestation. This dynamic is represented in the thick dotted arrow moving from (1) to (2), as compared to the thin dotted arrow from (2) to (1). As a result, hyping skews attention and actions towards aggressive development, often at the expense of cautious, measured approaches.

6. Contributions

We make two contributions with this study: (1) we advance a discursive perspective on technological hype by building on sociology of expectations research on the inherently political and performative nature of hype to highlight in some detail how the discourses of risk and responsibility are mobilized in discursive struggle over an emerging technology; (2) we additionally build on the literature on the sociology of expectations by showing how the discourses of risk and responsibility can be harnessed to expand constellations of actors and link issues in ways that give impetus and momentum to a particular nature, direction, and/or pace of development of an emerging technology.

First, we advance discursive perspectives on technological hype through our discursive perspective and discourse analysis, showing that hyping is a contested process in which advocates and dissidents both mobilize discourses of risk and responsibility, and that this process shapes the construction of an emerging technology. Existing research on hype commonly emphasizes investor losses when hype deflates (e.g., Momtaz, 2021), examining and criticizing negative consequences of hype from a morally charged resource efficiency perspective because investors in new technologies, such as shareholders and subsidy-offering governments, might be misleadingly enticed and suffer losses during the 'hype cycle' (Dedehayir & Steinert, 2016; Kriechbaum et al., 2021; Van Lente et al., 2013). This work communicates a strikingly narrow assessment of moral issues related to hype, however – one that is particularly problematic in the context of hyped emerging technologies that may pose novel risks to stakeholders way beyond financial risks to investors. Our study, in contrast, builds on sociological approaches that highlight a more political and performative dynamic in which the "promise and requirement" of articulated futures both enable and constrain subsequent action (Borup et al., 2006), demonstrating how the development of emerging technologies often involves other – arguably more important even if obscured – moral dimensions, wherein salient, tangible societal risks to state actors are managed at the expense of downplaying the potential risks posed by the technology itself to various social groups.

In this way, we contribute to existing research (e.g. Irwin, 2001; Petersen et al., 2017) a novel and timely (see Beck, 1992) discursive mechanism through which hype plays dual roles— amplifying transformative potential translated into non-monetized risks of 'paying' or suffering opportunity costs while sidelining critical conversations about risks, ethical implications, and alternative pathways associated with the emerging technology. Our findings, therefore, contribute to a more holistic and nuanced understanding of the role of hype in technology innovation and development, expanding extant sociology of expectations research by demonstrating how advocates' attachment of the meaning of risk management solution to a technology to construct it against a background of familiar, high-salience risks operates as a mechanism of exclusion, potentially marginalizing alternative visions and constraining the discursive space for responsible innovation. In this regard, our analysis also identifies something very interesting with discourses of economic growth, job creation, and industrial leadership which – while on the surface couched in the language of opportunity – were repeatedly phrased in counterfactual terms that emphasized the risks of inaction, loss of comparative advantage, or the erosion of national capabilities. This contribution is consistent with, but adds notably to, the sociology of expectations literature, which recognizes both imagined opportunities and imagined risks of emerging technologies as 'expectations' (Borup et al., 2006;), by shedding light on this translation of opportunity into non-monetized risk of suffering opportunity costs, particularly in competitive, high-stakes technological domains. By identifying this discursive maneuver, likely of increasingly rhetorical impact in our contemporary 'risk society' (Beck, 1992) in which risk has become a logic of organizing (Power, 2007), we show how advocates of emerging technologies strategically reposition prospective gains as defensive imperatives, discursively constructing emerging technologies not merely as pathways to prosperity but as essential bulwarks against decline.

Further, we demonstrate that hyping involves contestation among actors carrying out different discursive work; and we show how, for hype as a state to emerge, advocates of a positive collective vision eventually dominate, with discourse as both means and stakes of struggle (Maguire, 2002) —what we refer to as hyping. In the case of an emerging technology, advocates' hyping entails actors mobilizing the discourse of risk to construct a sense of urgency, directing attention and funding toward policy priorities in which the emerging technology is positioned as a risk management solution. Prior research reveals such hype to be a motivating cultural and financial force (Logue & Grimes, 2022), directing resources to emerging technologies to realize the benefits they promise. We contribute a deeper understanding of the nuanced interplay between different aspects of hyping and demonstrating how the discourse of risk is mobilized as part of hyping an emerging technology to create a sense of looming threat resulting in direct political action and commercial activity.

Additionally, we contribute insights into how the discourse of responsibility is mobilized in hyping as a mediator between the benefits (translated into non-monetized opportunity cost risks) of and risks posed by emerging technologies, downplaying responsibility obligations for social risks whilst emphasizing those for security and economic risks. Prior research indicates that organizing and responsibility are closely connected (Brunsson et al., 2022), but the role of the discourse of responsibility is not well understood (cf. Ädel & Östman, 2023; Gianni, 2018). We have shown how, as part of the hyping of emerging technologies, government actors *responsible* for national security and economic competitiveness construct very high economic and security *risks*, respectively, which is arguably self-serving in terms of ensuing resource flows in a society obsessed with risk, while leaving the articulation of a need for responsibility to social groups in the development of quantum technologies largely at the feet of civil society, since responsibility for managing emerging technologies' is diffuse and not clearly linked to actions or deliverables. Here, hyping clouds the need for specific actions by sufficing to communicate acknowledgement and concern. In these ways, our study contributes contemporary 'risk society' nuance to political and performative perspectives on hype in the literature on the sociology of expectations.

Second, we extend the sociology of expectations by showing that, in our contemporary capitalism and 'risk society' (Beck, 1992), expectations are systematically shaped by discourses of risk and responsibility in ways that expand coalitions in support of emerging technologies to which a meaning of 'risk management solution' to familiar, salient risks can be attached. Is it hype, as we noted the literature claims, that brings together actors around an emerging technology in ways that lead the technology to become valorized, eliciting collective efforts to position it as a hotbed of innovation and entrepreneurship (Gurses & Ozcan, 2015; Weber et al., 2008) that can address broader issues of societal importance to which the technology has been linked (van Lente et al., 2013) – or is it the discourse of risk harnessed in particular ways? Our study points to a 'yes, and' answer of "it is both?", which represents a significant contribution. The discourse of risk creates conditions of possibilities for powerful actors to become entangled – sometimes of their own volition and sometimes not – in a constellation of constructed interests around an emerging technology and to give impetus and momentum to the constellation. In this way, we contribute an understanding of the hyping of emerging technologies as a phenomenon that is geopolitically influenced at minimum, and, most likely, geopolitically relevant today, i.e. in a world in which 'responsible' state action includes alignment of scientific priorities with national security and economic imperatives through frames of technological sovereignty, as scholars (e.g. Edler et al., 2023; Mazzucato, 2018) have recently argued is the case.

7. Conclusion and future research directions

Our study demonstrates the nuanced way that hyping shapes emerging technologies by drawing on discourses of risk and responsibility. We demonstrate how hyping constructs these technologies as solutions to salient, familiar risks—such as economic and security threats—thereby accelerating their development and adoption while downplaying less salient, novel risks. This dynamic reveals a critical tension in how emerging technologies are constructed and commercialized: the prioritization of immediate, familiar risks often overshadows broader societal and ethical considerations. In a multipolar context, where geopolitical competition drives technological agendas, our findings reveal how hyping can be used to advance technological sovereignty agendas (Edler et al., 2023).

These dynamics have broader implications for understanding how technology innovation unfolds in an era of intensified global competition. The prioritization of critical technologies as tools for national advantage highlights how hyping contributes to reinforcing global asymmetries. While hyping may facilitate technological advancement, it simultaneously threatens to marginalize inclusive, democratic debates about the societal and ethical consequences of these technologies. In a multipolar world, this imbalance may undermine opportunities for global cooperation, emphasizing competition over collaboration. Accordingly, governance guardrails are needed to prevent the crowding-out of social risk assessments by security and economic risk constructions; clearer allocations of responsibility across public, private, and civic actors should specify who assesses, mitigates, and monitors which risks, and when; anticipatory and participatory review should be embedded in major funding and procurement decisions; and baseline international coordination norms (e.g., transparency, auditability, and interoperability) should preserve room for cooperation even amid geopolitical rivalries. These measures would temper hype's centripetal pull while sustaining legitimate pathways for innovation.

Despite its contributions, our study is not without limitations. Although our findings already capture major international inflection points prominently featured in Australian coverage (such as the escalating US-China technology rivalry and the 2021 AUKUS pact that explicitly emphasizes quantum capability), our empirical lens remains intentionally focused on domestic issues. We analyze global developments only insofar as Australian actors and texts reference them, because our purpose was to theorize how actors discursively construct quantum technologies in the Australian context. By bracketing the analysis in this way, we keep the scope analytically tractable and ensure depth in tracing the micro-processes of discourse formation within Australia, while recognizing that future work could extend our framework to map cross-border influences in greater detail. Such research may undertake a fuller examination of how external politics shape those narratives (e.g., by analyzing foreign-language media or diplomatic cables, or by comparing multiple countries) and consider the interplay between geopolitical competition and the governance of emerging technologies. Additionally, comparative studies could explore how multipolar dynamics influence the construction and prioritization of technologies across different regions, shedding light on the extent to which global cooperation or protectionism shapes technology trajectories. Examining the role of regulatory frameworks, ethical norms, and international agreements in mediating these dynamics could offer insights into fostering more balanced approaches to innovation.

In conclusion, our study highlights the significance of hyping in shaping the development of emerging technologies in a multipolar world. By revealing the ways in which risk and responsibility are mobilized in this process, we contribute to understanding how emerging technologies are constructed and contested.

4. Chapter Four: Paper Two

Responsible Innovation in Australia's Quantum Socio-Technical Imaginary: From Tension to Co-production

Abstract

Innovation of emerging technologies involves diverse stakeholders whose competing visions contribute to socio-technical imaginaries – collectively held expectations about how science and technology should shape society – that influence technological development. This paper examines how Australia's quantum sector navigated a fundamental tension between academic and industry stakeholders of quantum science as a public good and quantum technology as commercial and security asset. We investigate how the perspective of responsible innovation (RI) was introduced as a co-productive force to reconcile this tension. Through institutional embedding in Australia's National Quantum Strategy and related activates, we trace how RI produced a reciprocal shaping effect by positioning societal benefit and commercial success as co-dependent features of the quantum imaginary and being reshaped as an instrumental tool for accelerating societally acceptable commercialization. This study contributes to the literature on RI by revealing the motivations of governments to institutionalize RI in a commercialization context. It contributes to the literature on socio-technical imaginaries by revealing the mechanisms by which contested stakeholder visions move from tension to co-production. Our findings suggest that the introduction of a novel perspective can mediate stakeholder tensions when strategically introduced, and that this process can transform the concept itself as a result.

1. Introduction

Innovation requires the collective work of a diversity of stakeholders, including public and private actors, who contribute scientific expertise, infrastructure, funding, and manage public acceptance of emerging technologies. These actors imbue meaning to innovation and produce socio-technical imaginaries that have material and institutional impacts on the direction of technological innovation. Socio-technical imaginaries describe the collectively held visions of desirable (or undesirable) futures shaped by science and technology (Jasanoff, 2015), which influence the direction, governance, and legitimacy of technological development (Jasanoff, 2015; Jasanoff & Kim, 2013; Stilgoe et al., 2013). Diverse stakeholder groups contribute to a collectively envisaged imaginary, making the process fraught with tensions and contestations, as stakeholders are likely to hold differing perspectives on the purpose of innovation due to their embeddedness in differing social, cultural, and political contexts (Kuchler & Stigson, 2024). These tensions can inhibit the collective work of stakeholders that is required to achieve an innovation goal.

Researchers have suggested that contestation can serve as a powerful and productive force for illuminating tensions among stakeholder visions (Bareis & Katzenbach, 2022; Jasanoff & Kim, 2009; Mager & Katzenbach, 2020; Jasanoff, 2015). This establishes contestation as an important site of inquiry, as it can make explicit the power dynamics among stakeholder groups and reveal the assumptions and normative dimensions that shape how and why the futures envisioned differ (Mager, 2017; Jasanoff, 2015). As such, surfacing these tensions establishes contestation itself as a mechanism through which new forms of both knowledge and social organization co-productively emerge in the pursuit of a collective imaginary (Jasanoff, 2015). Jasanoff (2004, p.38) introduced the concept of co-production to interrogate "the constant interplay of the cognitive, the material, the social and the normative" inherent in the process of an imaginary establishing itself. Although tensions are expected to lead to co-production to accommodate the diverse interests and visions of stakeholders, the mechanisms for moving from tension to co-production are not well established. Research suggests that policymakers and governments may help to resolve tensions between competing stakeholder groups by favoring one vision over another to stabilize a socio-technical imaginary (Augustine et al., 2019). However, this skirts the questions of when, why, and how tensions give rise co-production to enable diverse stakeholders to work together in service of a collective socio-technical imaginary.

A tentative answer comes from Taylor's (2002) suggestion that a novel perspective in the form of a concept or theory might enter imaginaries and introduce dynamics that can lead to co-production. Taylor suggests that this process of introduction and application reshapes the concepts or theories themselves from within the imaginary. Responsible innovation (RI) might be one such perspective that policymakers and government actors are actively attempting to seed to minimize potential risks and maximize societal benefit through the governance of emerging technology innovation (Owen at al., 2021; Genus & Iskandarova, 2018; van Oudheusden, 2014). Originating in European research policy, the concept of RI calls for aligning the work of diverse stakeholders to achieve societally acceptable innovation outcomes. It is defined as "… a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the ethical acceptability, sustainability and societal desirability of the innovation process and its marketable products" (von Schomberg, 2013, p. 63). As a future-oriented concept, it employs approaches such as integrating a diversity of stakeholder perspectives, engaging stakeholders in reflexive practices to help them anticipate social and ethical issues from the earliest stages of research throughout the innovation pipeline, developing their capacity to respond to these as they surface, and channeling innovation toward areas of public good (Owen et al., 2013; Nazarko & Melnikas, 2019; Owen & Goldberg, 2010).

RI is inherently focused on the relationship between science, technology, and society and the underlying assumption that science and technology are socially and politically constituted (Stilgoe et al., 2013; Genus & Iskandarova, 2018). It draws attention to the ways in which conceptualizations of responsibility *and* innovation are interpreted differently by stakeholders depending on their contexts (Flipse, 2013; Scherer & Veogtlin, 2020). This has significant implications for the enactment of RI as a collective pursuit among diverse stakeholders. However, little empirical work has shown how the concept interacts with socio-technical imaginaries. Research reveals that the application of RI has had limited success in a commercialization context (Gurzawska et al., 2017; Blok et al., 2015). This is, in part, due to a misalignment between the values of scientific researchers and industry actors (Scherer & Voegtlin, 2020; Pandza & Ellwood, 2013). How RI might find resonance in a technology commercialization context remains an open question. Analyzing how competing stakeholder visions move from tension to co-production in socio-technical imaginaries offers insights into how RI, as a perspective, might be introduced to bridge academic research to industry commercialization. As such, we ask: *How and why does RI enter and shape socio-technical imaginaries of emerging technologies?*

To answer our research question, we conducted a longitudinal qualitative study of Australia's emerging quantum technology sector. In our study, we identified a tension between competing academic and industry stakeholder visions around the retention of public good value as quantum research is commercialized. We traced how government facilitated a consultative process in developing Australia's National Quantum Strategy and how the concept of RI was introduced and enacted as a tool for moving from tension to co-production. Our findings reveal how RI shaped Australia's quantum socio-technical imaginary and was, in turn, practically reshaped through the lens of societally beneficial quantum commercialization.

2. From Tension to Co-Production in Socio-Technical Imaginaries

Established technologies are deeply embedded in social, political, and cultural contexts. By extension, emerging technologies are in the process of becoming socially and politically constituted (Winner, 1980). Emerging technologies shape and are shaped by the values, institutions, and imaginaries of the societies that produce and adopt them. Social researchers have explored this phenomenon through the concept of socio-technical imaginaries, which describe how visions of the future are co-produced by society and technological innovation. They reflect how stakeholders imagine the role of science and technology in shaping their world—and how these visions influence policy, innovation, and governance. Socio-technical imaginaries are defined as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff, 2015, p. 4). Crucially, socio-technical imaginaries are normative and performative. They reflect underlying assumptions about progress, risk, justice, and identity, and they actively participate in the construction of social and technological realities. While non-determinist, imaginaries can help to stabilize certain trajectories of innovation while marginalizing others. This process is inherently political, raising important questions about whose visions are being realized, who is excluded from these processes, and what alternative futures are being foreclosed (Winner, 1980).

Socio-technical imaginaries are materially and discursively enacted through policies, scientific agendas, and public discourse from a range of state and non-state actors (Mager & Katzenbach, 2020). They guide the direction of technological development by encouraging collaborative activities, influencing regulatory frameworks to enable imagined futures, and shaping public expectations about what kinds of futures are possible, desirable, or inevitable. Practically, they can enable cohesion amongst diverse stakeholders to work collectively toward enacting these futures (Pfotenhauer & Jasanoff, 2017). However, socio-technical imaginaries are neither monolithic nor linear (Mager & Katzenbach, 2020). A recent literature review focused on the analytical unit of 'the collective' across studies on socio-technical imaginaries reveals "a rise in perceptive studies that address and engage with the national collective as a reservoir of several co-existing, alternative or competing [visions]" (Kuchler & Stigson, 2024, p.13). This body of literature engages with the dynamics of contestation inherent in the process of collective imagining that can contribute to the formation of national innovation policies.

The concept of socio-technical imaginaries explains "what makes a given social system—a nation or polity or movement or community—not only cohere… but also be capable of absorbing and coming to terms with its own internal tensions and contradictions?" (Jasanoff, 2015, p.25). By nature, socio-technical imaginaries encompass multiple, contested visions, as they are constructed and solidified by a constellation of actor groups, or stakeholders, with competing values and aspirations, shaped by a sense of belonging to a particular community (Kuchler & Stigson, 2024). The social, cultural, and political contexts in which stakeholders are situated influence the technological future(s) they envision, shaping their conceptualizations of what is 'good', 'desirable', and ought to be done, or conversely, what is 'undesirable' and to be avoided (Jasanoff & Simmet, 2021). While the "dynamic, un-settled and contested nature of collective imagining" (Kuchler & Stigson, 2024, p.11) is well established in the literature on socio-technical imaginaries, the process by which these tensions enter a state of co-production remains underexplored. This is important, as stakeholder visions only give rise to socio-technical imaginaries once they are communally adopted by the 'collective' (Jasanoff, 2015).

Co-production in socio-technical imaginaries refers to the intertwined development of scientific knowledge, technological systems, and social order. Jasanoff (2004) introduced the concept of co-production to highlight how societies envision and shape futures through both technological innovation and collective meaning-making. Co-production also plays a critical role in governance. Jasanoff and Kim (2009) explored how national identity and political culture influence nuclear energy imaginaries in South Korea and the United States, showing that technological trajectories are contingent on socio-political contexts. This underscores the importance of considering socio-political contexts in understanding the inclusive and reflexive dynamics of RI as a governance approach. Understanding co-production in socio-technical imaginaries allows scholars and policymakers to critically assess whose visions of the future are being prioritized, what assumptions underpin technological development, and how alternative imaginaries might be fostered (Kuchler & Stigson, 2024).

Stakeholders, including governments, industry, civil society, academia, and media, are central to shaping socio-technical imaginaries. Their actions, discourses, and decisions construct and stabilize imaginaries. Governments embed imaginaries in policy frameworks, funding priorities, and regulatory structures. Their visions of progress, national identity, and public good influence which technologies are promoted and how they are framed (Jasanoff & Kim, 2015). Industry stakeholders contribute by aligning imaginaries with market logics, technological feasibility, and innovation narratives. Their role is particularly influential in sectors where corporate visions shape public expectations and policy agendas (Rudek, 2022). Civil society actors, including

NGOs, activists, and community groups, challenge dominant imaginaries and advocate for alternative futures grounded in justice, sustainability, and inclusivity. Their engagement can reframe debates and introduce ethical and experiential dimensions often overlooked by institutional actors (Kuchler & Stigson, 2024). Academics also participate in the coproduction of imaginaries through basic research, expert knowledge and public discourse (Marcus, 1995). Finally, media disseminate and reinforce imaginaries, shaping public understanding and preparing citizens for anticipated futures (Eisenegger & Schäfer, 2023).

That a diversity of perspectives contribute to the shaping of socio-technical imaginaries can give rise to significant tensions, as stakeholders promote distinct values, priorities, and pathways for technological development and social organization. For example, Higham (2019) uncovers two distinct socio-technical imaginaries for cell therapies in the UK. One reflects the assumptions of commercial innovation and prioritizes economic success; the other embodies the cultural expectations of academia and emphasizes the importance of clinical care. While the two positions offer synergies to some extent, there are significant tensions between them. The study reveals how these imaginaries are embedded and enacted through trial regulation, funding mechanisms, and identity-making practices, which in turn shape the trajectory and viability of innovation in the field. Higham predicts that the success or failure to reconcile the tensions will determine the future shape of the cell therapy field.

Jasanoff (2015, p. 4) suggests that tensions in imaginaries can lead to co-productive relationships. Augustine et al. (2019) demonstrate that in the context of geoengineering, actors strategically reframe imaginaries, such as shifting from a vision of planetary control to one of risk management, to maintain legitimacy and accommodate competing concerns, without fully resolving underlying conflicts. If the forces of moving from tension to co-production are neither imaginary-immanent nor dependent on technological advancement, it would be likely that they might come from institutions of power, such as policymakers and governments. These institutions can introduce a new theory or perspective, which might enable alignment and mutual adaptation of competing stakeholder visions.

3. The Normative Perspective of Responsible Innovation

RI is an approach the governing the inclusion of a diversity of stakeholders in the innovation process to collectively deliberate, anticipate, and address the societal and ethical dimensions of innovation from the earliest stages of technological research and development (Da Silva et al., 2019; Bacq and Aguilera, 2022; Owen et al. 2013). The concept promotes for stakeholders to become mutually responsive to one another as they develop co-responsibility for innovation outcomes (von Schomberg, 2013). The initial formulation of RI derives from the European Union research policy (Owen et al. 2013; Kuhlmann and Rip, 2014; Lund Declaration, 2009), as such, the concept's original conceptualization is anchored in the democratic values of this context. While RI is an umbrella term encompassing its treatment as a framework (Stilgoe et al., 2013), a discourse (Maguire et al., 2004), and an innovation itself (Rip, 2014), we treat it as a normative, ethical perspective, applied "to disrupt existing institutional logics relating to research and innovation" (Owen at al., 2021, p.2).

In 2013, responsible research and innovation (RRI) was introduced as a major theme in Europe's Horizon 2020 funding program (Owen et al. 2013; Grunwald 2016). Related policies prescribed RRI as a method for directing scientific research and innovation toward addressing grand societal or wicked challenges and Sustainable Development Goals – complex problems requiring large-scale, multi-stakeholder collaboration (Voegtlin et al., 2022; Kuhlmann & Rip, 2018). Stilgoe et al. (2013) refined von Schomberg's conceptualization of RRI, dropping the second 'R' for *research* and focusing more directly on the *innovation* process. More than a semantic shift, this signaled the emergence of scholarly field of research focused on operationalizing RI, both in the lab and beyond, into the wider sociotechnical systems in which innovation unfolds. This re-conceptualization opened the doorway for the inclusion of new innovation actors, including commercial organizations. However, the translation of RI into the domain of technological development and market-driven innovation has proven difficult (Owen et al., 2013; Lubberink et al., 2017).

Research shows how RI faces challenges in commercial settings, where the emphasis on economic return overrides broader ethical considerations (Fisher et al., 2013; Owen et al., 2013; Lubberink et al., 2017). Studies on the uptake of RI by commercial organizations suggest that these organizations lack sufficient motivation or resources to act on its demands (Ko & Kim, 2020; Auer & Jarmai, 2018). While some RI activities occur in a piecemeal fashion across a diversity of organizational practices, including stakeholder engagement, and anticipating innovation outcomes (Auer & Jarmai, 2018; Martinuzzi et al. 2018), these activities are regularly de-prioritized in the face of commercial organization's existential need to fulfill market-driven demands (Auer & Jarmai, 2018; Pfotenhauer et al., 2021; Gurzawska et al., 2017; Lubberink et al., 2019; Ko & Kim, 2020; Martinuzzi et al., 2018). As a result, when left solely to firms, RI tends to remain fragmented or symbolic. These findings point to the need to consider the divergent values and motivations that animate the work of commercial stakeholders if they are to be induced to contribute to collective RI practices.

As such, researchers suggest that the normative dimensions of RI must be treated as a starting point in efforts to translate it to new domains. Tensions between stakeholders' divergent visions of the purpose of innovation and their roles and responsibilities in enacting technological futures are likely to impede their work as a collective. As Stilgoe et al. (2013) comment: "...in different areas of innovation, and in different cultural contexts, different values will be more or less pertinent, and they may be conflicted" (p.1577). This perspective foregrounds the need to focus on "agents and their embeddedness into social interactions in virtue ethics" to better understand the context-specific dynamics of innovation processes (Pandza & Ellwood, 2013, p.1113). Drawing attention to the specific socially and culturally constructed meanings, visions, expectations and institutional arrangements that shape a given innovation landscape is therefore fundamental to understanding how RI might be applied in contexts outside of its original arena. This assessment establishes our motivation for bringing the theory of socio-technical imaginaries into conversation with RI, as imaginaries reflect the underlying assumptions held by different societal groups that actively shape social and technological realities by encouraging collaborative activities, influencing regulatory frameworks to enable imagined futures, and shaping public expectations about what kinds of futures are possible, desirable, or inevitable.

Extant research indicates that coordinating the diversity of stakeholders involved in innovation to collectively enact RI requires some level of systemic coordination and social cohesion (Dryer et al., 2020; Stahl, 2017; Stahl, 2022). This suggests a role for policymakers and governments to foster RI in a way that compliments and extends the "de facto responsible innovation practices" (Lubberink et al., 2019, p.180) that occur in commercial organizations. This is important for governments because "the social outcomes of innovative activity are at the same time beneficial and taxing to society" (Valdivia & Guston, 2015, p.2). Likewise, RI can play an important role in mediating enduring tensions that surface in the governance of innovation due to the non-linear, uncertain, and distributed nature of innovation (Valdivia & Guston, 2015; Borrás, 2012). Critical among these, is a tension "between the scientists' and the technicians' own organizational rules, and the state's interest in using science and technology" to advance national goals such as "defense, economic growth, public health, and others" (Borrás, 2012, p. 431).

State institutions can help stabilize and extend the perspective of RI, not only by mandating certain practices, but by embedding new understandings, concepts or theories into commercialization policy itself. As Taylor (2002) argues, when a new perspective penetrates an imaginary, it becomes available to social actors in ways that reorganize their understanding of the world and guide their activities – even as those activities, in turn, reshape the perspective to fit specific contexts. Governments thus have the capacity to catalyze the transformation of imaginaries, especially when they embed new normative visions within the institutional structures that govern emerging technologies. In this way, RI might not simply be layered onto existing imaginaries of commercial success but could help generate hybrid or reconfigured imaginaries better suited to balancing economic and societal goals. As such, RI becomes part of socio-technical imaginaries by shaping the values, practices, and institutions that define how emerging technologies are envisioned and realized. However, it remains unclear how RI as a normative perspective might enter, transform or be reshaped via the stakeholders of socio-technical imaginaries, and what its role might be regarding the persistent tension. This paper provides an account of this process, revealing how RI was institutionally adopted to manage a tension between competing stakeholder visions, shaping Australia's quantum socio-technical imaginary and being reshaped itself through its strategic implementation.

4. Methods

The Australian quantum sector offers an exemplar case of how RI as normative perspective, concept or theory might influence the co-construction of imaginaries in a specific context (Eisenhardt & Graebner, 2007). With the aim of generating theory, an in-depth case study can provide an explanation for the connections between various constructs at play (Tsoukas, 2009). Following Jasanoff's (2015, p.22) advice that "the methods best suited to studying sociotechnical imaginaries therefore are the methods of interpretive research and analysis that probe the nature of structure-agency relationships through inquiries into meaning making", we applied an inductive approach to theory-building (Van Maanen et al., 2007), which entailed moving back and forth between the collected data, existing literature, and applying theoretical lenses to develop insights.

4.1 Exemplar Case: Australia's Quantum Field

To build fault-tolerant quantum computers, develop hackproof quantum communications, and bring quantum sensing to a range of industries, Australia is building on a reputation in quantum optics and condensed matter physics that harks back to the 1980s (Roberson & White, 2019). In 2003, the Australian Research Council (ARC) Centres of Excellence (CoE) scheme was established to support "transformational research and capacity building" by providing long-term, large-scale investment for basic and applied research (Australia's Chief Scientist, 2022, p.2). This initiative established a series of quantum CoEs, which brought researchers from universities across the country together to collaborate on addressing fundamental quantum physics problems. Over two-decades, this sustained government investment in academic quantum research across various domains, alongside supplementary funding from universities, expanded and strengthened

Australia's quantum expertise and research capabilities and created a scaffolding around which a national quantum knowledge network and specialist scientific talent pipeline emerged (Australia's Chief Scientist, 2022).

Drawn by Australia's growing international reputation as hub for quantum research excellence and the high-quality talent pool developed through the long-term government investment in quantum research, defense and commercial actors began to translate Australian quantum research to technological applications (CSIRO, 2020). As a result of investments from defense and commercial actors interested in securing an advantage in applied quantum capabilities, Australia's first quantum companies were founded in 2008 and 2017. These early native quantum commercialization efforts were predominantly university spinouts, recipients of either direct or indirect early-stage funding from defense, and beneficiaries of corporate funding from critical infrastructure industries, including telecommunications and banking. Multinational technology corporations, including IBM, Microsoft, Intel, and Google, initiated major collaborations with quantum researchers from several Australian Universities. By 2017, an inchoate Australian commercial quantum industry had begun to emerge (CSIRO, 2020). Notably, the early-stage quantum industry is heavily reliant on specialist academic expertise. As a result, nearly all quantum companies are founded by quantum physics researchers, many of whom in Australia maintain an academic affiliation even as they build commercial quantum endeavors.

In 2020, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, released the *Growing Australia's Quantum Technology Industry* roadmap, forecasting a four billion-dollar opportunity for a strong domestic quantum industry (CSIRO, 2020). In 2021, the Australian Army started to tap into quantum research to develop and retain a strategic security advantage through the exploitation of emerging quantum technologies (Army, 2021). That same year, the Australian Government Department of Industry, Science and Resources (DISR) designated quantum as a critical technology in the national interest (DISR, 2023b). Australia's quantum industry witnessed a rapid growth during this period, more than doubling the number of domestic quantum companies in the industry landscape, which includes partnerships between international tech companies like Microsoft and IBM with Australian universities, as well as the entry of several other international quantum technology to Australia (CSIRO, 2020).

After a year-long consultation period with public and private stakeholders, Australia's National Quantum Strategy was launched in May 2023. The Strategy set out five themes, each with an associated set of actions over 7 years. These are: (1.) creating thriving research and development, investment in and use of quantum technologies; (2.) securing access to essential quantum infrastructure and materials; (3.) building a skilled and growing quantum workforce; (4.) ensuring our standards and frameworks support national interests; (5.) building a trusted, ethical and inclusive quantum ecosystem (DISR, 2023a, p.7). Theme five included that the Australian government will "champion responsible innovation" (DISR, 2023a, p.41).

4.2 Data Collection

Data collection began in 2021 and was completed in 2025. It included the release of Australia's National Quantum Strategy in 2023, a series of federal announcements around the establishment of a national hub for quantum industry development, major funding announcements, and the Quantum Australia 2025 conference. We collected interview data, strategic documents, and digital media articles. Our research question was also informed by informal conversations and experiences at quantum sector events, including annual Quantum Australia conferences, ecosystem-building and RI workshops. These data sources revealed competing visions held by different stakeholders and, over time, showed ways in which a tension between these visions co-produced a collective quantum socio-technical imaginary.

We conducted a total of 38 interviews with actors purposively selected from industry, academia, government, and public organizations in two phases of data collection (see **Table 3**). Purposive sampling is a technique widely used in qualitative research "...for the identification and selection of information-rich cases for the most effective use of limited resources" (Palinkas et al., 2015, p.534). Specifically, interview invitations were targeted at actors working in organizations contributing or adjacent to Australia's quantum technology sector. In 2023, just before and just after the release of Australia's national quantum strategy, 19 interviews were conducted; one year later, in 2024, 18 further interviews were conducted, with four participants interviewed in both phases. Interview participants were selected to reflect a range of positions and perspectives on the development of Australia's quantum technology sector. These included actors from academia (5), government (9), industry (10), non-governmental organizations (3), not-for-profits (5), and venture capital (5). Interviews were open-ended, with questions asking participants to discuss Australia's history in quantum research and technology, individual and organizational roles in the quantum sector as it developed over time, perceptions of its development, and potential benefits and drawbacks of developing new quantum technologies.

We also collected 45 publicly available strategic documents (see **Table 5**). The historical narratives offered by interviewee participants led us to set the initial boundary condition for strategic document collection in 2020, as we determined this to be the start of publicly documented national strategic positioning in relation to developing Australia's quantum sector (CSIRO, 2020);

however, several texts published before 2020 were also collected to corroborate and supplement interviewee's historical narratives as required. Texts collected included state and federal roadmaps, strategies, funding announcements, and other policy documents, which highlight activities and programs aimed at developing Australia's quantum technology field. A wider set of data, including online news articles and opinion pieces (see **Table 4**), also informed who we considered to be the important stakeholders, events, and documents for this study. These texts helped to identify contested stakeholder visions and described how the quantum socio-technical imaginary was publicly articulated.

4.3 Data Analysis

We coded our data for traces of socio-technical imaginaries. Elements of imaginaries are expressed through rhetorical devices, metaphors, repeated narratives or 'myths', as well as future-forward language that conveys expectations about desirable (and undesirable) visions of the future (Bareis & Katzenbach, 2022; Jasanoff & Kim, 2015). Inspired by Jasanoff's (2015) observation that "languages, metaphors, and symbols… [are sources of] visions of technologically mediated progress or failure and backsliding" (p.25), we searched for future-oriented language that described the perceived role of quantum in Australia, including metaphors, assumptions, or references to what is taken for granted as true, along with statements of national priorities. For example, we coded tropes and analogies such as "Australia punches above its weight in quantum," "a quantum race," and "quantum is a strategic sovereign asset". Similarly, we coded future-forward statements from policy documents such as "In 2030, Australia is recognised as a leader of the global quantum industry, and quantum technologies are integral to a prosperous, fair and inclusive Australia."

Our analysis followed an iterative coding process. We began with first-order codes that closely reflected the language of participants and documents (e.g. "Federal government research funding provides long-term support for research", "Quantum research is considered safe in the lab", "Venture capital funding pressures startups to deliver quickly"). These codes were then interpretively grouped to form second-order themes – stakeholders, policy, funding, activities, and narratives – categories chosen to reflect how imaginaries are enacted through particular configurations of discourses, and practices. During analysis, it became clear that these themes carried different emphases across stakeholders and time: in some cases, prominent stakeholders were primarily academic researchers while in others industry and defense figures were foregrounded; some policies emphasized science as a public good while others stressed competitiveness and security; funding was framed at times as long-term capacity-building and at other times as short-term and commercially driven; activities ranged from celebrating scientific prestige to institutionalizing industry consultation; and narratives shifted between portraying quantum as safe in the lab and framing it as a race not to be missed. These patterned differences provided the basis for the analytical move to aggregate dimensions.

In reviewing stakeholders' imaginaries, we noticed two distinct visions: one was long-term and scientific, and another was near-term, commercialization and security driven. These two visions circulated at the same time, yet our second-order themes demonstrated significant shifts in how they became embedded and enacted as the quantum sector matured. Our data analysis revealed how a tension between these visions was reflected in concerns for the sustained development of the quantum sector expressed by stakeholders from academia and industry. We likewise traced how RI was discursively introduced as a perspective that addressed the tension between stakeholder visions. Our analysis showed how the concept shaped the development of a collective quantum socio-technical imaginary as it was, in turn, reshaped through its application in this process.

5. Findings

Our findings are reported as follows. First, we identify and detail a tension between stakeholder visions in Australia's quantum innovation landscape, with particular attention to fundamental science research and research-and-commercialization. We highlight the tension between these stakeholder groups, centered around concerns for the retention of the public good value from the development of quantum technologies in the face of industry- and defense-led innovation. Second, we interrogate how these distinct visions entered a state of co-production to produce a hybridized collective quantum imaginary through governmental strategizing efforts, which brought the discursive introduction of RI as a mediating force to address the normative societal and ethical tension between competing stakeholder visions, and the selective adaptation of the concept to suit this socio-political context. We discuss how the explicit inclusion of RI, without clear definition or framework, led to a presence where concepts from RI both shaped and were shaped by Australia's quantum innovation policy.

5.1 Tension between Competing Stakeholder Visions

As Australia's quantum sector matured and technologies moved from research to industry, we identified a tension that arose between stakeholder visions of a purely scientific pursuit for public good and the commercialization of quantum technologies for private gain. The societal value associated with pre-commercial quantum research envisioned by academics and reflected in Australian research policy texts sat in tension with the commercial gain envisioned by industry actors. Interviewees expressed concerns around the retention of public good value as quantum research was commercialized. As an interviewee involved in quantum research translation commented: "So there's definitely a disconnect, at that point around the use of public funds to generate IP, which the universities then don't treat as a public good" (Interviewee 16 – Research center director). Another interviewee echoed these concerns, "As we solve problems, are we solving problems for the few or for the many? I don't think there is much of a conversation about that" (Interviewee 19 – Government technology director). These comments highlighted a tension around the value for Australian society of quantum innovation as the development of quantum technologies became driven not by the pursuit of scientific excellence, but by commercial and security imperatives.

The tension was particularly noticeable in academics-turned-entrepreneurs, whose roles were prominent in that they drew attention to the sustainability of quantum sector development efforts across the timeline. Their research contributed to shaping the imaginary through the role of science (and scientists) in society and they were involved in the consultation process of the Strategy. As one academic-turned entrepreneur argued, quantum physicists "…are best positioned with their technical knowledge to be involved with commercializing some of these ideas" (Interviewee 1 – Quantum technology firm founder). The role of academic entrepreneur straddled the safe and secure research environment and the competitive commercial and security driven industry environment, highlighting questions of ethics, risk, and technological misuse. As an academic entrepreneur highlighted, there was a significant difference in ethics between academic and commercial environments:

> "…one could argue that the fact that most of the quantum industry is coming out of universities is a positive thing, because in general, it is my view that on average, academics tend to be more thoughtful and concerned about society as a whole, and about humanity and about climate. They are obviously generally more informed than the regular citizen. And they also mix with other academics that are generally a cohort that is concerned about those issues and thoughtful about those issues. And so, as a result, I think there is some hope that the leaders of this new industry will be thoughtful guardians of this space. But, you know, of course, there are also commercial imperatives that potentially can corrupt those ideal ethics." (Interviewee 8 – Quantum technology firm founder)

Interviewees also expressed concern for the sustained development of the quantum sector by questioning social license to invest public monies in the commercialization of quantum technologies, as the transitioning of quantum research to societally beneficial technological applications was uncertain and would likely occur over long horizons. As one interviewee commented:

> "...what is evident is that there's going to have to be a social license for Australia to invest in quantum, which really comes down to why is it responsible for the Australian people to

> invest in quantum, when I could be investing in other things? So that then brings a range of ethical questions that then derive out of how do you make those prioritizations for a social good and a commitment of sort of scarce resources?" (Interviewee 3 – Quantum technology firm founder)

Another interviewee echoed this concern for demonstrating a public good return on commercialization investment, stating:

> "I have a strong belief that fundamental research is really important, but it's publicly funded. So, we have to be able to show some return or benefit in order to justify the resource allocation. The funding for fundamental research is in competition with funding for defense, for education, for health, you know, there are a lot of really good potential uses of that money. And beyond just the cultural benefit of having done the research and then publishing it, I think that we as a sector owe it to society to provide a benefit, if we can, or at least be in a place where researchers can choose to do so." (Interviewee 16 – Research center director)

Likewise, concern around the need for RI practices in order to secure public acceptance of new technologies was positioned as a risk. As one interviewee commented:

> "There is a sense in this space that getting it right is important, and that the responsible research frameworks are a strength, in that the one of the worst things that could be happened would be a runaway, abusive application. In the domains that I mentioned - sensing and cryptography - the risk of something getting away is strongly understood. And you know, there'd be a massive collapse in social license. It'd be a massive collapse in, you know, support generally." (Interviewee 32 – Government technology director)

These observations illuminated a tension between the transition of quantum from an asset of the public domain inherent to its containment in the research environment to a private good. This surfaced a tension between the assumed public good value of sustained public funding for scientific capacity-building and the significant government investment required to support commercialization efforts. We will portray both sides of this tension, because it illuminates how the socio-technical imaginary was affected by it.

5.2 Quantum Science as a Public Good

Stakeholder: Academic researchers

The dominant actors in the early phases of Australia's quantum sector development were academic researchers. Quantum physicists discussed the role of prominent academic predecessors in establishing Australia's global reputation for research excellence in quantum. These academics were repeatedly identified as a central force in garnering the initial government support for quantum CoEs. Their work "…injected a point of focus that enabled Australia to fund and grow quantum research centres… and gave that critical mass of funding. But more importantly, the sustained funding to grow capability and to grow people over 20 years" (Interviewee 3 – Quantum technology firm founder). The world class expertise of Australia's quantum researchers is noted as the starting point for recognition of Australia's quantum advantage. As another interviewee comments, "We seem to have a deep history of expertise in these areas, which is making us globally relevant, even at this stage, even as countries all around the world are throwing so much money at quantum" (Interviewee 1 – Quantum technology firm founder).

Anticipating potential risks posed by quantum technologies was not a major concern of academics early in the sector's development, as the pre-commercial, fundamental research they were engaged in was perceived as low risk; there was a pervasive assumption that quantum was safe and secure within the confines of an academic research environment, where it was bound by the university ethics, legal responsibilities, and codes of conduct. We found that responsibility for the harmful impacts of the technologies was repeatedly placed on actors further downstream, as it was argued that potential risks could only be determined once quantum moved from theory to technological applications. As one interviewee commented:

> "You just have to assume that you're going to be a responsible human being in the end and not use these things for evil... I mean that's just the same one as, say, I'm a nuclear engineer and I come up with a better way to refine uranium, what is my responsibility? Like, it's the same question, right? If someone's going to misuse something, that's not a science question [...]. Because science is already complicated enough without having to think about how it might be misused." (Interviewee 6 – Technology association director)

Foresight of technological risks and harms was not considered to be a role within the remit of academics because, as another interviewee commented, "We're still too early to have been bitten. So we're still too early to have actually caused a problem. And we're still too early to have any precise discussions" (Interviewee 3 – Quantum technology firm founder).

While the potential for risks and harms produced by the development of emerging technologies was likewise noted by industry actors, there was again consistent placement of responsibility on government actors to address these rather than on commercial organizations developing the technologies. As one interviewee from a quantum startup commented:

> "...as you can probably appreciate, in any commercial organization, you're primarily, particularly in a startup, you're focused on keeping, you know, keeping the show on the road, ensuring that the money's coming in, and you know, that you've got runway for the future, and you can keep holding on to and expanding your team. So, as important as those [ethical] issues are, sometimes they just get pushed away from the very top of the concern list. And so, I think that this is where governments do have an important role to play." (Interviewee 8 – Quantum technology firm founder)

As another interviewee commented: "There's a responsibility somewhere in this ecosystem, to have something where KPIs are not [linked to] commercial revenue, because otherwise, no one's going to do it, right? Like, why would they do it?" (Interviewee 13 – Quantum technology firm founder). These quotes suggested that both academics and commercial actors were aware of the ethical implications of their work but expected that the government would address them through regulatory and policy mechanisms.

Policy: The critical role of science research for society

Research policy positioned fundamental science research as critical to achieving public good outcomes. This stance was woven through reports on Australia's national science programs. For example: "[science] underpins the social wellbeing of Australians by improving health outcomes, maintaining the quality of the environment, and contributing to solving significant social issues" (Australian Government, 2017, p.3). Public stewardship of science was linked to the "critical role" of science in society: "...contributing to building knowledge, solving problems and seizing opportunities, and improving the wellbeing of citizens" (Australian Government, 2017, p.7). The framing of quantum science research as connected to the production of inherent societal value promoted a vision of quantum as a public good. The future-forward and optimistic language employed in these texts illuminated a national vision of broad societal benefit and progress that justifies the use of public monies to support scientific research.

Funding: Long-term support for quantum research centers

Australia's public funding of science research aimed to foster a range of long-term impacts, including economic, social, environmental, cultural, and research capacity (ARC, 2023). As a 2007 Public Support for Science and Innovation report concluded, "public support for science and innovation has, by and large, provided widespread and important benefits for Australians" (Productivity Commission, 2008, p.XVII). The long-term funding from the ARC to establish quantum CoEs brought researchers across Australian universities together in pursuit of a shared mission, creating "focal points of expertise through which high-quality researchers maintain and develop Australia's international standing in research areas of national priority" (ARC, 2025). The central role of the ARC as an early driving force in Australia's quantum science domain reinforced the notion embedded in Australia's research policy for pre-commercial science research as inherently tied to nationhood and societal interests.

Activities: Designation of academics to high social order

The dominant position of quantum physics researchers became institutionally embedded through activities that increased their national visibility and public notoriety. While public engagement with quantum science was markedly low at this stage, primarily confined to specialist discourse via research output reported in scientific journals, the large-scale government investments that boosted the national profile of several Australian quantum scientists illustrated an emergent nation-building quality to quantum. For example, the high-profile award of Australian of the Year given to a quantum physicist Professor Michelle Simmons in 2018 "celebrates the achievements and contributions of eminent Australians [...] by profiling leading citizens who are role models for us all. They inspire us through their achievements and challenge us to make our own contribution to creating a better Australia" (Australian of the Year Awards, 2025). Additionally, Professor Robert Clark and Professor Halina Rubinsztein-Dunlop, two eminent quantum physics researchers, were appointed as Officers of the Order of Australia during this period, for their "distinguished service of a high degree to Australia or to humanity at large" (The Governor-General of the Commonwealth of Australia, 2025).

These proclamations of the public good contributions of quantum physics researchers designated a nationally distinguished quality to quantum, elevating the pursuit of research excellence from a solely academic pursuit to a strategic national advantage. These activities reflected a vision that began to re-shape the quantum imaginary, establishing the notion that advancing foundational quantum science expertise would produce a distinctive national advantage for Australia. As one interviewee comments:

> "Michelle Simmons being named Australian of the Year was [...] quite a striking demonstration of the way that the quantum ecosystem in Australia was really vibrant. And dominating is too strong a word, but it was definitely playing a pretty strong role in the broader physics community within Australia. And I guess then I picked up the subliminal sort of message that Australia is really in this game." (Interviewee 1 – Quantum technology firm founder)

A common refrain that Australia "punches above its weight" (Interviewee 16 – Research center director) in quantum began to take hold at this time, drawing a globally competitive thread into the quantum imaginary by way of established research excellence.

Narrative: Quantum is safe and secure in the lab

In the pre-commercial phase of quantum technology development, there was a pervasive story that quantum was safe and secure within the confines of academic investigation. As one interviewee comments:

> "Once we have the tech and [understand] how we're applying the tech, there should be boundaries. There should be guidelines. There should be a set of principles to apply when you start moving it beyond the lab. It's safe in the lab. It's going to be safe in the lab... Once you publish, it's out in the world, and may not be as safe" (Interviewee 28 – Research center director).

The dominance of the research domain at this envisioned quantum as existing in a safe environment, guarded under the auspices of academia and governed by university ethics. As one interviewee commented, "…one of the fundamental roles of the Academy of Science is to promote and guard the excellence of science [...]. If we don't guard against threats against scientific excellence, one of which is ethical and responsible research, then we're not doing our job" (Interviewee 28 – Research center director). Within a contained academic environment, quantum was envisioned as safe, existing in ethically governed spaces, where risks were implicitly low and science was protected by institutional norms such as peer review and codes of ethical conduct.

Potential risks associated with the development of quantum technologies were not salient at this time. Risks were perceived as downstream issues yet to be identified or understood, pertaining to applied, commercial innovation rather than fundamental science research. Reflecting on this, one interviewee's comment on the quantum research environment during this period echoed the vision laid out by the National Science Statement (2017) of the purpose of publicly funded science research framed as knowledge and solution development:

> "Can we build a quantum computer that can outperform a classical computer? Can we build a quantum computer that could be portable? Can we build a quantum information memory storage device that can store quantum information long enough for us to try doing something really crazy with like, you know, entangled two qubits, and then launch one of them into space and sort of see what happens? So, these have been, when you describe them, like they are just kind of really captivating goals and technology goals, just from a fundamental achievement perspective. And I do think that the community as a whole has become so captivated by these goals that we're very, very much at risk of moving rapidly to achieve the goal without pausing to reflect on where does it lead? And you know, what's the meaning of it?" (Interviewee 1 – Quantum technology firm founder)

There was a pervasive narrative that the role of academic researchers was to ask these impossible questions and pursue their advancement. Interviewees commented that this prerogative must be protected, cautioning against imposing regulations or limitations on quantum researchers. For example,

> "[The role of academic researchers] is to push the limits of the technology, to push the limits of physics, to understand and apply those new bits of knowledge in whatever way they see fit. That is the academic way, and that should not be changed. Freedom of investigation is really, really important" (Interviewee 10 – Technology firm manager).

New actors – including multinational technology corporations, defense, and industries contributing to Australia's national infrastructure – began to contribute to the commercialization of quantum technologies in Australia toward the end of this period, introducing a new element to the imaginary shaped around the intention to transition Australia's quantum research excellence to useful applied technologies. This emergent vision was anchored in the projected economic and security benefits presented by the development of quantum technologies and the risk of missing out, should coordinated action *not* be taken to support their development. This narrative envisioned Australia's quantum knowledge capital as a prominent security and economic asset to the nation. The government narrative over this period shifted in tandem from cultivating quantum science capabilities for public good associated with advancing foundational science research, toward positioning Australia's quantum research excellence as a strategic asset and economic resource.

5.3 Quantum Technology as a Commercial and Security Asset

Stakeholders: Industry emergence

As applied quantum research matured, entrepreneurial ventures sprouted from the academic community and venture capital rose to support the nascent industry. As one interviewee from a venture capital organization commented: "…we're seeing a lot more interest from academics looking to build, you know, tooling in that quantum ecosystem, but hoping to commercialize it through entrepreneurship. We've seen a noticeable uptick" (Interviewee 11 – Venture capital firm investor). Notably, native quantum startups were almost exclusively founded by academic researchers, as they were the only individuals with enough technical expertise to develop applied quantum technologies. This sectoral overlap differed significantly from other fields of emerging technologies, where scientific knowledge is not critical to commercialization efforts. Interviewees noted the direct efforts of prominent government actors, including Australia's Chief Scientist (herself a quantum physicist) and the Minister of Innovation, in "coalescing the national capability" (Interviewee 30 – Venture capital firm technology director) of the emergent quantum industry.

One interviewee commented on the impact of a strong industry voice at this stage shaping the institutionalization of quantum as a strategic economic opportunity: "There are some senior people in the quantum ecosystem who are regularly making public statements [...] to politicians in support of a particular pathway" (Interviewee 16 – Research center director). Quantum industry leaders also began to engage with government bodies, consulting firms, and think tanks to produce position pieces and inform strategy (for example, Brennen et al., 2021). The strong industry engagement during this period contributed to the construction of promise for Australia gaining a distinct economic and strategic advantage driven by a robust quantum industry.

Policy: Strategic roadmaps and economic forecasting

This period produced a strong uptick in documentary inertia taking stock of Australia's quantum 'opportunity' and presenting roadmaps to take advantage of it to obtain a competitive commercial and security advantages. Strategic documents outlining Australia's quantum capabilities and suggesting directives to foster a quantum industry proliferated. The CSIRO's Growing Australia's Quantum Technology Industry roadmap (2020) is referenced by interviewees across sectors as a pivotal catalyst in the public positioning of quantum as a strategic economic asset. The roadmap articulated a clear vision for an Australian quantum industry, "With the right support, CSIRO envisions that by 2040 Australia will maintain its globally competitive strengths in quantum technology R&D and develop a thriving quantum technology industry", and linked this to projected economic benefits: "In 2040, Australia's quantum technology industry could generate over $4B revenue and 16k new jobs" (CSIRO, 2020, p.17). The messaging of this document indicated a sharp focus on quantum industry development in Australia, indicating an emergent vision of quantum as a national economic opportunity that must be seized upon and intentionally shaped by the government into order to realize its forecasted benefits.

The new sense of urgency promoted throughout key strategic documents introduced a prerogative for the Australian government to secure a competitive advantage by implementing a coordinated national approach to developing a domestic quantum industry. As one interviewee commented, these documents signaled the national importance of quantum innovation:

> "In quantum, we've got some clear markers that it's the tech is important, it's been identified in a number of strategic documents, such as the 20 Year R&D Roadmap, and the Turning Ideas into Jobs strategy. So really, [quantum is] being thought about from the perspective of what it means to the economy" (Interviewee – Government data scientist).

Another interviewee added: "…if quantum computing works out, it will be immensely valuable, economically. There's a lot of IP to sort of discover and capture, that's a really key opportunity. So, it's about who can get there first, really" (Interviewee 32 – Government technology director).

A security imperative also began to shape the quantum imaginary, as evidenced through the publication of another key document at this time, the Australian Army's quantum roadmap. The Army roadmap called for a whole-of-government approach to gaining a strategic advantage in the "intensifying global competition to understand, co-develop and exploit quantum technologies for the land domain" (Army, 2021, p.5), promoting a sense of urgency and the risk of missing out on an advantage evidenced by Australia's "globally competitive strengths in quantum technology R&D". This critical advantage is referenced throughout the CSIRO roadmap and across interviews. The security imperative presented by the 'rapid identification and development' thesis of the Army roadmap is also framed as supportive of commercial benefits. As one interviewee from the defense sector commented, the process outlined in this roadmap should also "stimulate the broader development of the industry" alongside securing strategic military advantages (Interviewee 3 – Quantum technology firm founder).

Funding: Directed by commercial demands and defense imperatives

Most funding during this period came from venture capital investments in quantum technology companies. This fomented an industry environment that prioritized commercial demands over ethical concerns associated with developing the technologies. As one interviewee from a quantum startup commented, "The focus is on delivering the technology because otherwise we won't get funding. Otherwise, there won't be a business to be responsible about. So yeah, I guess that's the priority" (Interviewee 22 – Quantum technology firm manager). This commercial reality contradicted the assumption that once the technologies moved to industry applications, issues of potential misuse, harms, and risks would be considered and mitigated. As another academic entrepreneur commented, "Now, we want to get money to do work, you know, it's like a scramble to do that. And a little time and a lot of competition. So…things like ethics get deprioritized if you're if your measures of success are not based on that" (Interviewee 13 – Quantum technology firm founder). Venture capital funding reinforced a purely economic vision of quantum that contradicted the academic vision of safe and secure research.

Funding at this stage also came from the Army's Quantum Technology Challenge (QTC) program, which directed quantum innovation toward developing technological capabilities to address defense challenges. These grants provided important early-stage funding for many dual-use quantum technologies being developed by Australian quantum companies. It offered Australian startups opportunities to begin their entrepreneurial journey through collaboration with the Army. One interviewee voiced concern for the impact of defense funding on shaping innovation trajectories:

> "When you do a challenge-based approach, you're encouraging people [to work toward a specific goal], because they can put the effort in research into a number of directions. And that's the reason why, at the moment, the defence piece is concerning, because that's where all the funding is." (Interviewee 27 – Government research advisor)

Funding from the defense sector served as a mechanism to direct the development of quantum industry applications toward addressing security challenges.

Activities: Designation of quantum as a critical technology and industry consultation

In 2021, quantum was designated by the Australian government as a critical technology, defined as: "Current and emerging technologies that have the capacity to significantly enhance or pose risk to our national interest" (CTPCO, 2021). As the Blueprint for Critical Technologies stated, "Critical technologies…are fundamental to Australia's economic prosperity, social cohesion and national security, and are increasingly the focus of international geopolitical competition" (2021, p.4). Alongside the publication of the Army's roadmap and the provision of funding from the QTC program, the designation of quantum as a critical technology envisioned quantum as a strategic security asset and promoted a sense of urgency to mitigate the risk of losing an established advantage in quantum innovation. The quantum CoEs funded at this time reinforced to this position, underscoring a demand to develop applied quantum technologies to secure a strategic advantage in the "international race to build a scalable, quantum computer that transcends the capacity of conventional computers" (CQC2T, 2019).

By the end of this period, the commercialization of quantum technologies for sovereign economic and security benefit was solidified as a competing vision, directing innovation pathways through policy and funding. As one interviewee put it: "It's become a bit more cutthroat competitive, business oriented, which is fine, which is all part of […] how industries grow" (Interviewee 19 – Government technology director). The influence of this vision is evidenced by quantum companies positioning their offerings and messaging to capture the benefits of the opportunities articulated through this vision. For example:

> "…we believe in being a strategic sovereign asset of Australia. We believe that building a strong company like ours, that delivers a technology, which is important to national prosperity, and security is a good thing to do for Australia. And so, we very much believe that we have a responsibility to deliver that to Australia" (Interviewee 3 – Quantum technology firm founder).

Narrative: The fear of missing out

During this time, the backdrop of popular science media and geopolitics framed the increasing international interest in developing quantum technologies as a 'quantum race', in parallel to the Cold War era space race. As one interviewee comments, "It's a race, right? So, looking at it, Australia, I think we need to do more to actually make sure we take the lead and don't get don't lose out in this race" (Interviewee 17 – Government technology director). The fear of missing out is reflected in the tone of urgency propagated throughout the messaging of key policy documents and sits in sharp contrast to the patient capital invested in foundational quantum science research during the previous phase. A demand for direction, coordination, and planning rapidly became the imperative for Australia to take advantage of its research excellence and translate it into economic impact. There was a sense of losing out on a commercial opportunity, as has happened with previous waves of innovation, if Australia fails to do so. One interviewee's comments reflect this sentiment: "…the fear that we would have is that quantum research goes the same way as other research has in the past where it's commercialized overseas" (Interviewee 5 – Venture capital firm investor). Another interviewee affirms the urgency of strategic national direction required to retain benefit from Australia's quantum research:

> "Other countries are just outpacing us in terms of investment. The business climate [in Australia], I think, is a little bit cautious. And that means that to really kick things off, you have to have a pretty assertive strategy by the government. And that means, you know, taking a little bit of a risk on something that we're good at." (Interviewee 18 – Quantum technology firm researcher and director)

These insights speak to the framing of quantum as a sovereign economic asset to be captured through strategic national direction.

5.4 The Co-production of a Collective Quantum Socio-technical Imaginary

The development of Australia's National Quantum Strategy in 2022 was marked by an open and collaborative process, whereby multiple stakeholders across academia, industry, government, and the broader community were integrated into a process of co-development through extensive consultation across different modalities. This approach led to the surfacing of a tension between stakeholder visions. Facilitated by Australia's Chief Scientist, the consultative process drew heavily on the expertise, concerns, and perspectives of stakeholders elicited through submissions, roundtables, working groups and town hall meetings (DISR, n.d.). During this time, a National Quantum Advisory Committee (NQAC), comprised on leaders from business, science, technology and government with expertise across "research and development, commercialization, investment, supply chains, and national security" was also established to provide strategic advice on growing Australia's quantum sector (DISR, 2022). The deliberative effort is evidenced through the National Quantum Strategy Issues Paper – the government's appeal to quantum stakeholders to contribute to developing "a shared vision for Australia's future quantum technology ecosystem that promotes Australia's economic and national security interests" (DISR, 2022, p.14).

The Issues Paper solicited contributions related to specific opportunities and challenges, many of which were mentioned across our interviews. Based on "conversations we have held to date with industry and academia", the Issues Paper requested input across three themes: (1) research and development, (2) investment, commercialization, and industry growth, and (3) skills, social licence and diversity (DISR, 2022, p.7). The articulation of these themes indicates that a process of co-development between competing stakeholder visions was already informally underway. The top-down coordination of the consultation process shows how government took a leading role in systematically interrogating and integrating competing normative societal and ethical, as well as practical concerns of relevant stakeholder groups into the policy development process. As this tension was surfaced, RI offered a language for reconciling seemingly opposed priorities, allowing government to avoid choosing between stakeholder camps while appearing to address both sets of concerns. As such, it provided a discursive arena that appeared to address values-based concerns for societal benefit with pro-innovation lens. Rather than uplifting one vision over another, government gave space for both visions to become established and integrated in a collective socio-technical imaginary. This led to performative outcomes where RI was introduced as a disruptive perspective to mediate a tension between competing stakeholder visions, which was evidenced through its integration in the National Quantum Strategy, major funding programs, and collaborative activities.

Through institutional embedding, RI both shaped the collective socio-technical imaginary and became re-shaped through strategic implementation. RI provided a normative perspective to address and integrate both academic and industry stakeholder concerns into the quantum imaginary, while the practical demands of quantum commercialization reshaped what RI meant in practice. This was not a sequential process, but an iterative one – each shaped the other through ongoing implementation. In the following sections, we elaborate on how RI became an influencing perspective that was woven into the imaginary to facilitate co-production among academic, industry, and government stakeholders, practically reshaping the concept as it was applied in the context of Australia's quantum commercialization efforts.

RI Shapes the Socio-Technical Imaginary

With the release of the National Quantum Strategy in 2023, the role of the government became pivotal in communicating and coordinating a collective socio-technical imaginary of the future of quantum in Australia that envisioned benefits motivated by both academic and industry stakeholder visions. This strategic document presents a future-oriented vision for quantum in Australia, outlining an approach to achieve a stated vision: "In 2030, Australia is recognised as a leader of the global quantum industry, and quantum technologies are integral to a prosperous, fair and inclusive Australia" (DISR, 2023a). In the articulation of this imaginary, there is a distinct overlay of competing stakeholder visions, whereby quantum technologies are linked to social good outcomes while simultaneously offering Australia competitive commercial and strategic advantages.

In association with Theme Five of the Strategy, "building a trusted, ethical and inclusive quantum ecosystem" (DISR, 2023a, p.7), RI became discursively embedded in the official policy narrative on quantum: "The Australian Government will…champion responsible innovation…" (DISR, 2023a, p.41). While the concept of RI was circulating in the quantum field prior to its application in the Strategy (see for example KPMG, 2021; CSIRO, 2020), its official integration into the Strategy marks its institutional embedding, indicating a shaping effect on the imaginary. We found that the concept of RI was introduced to co-produce a collective socio-technical imaginary that addresses both normative and practical stakeholder concerns raised in the Strategy's consultative development process, shaping the imaginary as it mediated the tension between retaining public good outcomes as quantum technologies are commercialized. The integration of these concerns into the Strategy's approach suggests the consolidation and hybridization of competing visions within Australia's quantum socio-technical imaginary, where RI is offered as a vehicle for enabling the development of a quantum sector that will produce societally beneficial outcomes while delivering competitive commercial and strategic advantages. In doing so, its introduction positions commercial gain and societal good as a co-dependent and entangled central feature of Australia's quantum socio-technical imaginary.

Through its discursive deployment in the Strategy, RI shaped a quantum socio-technical imaginary that joined elements of competing stakeholder visions. The Strategy suggests that RI is required to (1) deliver public good outcomes ("Quantum technologies present nearly endless opportunities. But these opportunities must serve the interest of Australian society and contribute to our national wellbeing"), (2) secure public acceptance ("The public is increasingly aware of the ethical and social implications of new technologies, and we should not assume they will enthusiastically embrace quantum technologies"), and (3) attract international companies and investors ("By adopting this approach, Australia can cement itself as a responsible technology developer") (DISR, 2023a, p.41). The Strategy therefore frames RI as necessary for channeling innovation toward public good outcomes, instrumental for securing public trust, and a strategic asset rather than a constraint. In this context, RI shaped the socio-technical imaginary as it was employed as a normative perspective to weave competing stakeholder visions into the collective imaginary.

While RI shaped the imaginary by positioning commercial and social outcomes as entangled, this framing simultaneously constrained and redirected how RI itself was understood as an enabling tool for quantum innovation. As we will show in the following section, RI was selectively enacted to address the normative social and ethical tension between competing stakeholder visions, enabling the collective work of diverse stakeholders. Through its strategic implementation, the concept itself became reshaped, resulting in a unique practical conceptualization that diverges from RI theory.

RI is Shaped by the Socio-Technical Imaginary

By positioning quantum as both commercially viable and socially beneficial the Strategy in turn required RI to be enacted not as a constraint but as a catalyst, producing a notable reshaping of the concept from its academic origins. We found that RI was not holistically adopted as a prescriptive framework or a set of principles, as academic work on RI presents it (see for example Owen et al., 2013). Rather, it was selectively adapted and strategically applied through funding programs and collaborative workshops to enable the collective work of diverse stakeholders to transition quantum technologies from research to industry. For example, the Critical Technologies Challenge Program (CTCP) was launched in 2024 to incentivize innovation toward areas of national priority such as "[optimising] the performance, sustainability, and security of energy networks]" and "[optimising] and [reducing] the impact of resource exploration, extraction, and mineral processing" (DISR, 2025). This funding specifically linked the development of commercialization activities to the achievement of public good outcomes by inviting quantum researchers to partner with end-users to develop solutions to "market-led challenges of national significance" (DISR, 2025).

The operationalization of RI through the CTCP reveals a fundamental reshaping of the concept. Whereas academic literature on RI suggests that innovation trajectories should remain open and interrogated, the CTCP operationalized RI in pursuit of pre-determined national priorities. In this example, responsibility shifted from a reflective stance that questions innovation pathways to an instrumental tool that optimizes them. By tying funding to pre-identified national priorities, RI was reframed as a mechanism for directing innovation toward strategic goals rather than opening up deliberation about what those goals should be.

Another example of RI's introduction is the Quantum Meets workshop series, hosted by Australia's Chief Scientist. The series "introduces the quantum opportunity to sectors across the economy, bringing business, government and researchers together to identify industry challenges that quantum technologies could address and define the problems that need attention" (Australia's Chief Scientist, 2024). These workshops brought stakeholders across the ecosystem together to facilitate opportunities for producers and potential end-users of quantum technologies to ideate and discuss sector-specific challenges and opportunities for collaboration. RI researchers and ethicists were notably included as panelists and participants in the workshops. The series brought a use case or application focus to the fore, with a specific focus on "applications that can benefit everybody" and a stated aim to "accelerate the uptake of quantum technologies in Australia's economy" (Australia's Chief Scientist, 2024). The dual aim of the workshops reinforced co-production in the imaginary by promoting a sentiment that commercial quantum advancements can be made to the benefit of society. At the same time, it showed how the concept of RI was employed to suit the need to bring stakeholders together for a continued process of co-development between academia and industry.

The Quantum Meets events reshaped RI by collapsing the distance between ethical reflection and commercial promotion. Rather than creating space for independent critical assessment, RI became embedded within the very process of accelerating quantum commercialization, transforming the concept from a potential brake to an active accelerator. Likewise, these events brought a selection of stakeholders together, including RI researchers and ethicists, to identify industry challenges. This placed RI experts in the role of facilitators of commercialization, rather than critical observers. Questions of risk, ethics, and societal benefit surfaced at these events mobilized, rather than detracted from, the commercialization process by reframing RI as technical problem-solving rather than normative questioning.

Interviewees seemed to absorb this reformulation, offering insights into how they envisioned to the role of RI as contributing to the collective goal of quantum commercialization. As one interviewee reflected on Quantum Meets:

> "The value there I saw was in in facilitating the conversations. So having, you know, having policy makers being able to start to cut through some of that hype, but also identify potential areas that the researchers are saying is, you know, this could be a risk. So yeah, that's not formal foresight. But you know, it's a start." (Interviewee 28 – Research center director)

This example revealed how RI was reshaped through its introduction into the collective imaginary in service of co-producing Australia's quantum innovation policy. This enabled stakeholders to understand the concept as a component of a collective project over which they felt some ownership. As one interviewee commented: "I think responsible innovation has got to be opening things up, not closing things down...you know it's opening up opportunities for new uses that have a broad benefit to society" (Interviewee 27 – Government research advisor). These programs demonstrated how RI was not undertaken as a standalone activity, but rather, became an embedded feature of an innovation approach that reflected elements of diverse stakeholder visions.

We found that RI became reshaped during this period as an essential ingredient for *good* commercialization, conferring legitimacy to and justifying continued public investment toward developing an emerging technology sector. RI functioned as a mechanism for reintegrating the social good associated with foundational quantum research into the national effort to develop quantum technologies as a strategic sovereign asset. Several interviewees' comments reveal the meaning of RI as they understood it through its inclusion in the Strategy and related programs. As one interviewee commented: "…in terms of responsible innovation, I think it's also kind of making the most of what you've got so that you can use it in ways that are really beneficial" (Interview 33 – Industry association researcher). Others discuss how it can provide a competitive edge, both nationally and on a company-scale:

> "I mean, particularly, you know, for Australia, where we're looking for, you know, an asymmetric advantage… now would be the time to actually get in there here and say, you know, there could be a competitive advantage for you in actually in having a small social science program to go along with what you're doing." (Interviewee 32 – Government technology director)

> "But, you know, if, if you're a company and you can say, look, we think that our developments can be used to help in this area that, you know, is a clear benefit for humanity. I think that can give them a competitive edge." (Interviewee 18 – Quantum technology firm researcher and director)

These quotes show how stakeholders' perspectives on RI shifted over time from a burden on commercial organizations to a competitive advantage as the concept became absorbed into the collective socio-technical imaginary. These insights demonstrate how stakeholders made sense of RI through the lens of the imaginary and became inducted into new practices in line with this outlook. This process of iterative shaping produced an understanding of RI that became accessible and relevant to stakeholders.

This reciprocal shaping process reveals how RI and the quantum socio-technical imaginary became co-constituted. RI influenced how the imaginary reconciled competing visions of producing positive societal and commercial benefits, while RI gained institutional traction as it was filtered through the imaginary's commercial imperatives. Neither determined the other; rather, they evolved together through iterative cycles of policy development, stakeholder consultation, and program implementation. The result was a distinctly Australian quantum imaginary where RI meant competitive advantage, and a distinctly commercialized version of RI, where social good became instrumentalized for economic strategy.

6. Discussion

Our study traced the emergence of RI as a mediating concept in Australia's quantum technology sector, reconciling a tension between two competing stakeholder visions: one centered on quantum science as a public good and another on quantum technology as a strategic commercial and security asset. Through its inclusion in the 2023 National Quantum Strategy and subsequent introduction into industry development activities, RI facilitated the stabilization of a collective quantum socio-technical imaginary that seeks to balance commercial success with societal benefit. By analyzing this change, we demonstrated how RI functioned not as a framework or set of practices, but as a novel perspective that shaped the approach to national innovation policy and was in turn reshaped by its selective application. This finding highlights the role of governments in RI beyond research settings, as they navigate the complex transition from fundamental science research to market-oriented innovation.

Contributions to Responsible Innovation

This study makes key contributions to the RI literature. We provide an empirical account of how a national government mobilized RI through innovation policy to reconcile competing stakeholder visions. While most RI studies concentrate on implementation within research settings (e.g. Owen et al., 2013; von Schomberg, 2013) or at the firm level (Auer & Jarmai, 2017; Ko & Kim, 2020), few investigate how governments embed RI into policy instruments to guide industry development. Our findings demonstrated how government served as a central agent in institutionalizing RI, not only by mandating specific practices but also by reshaping the imaginary frameworks that confer legitimacy on emerging technologies and the innovation practices that develop them.

Our findings demonstrated how strategic programs absorbed and reshaped several aspects of RI – including directing innovation toward public good outcomes, anticipating potential risks, integrating the perspectives of diverse stakeholders, and inducing reflexivity through collective deliberation – to fit a commercialization agenda. This was done selectively, without a holistic or centralized approach to enacting it. Interestingly, the ways in which RI was reshaped through the lens of the imaginary contradicts theoretical research on RI, which stipulates that these dimensions "do not float freely but must connect as an integrated whole" (Stilgoe et al., 2013). Rather, we found that RI became reshaped as an archipelago-like presence as it was woven into the fabric of funding and events to facilitate continued co-production among diverse stakeholders through a pro-innovation lens. We showed how this produced a new understanding of the concept that reoriented RI practices toward accelerating societally beneficial avenues of quantum commercialization.

Our study also advanced understanding of RI by addressing a key gap: how RI operates within systems of innovation through its role for socio-technical imaginaries. Responding to calls for a "systemic turn" in RI (Stahl et al., 2017; Dreyer et al., 2020; Smolka & Böschen, 2023), we demonstrated that RI took shape through a distributed configuration of actors, agendas, and instruments. Echoing Dreyer et al.'s (2020) argument that RI "needs to be anchored in an … ecosystem of stakeholders" (p. 2), we showed how the Australian government worked through a consultative process to integrate RI into national strategy, engaging academics and industry actors alike. Crucially, we moved beyond normative appeals for stakeholder engagement by identifying the concrete policy mechanisms that enabled RI to function as an organizing perspective (Taylor, 2002) within a commercialization context for the governance of emerging technologies.

Finally, we offered new insights into the motivations and capacities of governments to advance RI. Whereas prior research highlights the challenges firms face in adopting RI – such as short-term commercial pressures or lack of incentive structures (Lubberink et al., 2019; Gurzawska et al., 2017) – our findings foreground the structural role of the state in shaping innovation environments. We showed how stakeholders, motivated by concerns about social license, ethical risk, and the long-term legitimacy of quantum innovation, strategically position RI within national priorities. Unlike firms, which often pursue RI based on individual values or reputational aims (Auer & Jarmai, 2018; Ko & Kim, 2020), governments may draw on RI to justify public investment, address stakeholder concerns, maintain public trust, or create a strategic advantage.

Contributions to Socio-Technical Imaginaries

Our study offers a detailed account of how contested visions emerge, come into tension, and lead to co-production within the governance of emerging technologies. While previous work has established that imaginaries are collective, performative visions of desirable futures that shape and are shaped by science and technology (Jasanoff & Kim, 2015), fewer studies have examined the processes through which these imaginaries are reconfigured (c.f. Higham, 2019). We contributed new understanding by showing how the introduction of RI into discourse and actions acted upon the tension between a public research-based vision and a commercialization-driven vision, and how this led to a state of co-production that stabilized the socio-technical imaginary.

Where much of the existing literature typically treats socio-technical imaginaries as relatively stable frameworks that guide technological development, institutional discourse, and public expectations (Jasanoff, 2015; Mager & Katzenbach, 2020), Mager (2017) and Higham (2019) argue that imaginaries are often multiple, dynamic, and contested, particularly when they co-exist within fragmented or transitional innovation regimes. Our study builds on this insight by demonstrating how competing visions are brought into a co-productive relationship through the introduction of a novel perspective – in this case, the concept of RI. This perspective served to enable partial alignment and the willingness to act upon the co-produced and stabilized imaginary between competing stakeholder visions.

Drawing on the analytical repertoire of socio-technical imaginaries by foregrounding the material and discursive mechanisms through which imaginaries are stabilized, reconfigured, or synthesized, we traced the roles of stakeholders, policy, funding, activities, and narratives, thus revealing how imaginaries are embedded within broader socio-technical infrastructures. Following

Jasanoff's (2015) call for attention to the "social thickness and complexity" of imaginaries, we demonstrated how state-led efforts to institutionalize RI enabled the co-production of a collective imaginary that keeps societal and economic goals in balance through the introduction of RI. Our analysis, through the lens of stakeholders, policy, funding, activities, and narratives that shape the emergence of socio-technical imaginaries over time, clarifies how socio-technical imaginaries come to be through "…resonance among collectives, the allocation of resources and the adoption into practices of making, governing and doing…." (Mager & Katzenbach, 2020, p.3).

As Mager (2017) contests: "sociotechnical imaginaries should not be seen as monolithic or stabilized, but rather as multi-faceted and dynamic" (p.256). Socio-technical imaginaries contain multiple, competing visions held by diverse stakeholder groups. Studying how these relate to one another reveals important tensions between them that says something about society and the imagined future(s) of its creators (Mager & Katzenbach, 2020; Jasanoff, 2015). Our study adds a case to this description, offering nuance and depth to understanding how particular stakeholders within a given national and technology-specific context can generate contesting visions, particularly in relation to the context of an emerging suite of technologies as they move from one domain (research) to another (commercialization) over time. We showed how competing visions entered a state of co-production and how a disruptive perspective, in this case RI, was employed to mediate a tension between the two camps, resulting in a "rearticulated awareness of order in social life" (Jasanoff, 2015, p.7) through a resulting collective quantum imaginary.

Our study also provides an account of how theory itself, RI, can function as both a shaping and shaped element of socio-technical imaginaries. Drawing on Taylor's (2002) notion of social imaginaries as deeply internalized perspectives that both orient and are influenced by collective practice, we demonstrate how RI entered the quantum innovation landscape not as a fixed framework, but as a flexible interpretive lens. It was selectively adopted, reshaped through the logics of industry activation, and ultimately integrated into national policy as part of a future-oriented imaginary. In doing so, our findings respond to Higham's (2019) call to examine how imaginaries may transition from a state of fragmented antagonism to productive synthesis, not through resolving foundational differences, but through the mediated evolution of a new hybrid imaginary.

7. Conclusion

Through our case study, we enhanced understanding of how governments can take a more active role in RI by coordinating practices and helping to shape the imaginaries that guide innovation itself. We demonstrate that RI, when embraced by the state, can function as both a normative, ethical imperative and a strategic orientation that offers direction and legitimacy to national innovation policy. However, this shaping process is not one-sided. As we traced, imaginaries evolve through ongoing interactions among actors, agendas, and institutional structures. RI, as both theory and policy, is reshaped through this engagement. By making these dynamics visible, we hope to inspire further inquiry into how societies co-produce their technological futures—and the role RI can play in steering those futures toward more inclusive and ethical outcomes.

5. Chapter Five: Paper Three

Orchestrating Responsible Innovation in Knowledge Ecosystems

Abstract

There is an increasing awareness amongst governments and policymakers that tackling complex societal challenges requires coordinating the collective knowledge and skillsets of societal innovation actors before emerging technologies reach commercial applications. Responsible innovation (RI) has been hailed as a promising approach to this challenge, because it denotes the integration of a broad diversity of actors to reflect on and respond to the societal and ethical dimensions of innovation processes. However, research has revealed that commercial organizations experience tensions that stifle their efforts to engage with RI, all but removing them from RI. In response to this, researchers suggest that RI is better suited to application on an ecosystem level, rather than an organizational one, where it can be enacted as a meta-level commitment. This paper responds to this call by interrogating how RI orchestration in knowledge ecosystems can ease the tensions faced by commercial organizations. We offer three propositions for how RI orchestrators develop robust and responsible knowledge ecosystems for emerging technologies.

1. Introduction

As governments worldwide seek to encourage innovation, there is a growing concern for doing so in a way that both fosters competitive technological advancement and generates societal benefits (Voegtlin et al., 2022; Kuhlmann, 2018; Kuhlmann & Rip, 2014). It denotes a shifting view of the role of innovation in and for society, where commercial organizations are critical to developing solutions to societal challenges, such as climate change, access to water, or global pandemics, in partnership with other societal actors (Voegtlin et al., 2022; Owen et al., 2021). As these challenges or 'wicked problems" (Ritala, 2024) are too big for one organization alone to solve, tackling them entails bringing stakeholders from public, private, and non-profit organizations together to direct technological development toward these challenges, often in the pre-commercial phase, while assuring that societal risks are avoided and societal benefits guarded (Voegtlin & Scherer, 2017; Kuhlmann & Rip, 2018).

This effort has been coined responsible innovation (hereafter RI), and it is defined as "a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the ethical acceptability, sustainability and societal desirability of the innovation process and its marketable products" (von Schomberg, 2013, p. 63). The initial formulation of RI derives from the European Commissions (Owen et al., 2021) and was later applied as a major theme in Europe's research and innovation funding program, Horizon 2020 (Owen et al. 2013; Grunwald 2016). Since then, several countries have embedded RI into their respective science research policies and conditions of funding (Stilgoe et al., 2013) to "shift the attention in the governance of innovation from the output side to the input side" (Brand & Blok, 2019, p.5). RI involves identifying social and ethical issues from the earliest stages of research and developing responses to these as they surface throughout the innovation pipeline (Stilgoe et al., 2013; Lubberink et al., 2019; Nazarko & Melnikas, 2019; Owen & Goldberg, 2010). The initial European policy formulation of RI has sprouted a stream of literature within the larger corpus that identifies RI as critical to the achievement of grand societal challenges or wicked problems (European Commission, 2011; Owen et al., 2021; von Schomberg, 2013). Others suggest that the mission-oriented approach compatible with RI objectives could provide an important inroad for inducing commercial organizations to commit to RI practices (Voegtlin et al., 2022; Degbey et al., 2024), and to reflect on and respond to the societal dimensions of innovation as they work toward a collective goal (da Silva et al., 2019).

However, research on RI in commercial organizations has revealed stifling tensions between for-profit demands and the requirements of RI (Auer & Jarmai, 2017; Pfotenhauer et al., 2021; Gurzawska et al., 2017; Lubberink et al., 2017; Ko & Kim, 2020; Martinuzzi et al., 2018).

While these tensions seem almost insurmountable at the organizational level, recent studies suggest that ecosystems can provide a 'club approach' (Stahl, 2022; Dreyer et al., 2020) whereby diverse innovation actors, including commercial organizations, would be required to satisfy certain rules and conditions related to RI in order to access ecosystem-level benefits and collective resources, including access to programs, funding, and infrastructure (Agrawal & Cockburn, 2002). We therefore contend that knowledge ecosystems, rather than commercial organizations, are the starting point for policies that foster an orchestration of RI principles and practices.

RI provides a compatible framework for facilitating the multidimensional dynamics of ecosystems because it promotes collaboration among member organizations in alignment with a collective goal (Smolka & Böschen, 2023; Jakobsen et al., 2019; Stahl, 2022; Stahl, 2017; Foley & Wiek, 2017; Dreyer et al., 2020). With governments providing support for ecosystem development, policies aimed at establishing these structures therefore provide an opportunity to influence the uptake of RI in participating organizations at a pre-commercial stage (Foley & Wiek, 2017). These observations bring knowledge ecosystems into view. Knowledge ecosystems call for the inclusion of a broad diversity of innovation actors, foster a culture of collective deliberation in the innovation process, and demand a meaningful level of transparency and knowledge sharing amongst actors, all of which are fundamental conditions for the implementation of RI (Stahl et al., 2017; Jakobsen et al., 2019; Stahl, 2022; Foley & Wiek, 2017; Dreyer et al., 2020; Smolka & Böschen, 2023).

Knowledge ecosystems are collectives "…in which actors such as universities, public research institutions, and for-profit firms collaborate to create new knowledge in a pre-competitive setting" (Järvi et al., 2018, p.1523). They are formed around specific technological advances or societal challenges, rather than immediate economic value creation and capture (Clarysse et al., 2014; van der Borgh et al. 2012; Dougherty & Dunne, 2011). In knowledge ecosystems, value is created and captured through a joint search for knowledge as it is collaboratively developed by a diversity of innovation actors (Cobbens et al., 2022; Fiandrino et al., 2025). As such, innovation in knowledge ecosystems is driven by a collective goal whereby "the variety and complementarity of organisations and actors in the knowledge ecosystem contribute to positive development" (Fiandrino et al., 2025, p.216). In addition to addressing complex technological challenges, knowledge ecosystems are often organized around grand societal challenges or wicked problems, which serve as a common goal (Fiandrino et al., 2025; Järvi et al., 2018; Gifford et al., 2021). To achieve a collective outcome, knowledge exploration must be facilitated through collaborative practices that align the diversity of values, expertise, and motivations of contributing organizations (Dougherty & Dunne, 2011; Valkokari, 2015).

While policymakers are integral to setting the conditions for the creation of knowledge ecosystems (Scaringella & Radziwon, 2018; Rådberg & Löfsten, 2023), ecosystem orchestrators – "interested in nurturing and developing a given ecosystem as a whole" (Daymond et al., 2023, p.1) – tend to play a pivotal role in ecosystem development by coordinating activities in co-evolutionary ways (Gomes et al., 2021; Burmaoglu & Saritas, 2019; Blasi & Sedita, 2019; Gomes et al., 2018). However, in contrast to other types of ecosystems, orchestration in knowledge ecosystems does not receive much attention in the literature. Knowledge ecosystems are not led by a focal firm (Cobbens et al., 2022); rather, inter-disciplinary collaboration tends to be facilitated, rather than directly led, by knowledge intermediaries such as universities, independent management teams, research organizations, and innovation hubs (Marinelli et al., 2024; Cobbens et al., 2022; Shi & Chen, 2022; Fiandrino et al., 2025; Clarysse et al., 2014). This is because the focus of knowledge ecosystems is on the facilitation of the innovation process for system-level value creation. As Cobbens et al. (2022) state: "The value creation mechanisms focus on creating a community for knowledge generation and innovation. The value capture mechanisms in knowledge ecosystems focus on capturing value from the jointly developed knowledge" (p.144).

However, aligning the work of diverse actors in knowledge ecosystems to develop a scientific or technological solution to a complex challenge requires coordination (Sinnewe et al., 2016). As Fiandrino et al. (2025) argue, "to cope with wicked problems, the coordination of objectives, interests and practices among different stakeholders requires the institutionalisation of appropriate policy games" (p.218). Likewise, the literature on RI identifies the need to detect the agents responsible for coordinating activities of stakeholder inclusion, deliberation, and knowledge integration across diverse actor portfolios (Stilgoe et al., 2013; da Silva et al., 2019). In short – RI in knowledge ecosystems requires the deliberate orchestration of collaborative activities. In this paper, we advocate for the role of policymakers in incentivising the orchestration of RI through activities and practices compatible with the objective of value creation in knowledge ecosystems. Designated RI orchestrators can encourage and facilitate RI and provide pathways for exposure to and participation in RI practices for both public and commercial actors through their collective interest in the technological outcomes generated through a knowledge ecosystem. The shift in practical perspective from the organizational to the ecosystem level opens avenues for future research on RI and offers recommendations for policymakers.

2. Knowledge Ecosystems and their Orchestrators

Knowledge ecosystems are comprised of a broad diversity of actors who are involved in scientific activities, seek complementarities, and participate in knowledge creation to give rise to innovation opportunities (Vodă et al., 2023; Bray, 2007; Bratianu & Hadad, 2019; Reischauer et al. 2021). Knowledge ecosystem actors include universities, public and private research institutions, alongside established firms, small technology firms, incubators and makerspaces, governments, and policymakers (Rådberg & Löfsten, 2023; Shi & Chen, 2022), whilst orchestrators connect the diverse actors in the ecosystem and facilitate the innovation process (Scaringella & Radziwon, 2018; Agarwal & Cockburn, 2003). As knowledge ecosystems are pre-competitive and pre-commercialization, they are further upstream in the innovation process than innovation and business ecosystems, which are specifically concerned with commercialization activities (Järvi et al., 2018; Perkmann & Schildt, 2015; Valkokari, 2015). However, they made lead to commercial and entrepreneurial outcomes (Clarysse et al., 2014).

In knowledge ecosystems, orchestration refers to "the set of deliberate and purposeful actions constructed by multiple actors as they seek to share, integrate, diffuse, and create knowledge and value" (Shi & Chen, 2022, p.2). Knowledge ecosystems require orchestrating actors to facilitate the process of knowledge creation in a way that brings opportunities for science and technology to solve large-scale societal challenges by aligning the work of diverse ecosystem participants toward achieving a collective impact (Mbitse et al., 2024; Gifford et al., 2021). Orchestration in knowledge ecosystems is less centralized and hierarchical than other ecosystems formulations due to the nature of the types of complex challenges established as the system-level goal, which tend to be abstract and demand an evolutionary and flexible approach to enable the participating set of heterogeneous actors to collectively explore solutions (Järvi et al., 2018; Valkokari, 2015). As Garud et al. (2008) establish, it is often the case that in knowledge ecosystems, "problems are ill-defined, preferences are fluid, and solutions emerge in action" (p.352). As such, the aim of orchestration in knowledge ecosystems is to facilitate inter-organizational collaboration by aligning the incentives, motivations, and cognitions of diverse ecosystem members to jointly develop new knowledge across knowledge boundaries (Järvi et al., 2018).

The objective of knowledge ecosystem orchestrators is distinct from that of orchestrators in other types of ecosystems because value creation is linked to exploration rather than exploitation (Valkokari, 2015). The formalized, centralized, and hierarchical orchestration that generally characterizes other types of ecosystems (Cobben et al., 2022) can be counterproductive to this aim, as it can limit the fluidity and flexibility required for inter-organizational exploration. Although orchestration in knowledge ecosystems may be de-centralized and distributed, it is nevertheless present and critical to facilitating synergies and linkages for knowledge exchange between heterogenous ecosystem actors. The different orientations of actors in diversity-rich knowledge ecosystems "are structurally imposed because they result from the broader societal sphere (e.g.

industry or academia) in which an organization mainly operates" (Reischauer et al., 2021). Therefore, aligning the diversity of actor's priorities and capabilities in knowledge ecosystems is fundamental to their success (Sinnewe et al., 2016). Bridging knowledge boundaries to create the conditions for a collaborative and exploratory environment requires the orchestration of specific activities (Gifford & McKelvey 2019; Gifford et al., 2021).

Knowledge ecosystem orchestration activities can include the promotion of a shared culture of innovation and values among ecosystem participants, the provision of facilities, services, and resources, acting as a broker between firms and universities around the shared development of novel technologies and business ideas, managing intellectual property (IP), and reducing information asymmetries between ecosystem participants through the provision of information on activities, capabilities, resources, and offerings (van der Borgh, 2012). Knowledge ecosystems tend to be facilitated, rather than led, by knowledge intermediaries such as universities, independent management teams, research organizations, and innovation hubs (Marinelli et al., 2024; Cobbens et al., 2022; Shi & Chen, 2022; Fiandrino et al., 2025; Clarysse et al., 2014; van der Borgh, 2012). In their orchestrating activities, they reflect the policies that imbue structure to enable member organizations to operate effectively (Reischauer et al., 2021; Fiandrino et al., 2025). As Järvi et al. (2018, p.1525) assert, "there is always some meta-level intentional action" involved in knowledge ecosystem development to establish the appropriate infrastructure through policies, incentives, and resource provision.

While incentivizing ecosystem formation to foster innovation has received growing attention from regulators, governments, and funding bodies worldwide (Jacobides et al., 2018), considerably less attention has focused on encouraging the specific roles of orchestrators amongst the diversity of knowledge ecosystem actors (Daymond et al., 2023; Shi & Chen, 2022; Mbitse et al., 2024; Reischauer et al., 2021). Given their interest and responsibility in the development of ecosystems, orchestrators are important actors in enacting policy mandates and structuring knowledge ecosystem activities. Establishing a specific role for RI orchestrators in knowledge ecosystems could complement the orchestration activities undertaken by existing actors to create alignment amongst ecosystem participants, while providing a pathway for exposure to and experience with enacting RI for both public and commercial ecosystem members.

3. Tensions Inhibiting RI in Commercial Organizations

By instating participation in RI activities as a condition of knowledge ecosystem membership, RI orchestrators could help to ease tensions faced by commercial organizations when they endeavor to address RI demands in isolation because it is elevated to and conducted as a collective, meta-level requirement. It would address that RI has had limited success at percolating through to private companies and entrepreneurial ventures (Gurzawska et al., 2017; Blok et al., 2015). These actors fail to manage the adoption of RI practices on their own (Gurzawska et al., 2017; Lubberink et al., 2017) because RI sits in tension with their organizational aims and processes, such as fiduciary responsibilities to shareholders, organizational efficiency, and protecting competitive advantage. As a result of these tensions, policies directed at implementing RI in the isolated context of organizations are ineffective (Auer & Jarmai, 2017; Pfotenhauer et al., 2021; Gurzawska et al., 2017; Lubberink et al., 2019; Ko & Kim, 2020; Martinuzzi et al., 2018). While the personal views of CEOs (Ko & Kim, 2020; Auer & Jarmai, 2018), the values of employees (Gurzawksa et al., 2017), and the shifting discourse around the role of business in society (Dreyer et al., 2020; Scherer & Voegtlin, 2020) do provide motivation for organizations to "do something good" (Auer & Jarmai, 2018, p.9), the lack of meta-level coordination remains a significant barrier to organizational adherence to RI practices and principles.

As Dreyer et al. (2020) posit: "Academic research on Responsible Innovation has so far failed to generate models that could be implemented in R&D operations, most probably because they do not align with current practices and constraints" (p.3). This observation indicates that the concept has not been successfully adapted from its original research policy context to encompass the values, motivations, and practical objectives of commercial innovation actors. While some "de facto responsible innovation practices" (Lubberink et al., 2019, p.180) are conducted in commercial organizations, such as anticipating risks and responding to these, studies reveal significant barriers to the RI demands of societal responsibility, inclusion, reflexivity, transparency and knowledge sharing (van de Poel et al., 2020; Auer et al., 2018). We argue that while these tensions hamper the uptake of RI in commercial organizations, they provide opportunities for the orchestration of RI-driven activities in knowledge ecosystems.

3.1 Fiduciary Responsibility versus Collective Societal Responsibility

The European Union declared RI indispensable to addressing societal grand challenges such as climate change, energy, water, food supplies, aging societies, public health, pandemics, and security (Lund Declaration, 2009). It posits that "innovations should be steered toward (ethical) acceptability, societal desirability and sustainability" (Lubberink et al., 2019, p.182). This demand sets RI as an effort to innovate for societal good, and it identifies RI as a means for innovation actors to become co-responsible for integrating societal concerns into their innovation activities, thus, "attending to the societal dimensions of science and technology development" (Smolka & Böschen, 2023, p.7). It calls on innovation actors to be continuously engaged throughout the innovation process in reflecting on their roles and responsibilities therein so that they may take responsibility for steering innovation projects in a way that is responsive to societal concerns (Kuhlmann & Rip, 2018). Responsibility for the societal dimensions of innovation outcomes requires governance mechanisms for "provisional, flexible, revisable, dynamic and open approaches that include experimentation, learning, reflexivity, and reversibility" (Kuhlmann & Rip, 2018). Therefore, in the context of RI, societal responsibility is related to both the purpose of innovation as well as the innovation process itself.

In commercial organizations, responsibility is predominantly tethered to fiduciary outcomes. One perspective is that commercial organizations are expected to maximize shareholder value rather than stakeholder benefit (Dreyer et al., 2020), and in these contexts "innovation, whether it concerns products or processes, can have only one aim: to protect or enhance the competitive advantage of firms in order to maximize their profits" (Scherer & Voegtlin, 2020, p.11). The tension between the RI mandate for "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013, p.1570) and decision-making driven by short-term fiduciary responsibilities to shareholders is repeatedly problematized in the RI literature. As Auer and Jarmai (2018) observe across interviews with CEOs of SMEs in the Austrian medical device sector, "Respondents share the view that the implementation of [RI] in practice will be strongly dependent on market dynamics… research and innovation activities are generally pursued to gain positive future economic value and long-term profits. A clear incentive for the respondents to implement [RI] in their companies would be the prospect of growth or reduction of costs" (p.12). Likewise, Martinuzzi et al. (2018) find that recurring themes in the literature on RI implementation in commercial organizations include "…the conflicting priorities of corporate aspirations in terms of profits, growth, competitive advantage, and market shares, on the one hand, and societal objectives including prosperity, well-being, and sustainability, on the other hand" (p.1).

While some efforts are made by commercial organizations to consider their impact and contribute to areas of societal benefit – demonstrated for example, through B-Corp certification, or corporate social responsibility (CSR) – these approaches alone are unlikely to create a phase shift in 'business as usual' practices, and may be more demonstrative of virtue signalling than system-level change (Scherer & Voegtlin, 2020). The variety of mechanisms that exist for commercial organizations to create and communicate impact indicate that social values motivate these initiatives, both internally from within organizations and externally through societal pressures (Ko & Kim, 2020; Gurzawksa et al., 2017, Auer & Jarmai, 2018). However, systemic change can only be achieved through collective coordination. For example, the development of biopharmaceuticals is driven by intellectual property (Pisano, 2006), which effectively disincentivizes knowledge sharing and inhibits inter-organizational learning. Another example can be found in the energy sector, which is characterized by a diversity of operating principles. The resultant lack of system interoperability impedes the ability to combine alternative energy sources, which presents as a critical limitation for a clean energy transition (Totty, 2010). Dougherty and Dunne (2011) offer that the complexity inherent in systems of innovation must be actively harnessed, rather than be allowed to fracture and dissolve, to achieve holistic returns for society.

Knowledge ecosystems, in contrast, tend to form around specific technical, scientific and societal challenges (Järvi et al., 2021; Dougherty & Dunne, 2011; Vodă et al., 2023). Inviting the participation of a diversity of organizational actors to address these challenges is based on the insight that they are too complex and multidimensional to be tackled by any one organization alone. Rather, inter-organizational arrangement is required to discover solutions that address the "multi-causal, multi-domain, multi-phase, multi-level" nature of such challenges (Bogers et al., 2016, p.8). Knowledge ecosystems aim to harness the multiplicity of perspectives and skillsets offered by innovation actors to co-design solutions by leveraging science and technology to solve complex challenges (Gifford et al., 2021). These emergent ecologies must be managed and shaped effectively to precipitate the formation of new knowledge, which can ultimately lead to new products and applications that address an area of societal concern (Dougherty & Dunne, 2011).

For example, Vodă et al. (2023) explore how knowledge ecosystems can provide an infrastructure for integrating a sustainability paradigm in the innovation process: "The sustainability paradigm has emerged as a key framework for addressing the complex and interconnected challenges facing humanity, including a wide range of issues such as economic, climate change, biodiversity, and social issues" (Vodă et al., 2023, p.61). The researchers posit that because knowledge ecosystems are conceptualized in the broader context of a socio-economic system (Carayannis & Campbell, 2009) and focussed on integrating the perspectives and experience of a broad diversity of innovation actors (Shi & Chen, 2022; Järvi et al., 2018), they offer a system for inter-organizational collaboration that can facilitate a more holistic approach to solution discovery for complex social, economic, and environmental challenges. This approach is well-suited to the type of adaptive, inclusive, and reflexive engagement between innovation actors demanded by the concept of societal responsibility in RI.

3.2 Organizational Efficiency versus Stakeholder Inclusion and Reflexivity

In RI, all actors involved – both public and private – should become co-responsible for the innovation outcomes for society (Owen et al., 2013; von Schomberg, 2013). This means engaging in dialogue with a variety of external stakeholders, including consumers, regulatory bodies, non-governmental organizations, and other societal groups that have a vested interest in the long-term impacts of innovation activities and outputs (da Silva et al., 2019; Owen et al., 2013; von Schomberg, 2013). The establishment of "deliberative forums" for the "opening up" of public debate around innovation trajectories is a core tenet of RI, known as inclusion (Stilgoe et al., 2013, p.1571). This engagement should be carried out to gain feedback on innovation processes. The ability to take this feedback into consideration is referred to as reflexivity: "holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held" (Stilgoe et al., 2013, p.1571). Inclusion and reflexivity are intended to establish a mode for diverse stakeholders to collectively govern innovation to achieve "collective responsibility" of innovation outcomes (von Schomberg, 2013, p.60).

Dreyer et al. (2020) suggest that because RI requires value alignment and collaboration amongst a diversity of stakeholders, "[it] cannot be implemented in isolation. To flourish, it needs to be anchored in an […] ecosystem of stakeholders comprising government, citizens, academia and business, each playing its role and assuming its responsibility" (p.2). However, inviting a broad diversity of stakeholders to contribute to the innovation process, as RI demands, stands in tension with the economic rationality (Jensen, 2022) that governs commercial actors (van de Poel et al., 2020). Noland and Phillips (2010) point out that whilst stakeholder engagement is a critical aspect of CSR from both an ethical and strategic standpoint, the radically democratic interpretation of RI where all stakeholders participate in an equal capacity to decision-making processes goes beyond what most organizations are willing to accept. As Brand and Blok (2019) state: "Markets are efficient and companies are innovative because companies compete for the favour of customers, and not because they deliberate with them" (p.12).

If organizations try to satisfy RI's demand of inclusiveness and reflexivity, incorporating multiple stakeholders' perspectives and values into the innovation process can lead to conflicts and the need for intricate negotiations (Scherer & Veogtlin, 2020). In one case from a study by van de Poel et al. (2020), a synthetic biology company committed to increasing transparency experienced conflict and a lack of trust when attempting to engage stakeholders such as public think tanks and consumer organizations. As a result, they received "fierce public criticism" about their products from some NGOs, which refused to engage in further dialogue (van de Poel et al., 2020, p.699). The divergent opinions of the company and the public stakeholders it sought to engage demonstrate how the requirement of the democratic and inclusive approach to innovation governance demanded by RI can be perceived as a risk to commercial organizations' reputation and productivity. In this example, the company thereafter pivoted to introduce a new strategy "with a strong focus on profit making at the expense of stakeholder engagement and public transparency" (van de Poel et al., 2020, p.699). If organizations are pressured by fast-paced development and rapid market deployment, the result is likely to collapse into an either-or response where commitment to RI falls to economic rationality.

In contrast, knowledge ecosystems are regarded as "versatile and inclusive" (Vodă et al., 2023, p.54). In knowledge ecosystems, effective knowledge search hinges on integrating the diversity of ecosystem participants' complementarities to produce solutions based on a broader set of perspectives and skills than any one actor alone may hold (Vodă et al., 2023; Järvi et al., 2018). Utilizing knowledge offered by actors from an array of sectors to solve complex societal and scientific problems requires the inclusion of participants from overlapping systems of knowledge production and innovation to engage in reflexivity through the process of sharing and co-creating knowledge (Järvi et al., 2018; Shi & Chen, 2022; Carayanni & Campbell, 2009). In fact, the success of a knowledge ecosystem hinges on the effective inclusion of a multiplicity of perspectives and skillsets. As Carayanni and Campbell (2009) write: "[T]he competitiveness and superiority of a knowledge system is highly determined by its adaptive capacity to combine and integrate different knowledge and innovation modes via co-evolution, co-specialisation and co-opetition knowledge stock and flow dynamics" (p.210). It is the meta-organizational structure of knowledge ecosystems that enables collective agency to create joint value while preserving the independence of individual actors (Järvi et al., 2018).

3.3 Protecting Competitive Advantage versus Transparency and Knowledge Sharing

Transparency is a crucial ingredient for enabling stakeholders enough visibility into the innovation process to assess the potential social, ethical, and environmental impacts of innovations (Blok et al., 2015; Blok et al., 2018). Simply put: "Without transparency and interaction with stakeholders, actors cannot develop shared objectives and cannot share responsibility for the innovation..." (Blok and Lemmens, 2015, p.151). Transparency is thus a bottom-line requirement for the deliberative engagement of stakeholders, which is a core differentiator of RI practices from other efforts to responsibly govern innovation processes (Blok et al., 2018; Blok et al., 2015; Lubberink et al., 2017). However, the RI literature is notably vague in terms of the level of transparency required to create a mutually responsive innovation environment, and non-prescriptive as to exactly how this should be facilitated (Blok et al., 2015).

Competition can incentivize innovation (Brand & Blok, 2019). The literature on innovation establishes that information asymmetry— "a condition wherein one party in a relationship has more or better information than another" (Akerlof, 1970 as cited in Bergh et al., 2019, p.123)—is an important source of market opportunities (Shane & Venkataraman, 2000) and competitive advantage (Miller, 2003). Accordingly, information asymmetry presents a major source of competitive advantage for commercial organizations, establishing an point of differentiation that enables them to "create, identify and seize business opportunities" (Barbaroux, 2014, p.2). This commercial reality has significant implications for establishing an open innovation environment. Inter-organizational collaboration is often restricted, as this could lead to knowledge leakage, endangering the competitive advantage produced by information asymmetries commonly protected through corporate secrecy and the private ownership of IP (Flipse, 2013). Herein lies a tension: While RI theory argues that "The throughput of the innovation process should be characterized by transparency, interaction and mutual responsiveness" (Blok & Lemmens, 2015, p.23), commercial organizations rely on information asymmetries to produce and protect a competitive advantage (Flipse, 2013). By being transparent about their innovation process, commercial organizations may put their competitive advantage at risk (Blok et al., 2015). This tension is likely even more pronounced in the case of the fast-paced emerging technology market, where incremental technological advances can produce significant market impacts; it is likewise acutely pertinent in the case of dual-use technologies, such as AI or quantum computing, where technological advancement is deemed critical to a securing a geopolitical advantage.

Transparency and knowledge sharing between organizations such as universities, public and private research institutions, and industrial firms are central enablers of the structure and functioning of knowledge ecosystems (Clarysse et al., 2014; Valkokari, 2015; van der Borgh et al., 2012; Rådberg and Löfsten, 2022). Actors in knowledge ecosystems must actively collaborate with each other in the search for valuable solutions through sharing knowledge and leveraging complementarities across sectoral and disciplinary boundaries (Jarvi et al., 2018; Vodă et al., 2023). Knowledge ecosystems enable participants to retain a certain degree of autonomy while requiring a level of adaptation capacity (Vodă et al., 2023, p.53). As Järvi et al. (2018) write: "In general, any multi-partner collaboration for knowledge creation requires some level of joint goal setting and collective action toward that goal" (p.1524). As such, a knowledge ecosystem can be understood as a meta-organization that "facilitates knowledge production, transfer, and exploitation, in reaching established common goals" (Vodă et al., 2023, p.55).

While the management of IP rights and spinouts may be negotiated through contractual agreements up-front (Van der Borgh et al., 2012), trust plays a fundamental role in the coordination of inter-organizational relationships in knowledge ecosystems (Scaringella & Radziwon, 2018; Järvi et al., 2018). In an applied sense, transparency and knowledge sharing are evidenced through examples such as The Human Genome Project, a multidisciplinary research project "built on the principle of free, unrestricted and timely access to research findings for all interested parties" (Perkmann & Schildt, 2015, p.1133). In this case, commercial organizations with competing projects based on proprietary IP collaborated with academic researchers, public research organizations, international governments, and other stakeholders in a bid to progress public science.

The benefit of participating in knowledge ecosystems comes down to the opportunity to engage in a joint knowledge search to achieve scientific or technological goals that may be unattainable or prohibitively resource-intensive independently (van der Borgh et al., 2012; Vodă et al., 2023). Members of these ecosystems also benefit from collective resources, including access to programs, funding, and infrastructure (Agrawal & Cockburn, 2002). They also stand to benefit from "linkages among firms and with universities and public research organizations as well as intense labor mobility across different players facilitate collective learning and increase the speed of innovation diffusion" (Clarysse et al., 2014, p.1165). A study by Yu et al. (2022) demonstrates how collaboration in knowledge ecosystems can also enhance the resilience of small and medium-sized enterprises by providing a forum to develop new business ideas and respond quickly to crises. These benefits motivate the participation of commercial organizations in knowledge ecosystems; however, their membership hinges on adherence to the collective rules and conditions at the system-level (Smolka & Böschen, 2023; Stahl, 2022).

4. Orchestrating Responsible Innovation in Knowledge Ecosystems

4.1 Fostering a shared understanding of RI

Across case studies of RI application, commercial organizations report low levels of understanding of RI (Gurzawska et al., 2017; Lubberink et al., 2017; Stahl et al., 2017; Blok & Lemmens 2015; Lubberink et al., 2019). The first roadblock an organization will encounter on its journey to implement RI is "to figure out what RI means and how to characterize it" (Ko & Kim, 2020, p.2667). Contrastingly, understanding of RI among actors is stronger in a research policy context, possibly since the meaning and activities associated with RI were initially disseminated via research policy frameworks and related mediums such as funding requirements and workshops (Stilgoe et al., 2013). Understanding RI requires "a willingness among all participants to act and adapt according to these ideas" (Lubberink et al., 2017, p.5). For knowledge ecosystems to be made more responsible, the values, norms, and principles of RI must first be communicated at a conceptual level before it can be facilitated at a procedural level.

One of the primary roles of orchestrator in knowledge ecosystems is to provide information to ecosystem participants (Van der Borgh et al., 2012; Shi & Chen, 2022; Rådberg & Löfsten, 2023). Orchestrators ensure critical information is disseminated to ecosystem participants to increase knowledge of programs, facilities, and funding (Rådberg & Löfsten, 2023). This responsibility calls on orchestrators to develop a shared knowledge stock and ensure it is delivered to ecosystem participants through workshops, presentations, and digital platforms (Shi & Chen, 2024; Rådberg & Löfsten, 2023). As such, providing information on RI is well within the existing remit of orchestrators. RI orchestrators can ensure ecosystem participants have access to information on what RI is and how to approach it by developing a shared knowledge stock on the topic and delivering programs on RI best practices. In one example offered by Smolka and Böschen (2023), presentations based on socio-technical integration research (STIR) were delivered on an ecosystem-wide level with the goal of "[p]roviding evidence that the method can enhance efficiency, creativity, and scientific robustness" (p.14). The researchers contend that this effort persuaded ecosystem actors unfamiliar with the concept to engage with and participate in STIR. Similarly, RI orchestrators can provide information on RI framed in a relevant context for ecosystem participants.

Fostering the development of a shared vision for achieving an innovation goal is another important role for orchestrators that can be used to foster RI in knowledge ecosystems (Mbitse et al., 2024; Vodă et al., 2023; Järvi et al., 2018; Agarwal et al., 2021). Since knowledge ecosystems can be formed around a joint knowledge search to achieve a given societal or innovation goal, agreement on a shared vision of the innovation objective motivates organizations to collaborate and co-evolve in pursuit of that goal (Agarwal et al., 2021; Vodă et al., 2023l). As Öberg and Lundberg (2022) establish: "Firstly, parties in a knowledge ecosystem need to reach a certain and similar level of understanding before they are able to develop knowledge together" (p.302). Further, Järvi et al. (2018) provide motivation for this demand, arguing that "…the existence of a clear overarching goal and a sense of direction allows the ecosystem members to bond, enables collaboration and shapes the ecosystem-level focus" (p.1533). Orchestrators, given their positions to frame ecosystem information, can seek to accommodate RI in the shared vision of ecosystem participants as they collaborate to achieve a societal goal. This can help to elevate the meaning of RI from work undertaken by the individual organization for the uncertain benefit and at a near-certain cost to a higher level of meta-responsibility. From this perspective, "When understood as a meta-responsibility, the role of [RI] is to shape, maintain, develop, coordinate and align existing and novel [research- and innovation]-related processes, actors and responsibilities, with a view to ensuring desirable and acceptable research outcomes" (Stahl et al., 2017, p.1036). This conceptual turn can help to alleviate the burden on commercial organizations alone to interpret and engage in RI without the infrastructure or tools to do so.

Communication around what RI is and why it is important can help to create an approach whereby knowledge ecosystems "actively seek to align their processes and expected outcomes with societal needs and/or preferences, to ensure they are acceptable, desirable and sustainable" (Stahl, 2022, p.5). At a minimum, a commercial organization participating in a knowledge ecosystem where RI is communicated as an integral aspect of the mission would recognize that "their work has social and ethical consequences and that it has a part to play in addressing these" (Stahl, 2022, p.8). Developing a shared understanding of RI is not only a primary condition for enabling organizations to adopt it, but it can also center the need for inter-organizational work toward achieving a collective goal, thereby inducing greater levels of collective responsibility for innovation outcomes. While commercial organizations are ultimately responsible for their innovation outcomes, introducing the concept as a meta-responsibility acknowledges that a set of actors are responsible for some aspects of disseminating a broad understanding of RI and coordinating collective action toward achieving innovation goals.

Proposition I: RI orchestrators enhance commitment to RI by fostering a shared understanding of responsibility as fundamental to innovation objectives.

4.2 Facilitating RI activities and interactions

Key activities associated with RI include stakeholder and public engagement forums, inclusive multistakeholder workshops, and RI training programs (Owen & Goldberg, 2010). These activities and interactions are essential for fostering inclusivity, reflexivity, and responsiveness in innovation processes; they aim to enhance RI awareness and capabilities and induce a culture of co-responsibility in the innovation process (Lubberink et al., 2017). In this respect, knowledge ecosystems "accommodate complementarities in value creation" (Järvi et al., 2018, 1523) as participating organizations engage in joint knowledge search (Clarysse et al., 2014), meaning that organizations in a knowledge ecosystem must work collaboratively to achieve a greater impact than the sum of its parts. Therefore, creating and sustaining an environment where cross-organizational collaboration can occur is one of the key roles of orchestrators (Van der Borgh et al., 2012; Järvi et al., 2018; Clarysse et al., 2014). As such, orchestrators coordinate activities to stimulate cross-organizational interactions and encourage meaningful collaboration between ecosystem participants to transform individual organisations "from knowledge users to knowledge sharers and knowledge creators" (Vodă et al., 2023, p.53). This is important, as knowledge work needs to be facilitated across the various disciplines, sectors, and boundaries of diverse organizations in knowledge ecosystems (Järvi et al., 2018; Dougherty & Dunne, 2011).

Specific actions that RI orchestrators could undertake to facilitate its uptake in knowledge ecosystems include developing platforms for collaboration and knowledge sharing (Agarwal et al., 2021), organizing forums to engage stakeholders and creating space for ethical review and scenario planning (Stahl, 2022), and providing training and organizational capacity-building (Shi & Chen, 2022; Rådberg & Löfsten, 2023). These activities increase interactions between ecosystem participants, enabling them to build trust and foster cooperative and collaborative relationships (Scott et al., 2022). For example, multistakeholder workshops, an integral aspect of RI practice (Owen et al., 2010), function as "bridging events" that create connections between "actors from different streams of an innovation ecosystem [helping them] to understand each other's values and perspectives" (Smolka & Böschen, 2022, p. 11). Orchestrators coordinate multi-stakeholder workshops to create intentional spaces for engagement and collaboration amongst diverse ecosystem participants to help "develop knowledge-and competence-based trust, procedures and expectations" (Scott et al., 2022, p.176). Such interactions enable "norms of commitment, dialogue, and improved expectations (including about frequency of exchanges or meetings) to emerge as mechanisms to reinforce and encourage further collaborations" (Scott et al., 2022, p.176). Events such as conferences and working groups that bring diverse stakeholders together also foster collaboration between ecosystem actors and provide the ability to unlock access to (or share) resources and knowledge with others (Bouncken et al., 2020; Agarwal et al., 2021).

Shi and Chen (2022) highlight how makerspaces in China facilitate knowledge linkages between actors within "the complex system of multiple agents... including state or government, university, industry or business, and civil or public" (p.4-5). These orchestrators invite ecosystem participants to participate in knowledge-sharing activities where they can meet and collaborate with other organizations, industry leaders, and related enterprises. By regularly facilitating interactive activities, orchestrators work to actively reinforce relationships in knowledge ecosystems and promote organizations' co-evolution as the ecosystem develops and membership expands. Orchestrators not only provide critical infrastructure, such as meeting rooms, event spaces, and offices, but also invite participation from a broad range of actors to exchange complementarities as a resource for value co-creation (Rådberg & Löfsten, 2023; Shi & Chen, 2022). As such, orchestrators provide a point of connection into the knowledge ecosystem for domain experts, such as business and interdisciplinary advisors, to share information with ecosystem participants through training and capacity-building activities (Shi & Chen, 2022, p.12). The provision of RI expertise could be similarly offered by RI orchestrators in knowledge ecosystems to help participating organizations build capacity and reflexivity in their innovation projects.

By coordinating interactive activities, orchestrators foster an environment of trust-based collaboration between diverse participants in knowledge ecosystems. Many of the activities that orchestrators offer can be considered as dual-purpose for ecosystem development and facilitating RI: multistakeholder workshops, conferences and events, and training and capacity-building programs both create opportunities for inclusive cross-organizational interactions and knowledge sharing, as well as provide a platform for the dimensions of inclusion, reflexivity, and responsiveness of RI to be practiced. These activities offer an opportunity to integrate RI practices in knowledge ecosystem activities that can lead to higher levels of interaction between ecosystem participants, enabling them to communicate across knowledge boundaries and support the pursuit of value co-creation in knowledge ecosystems.

> **Proposition II: RI orchestrators strengthen the enactment of responsible innovation by organizing inclusive, deliberative activities that bring diverse ecosystem actors together to share and co-create knowledge.**

4.3 Incentivizing, mandating and monitoring RI

While fostering a broad understanding of RI amongst ecosystem actors and creating the conditions for collaboration are important, orchestrators also play a central role in providing incentives to engage commercial organizations in the pursuit of a collective goal and enforcing mandating mechanisms to monitor ecosystem participants' progress. This entails the strategic management of the innovation process with the aim to develop "the capacity of diverse actors to reflect on socio-ethical horizons in different streams of the ecosystem" (Smolka & Böschen, 2023, p.1). Providing financial and non-financial strategic incentives can be a powerful 'carrot' to encourage commercial organizations to join knowledge ecosystems targeting emerging technologies and societal initiatives (Gifford et al., 2021; Agarwal, 2021; Shi & Chen, 2022). Likewise, enforcing regular RI mandates to monitor progress over time, such as impact and risk analyses, could help commercial organizations to develop a capacity for responsible innovation practice and mitigate potential downstream legal issues and negative societal impacts (Voegtlin & Scherer, 2017; Dreyer et al., 2020; Stahl, 2022; Smolka & Böschen, 2023). By enforcing such requirements as a condition of ecosystem participation, RI orchestrators could "improve ecosystem resilience and stability…and allow ecosystems members to work together, structure interactions and promote specific outcomes… [in line with what] society deems to be desirable" (Stahl, 2022, p.7).

Agarwal et al. (2021) interrogate the efforts by public agencies in the U.S. to align various organizational actors around mission-oriented challenges including the development of the world's first computer network (ARPANET), radar technology, and the antibiotic penicillin. Participation was incentivized by providing access to networks and knowledge-sharing platforms in each case. The researchers show how public procurement policies, such as guaranteed purchase and advance contracts, helped to offset the costs of innovation activities associated with high-risk innovation stretch goals (Agarwal et al., 2021; Knudsen et al., 2021). These cases demonstrate how orchestrators can play an important role in the pre-commercialization phase of innovation to bring commercial organizations along in the pursuit of a common societal goal. Likewise, Shi and Chen (2022) show how governmental orchestrators in Chinese knowledge ecosystems often act as "[an initiator in] the essential resource of budgeting, the authority of resource configuration, the regulator of resource management, and resource preservation through public funding and support programs" (p.8). Government-driven initiatives such as "[o]nline services, problem-solving initiatives, multi-sector collaboration, political administrations, social networks, crowd sourcing, EG (e-government), and government–university-business coordinated efforts" motivate participation and collaboration in knowledge ecosystems (Shi & Chen, 2022, p.8).

Regular monitoring through compulsory impact analyses and risk assessments can help to establish and enforce norms for RI activities and promote reflexivity among organizations in knowledge ecosystems. In their 2009 pilot study with the U.K. Engineering and Physical Sciences Research Council (EPSRC), Owen and Goldberg (2010) explore how mandatory participation in RI activities in the form of both anticipation and reflexivity can be achieved through requirements attached to grant applications and funding. The study describes an effort to translate RI concepts such as adaptive and anticipatory technological governance into operational practice through ESPRC research funding for grand challenge-style projects, where specific RI criteria were included in proposal evaluation by the research council. Apart from the up-front need to address RI criteria in their proposals, applicants were encouraged to conduct risk and benefit analyses, technology assessments, and stakeholder engagement as part of the application process. As the researchers explain, "By asking for such considerations in the proposal, applicants were mandated to develop new forms of interdisciplinarity and think reflexively and imaginatively about the potential applications and impacts of their science, with further potential to inform ongoing policy discussions" (Owen & Goldberg, 2010, p.1705). Within the remit of an RI framework, the aim of these mandates was to create an opportunity to embed an adaptive learning process, stakeholder engagement, and anticipation of potential risks or harms into the earliest stages of the innovation process.

As Dreyer et al. (2020) comment, "[o]perating in [a] risky business environment requires continuous adjustments of the assumptions underpinning business plans. Effectively implementing innovation means carefully monitoring emerging risks and responding swiftly with appropriate action" (p.14). RI orchestrators could help to improve the resilience of knowledge ecosystems and mitigate the risks of unintentional harms or litigation by enforcing mechanisms such as regular impact and risk analyses to help organizations spot emerging issues as they arise. This could help to induce a culture of reflexivity, knowledge-sharing, and transparency amongst ecosystem participants. By mandating formal monitoring mechanisms such as these, RI orchestrators can track "the progress of joint research activities and improve the visibility of members' contributions" (Järvi et al., 2018, p.1532), providing a useful benchmark for the implementation of RI as organizations collaborate to advance societal or innovation goals in knowledge ecosystems.

Proposition III: RI orchestrators govern RI by incentivizing participation, mandating relevant practices and monitoring progress toward shared compatible goals.

5. Discussion

This paper directs scholarly attention to RI on the ecosystem level as a hitherto overlooked in-between of government intervention and commercial organizations. Stahl et al. (2017) argue that RI must be conceptualized at a higher level of 'meta-responsibility' in order to make it practical: "When understood as a meta-responsibility, the role of [RI] is to shape, maintain, develop, coordinate and align existing and novel R&I-related processes, actors and responsibilities, with a view to ensuring desirable and acceptable research outcomes" (Stahl et al., 2017, p.1036). Knowledge ecosystems, encapsulating a broad spectrum of actors that contribute to innovation—including, importantly, universities and research organizations, commercial organizations, regulators, policymakers, and other orchestrators—provide a practical avenue for theorizing the interrelationships between RI and knowledge creation for joint value (Gomes et al., 2021) and provides an important site for studying how RI might be transitioned from academic to industry environments. Designating RI orchestrators as coordinators of RI in knowledge ecosystems could enable the concept to permeate beyond corporate efforts to implement RI, which at current, are predominantly confined to the intrinsic or strategic motivations of CEOs outside of the limited regions in which RI policy mandates exist (Ko & Kim, 2020; Auer & Jarmai, 2018) and hampered by significant tensions on the organization-level.

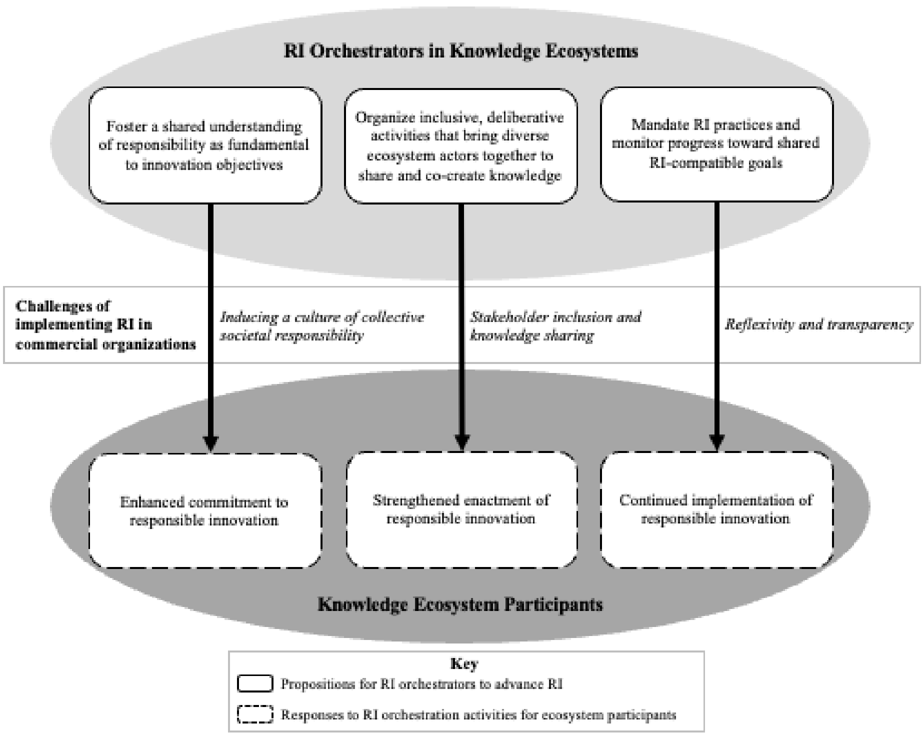
Prior research indicates that commercial organizations require system-level support to overcome identified barriers as they seek to implement RI (Auer & Jarmai, 2018; van de Poel et al., 2020). This limitation is important to consider, as these actors can be central contributors to societally beneficial innovation projects (Agarwal et al., 2021; Voegtlin et al., 2022). As such, this paper presents a critical perspective on how RI can be orchestrated on the ecosystem level, complementing the existing work undertaken by orchestrators in knowledge ecosystems. We argue that orchestrators are well positioned to coordinate RI as a collective understanding, practice, and outcome of innovative knowledge co-production. From this perspective, organizations in a knowledge ecosystem might have implemented RI to varying degrees, with non-profit and government organizations probably having done so more profoundly, while participating commercial organizations might have struggled to do so due to inherent tensions (Gurzawska et al., 2017; Blok et al., 2015). We theorize that through orchestration in knowledge ecosystems, RI could arise as a collective achievement imbued in ecosystem activities. We remain to speculate that RI at a collective level in a knowledge ecosystem holds potential for RI practices to percolate to the organization level, contributing to a transformation of corporate culture by equipping organizations with the skills, knowledge, and tools required to enact RI and to maintain it once they exit the pre-commercial stage.

Conceptually, orchestration enables a perspective on how RI can be elevated to a meta-level commitment to influence its uptake in commercial organizations participating in knowledge ecosystems. We utilize knowledge ecosystems as our site of inquiry, as we contend that the specific formulation of actors and values of these structures are highly compatible with and conducive to the aims of RI. However, RI will not happen without the designation of specific actors to orchestrate it. As such, we theorize a role for RI orchestrators in knowledge ecosystems to undertake the coordination of RI practices and activities that can serve as a modality for all ecosystem members, including commercial organizations, to become familiar with the concept and enacting its demands. That orchestration in knowledge ecosystems tends to be decentralized and dispersed offers a practical avenue for theorizing a role for orchestrators with a designated responsibility enacting our propositions. These actors could be RI managers with skills in innovation and project management, design thinking, research ethics, or impact assessment (Dreyer et al., 2020), in-house specialists in makerspaces or innovation hubs (Shi & Chen, 2022), or external social scientists (Stilgoe et al., 2013) who act as "engagement agents" to apply relevant research approaches to innovation environments (Smolka & Böschen, 2023, p.11). It falls on policymakers to create the conditions for RI orchestrators in knowledge ecosystems by designing appropriate incentives and designating resources for the establishment of such a role.

We summarize our argument in *Figure 1.*, following the structure of this paper. It outlines how significant tensions faced by commercial organizations in implementing and adhering to RI may be ameliorated by their participation in knowledge ecosystems that integrate RI dimensions into the rules and conditions of membership on a collective level. It illustrates how RI orchestrators in knowledge ecosystems can coordinate RI efforts for ecosystem participants by fostering a shared understanding, organizing inclusive deliberative activities, and providing incentives for and monitoring progress toward continuous alignment with RI expectations at the ecosystem level. Ecosystem participants, including commercial organizations, would be expected to respond to these efforts by enhancing their commitment to RI, strengthening their enactment of RI, and continuing to implement RI as members of knowledge ecosystem.

In what we might call 'collective responsible innovation', even commercial organizations that have not been able to implement RI internally due to persistent challenges can contribute and gain from participating a knowledge ecosystem with designated RI orchestrators that set RI as the standard by inducing a culture of collective responsibility, stakeholder inclusion and knowledge sharing, and reflexivity and transparency. As we have shown, these core dimensions of RI are likewise critical to the success of knowledge ecosystems. Our model contributes to research in the areas of RI and knowledge ecosystems, offering an approach to address the identified gap in the application of RI in organizations (Auer & Jarmai, 2017; Pfotenhauer et al., 2021; Gurzawska et al., 2017; Lubberink et al., 2019; Ko & Kim, 2020; Martinuzzi et al., 2018).

Figure 4: Model of orchestrating RI in knowledge ecosystems



Governments and funders interested in establishing knowledge ecosystems can create the conditions for RI in to be implemented by designating a specific role for RI orchestrators to facilitate these mechanisms through policy and the distribution of resources. RI orchestrators will reflect these conditions in their work as they coordinate RI activities that develop synergies between organizations, contributing to nurturing the development of knowledge ecosystems as a whole (Daymond et al., 2023; Shi & Chen, 2022; Mbitse et al., 2024; Reischauer et al., 2021; van der Borgh et al., 2012). We offer three propositions for RI orchestrators and suggest enabling activities that could serve to enhance member organization's commitment to RI by fostering a collective understanding of responsibility (P1), integrating the perspectives of a diversity of stakeholders by facilitating deliberative activities and knowledge sharing (P2), and ensuring the continued implementation of RI by mandating RI practices and monitoring progress toward RI-compatible goals (P3). Effective RI orchestration in knowledge ecosystems could ameliorate tensions that commercial organizations face when attempting to undertake RI in isolation: enacting collective responsibility, practicing reflexivity and including a diversity of stakeholders in the innovation process, and committing to transparency and knowledge sharing.

6. Avenues for Future Research

Building on our propositions and associated model, we outline three avenues for future research that could investigate the proposed perspective: (1) explore the role that orchestrators play for RI in knowledge ecosystems, (2) investigate the impacts of RI orchestration on the evolution of knowledge ecosystems, as well as the impact of implementation in knowledge ecosystems on RI, and (3) study the adherence (or not) to RI in organizations as the knowledge ecosystem transitions from a pre-commercial to a commercial setting. We briefly expand on each of these avenues for future research.

Orchestrators in knowledge ecosystems reflect policy in their activities aimed at fostering collaboration between the diversity of ecosystem participants working toward a shared goal (Daymond et al., 2023; Shi & Chen, 2022; Mbitse et al., 2024; Reischauer et al., 2021). We illustrated this through examples from the literature of TTOs (Reischauer et al., 2021) and makerspaces (Shi & Chen, 2022), which identified activities of orchestrators relative to RI. Qualitative research would potentially identify additional concepts as well as the dynamics of orchestrating RI in knowledge ecosystem collaborations. Such research would enable a better understanding of the place and influence RI activities have within the wider scope of activities and concerns in knowledge ecosystems. This analysis could also reveal important ecosystem-level tensions between other ecosystem orchestration activities and those directed at RI.

Future research could also address the question of how orchestrating RI might change as knowledge ecosystems evolve and mature, as well as how implementation in knowledge ecosystems might affect the conceptualization of RI. For example, RI multi-stakeholder dialogues and frameworks might lead to a more inclusive and democratic innovation processes. This would represent a shift from traditional, top-down governance models to more participation and transparency, where greater trust and cooperation among ecosystem participants is fostered. The increased engagement and collaboration among various stakeholders, including industry, academia, government, and civil society, that RI thrives on could enrich the innovation processes and enhance the societal relevance and acceptance of emerging technologies. Likewise, a shared understanding of RI and strategic management mechanisms might pivot the knowledge ecosystem towards a more sustainability-oriented and ethically conscious approach. Consequently, the knowledge ecosystem's overall innovation strategy would align more with long-term societal benefits rather than being solely driven by short-term economic gains, possibly producing a more balanced approach to innovation, where economic growth is pursued in harmony with societal well-being and environmental sustainability. As RI is a normative concept, the ways in which it is defined and enacted as a collective goal may produce adaptations relevant to the environments in which it is implemented (Macnaghten et al., 2014). Investigating these ideas further would require longitudinal qualitative studies that could empirically test these theories by studying the evolution of RI in knowledge ecosystems throughout their evolution (and dissolution).

Building on this avenue, future research could also explore RI in the transition of knowledge ecosystems into innovation ecosystem or business ecosystems (Clarysse et al., 2012). Would the ecosystem's in-built concern with RI be maintained, or would it be crowded out by the tensions we have identified once the output of the knowledge ecosystem transfers to a commercial environment? This strand of research would further knowledge ecosystem research, particularly the work of Clarysse et al. (2012). Relatedly, we propose that future research could investigate how participation in RI knowledge ecosystems may impact the governance of RI in for profit organizations (Scherer & Voegtlin, 2020). This research could study whether the tensions that we highlight at the organizational level are indeed transcended through the implementation of RI on the ecosystem level. Likewise, future longitudinal studies could focus on whether the provision of incentives and mandates by orchestrators does in fact lower organizational learning barriers sufficiently, so organizations are equipped adopt RI as part of their governance.

7. Conclusion

This paper offers propositions for RI orchestrators to develop robust and responsible knowledge ecosystems for emerging technologies. Interest in ecosystem development from governments, policymakers, and funding bodies is high, because coordinating collaboration amongst the diversity of innovation actors, including commercial organizations, is understood as critical to addressing grand societal challenges. Yet, commercial organizations have proven unwilling or ill-equipped to tackle the implementation of RI on their own due to inherent tensions between RI and corporate practices. We theorize that some of the major pain points highlighted in the literature on organizational application of RI, identified as enacting collective responsibility, practicing reflexivity and including a diversity of stakeholders in the innovation process, and committing to transparency and knowledge sharing, can be ameliorated through participation in knowledge ecosystems, where RI orchestrators coordinate RI activities in line with the conditions established and resources offered by policymakers to develop robust and responsible knowledge ecosystems.

6. Chapter Six: Discussion

Innovation is an open-ended process that can lead to any number of possible outcomes depending on the social circumstances that shape it (Pinch & Bijker, 1984; Jasanoff, 2004; Jasanoff, 2015). These social circumstances refer to the socio-political contexts that motivate certain objectives on range of scales – from geopolitical to national, to regional, the institutions that reflect and support the enactment of strategic objectives, and the actors that contribute to innovation. The governance of innovation is not separate from these circumstances. Rather, it is situated within and shaped by them, just as it shapes technological development itself (Jasanoff, 2004). RI, as an approach to innovation governance that focuses on "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013, p.1570), is no exception. RI does not stand outside the social circumstances of innovation but is co-produced alongside them. A social constructionist perspective makes this claim theoretically tractable, providing the theoretical and methodological foundation for this thesis. This thesis asks: how does the social construction of RI shape its orchestration in commercialization contexts? This question has both theoretical and practical stakes. It asks not only how the meaning of RI is constructed but also how that understanding can inform efforts to orchestrate it in commercialization contexts where it has struggled to take hold.

This thesis positions RI as socially constructed rather than an epistemic given by framing the concept as contested and context-dependent. It argues that the application of RI cannot be separated from the socio-political circumstances in which it is enacted. RI is rooted in STS traditions that view scientific knowledge as a social construct (van Oudheusden, 2014), and it shares this critical orientation toward the relationships between science, innovation, politics, and society (Owen & Pansera, 2019). Yet despite these constructionist roots, the RI literature has largely treated the concept as a framework or a set of principles and practices to be implemented, rather than as a concept whose meaning is itself subject to construction and contestation. As a result, a body of implementation research establishes the barriers to RI adoption in commercial contexts (Lubberink et al., 2017; Blok & Lemmens, 2015; Martinuzzi et al., 2018) without theorizing how those tensions might be the starting point for developing a more practicable formulation of RI.

This thesis argues that the persistence of these barriers is not simply an obstacle to RI's implementation – rather, the divergent values and normative commitments of diverse innovation actors are the very material through which RI's meaning is produced. As such, RI does not arrive in a commercialization context as a neutral framework. It lands in a contested discursive and institutional landscape already structured by competing notions of risk, responsibility, and meanings of the purpose of innovation. Without attending to how these constructions emerge, compete, and how they might be provisionally reconciled, efforts to implement RI at the organizational level will remain stymied. These ideas are not without foundation in the RI literature. Macnaghten et al. (2014) argue that RI is interpretively flexible, culturally framed, and politically entangled; Owen and Pansera (2019) insist that any consideration of RI systems cannot be divorced from their political and ideological imaginaries; and Pandza and Ellwood (2013) suggest that operationalizing RI requires attention to agents and their embeddedness in social interactions. Yet none have systematically interrogated RI itself as a social construction. This thesis undertakes a social constructionist analysis of RI in response to these hints, addressing a gap that it considers fundamental to furthering the ongoing project of RI.

To address this gap, this thesis applies a social constructionist lens to RI across three distinct but interconnected sites of inquiry: the discursive construction of technological meaning through hyped discourse, the institutional embedding of competing visions through socio-technical imaginaries, and the theorization of RI orchestration as a negotiated process within knowledge ecosystems. The empirical focus of Australia's developing quantum innovation field is examined longitudinally as quantum technologies transition from research to commercial environments. This case surfaces the contested processes through which diverse actors – including academic scientists, industry actors, venture capital organizations, government, civil society organizations, and media –construct, negotiate, and enact visions of responsible technological futures. Each of the three papers that comprise this thesis examines a distinct dimension of this process, building sequentially from discursive construction to institutional embedding to normative theorization, and contributing collectively to the overarching research question. The three sub-questions addressed across these papers are:

1. How does hyping, understood as a discursive process involving contestation through discursive struggle, influence the meaning of an emerging technology?
2. How and why does RI enter and shape socio-technical imaginaries of emerging technologies?
3. How does orchestration in knowledge ecosystems ameliorate tensions between enacting the requirements of RI and addressing the market-led priorities that drive innovation?

6.1 Contributions

6.1.1 A Social Constructionist Account of RI

This thesis set out to answer an overarching research question: how does the social construction of RI shape its orchestration in commercialization contexts? The three papers contribute to answering this question across three interconnected sites of inquiry and their findings, taken together, advance a theoretical argument that is greater than the sum of its parts. Namely, this thesis contributes an understanding of RI that is not a stable framework applied to innovation from the outside. Like the technologies it seeks to govern, its meaning is not fixed or given but continuously (re)produced through the interactions of the diverse actors who engage with it. It follows that to understand how RI operates in any given context, the social processes through which its meaning is constructed, contested, and potentially stabilized must be attended to. This reframes the central challenge of RI from an implementation problem to a meaning-making problem across competing normative worlds. This reframing has significant consequences for both theory and practice.

As previously noted, RI is rooted in STS traditions that view scientific knowledge as a social construct. Foundationally, it shares with those traditions a critical orientation toward the relationships between science, innovation, politics, and society (van Oudheusden, 2014). Yet despite this critical observation, the RI literature has not systematically applied a social constructionist analysis to RI itself. This thesis surfaces and develops that implicit foundation, undertaking the first systematic social constructionist analysis of RI in a commercialization context. It reframes RI as an innovation governance approach whose meaning is not pre-determined but produced through the interactions of the diverse actors who engage with it. This perspective foregrounds the role of competing stakeholder values and normative commitments in shaping what RI means, what it demands, and what it makes possible in any given context.

This thesis applies the conceptual apparatus of SCOT to RI itself. SCOT was originally developed to explain how the meaning and form of technological artifacts are shaped by relevant social groups, interpretive flexibility, and processes of stabilization and closure (Pinch & Bijker, 1984). Just as SCOT demonstrates that technologies are not objective, pre-determined objects but artifacts shaped by social, political, and cultural forces, this thesis demonstrates that RI is not a neutral governance framework but a contested concept whose meaning is shaped through the very same forces. This thesis reveals how relevant social groups, including academic scientists, industry actors, venture capital organizations, government, civil society, and media, hold divergent understandings of what RI is for, what it demands, and what counts as responsible development.

These understandings sit in interpretive tension with one another, and the process through which they are contested, negotiated, and provisionally stabilized determines what RI comes to mean in Australia's quantum innovation field. By tracing this process through this case study, this thesis extends SCOT's analytical vocabulary from the level of technological artifacts to the level of innovation governance itself. It develops and applies a theoretical framework that accounts for how the meaning of RI is constructed, contested, and negotiated through the divergent (and at times competing) values and norms of diverse actors contributing to commercialization.

6.1.2 Hyped Discourse: Surfacing the Construction of RI in Practice

The concept of hype provides an avenue for identifying the specific discursive mechanisms through which RI's meaning is enacted in practice. This thesis employs the concept of hype to surface how innovation actors mobilize visions of technological futures in ways that shape what counts as responsible. As such, it advances an understanding of how specific visions of technological futures are discursively enacted (Borup et al., 2006; Logue & Grimes, 2022). In this way, hype helps to illuminate how socio-technical imaginaries become mobilized in practice. In the context of this thesis, hype is used to surface the social construction of actor- and context-specific conceptualizations of risk and responsibility, which directs the developmental trajectory of innovation.

Paper One interrogates how relevant social groups within Australia's quantum ecosystem deploy hyped narratives to advance their specific understandings of the purpose of quantum innovation. Specifically, it shows how innovation actors mobilize concepts of risk and responsibility to construct quantum technologies as a solution to salient risks of geopolitical rivalry and economic loss. It also demonstrates how, to a lesser extent, actors engaged with the possibility of novel societal risks these technologies may produce or exacerbate. Importantly, it establishes how the former construction overwhelms the latter. This contestation produces significant consequences for the meanings and actions considered responsible by actors engaged in quantum innovation. More immediate, familiar risks overshadow broader societal and ethical considerations, demonstrating how alternative perspectives such as RI may be marginalized or overwhelmed as the discursive space enables more dominant constructions of responsibility to take hold. Paper One thereby reveals the normative commitments and socio-political expectations embedded in Australia's quantum innovation discourse, surfacing how these shape the conditions under which RI must be negotiated. These findings provide the empirical foundation for Paper Two's analysis of how these competing discursive constructions enter a state of co-production to form a collective socio-technical imaginary of responsible quantum innovation.

The sociology of expectations literature recognizes that hype mobilizes collective visions and promises of possible futures (Borup et al., 2006; Logue & Grimes, 2022) and the socio-technical imaginaries literature establishes that such visions are materially and discursively enacted through the practices of diverse actors (Jasanoff & Kim, 2009; Mager & Katzenbach, 2020). Yet the relationship between these two traditions has remained implicit rather than theorized. This thesis makes that connection explicit, demonstrating how hyped discourse functions as an analytical mechanism for identifying socio-technical imaginaries in practice and surfacing how collectively held visions of responsible innovation are constructed, contested, and mobilized in emerging technology contexts.

6.1.3 Socio-Technical Imaginaries: Co-Production RI's Institutional Embedding

Socio-technical imaginaries provide a vehicle for understanding how the broader visions and normative commitments that animate innovation at a collective level shape the construction of RI. Despite the explicit future orientation of RI, defined as "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al. 2013, p.1570), there has been surprisingly little engagement between the RI literature and the socio-technical imaginaries within which it operates. As Jasanoff (2015) argues, imaginaries offer a tool for interrogating the socio-political dynamics that contribute to the production of innovation processes, revealing which values are embedded in governance and which actors are empowered. The ways in which different imaginaries compete or coexist therefore influence the direction, governance, and legitimacy of emerging innovation fields (Jasanoff, 2015; Jasanoff & Kim, 2013). This thesis contributes to both the RI and socio-technical imaginaries literatures by theorizing RI as a co-productive force across competing stakeholder visions through Australia's National Quantum Strategy and related approaches to quantum innovation governance.

Co-production, defined as "the constant interplay of the cognitive, the material, the social and the normative" (Jasanoff, 2004, p.38), describes the process through which competing stakeholder visions can move from a state of contestation toward communal adoption and institutional embedding. Paper Two applies this concept to examine how a tension between the competing stakeholder visions of retaining public good value and generating commercial and strategic benefits gives rise to a collective socio-technical imaginary of responsible quantum innovation. It foregrounds the role of government in facilitating this process by introducing RI as a novel outlook through the National Quantum Strategy to mediate this tension. RI offers a language for reconciling seemingly opposed priorities, allowing government to avoid choosing between stakeholder camps while appearing to address both sets of concerns. In doing so, RI acts as a co-productive force, shaping the collective socio-technical imaginary as it becomes reshaped through strategic implementation.

This provides a novel account of how RI can function as both a shaping and shaped element of socio-technical imaginaries. At a broader level, this analysis also illuminates the ways in which institutional, social, and political commitments contribute to unique formulations of innovation policy across different contexts (Jasanoff et al., 2007). As such, Paper Two establishes how the normative dimensions of RI can be a barrier to its direct transferability across differing innovation contexts. These findings build on insights that the existing RI literature has gestured toward: Macnaghten et al. (2014) position RI as interpretively flexible, culturally framed, and politically entangled; Owen and Pansera (2019) argue that RI systems cannot be divorced from their political and ideological imaginaries; and Pandza and Ellwood (2013) call for attention to agents and their embeddedness in social interactions. This thesis extends these arguments by providing a systematic theoretical account of how the divergent values and normative commitments of diverse innovation actors are the very material through which RI's meaning becomes co-produced.

Read together, Papers One and Two establish a finding that neither produces alone. The meaning of RI is not fixed by its academic origins nor its normative frameworks. Rather, it is continuously constructed and reconstructed through the discursive and institutional dynamics of the innovation contexts it inhabits. It is contested through hyped discourse, negotiated through competing stakeholder visions, and provisionally stabilized through co-production and institutional embedding. These papers offer a jumping off point for further exploration of how individual identities shape and are shaped by participation in collectives (Hendriks et al., 2025), surfacing the dynamics of stakeholder coordination fundamental to developing co-responsibility for RI across diverse actor landscapes.

6.1.4 Knowledge Ecosystems and the Social Construction of Orchestration

This reframing of RI has direct normative implications for how it can be orchestrated. As this thesis has established, the challenge of orchestrating RI in a commercialization context is not primarily a logistical or technical one, but a challenge of collective meaning-making across competing normative worlds. This reframing challenges how much of the literature has theorized RI as a pre-defined framework to be implemented by repositioning RI as a process of constructing sufficient shared meaning across actors whose understandings of responsibility, innovation, and collective purpose are shaped by divergent institutional logics.

This thesis offers a novel perspective that knowledge ecosystems provide a particularly productive site for a social constructionist analysis of this challenge. The coexistence of academic and commercial actors within a shared but normatively pluralistic environment (Clarysse et al., 2014; Järvi et al., 2018; Reischauer et al., 2021) foregrounds the critical role of the processes of interpretive flexibility, contestation, and provisional stabilization that SCOT describes (Pinch & Bijker, 1984; Klein & Kleinman, 2002). Likewise, the orientation of knowledge ecosystems around grand challenge-style problems (Järvi et al., 2018; Valkokari, 2015; Garud et al., 2008) creates the necessary conditions for collective negotiation of meaning, without dissolving the actor divergence that makes that negotiation necessary (Blok & Lemmens, 2015; Sinnewe et al., 2016).

Applying a SCOT perspective to orchestration in knowledge ecosystems positions orchestration itself as an adaptable construct that can be used to facilitate system-level RI. This is a novel contribution to the literatures on knowledge ecosystems and orchestration. In the existing literature, orchestration tends to be understood as a functional coordinating role whose meaning, form, and legitimacy are largely taken as given. A social constructionist perspective challenges this assumption directly, enabling interrogation of what counts as legitimate orchestration, who holds the authority to orchestrate, what methods are appropriate, and toward what ends. Understood from this perspective, orchestration is constructed through the same processes of interpretive flexibility, contestation, and provisional stabilization that shape the meaning of RI itself. Treating orchestration as socially constructed therefore opens up space to ask questions about power, legitimacy, normative alignment, and the conditions under which shared commitment to RI can be collectively produced rather than hierarchically imposed.

Paper Three responds to calls for a systemic turn in RI (Smolka & Böschen, 2023; Jakobsen et al., 2019; Dreyer et al., 2020) by treating orchestration as an emergent, negotiated process. It theorizes how diverse actors can be brought into productive alignment around the collective pursuit of RI and how ecosystem orchestrators can work with the divergent values and normative commitments of knowledge ecosystem actors to construct the conditions under which RI becomes a shared and sustained commitment. It develops three propositions grounded in the RI and knowledge ecosystem literatures through a thought experiment that takes actor divergence as its starting point rather than as an obstacle to be overcome: fostering a shared understanding of RI, organizing inclusive deliberative activities, and incentivizing and monitoring progress toward continuous alignment with RI expectations at the ecosystem level. These propositions follow directly from the insights developed through these papers, that shared commitment to RI must be collectively produced rather than externally imposed. In theorizing how RI could be orchestrated in knowledge ecosystems, Paper Three extends the social constructionist framework developed across the thesis to show not only how the meaning of RI is collectively produced by actors engaging with it, but also to offer a practical avenue for how this understanding can be put to work in practice.

6.1.5 An Integrated Social Constructionist Framework for RI

Paper One examines hyped discourse in Australia's quantum ecosystem. Paper Two examines the socio-technical imaginaries that animate and contest responsible quantum innovation within it. Paper Three develops a novel conceptual framework for the orchestration of RI as an emergent, negotiated process within knowledge ecosystems. Read together, these three papers advance a systematic social constructionist analysis of RI in a commercialization context, responding directly to the calls made in the existing literature and opening new ground for both theory and practice. Together they demonstrate that RI's meaning is not fixed but negotiated – shaped by discourse, institutionalized through socio-technical imaginaries, and open to purposeful construction through orchestration. This is the core theoretical contribution this thesis offers to the ongoing project of RI.

7. Chapter Seven: Conclusions

The aim of this thesis was to understand how and why RI is adapted (or not) from a research policy to a commercialization context through the social shaping of the innovation process. This work was motivated by my interest in RI and my involvement in the emergent quantum innovation field in Australia, which provided a unique case study to explore how a supportive socio-political environment could establish RI as it seeks to develop a commercial quantum sector. My research philosophy and methodologies were selected to reflect these dynamics through the adoption of a social constructionist lens and a single, in-depth case study approach. I began by interrogating how hyping, as a discursive process involving contestation, influenced the meaning of emerging quantum technologies in Australia.

My findings suggested the presence of contested stakeholder visions, which led me to interrogate the ways in which RI was introduced as a novel perspective to reconcile tensions between these camps. I found that government introduced RI as a novel perspective to mediate a tension between public good and commercial benefits envisioned by stakeholder groups. As a co-productive force, RI shaped the quantum socio-technical imaginary and became reshaped RI itself as it was filtered through the imaginary and strategically applied. Following from these findings, I undertook a thought experiment to explore how the orchestration of RI in knowledge ecosystems might ameliorate tensions faced by commercial organizations between enacting the requirements of RI and addressing the market-led priorities that drive innovation.

The prologue of this thesis establishes my personal experience and motivation that led me to delve deep into the subject matter of my research – using the case of emerging quantum technologies to explore how RI is (or is not) applied to this emerging suite of technologies as they move from fundamental science research to industry commercialization in Australia. Chapter One contextualizes this pursuit by identifying a critical gap in RI practice of expanding the concept's application from its original European research policy context to govern responsible, industry-led innovation by drawing on research that interrogates the motivations and tensions commercial organizations encounter as they seek to implement RI practices. Here, I introduce the social shaping of innovation processes as a hitherto overlooked aspect that requires specific attention to better understand how RI can find practical relevance across diverse innovation landscapes, particularly when innovation actors with divergent values are to be integrated into the collective pursuit of RI. I introduce the SCOT perspective as a useful modality for surfacing contested visions of technological futures held by different innovation actors to reveal the mechanics supporting specific technological outcomes.

Chapter One also offers a brief overview of the research context of Australia's quantum innovation landscape and lays the groundwork for this thesis by outlining the relevant bodies of literature it draws on: RI, socio-technical imaginaries, and knowledge ecosystems. The theory section aims to give the reader a workable overview of the main theories this thesis engages with and links them together to produce an argument for their relevance to this research project, relationship to each other, and utility in interrogating the overarching aim and specific research questions that motivate chapters Three to Five. Subsequently, I present a summary of these papers at the end of this section.

Chapter Two presents the research philosophy and methodological approaches undertaken to address my research questions. It outlines the ontological and epistemological position that frames the theoretical perspective of this thesis, and justified the use of a longitudinal, single case study approach. It then outlines the data collection and analysis approaches used in each paper and presents a rationale for the 'thought experiment' (Weick, 1989) approach of Chapter Five. Finally, it discusses specific challenges and limitations to the chosen methodological approaches.

Taken as a whole, this thesis contributes to RI theory by bringing into conversation with the social construction of emerging technologies and innovation processes. In doing so, it bridges a critical gap in extant knowledge on the implementation of RI in commercial innovation contexts, which problematizes the compatibility of the concept's normative, Euro-centric, research policy origins with the divergent demands and values of market-led innovation in different national contexts. By interrogating the perspectives and practices of diverse innovation actors driving quantum technology innovation from research labs to commercial organizations in Australia, I shine a light on the contested process of the social construction of emerging technologies and innovation itself. This thesis considers an array of innovation actors that contribute to developing, communicating, and enacting visions of a responsible technological future, including academic scientists, industry actors, venture capital organizations, government, civil society organizations, and media. While RI demands the inclusion of diverse innovation actors, it does not dictate how the divergent values, ethics, and normative commitments of these actors can be brought into a collaborative and deliberative dynamic to enable co-responsibility for innovation outcomes. This thesis offers an inroad to revealing how this process occurs at an early stage of technology commercialization, contributing a practical account that helps to bridge this gap in RI scholarship.

My findings likewise contribute to the literature on RI implementation, especially in relation to inducing the participation of commercial organizations. I analyze how RI becomes accessible and takes on a new meaning as it is reshaped through innovation policy and theorize how it might be orchestrated in knowledge ecosystems. I respond to a call for a system-level approach to RI by suggesting how knowledge ecosystems can be a practical venue for the introduction of RI practices targeting the inclusion of commercial organizations alongside other innovation actors as they collaborate to achieve a collective technological or societal goal. My findings suggest that government and policymakers have a strategic motivation and capacity to play an active role in establishing the conditions to embed RI into innovation processes as emerging technologies are transitioned from research to industry.

This thesis began with the observation that the meaning of RI is not given in advance but shaped by the social circumstances of the innovation contexts in which it operates. By tracing this process across Australia's quantum innovation field through hyped discourse, socio-technical imaginaries, and the theorization of knowledge ecosystem orchestration, it has demonstrated that the challenge of RI is fundamentally a challenge of meaning-making across competing normative worlds. Addressing that challenge requires not better implementation of a pre-defined framework, but a deeper understanding of how RI's meaning is constructed, contested, and negotiated amongst the diverse actors who engage with it. This thesis presents an understanding of RI as a process that is continuously negotiated, contributing both a theoretical foundation and a practical pathway for the ongoing project of responsible innovation.

7.1 Limitations and Future Research

A number of opportunities exist for future research to extend the findings of this thesis. I highlight the research limitations that have shaped my own line of analysis and discuss several potential avenues for further inquiry in this section.

First, this thesis is built on a single case study approach of Australia's quantum innovation sector. As I outlined in my methods chapter, this analytical approach offers both challenges and opportunities for research. Briefly, the methodological limitations of a single case study approach pertain to its generalizability across different contexts, cultures, and domains (Yin, 2003; Stake, 2000; Flyvbjerg, 2006). However, as the aim of this thesis was to understand a phenomenon in a specific context to develop a rich description of a revelatory or exemplar case (Eisenhardt & Graebner, 2007), this approach is well suited to that purpose. This methodological approach is particularly useful for generating theory, as an in-depth case can produce a novel perspective that offers explanatory power by revealing the dynamics between various constructs at play (Tsoukas, 2009). The single case study approach of this thesis contributes to a small body of literature that interrogates how RI is or can be applied in innovation contexts outside of continental Europe

(Macnaghten et al., 2014; Santos & Nabavi, 2025; Pansera & Owen, 2023; Srinivas, 2022). While Australia may be somewhat culturally and politically aligned with European normative values, it is nonetheless distinct in the socio-political context that contributes to its innovation approach. As such, it provides important insights into the specific dynamics that shape understandings and approaches to RI in a practical context.

There is an opportunity to build on these insights through a cross-national, comparative case study approach. This could reveal patterns, divergences, and relationships across cases (Eisenhardt and Graebner, 2007) from which researchers could develop insights into how different concepts of nation-hood frame and influence the motivations, meanings, and application of RI. For this reason, a cross-national analytical approach is common in research on socio-technical imaginaries (Jasanoff & Kim, 2008; Kuchler & Stigson, 2024) and could be used to reveal differences and commonalities across diverse socio-political contexts. Additionally, comparative studies could explore how multipolar dynamics influence the construction and prioritization of technologies across different regions, shedding light on the extent to which global cooperation or protectionism shapes technology trajectories.

While this research endeavored to include a diversity of innovation perspectives, it is limited in its scope to include perceptions of societal actors (McCrea et al., 2024; Stilgoe et al., 2014). Despite this limitation, I recognize that the public is an important stakeholder in shaping innovation. Public trust, especially in the context of disruptive innovation, has been identified as an original motivator for the development of RI theory (Owen et al., 2021; Schuijff & Dijkstra, 2020; Coenen & Grunwald, 2017). While media texts and interviews with civil society organizations informed this research, subsequent studies could extend my findings by integrating public perspectives into the dataset. Analyzing how public stakeholders envision the future(s) that can, should, or should not be brought to life through the development of emerging technologies can reveal important avenues for other innovation stakeholder to consider as they undertake innovation activities. These might offer fruitful avenues for industry to explore and for government to incentivize as it fosters industry development.

Finally, the introduction of RI into the quantum innovation environment is in the early stages. Australia's National Quantum Strategy that officially embeds this dimension was only released in 2023, and related activities and funding stemming from this policy are only just being applied. As this sector develops and quantum technologies become more commercially useful, it remains to be seen what effect this institutional embedding with have. Will the decentralized approach to RI have a structuring and enduring impact on commercial organizations, or will RI be de-prioritised once the industry is further developed? Further, the dynamics of contestation reveal the power dynamics between stakeholder groups (Jasanoff, 2015). While I have shown how academic actors continue to be relevant in the commercialization of quantum technologies at this stage, it remains to be seen if the prominence of their role will continue as the technology itself develops and scientific expertise becomes less important in the establishment of commercial organizations. To address these questions, future studies could extend longitudinal analysis, not only of the case this thesis considers, but in the contexts of other emerging technologies with similar stakeholder dynamics. Future studies could provide a longer horizon or comparative perspective on the dynamics of social construction inherent in the process of innovation to capture the full spectrum of the process as technologies move from fundamental research to industry application and adoption on a broad scale.

There are many opportunities to add nuance and depth to the research in this thesis on how the social construction of innovation processes interacts with RI as it is transitioned from a research policy to a commercialization context. Among these, this thesis issues a call to action to empirically study the orchestration of RI in the context of knowledge ecosystems. While I have offered a thought experiment to conceptually and theoretically apply and explore this avenue, the field of RI as an experiment in and of itself would benefit from the opportunity to test this theory through practical application. This will require the work of government, research, and innovation stakeholders to enact this approach. The propositions developed in Paper Three offer guidance as to how this can be done.

7.2 Concluding Remarks

Since human beings first created technologies to shape our world and the ways in which we engage with it, this topic holds relevance and importance for understanding the agency of society in constructing technologically driven future(s). This is an important topic, as technologies and society will only become further entwined through innovation. The question of who shapes that process and in whose interests is therefore not merely academic but one of the most pressing governance challenges of our time Understanding how and why stakeholders contribute differently to this process is critical for directing innovation trajectories that produce less harm and increase benefits for a broader range of society. This thesis therefore presents a timely and important perspective on RI and the commercialization of quantum technologies, contextualizing this pursuit in the fundamental processes of social construction and anchoring the agency to enact more responsible technological futures in society's hands.

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