Mikko Punnala

Internationalising in the Space Economy

Ecosystems, Institutions, and the Strategic Behaviour of Small and Medium-Sized Enterprises in the New Space Economy

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Tiivistelmä

Tässä väitöskirjassa tarkastellaan pienten ja keskisuurten yritysten (pk-yritysten) kansainvälistymistä uuden avaruustalouden (New Space Economy, NSE) kontekstissa. NSE:tä luonnehtivat korkea teknologinen intensiteetti, monimutkaiset sääntelyrakenteet ja nopeasti muuttuvat institutionaaliset puitteet. Vaikka pk-yritysten merkitys avaruussektorilla kasvaa, perinteiset kansainvälistymisteoriat eivät riittävästi selitä niiden etenemistä erityisesti epäsymmetrisesti säädellyllä ja geopoliittisesti herkällä toimialalla.

Väitöskirjan tavoitteena on kehittää integroitu teoreettinen viitekehys, joka selittää, kuinka pk-yritykset kansainvälistyvät institutionaalisesti ja teknologisesti kompleksisissa olosuhteissa. Lähestymistapa yhdistää neljä näkökulmaa: verkostopohjaisen kansainvälistymismallin (NMI), resurssiperusteisen näkemyksen (RBV), dynaamisten kyvykkyyksien teorian (DCT) ja ekosysteemiteorian (ET). Näiden pohjalta rakennettu malli kokoaa yhteen yritystason kyvykkyydet, institutionaalisen kytkeytymisen ja verkostoitumisen dynamiikat.

Empiirinen osuus koostuu kolmesta vertaisarvioidusta artikkelista ja yhdestä käsikirjoituksesta, joka on esitetty akateemisissa seminaareissa. Tutkimuksissa hyödynnetään systemaattista kirjallisuuskatsausta, tapaustutkimuksia ja ekosysteemianalyysiä. Artikkeleissa tarkastellaan, miten institutionaaliset rakenteet, kyvykkyyksien kehittäminen ja ekosysteemien hyödyntäminen vaikuttavat pk-yritysten kansainvälistymiseen. Tulokset osoittavat, että onnistunut kansainvälistyminen perustuu dynaamiseen vuorovaikutukseen sisäisten strategisten valmiuksien, sääntely-yhteensopivuuden ja verkostoihin integroitumisen välillä. Työssä esitellään myös käsite institutionaalinen ketteryys (institutional agility), joka kuvaa pk-yritysten sopeutumiskykyä monimutkaisissa kansainvälisissä sääntely-ympäristöissä.

Väitöskirjan kontribuutio on kolmiosainen: teoreettisesti se laajentaa verkostopohjaista kansainvälistymismallia huomioimalla institutionaaliset ja kyvykkyysperustaiset tekijät; empiirisesti se syventää ymmärrystä pk-yritysten toimintastrategioista NSE-kontekstissa; ja käytännöllisesti se tuottaa politiikkasuosituksia, jotka tukevat pk-yritysten integroitumista kansainvälisiin avaruusmarkkinoihin esimerkiksi innovaatiotuella sekä julkisen ja yksityisen sektorin kumppanuusmalleilla.

Asiasanat: pienet ja keskisuuret yritykset (pk-yritykset), uusi avaruustalous (NSE), Kansainvälistyminen, verkostopohjainen kansainvälistymismalli (NMI), julkisen ja yksityisen sektorin kumppanuudet (PPP), avaruusteollisuus

Abstract

This dissertation examines the internationalisation of small and medium-sized enterprises (SMEs) within the emerging New Space Economy (NSE), an environment characterised by high technological intensity, complex regulatory regimes and rapidly evolving institutional frameworks. Although SMEs are playing an increasingly significant role in space-related markets, existing international business theories offer only limited explanatory power for their expansion, particularly under the asymmetric and politicised conditions characteristic of the space sector.

The primary aim of the dissertation is to develop an integrative theoretical framework that explains how SMEs internationalise in the technologically and institutionally complex context of the NSE. The framework synthesises four complementary perspectives: the network model of internationalisation (NMI), the resource-based view (RBV), dynamic capabilities theory (DCT) and ecosystem theory (ET). Together, these provide a multilevel lens that captures firm-level capabilities, institutional embeddedness and network-based relational dynamics.

Empirically, the dissertation consists of three peer-reviewed articles and one manuscript presented in academic seminars. The studies employ a systematic literature review, single-case and multiple-case analyses and ecosystem analysis. They examine how institutional conditions, capability development and ecosystem engagement shape SME internationalisation. The findings show that successful internationalisation depends on the dynamic interplay between internal strategic agility, regulatory alignment and integration into ecosystems. The study also introduces the concept of institutional agility to describe SMEs' adaptive responses to complex international regulatory environments.

The contribution of this dissertation is threefold. Theoretically, it extends the NMI by incorporating institutional and capability-based dynamics specific to the NSE. Empirically, it deepens understanding of SME strategies across varied institutional and technological settings. Practically, it provides policy recommendations on innovation support and public–private partnership models to facilitate SME participation in global space markets.

Keywords: small and medium-sized enterprises (SMEs), New Space Economy (NSE), internationalisation, network model of internationalisation (NMI), public–private partnerships (PPP), space industry

'*Life is full of great miracles for those who are ready to receive them.*'

— Moominpappa, Moominpappa at Sea

> May this work stand as a lasting tribute to my father, whose presence continues to guide me, and whose love remains immeasurable.

The space economy is not merely a technological or economic phenomenon—it is also a testament to humanity's desire to see possibility where others see emptiness.

This dissertation is written with the hope that the invisible can become visible if only we look closely enough.

DEDICATION

In loving memory of my father

This dissertation is dedicated to my father, who learned of his aggressive and advanced cancer at midsummer and passed away only a month later, without the chance to see its completion. Throughout my life, I may not have always found the words to express my closeness, gratitude, and deep admiration for him, yet these feelings have been constant. His pride in this work was profound—perhaps even greater than my own—and he longed to witness its final fulfilment.

This achievement belongs as much to him as to me. Though no longer present in this world, I carry the conviction that he now sees this milestone from heaven, released from suffering and at peace. I feel his presence in my thoughts, and his example continues to guide me. Just as the space economy reflects humanity's quest to find opportunities in the vastness of the unknown, so too do I imagine my father dwelling in the expanse of heaven—ever near, though unseen—where light prevails and physical distances no longer divide us.

ACKNOWLEDGEMENT

I am profoundly grateful to Professor Arto Ojala for his unwavering guidance and intellectual precision throughout this research. His incisive feedback, particularly on the theoretical framework, consistently elevated the quality of this dissertation.

My sincere thanks to Professor Heidi Kuusniemi, whose scientific expertise in space research and generous commitment of time and insight under significant professional demands have left a lasting impact on this work.

I warmly thank my coauthors Jari Ratilainen, Eldrige de Melo, and Santeri Punnala. Their collaboration has been essential to this dissertation. Eldrige's contributions to Article IV—particularly his insights into ecosystemic approaches and the internationalisation of local firms—were pivotal. I also thank Eldrige and Jaakko Yliaho for their vision and commitment during the emergence of Sharpnav, which developed in parallel with this research and is intimately linked with its theoretical and empirical dimensions.

A special acknowledgement is due to my son and coauthor, Santeri Punnala. His analytical rigour, consistent support, and outstanding competence in managing complex datasets strengthened the empirical foundation of this research. His dedication to excellence has been a continual source of motivation and a model of scholarly discipline. Santeri, along with Sonja and Susanna, has walked this path with me. Your support, patience, and assistance with language refinement have added both clarity and sophistication to the final manuscript. More importantly, your belief in this project—and in me—has been invaluable. Your curiosity, critical insights, and evolving perspectives have taught me more than any text or theory ever could. I am honoured and deeply grateful to be your father.

I extend my appreciation to Professor Peter Gabrielsson, whose expansive expertise in international business helped refine the global dimensions of this dissertation.

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To my wife, Tanja—your steadfast presence has been the bedrock of this work. In moments of doubt and fatigue, your calm encouragement, inner strength, and unshakable belief in this journey sustained its momentum. You bore the invisible weight of this dissertation with patience and grace, often more than I did. You created the space I needed to think, to write, and to return to the task when it faltered. This dissertation would quite literally not exist without you. You listened, questioned, encouraged, withdrew, and stepped in—always without expectation of recognition. There is no part of this work untouched by your presence. It is as much yours as it is mine. Thank you.

May the commitment, perseverance, and collective vision that shaped this dissertation continue to inspire and illuminate the possibilities ahead in the evolving New Space Economy.

Jyväskylä, Finland, 20th August 2025

Mikko Punnala

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Abbreviations

DCT	Dynamic Capabilities Theory
EAR	Export Administration Regulations (U.S.)
EO	Earth Observation (satellite-based Earth imaging/monitoring)
ESA	European Space Agency
ESABIC	European Space Agency Business Incubation Centre
ET	Ecosystem Theory
EU	European Union
GNSS	Global Navigation Satellite System
ITAR	International Traffic in Arms Regulations (U.S. export control)
ITU	International Telecommunication Union
NASA	National Aeronautics and Space Administration
NMI	Network Model of Internationalisation
NSE	New Space Economy
OECD	Organisation for Economic Co-operation and Development
PNT	Positioning, Navigation, and Timing (satellite navigation services)
PPP	Public–Private Partnership
RBV	Resource-Based View
R&D	Research and Development
SME	Small and Medium-Sized Enterprise
UN	United Nations
UNOOSA	United Nations Office for Outer Space Affairs
VC	Venture Capital

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1 INTRODUCTION

The global space economy has undergone a profound transformation, shifting from a state-led, exploration-focused domain into a dynamic, commercially driven sector increasingly shaped by private enterprise (Peeters, 2021; Weinzierl, 2018). Central to this shift is the emergence of the New Space Economy (NSE), characterised by technological disruption, accelerated commercialisation, and transnational collaboration (Denis et al., 2020; OECD, 2022). Although legacy actors, such as public agencies and large aerospace firms, continue to dominate core infrastructure and policy frameworks, small and medium-sized enterprises (SMEs) are playing an increasingly prominent role within this evolving ecosystem. These firms contribute significantly to technological innovation, market agility, and competitive intensity, particularly within niche domains such as Earth Observation (EO), small satellite manufacturing, and space-based data analytics (Saeed et al., 2020; Sweeting, 2018; Weinzierl, 2018).

Notwithstanding their rising visibility, SMEs encounter substantial challenges in pursuing internationalisation within the NSE. The sector is characterised by high entry thresholds, fragmented regulatory regimes, and heavy capital requirements, all of which are compounded by dependencies on institutional networks and policy alignment (Jakhu et al., 2020) . Conventional internationalisation theories, such as the Uppsala model (Johanson & Vahlne, 1977), offer limited explanatory value in this context, as they are predicated on gradual, incremental learning and staged market entry. In contrast to this stepwise logic, many space-sector SMEs follow a path more closely aligned with the 'born global' perspective (Bell et al., 2003; Rennie, 1993) and with the international new venture logic (INV) (Oviatt & McDougall, 1994). In this dissertation, the term 'born global' follows early accounts focused on SMEs (Bell et al., 2003; Rennie, 1993). Oviatt and McDougall analyse the closely related construct of INV (Oviatt & McDougall, 1994). While both emphasise rapid internationalisation, they are treated here as analytically distinct but overlapping perspectives. This distinction underscores the need for theoretical frameworks that can accommodate rapid, network-enabled internationalisation.

This dissertation addresses this theoretical and empirical gap by examining how SMEs internationalise within the institutional, technological, and regulatory architecture of the NSE. The study integrates multiple theoretical perspectives and empirical cases to investigate the structural, strategic, and policy-oriented dimensions of internationalisation. Drawing on three peer-reviewed articles and one manuscript presented in academic seminars, this research explores how innovation ecosystems, public–private partnerships (PPPs), business model innovation, and

network positioning enable SME engagement in global space markets (de Melo et al., 2025; Rausser et al., 2023; Salenius et al., 2023). In doing so, the study contributes to international business theory and advances the broader discourse on space-sector development, competitiveness, and entrepreneurship (Teece et al., 1997; Thomas & Autio, 2020)

1.1 Background and Relevance of the Research

The global space sector is undergoing a fundamental transformation, defined by the rise of the NSE. In this study, the New Space Economy (NSE) is defined as the emerging space-sector ecosystem characterised by increasing private sector involvement, innovation-driven ventures, and evolving institutional frameworks (OECD, 2022). This transition has opened new avenues for SMEs to participate in domains historically dominated by public agencies and large aerospace corporations. Enabled by digitalisation, miniaturisation, and increasing commercial viability, the NSE offers opportunities for SMEs to engage in technological innovation, contribute to regional economic development, and establish cross-border partnerships (Salenius et al., 2023).

Despite these opportunities, the operational environment for SMEs remains institutionally and structurally complex. Regulatory fragmentation, dual-use technology controls, export restrictions, and geopolitical tensions present formidable obstacles for often from inception seeking to expand beyond national markets (Jakhu et al., 2020; OECD, 2022). These are compounded by limited access to strategic resources, credibility-enhancing networks, and public funding mechanisms, which further restrict SMEs' ability to compete on a par with larger, often state-aligned actors (Denis et al., 2020; Peeters, 2021).

This dissertation investigates how SMEs operating in the NSE construct internationalisation strategies under such institutional constraints. Rather than focusing exclusively on regulation, the study explores how regulatory structures intersect with strategic networks, institutional alliances, and regional innovation ecosystems. The analysis applies the network model of internationalisation (NMI) (Johanson & Mattsson, 1988) as its core theoretical lens, and is further enriched by insights from the resource-based view (RBV) (Barney, 1991), dynamic capabilities theory (DCT) (Teece et al., 1997), and ecosystem theory (ET) (Moore, 1993), thereby offering a multitheoretical perspective on SME behaviour in complex environments.

Empirical evidence is drawn from case studies situated within Nordic innovation platforms, including the Kvarken Space Center and the European Space Agency's Business Incubation Centres (ESABIC). These cases illustrate how SMEs leverage

institutional scaffolding and ecosystem participation to overcome fragmentation, secure legitimacy, and construct global linkages (Salenius et al., 2023).

Ultimately, this contributes to a broader understanding of SME internationalisation in strategically sensitive and innovation-intensive sectors. It demonstrates that success in the NSE requires more than regulatory compliance; it demands strategic positioning within a multilayered institutional and ecosystemic architecture that shapes access to markets, capital, and credibility (OECD, 2022; United Nations Office for Outer Space Affairs, 2024).

1.2 Theoretical and Practical Significance of the New Space Economy

The NSE represents a fundamental restructuring of the global space sector, signifying a shift from state-led, exploration-oriented activity to a commercially viable, innovation-driven industry (Punnala et al., 2024). Enabled by rapid technological advancement, the growing presence of private actors, and the integration of space-based services into diverse economic domains, the NSE challenges established models of international business, governance, and regulation (Denis et al., 2020; Peeters, 2021).

From a theoretical perspective, the NSE exposes the limitations of traditional internationalisation frameworks. While the NMI (Johanson & Mattsson, 1988), RBV (Barney, 1991), DCT (Teece et al., 1997), and ET (Moore, 1993) each provide partial insights into firm behaviour, they remain insufficient in isolation to capture the sector's defining characteristics—namely, regulatory asymmetry, technological interdependence, and institutional embeddedness. A more integrated theoretical approach is required, one that acknowledges the sector's hybrid structure where commercial, strategic, and geopolitical logics intersect.

Practically, the NSE offers a pathway for SMEs to engage in high-technology, capital-intensive industries that were historically inaccessible. Strategic mechanisms, such as PPPs, regional innovation ecosystems, and incubation schemes, are essential to lowering market entry barriers and facilitating access to infrastructure, funding, and political legitimacy (Peeters, 2021; Salenius et al., 2023). This is particularly salient in smaller economies, such as those in the Nordic region, where firms rely on geographically embedded clusters—such as the Kvarken Space Center—for international market engagement.

The expansion of commercial space activity also has wider implications for international trade and global value chain participation. SMEs, once peripheral to the

space sector, are increasingly integrated through mechanisms such as the ESABICs and national programmes that support their entry into strategic domains including EO; Positioning, Navigation, and Timing (PNT); and satellite communications (Denis et al., 2020; Punnala et al., 2024). Nevertheless, the persistence of fragmented regulation, coupled with dual-use and security constraints, continues to pose structural challenges to SME scalability (Jakhu et al., 2020; OECD, 2022).

This research is also timely in light of global policy agendas focused on the sustainable and inclusive governance of outer space. Issues such as orbital debris mitigation, responsible satellite deployment, and the environmental sustainability of launch systems are now central to future access to and the use of space (Palmroth et al., 2021; United Nations Office for Outer Space Affairs, 2024). Although SMEs are typically agile and innovation-oriented, their capacity to contribute meaningfully to these objectives is contingent on supportive institutional frameworks and well-coordinated regulatory environments.

By integrating these theoretical and practical considerations, this dissertation positions the NSE as a multilayered institutional field in which innovation, regulation, and strategic interest converge. It offers conceptual advancements in internationalisation theory while delivering actionable insights for both industry stakeholders and policymakers aiming to build globally integrated, secure, and inclusive space economies. Although rooted in the Nordic context, the analytical framework and the empirical findings have relevance for other emerging space nations and innovation-driven sectors more broadly.

1.3 Research Objective and Questions

The central objective of this dissertation is to develop an integrative theoretical framework that explains how SMEs internationalise within the institutional, technological, and regulatory complexity of the NSE. By applying and extending the NMI, the research seeks to uncover how SMEs construct global linkages through embeddedness in ecosystems, alliances, and institutional infrastructures.

This objective is addressed through the following research questions:

1. **What structural and institutional conditions shape the internationalisation opportunities and constraints for SMEs operating in the NSE?**

This question explores how macro-level forces—such as regulatory regimes, geopolitical pressures, and sectoral transformation—affect SME access to global markets and influence network formation.

In this dissertation, SME internationalisation refers to the processes by which SMEs expand beyond their domestic markets. This includes entering and operating in foreign markets, forming cross-border networks, and developing strategies to access international customers, partners, and institutional frameworks (Johanson & Vahlne, 1977; Knight & Cavusgil, 2004).

2. **How do SMEs develop and mobilise strategic capabilities through networks, partnerships, and innovation ecosystems to internationalise?** This question investigates the mechanisms through which firms engage with external actors to gain legitimacy, mobilise resources, and establish international presence.

3. **How can existing internationalisation theories be adapted to account for the regulatory asymmetries, institutional embeddedness, and accelerated growth dynamics specific to the space sector?**

This question addresses the need to refine and extend existing theoretical models—particularly the NMI—by incorporating empirical insights from firms navigating the NSE.

Together, these questions guide a multilevel investigation of SME behaviour in the NSE, linking empirical evidence to theoretical development and generating policy-relevant insights for both the academic and practitioner communities.

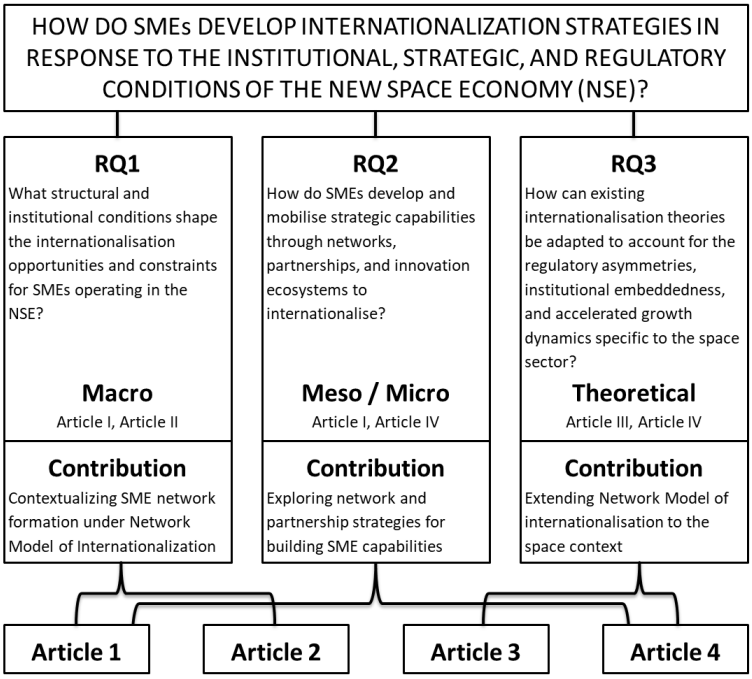

Figure 1. Research questions and related essays for SME internationalisation in the NSE.

1.4 Research Contributions and Expected Impact

This dissertation makes original contributions to the fields of international business and space-sector policy by examining how SMEs navigate internationalisation in a domain defined by institutional complexity, regulatory fragmentation, and dual-use technological constraints. Drawing on network-based, resource-based, and ecosystem-oriented theoretical approaches, the study refines existing models to better capture the specificities of emerging, high-technology environments such as the NSE.

Theoretically, the research extends the NMI (Johanson & Mattsson, 1988) by integrating insights from the RBV (Barney, 1991), DCT (Teece, 2007), and ET (Moore, 1993). This synthesis supports a multidimensional understanding of SME strategies as embedded within institutionally governed, multiactor environments. The dissertation contributes to theory-building by demonstrating how SMEs generate legitimacy and scalability not only through proprietary capabilities but also through ecosystem positioning and participation in formalised institutional structures.

The empirical contribution lies in the application of a multimethod research design to the Nordic space sector. Through the examination of platforms such as the Kvarken Space Center and the ESABICs, the study illustrates how SMEs mobilise regional

innovation ecosystems to overcome key internationalisation barriers, including regulatory ambiguity, financial risk, and strategic uncertainty. The Nordic context serves as a compelling testbed for theoretical refinement and offers a transferable model for other emerging space economies seeking to cultivate SME-led innovation and integration.

In terms of practical relevance, the research provides value for several stakeholder groups. For SMEs, it identifies effective strategies for scaling internationally in regulated and capital-intensive environments, highlighting the importance of network embeddedness, capability development, and institutional legitimacy. For ecosystem developers and industry actors, it underscores the enabling role of regional clusters and public–private consortia in supporting SME growth—particularly in globally connected but structurally complex niches, such as EO, satellite communications, and PNT services. For policymakers, the dissertation offers actionable recommendations for enhancing regulatory coherence, aligning national frameworks with international standards, and designing institutional mechanisms that support responsible commercial activity. These include measures related to orbital debris mitigation, sustainability governance, and dual-use technology management (OECD, 2022; United Nations Office for Outer Space Affairs, 2024).

The anticipated impact of the research is multidimensional. At the academic level, the study advances internationalisation theory by adapting classical models to new institutional and technological contexts, emphasising the need for frameworks that capture ecosystem interdependence and regulatory heterogeneity. Strategically, it informs how SMEs can pursue high-value international market positions while managing constraints related to compliance, security, and capital intensity. At the global level, the research contributes to ongoing discussions on equitable access to space, sustainable orbital operations, and the alignment of commercial objectives with societal and environmental responsibility (Rementeria, 2022; Salenius et al., 2023).

The orientation of the dissertation is illustrated in Figure 2, which situates the study at the intersection of three interrelated domains: the NMI, institutional engagement, and ecosystem participation. The shaded core represents the integrative focus of the work—combining relational theory with capability and ecosystem perspectives to explain SME entry and growth trajectories within the NSE. Each surrounding domain reflects a structural layer—strategic alliances and institutional networks, regulatory and geopolitical environments, and technology-driven ecosystems—that shapes the patterns and outcomes of internationalisation in this complex sector.

By connecting theoretical abstraction with policy analysis and firm-level strategy, this dissertation establishes a foundation for future research on SME participation in

space-sector innovation systems. It offers insights that are scalable across institutional settings and applicable in both established and emerging space economies, reinforcing the importance of inclusive, collaborative, and sustainable approaches to global space development.

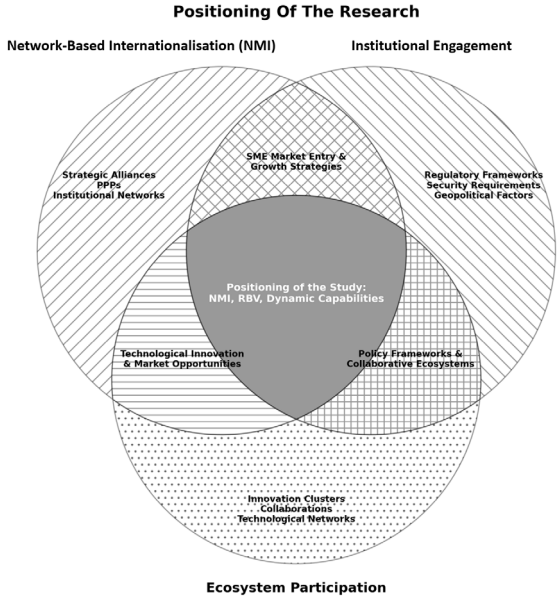

Figure 2. Positioning of the research at the intersection of three domains: NMI, institutional engagement, and ecosystem participation.

1.5 Structure of the Dissertation

This dissertation is structured to lead the reader through a coherent and cumulative analysis of how SMEs internationalise within the institutional and technological contours of the NSE. The composition of the work integrates theoretical development, empirical evidence, and policy-oriented reflection in a progressive manner that supports both conceptual rigour and practical insight.

Chapter 1 introduces the thematic and theoretical contexts of the study. It outlines the transformation of the global space sector, articulates the relevance of SME participation in this emerging field, and presents the central research objective alongside three guiding research questions. These questions frame the inquiry into the institutional, strategic, and theoretical dimensions of SME internationalisation in the NSE.

Chapter 2 offers a critical review of existing literature on internationalisation theory, network strategies, innovation ecosystems, and the specific regulatory and

geopolitical conditions that shape commercial activity in the space sector. Particular attention is paid to the limitations of traditional international business models when applied to high-velocity, policy-bound environments, such as the NSE. This review identifies both the conceptual gaps and empirical needs that inform the analytical direction of the dissertation.

Chapter 3 presents the integrated theoretical framework developed to analyse SME internationalisation in this context. Anchored in the NMI and complemented by insights from the RBV, DCT, and ET, the framework supports a multidimensional understanding of firm behaviour, one that reflects both resource dependencies and institutional embeddedness. The chapter clarifies how these perspectives are synthesised and operationalised across the study.

Chapter 4 outlines the methodological approach of the dissertation. It details the rationale for combining a systematic literature review with qualitative case study analysis and describes the empirical materials, interview strategies, and validation procedures employed across the four articles. This chapter also addresses the researcher's positionality and methodological choices in relation to the sensitive and evolving nature of the space economy.

Chapter 5 presents three peer-reviewed articles and one manuscript presented in academic seminars (Articles I–IV), each in a separate subsection. Each article examines a distinct dimension of SME internationalisation, ranging from regional ecosystem integration and firm-level strategic positioning to institutional collaboration and theoretical refinement. Together, these studies form a cohesive analytical arc that links macro-level institutional conditions with firm-level action and theoretical advancement.

Chapter 6 synthesises the findings of the four articles and relates them to the theoretical frameworks of the study. It highlights how SME internationalisation in the New Space Economy is conditioned by institutional embeddedness, ecosystem participation, resource mobilisation, and regulatory alignment, and reflects on the implications for theory, practice, and policy.

Chapter 7 synthesises the cumulative findings of the articles and assesses their implications for theory, practice, and policy. It reflects critically on the limitations of the research and identifies avenues for future investigation, particularly in relation to governance architectures, comparative institutional environments, and digital infrastructure supporting SME internationalisation in the space sector.

Chapter 8 summarises the contributions of the doctoral candidate and co-authors to the included articles. It clarifies the division of responsibilities and demonstrates the candidate's primary role in the conception, execution, and reporting of the research.

The structure of the dissertation thus progresses from conceptual framing and theoretical synthesis to empirical investigation and strategic reflection. This layered design enables the development of a contextually grounded and theoretically robust understanding of how SMEs operate within the complex, institutionally mediated environment of the NSE. The dissertation's architectural logic is summarised in Figure 3, which illustrates the alignment between the research questions, analytical levels, and article contributions.

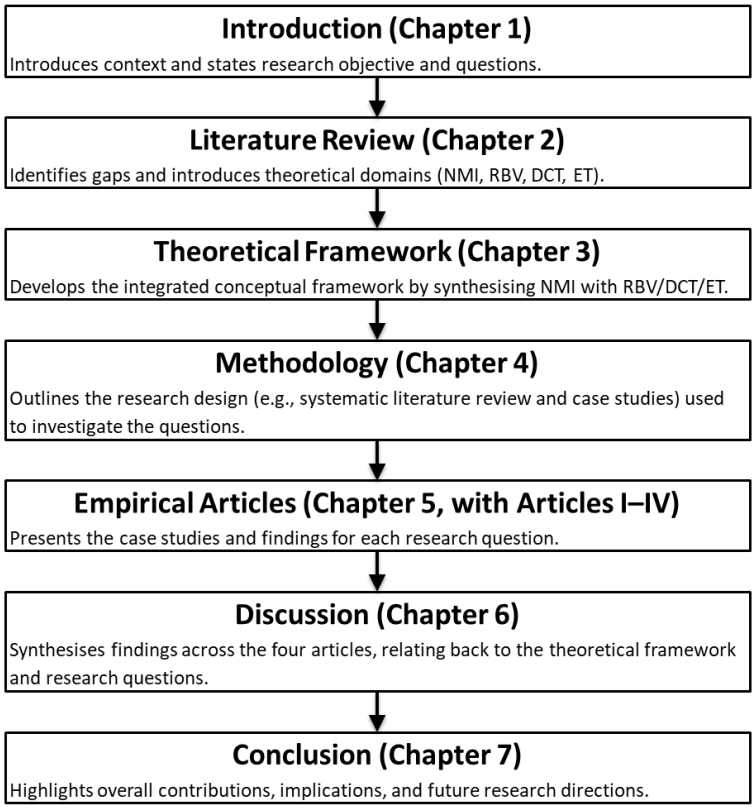

Figure 3. Structure of the dissertation and progression of the research.

2 LITERATURE REVIEW

This chapter offers a focused review of the relevant literature on SME internationalisation and the NSE. It first outlines the core NMI and then discusses complementary theoretical perspectives—including the RBV, DCT, and ET—that will inform the study's framework (Barney, 1991; Johanson & Mattsson, 1988; Moore, 1993; Teece et al., 1997). The chapter also examines prior research on SMEs in the space sector—such as PPPs, innovation clusters, and regulatory challenges—to highlight key concepts and gaps in existing work (Peeters, 2021; Punnala et al., 2024; Salenius et al., 2023). This concise review establishes the context and rationale for the dissertation's research approach without presenting any of the dissertation's own findings.

2.1 The Network Model of Internationalisation (NMI) as the Core Framework

The NMI, introduced by Johanson and Mattsson(1988), provides the central theoretical foundation for this dissertation. In contrast to stage-based approaches that conceptualise internationalisation as a gradual and experiential learning process, the NMI views international expansion as a relational and embedded process whereby firms mobilise strategic ties within evolving networks. This network-based perspective is particularly suited to the context of the NSE, where high capital intensity, regulatory asymmetry, and institutional complexity render incremental entry strategies impractical or even untenable (Johanson & Vahlne, 2009).

In the NSE, SMEs face considerable constraints: technological barriers, dual-use controls, fragmented governance, and dependency on procurement access all complicate their capacity to engage in global markets (OECD, 2022). Rather than relying solely on firm-internal resources, these firms internationalise by embedding themselves in institutional, public–private, and ecosystemic networks that provide legitimacy, access, and structural positioning (Peeters, 2021; Punnala et al., 2024). The NMI thus offers a powerful lens through which to understand how SMEs construct these linkages, often from the periphery of established space-sector networks.

Recent refinements to the NMI underscore the importance of distinguishing between insidership and outsidership in relevant business and institutional networks (Johanson & Vahlne, 2009). This distinction is especially salient in the space sector, where relational asymmetries and strategic gatekeeping define who participates in which constellations of actors. In such contexts, SMEs must navigate uneven power relations, access hierarchies, and informal legitimacy thresholds to enter value-

generating networks. Strategic insidership—whether through national procurement consortia, ESA programmes, or bilateral PPP arrangements—becomes a prerequisite for resource access and risk mitigation.

Trust also emerges as a decisive mechanism in these networked environments. In sectors characterised by high technical uncertainty, long time horizons, and dual-use sensitivities, formal contracts are often insufficient. Instead, SMEs must develop relational capital and long-term alignment with anchor institutions—ranging from space agencies to prime contractors—to secure and sustain their international roles. This reliance on trust and institutional credibility further reinforces the NMI's explanatory power, especially when supplemented by additional theoretical lenses.

While the NMI effectively captures the structural embeddedness of firms, it requires augmentation to fully account for the endogenous capabilities SMEs must develop in high-velocity environments, such as the NSE. Here, the RBV (Barney, 1991) contributes by explaining how unique, inimitable, and strategically valuable firm-level resources—such as proprietary algorithms, EO platforms, or miniaturised payload technologies—enable competitive differentiation within networks. However, in the NSE, many such resources are developed or refined within ecosystems, making ecosystem-embedded RBV logic more appropriate than purely firm-internal views.

The DCT (Teece et al., 1997) further enhances the model by addressing the temporal and adaptive aspects of internationalisation. SMEs in the NSE must not only build static assets but must also dynamically reconfigure capabilities in response to shifting regulatory environments, emerging technologies, and geopolitical fluctuations. Concepts such as 'institutional agility' become relevant here, referring to the capacity of firms to coevolve with external structures rather than simply adapting reactively. This is especially critical in navigating dual-use regimes or adjusting to the institutional layering of the global space governance landscape. In this dissertation, institutional agility is defined as the anticipatory capacity of SMEs to align with, adapt to, and strategically reposition themselves within evolving regulatory and institutional frameworks, thereby transforming compliance into a source of competitive advantage.

In sum, the NMI—when extended through the RBV and DCT—provides a multidimensional framework for analysing SME internationalisation in the NSE. It foregrounds the interdependence between strategic agency and structural constraint, between internal capability and external embeddedness, and between formal institutional rules and informal network logic. As the following chapters demonstrate, this integrated perspective allows for a more accurate and nuanced

understanding of how SMEs participate in, and shape, complex transnational innovation ecosystems within the global space economy.

2.1.1 Conceptual Foundations of NMI

At the heart of Johanson and Mattsson's (1988) framework lies a typology of firms based on their degree of embeddedness in domestic and international networks. This categorisation highlights how relational positioning conditions both the pace and pattern of internationalisation. Firms with limited connections in either domain—referred to as early starters—typically expand incrementally by forming initial partnerships to gain access to new markets. In contrast, late starters possess strong domestic networks but limited international linkages and, thus, depend on domestic intermediaries to facilitate their international entry. A third category, labelled lonely internationals, describes firms with global reach but weak domestic ties; these firms tend to rely on foreign partners to sustain their operations abroad. The most integrated group, international among others, consists of firms that are embedded across both domestic and international networks and are therefore best positioned for accelerated global integration.

For SMEs in the NSE, this embeddedness is not merely advantageous but essential. Given their limited internal resources and constrained access to capital, these firms rely heavily on external relational infrastructures to mobilise capabilities and navigate institutional complexity (Punnala et al., 2024; Salenius et al., 2023). Network participation enables access not only to financial and technical resources but also to critical market intelligence, standard-setting platforms, and legitimacy-enhancing affiliations.

Such embeddedness is particularly vital in the space sector, where operational risks are high, development timelines are extended, and regulatory frameworks are dense and multilayered. SMEs that are strategically positioned within ecosystems—via PPPs, incubator programmes, or transnational consortia—are able to benefit from co-innovation opportunities, infrastructure sharing, and policy alignment. These networked positions serve as accelerators of internationalisation, allowing SMEs to offset structural disadvantages and build adaptive capacity within the broader space economy (Peeters, 2021).

2.1.2 NMI in High-Technology Sectors: Key Implications for the Space Economy

High-technology industries, such as the space sector, are characterised by high uncertainty, capital intensity, and dense institutional regulation. Within this environment, the NMI proves especially relevant as it explains how firms overcome market entry barriers, reduce structural inertia, and construct legitimacy through participation in evolving networks. Unlike firms in more traditional industries, SMEs operating in the NSE seldom follow linear, incremental internationalisation paths. Instead, they are often required to embed themselves directly into preexisting and frequently exclusive constellations of collaboration, procurement, and technological development (Johanson & Vahlne, 2009).

These dynamics are particularly visible in the functioning of collaborative platforms and regional innovation ecosystems. The Kvarken Space Center serves as a case in point, enabling SMEs to interface with academic institutions, space agencies, and industrial actors. Through such platforms, firms gain access to R&D infrastructure, cross-border funding mechanisms, and institutional expertise—resources that are indispensable for navigating the dual demands of regulatory compliance and continuous innovation (Punnala et al., 2024).

Participation in these ecosystems also allows SMEs to mitigate financial risk through shared investment structures, reduce regulatory exposure by aligning with institutional standards, and accelerate time-to-market through pooled knowledge and technical synergies (Thomas & Autio, 2020). Moreover, network visibility and reputational legitimacy gained through such embeddedness are frequently prerequisites for securing external investment and entering global partnerships. In this respect, embeddedness in strategic networks does not merely enhance internationalisation—it constitutes its precondition. For SMEs in the NSE, network positioning is fundamental to both business model viability and long-term strategic scalability.

2.1.3 The Role of Networks, Institutions, and Strategic Alliances in SME Internationalisation

The explanatory strength of the NMI is significantly enhanced when situated within institutional and ecosystem-based perspectives. In the context of the NSE, access to international markets, regulatory frameworks, and innovation infrastructures is mediated by a range of institutional actors, including the European Space Agency (ESA), the United Nations Office for Outer Space Affairs (UNOOSA), and the International Telecommunication Union (ITU) (OECD, 2022). As a result, SMEs are

required to navigate not only commercial networks but also a multilayered governance environment in which institutional legitimacy is often a precondition for international engagement.

Within this setting, strategic alliances serve as critical bridging mechanisms. These alliances—ranging from technology partnerships and joint ventures to value-chain integration—enable SMEs to access specialised capabilities, scale operations, and engage with global markets while navigating regulatory complexity (Peeters, 2021). Particularly in sectors marked by export controls, licensing regimes, or security-screened procurement, alliances often function as intermediaries, facilitating indirect access to otherwise restricted institutions and contracting channels (Denis et al., 2020).

PPP arrangements further institutionalise these dynamics. By participating in PPPs, SMEs are granted preferential access to public funding, technical infrastructure, and procurement pipelines, while simultaneously enhancing their credibility within international networks (Denis et al., 2020; Peeters, 2021). These are not merely transactional arrangements; they are embedded, long-term collaborations that structure firm trajectories and influence the evolution of regional and transnational innovation ecosystems. In this dissertation, PPPs are defined as structured, long-term collaborations between governmental or intergovernmental organisations and private firms. In the NSE, PPPs serve not only as funding mechanisms but as institutional platforms through which SMEs gain access to infrastructure, procurement opportunities, and international legitimacy (Denis et al., 2020; Rausser et al., 2023).

Together, network positioning, institutional alignment, and strategic collaboration form the triadic foundation of SME internationalisation in the NSE. The NMI, when enriched through these dimensions, captures not only the relational mechanisms through which firms internationalise but also the structural and institutional preconditions that enable such trajectories. In this regard, the framework offers a robust analytical tool for assessing how SMEs construct and sustain international market access in a sector defined by asymmetrical entry conditions, institutional gatekeeping, and high barriers to legitimacy.

2.2 The New Space Economy: Economic and Market Developments

The NSE represents a structural shift in the organisation and logic of the global space sector. No longer driven solely by state-led exploration or national defence imperatives, the sector increasingly reflects market-based dynamics where private

enterprises—particularly SMEs and start-ups—serve as principal agents of innovation, commercial expansion, and internationalisation (Denis et al., 2020; OECD, 2022; Peeters, 2021; Weinzierl, 2018).

This transformation has been facilitated by rapid advances in core technologies, including satellite miniaturisation, reusable launch systems, and integrated data architectures. These developments have significantly lowered entry barriers, enabling SMEs to engage in a broad array of activities spanning EO, satellite communications, PNT, and in-orbit servicing (Eugeni et al., 2022; Sweeting, 2018). Therefore, new business models such as satellite-as-a-service (SaaS), orbital logistics, and space-based broadband have emerged, allowing SMEs to penetrate markets previously accessible only to large, state-supported incumbents (Peeters, 2021; Salenius et al., 2023).

However, this technological democratisation has not been matched by institutional adaptation. Regulatory structures remain grounded in legacy governance models shaped by national security priorities. Export controls, dual-use technology restrictions, and fragmented licensing systems continue to impose disproportionate compliance burdens on SMEs, constraining cross-border scalability and undermining commercial agility (Jakhu et al., 2020). The resulting asymmetry between regulatory oversight and entrepreneurial responsiveness is one of the central structural barriers to the international expansion of SME-led space ventures (OECD, 2022).

To overcome these constraints, SMEs increasingly embed themselves in collaborative innovation ecosystems and regionally anchored support structures. Platforms such as the Kvarken Space Center and the ESABICs act as intermediaries that connect firms to regulatory expertise, research infrastructure, and targeted funding mechanisms (Punnala et al., 2024). These ecosystems not only lower entry thresholds but also facilitate institutional alignment, enhance trust-building, and enable collective capability development—prerequisites for sustainable positioning in global space markets (Harri et al., 2020; Peeters, 2021). Beyond the Nordic context, international clusters in Toulouse, Bangalore, and Silicon Valley further consolidate competitive advantage by concentrating financial capital, supplier networks, and world-class research institutions (Denis et al., 2020).

Financing constitutes a critical structural variable. While specialised venture capital (VC) and private equity are gaining relevance in commercial space, early-stage and high-risk innovation remains heavily dependent on public funding schemes, including ESA programmes, Horizon Europe, and national procurement systems. At the same time, alternative mechanisms, such as revenue-sharing models and equity crowdfunding, offer more flexible avenues for firms with long development cycles and intangible assets to secure growth capital (OECD, 2022; Pomeroy et al., 2019).

In summary, the NSE has transformed the operating conditions for SMEs by opening new pathways to international markets and technological innovation. However, persistent regulatory rigidity and uneven financial access continue to delimit this potential. For SMEs to participate fully in the global space economy, strategic integration into institutional networks, sustained ecosystem engagement, and access to diversified capital structures remain indispensable.

2.3 Comparative Theoretical Perspectives on Internationalisation in the NSE Context

While the NMI remains the central analytical lens of this dissertation, the complexity of the NSE requires a more integrative theoretical approach. The sector is defined by its high capital intensity, technological sophistication, and layered regulatory environments—conditions that routinely challenge the explanatory reach of any singular model (OECD, 2022; Peeters, 2021; Punnala et al., 2024; Salenius et al., 2023). This section critically engages with complementary frameworks—namely the Uppsala model, the RBV, DCT, and ET—to examine how each contributes additional conceptual clarity to understanding SME internationalisation in the NSE.

The Uppsala model (Johanson & Vahlne, 1977) conceptualises internationalisation as a gradual, incremental process driven by experiential learning and risk management. While foundational to the field of international business, its relevance diminishes in contexts such as the NSE, where firms often face compressed timelines, capital urgency, and regulatory entanglements that necessitate immediate market entry. In such environments, SMEs frequently internationalise through simultaneous engagements across jurisdictions, PPPs, or strategic alliances, bypassing the phased commitments that underpin the Uppsala logic (Oviatt & McDougall, 1994). In this dissertation, I use 'born global' to denote SMEs that internationalise rapidly from inception or within a few years of founding, as per early and SME-focused accounts (Bell et al., 2003; Rennie, 1993). Where I cite Oviatt and McDougall (1994), I refer specifically to their concept of international new ventures (INVs)—a closely related but analytically distinct construct that emphasises early, coordinated international activity by new firms (Oviatt & McDougall, 1994). Thus, while useful in historically stable contexts, the model is misaligned with the structural volatility and institutional density of the NSE.

The RBV (Barney, 1991) shifts focus to the internal resources and capabilities that confer a sustainable competitive advantage. For SMEs in the NSE, this includes proprietary technology, intellectual property, and domain-specific human capital. These intangible assets often serve as enablers of differentiation and resilience.

However, the RBV's emphasis on firm-internal assets neglects the external conditions that govern access to international markets—particularly in sectors where public procurement, regulatory compliance, and legitimacy are coproduced through interorganisational relations. While the RBV offers explanatory power regarding why certain firms outperform others, it does not sufficiently capture how firms navigate institutional architectures and collective infrastructures (Lavie, 2006; Wernerfelt, 1984).

The DCT (Teece et al., 1997) addresses this shortcoming by highlighting the importance of adaptability and resource reconfiguration in dynamic environments. Within the NSE, SMEs must continuously adjust to changing geopolitical contexts, emerging regulatory constraints, and fast-moving technological frontiers. Dynamic capabilities—such as the ability to pivot between civil and dual-use applications or restructure value propositions—are thus indispensable for maintaining strategic flexibility and international relevance (Teece et al., 1997). Empirical cases, including firms such as Iceye and GomSpace, illustrate how adaptive capabilities underpin market responsiveness and cross-border scalability.

ET (Moore, 1993) adds a further layer by conceptualising firms as interdependent actors within coevolving innovation systems. In the NSE, SMEs rarely internationalise in isolation; rather, they participate in dense webs of collaboration involving research institutions, government bodies, and incumbent industry actors. Ecosystem engagement facilitates not only access to technical and financial resources but also the attainment of regulatory credibility and sectoral legitimacy—preconditions for scaling in highly governed markets. The role of PPPs, particularly those coordinated through ESA incubators and national space agencies, underscores how institutional affiliation and relational embeddedness jointly mediate international growth (Jacobides et al., 2018; Thomas & Autio, 2020).

Taken together, these complementary perspectives extend the analytical reach of the NMI by addressing internal capability-building (RBV), adaptive strategy (DCT), and structural codependence (ET). This multidimensional lens enables a more nuanced understanding of how SMEs navigate the complex institutional, technological, and relational landscape of the NSE.

2.4 Integrating Structural Insights into NMI: Contributions from the Systematic Review of the Space Economy

Recent literature underscores the need to refine the NMI by incorporating the structural and institutional dynamics specific to the space economy. While the NMI

traditionally emphasises firm-level network embeddedness (Johanson & Mattsson, 1988), emerging research suggests that network formation and strategic positioning in the NSE are also shaped by macro-level forces—such as regulatory architectures, geopolitical alignments, and sectoral technological evolution (OECD, 2022; United Nations Office for Outer Space Affairs, 2024). Rather than progressing through linear, country-by-country expansion, SMEs often enter global markets by embedding within preexisting ecosystems of space agencies, PPPs, and transnational regulatory bodies (European Space Agency, 2023; Jakhu et al., 2020). These findings imply that relational embeddedness must be considered in tandem with institutional embeddedness in legal, technological, and geopolitical systems—dimensions that are more commonly theorised through institutional and ecosystem perspectives.

Technological paradigms, such as small satellite platforms, reusable launch capabilities, and orbital data infrastructures, further mediate how SMEs participate in and construct international networks. These sector-specific regimes influence both the opportunities and constraints that define network entry, evolution, and resource flows (Ali et al., 2020; Eugeni et al., 2022). Consequently, the NMI must be extended to incorporate these enabling or limiting sectoral features as structural preconditions of internationalisation, particularly in fields marked by rapid technological convergence and layered institutional regulation.

The findings of the review therefore support a more multidimensional reading of the NMI, in which firm-level network positioning is not merely a relational achievement but a systemic outcome shaped by external dependencies. This includes access to funding architectures, standard-setting processes, and geopolitical gateways that condition the very possibility of international expansion. The evidence confirms that relational embeddedness and institutional positioning operate as parallel logics of SME internationalisation in the NSE.

This expanded interpretation maintains the conceptual integrity of the NMI while recognising the need for contextual adaptation. It reinforces the dissertation's argument that SME internationalisation in the space sector must be understood not only as a network-driven process but also as a structurally mediated trajectory embedded in interdependent technological, regulatory, and political ecosystems.

3 THEORETICAL FRAMEWORK

This chapter builds on the integrative theoretical synthesis presented in Chapter 2. While the NMI serves as the central analytical framework of this dissertation, the empirical realities of the NSE necessitate a broader conceptual lens. To capture the complexity of SME internationalisation in this context, the NMI is extended through complementary perspectives, including the RBV, DCT, and ET. Together, these frameworks form a unified theoretical architecture that guides the dissertation's empirical analysis.

The NMI conceptualises internationalisation as a relational and embedded process, emphasising the centrality of interorganisational networks, institutional ties, and strategic positioning (Johanson & Mattsson, 1988). This logic is particularly relevant in the NSE, where SMEs gain market access and legitimacy through alignment with PPPs, policy frameworks, and collaborative innovation ecosystems. However, the NSE also demands a more nuanced account of internal strategic resources and adaptive behaviour under regulatory and technological uncertainty.

To this end, the RBV (Barney, 1991) adds an internal strategic layer to the NMI by identifying how SMEs create competitive advantage through proprietary technologies, intellectual property, and firm-specific knowledge. These resources are especially salient in the space sector, where innovation, reliability, and differentiation are prerequisites for entry and growth. However, the RBV alone cannot explain how such resources are mobilised in institutional environments characterised by regulatory asymmetry and ecosystem interdependence.

DCT (Teece et al., 1997) complements this perspective by highlighting the temporal and adaptive capabilities that SMEs require to manage change. In the NSE, dynamic capabilities are critical for responding to volatile regulatory regimes, dual-use technology controls, and shifting geopolitical alliances. SMEs must continuously reconfigure assets, adjust business models, and build responsive supply and knowledge networks to maintain strategic relevance in a rapidly evolving sector.

ET (Moore, 1993) introduces a structural dimension that reorients attention from firm autonomy to ecosystem participation. In highly institutionalised sectors such as space, SMEs depend on external platforms—such as ESA incubators, national innovation programmes, and regional space clusters—for access to capital, legitimacy, infrastructure, and standards. Ecosystem engagement becomes a central vehicle through which firms coevolve with public agencies, research institutions, and lead firms.

Rather than treating these theories as separate or sequential, this dissertation conceptualises them as mutually reinforcing components of an integrated model. Table 1 summarises the core insights, relevance, and limitations of each perspective as applied to SME internationalisation in the NSE.

Table 1. Comparative overview of theoretical frameworks.

Theory	Core Insights	Relevance to SMEs in the NSE	Limitations
NMI	Internationalisation is relational and embedded in institutional networks	Explains network formation, PPPs, and embeddedness within ecosystems	May underplay firm-internal capability development
Uppsala Model	Gradual internationalisation via learning and commitment	Useful for understanding early-stage market engagement and institutional learning	Misaligned with rapid and nonlinear expansion in the NSE
RBV	Competitive advantage stems from valuable, rare, inimitable resources	Highlights internal innovation, IP, and differentiation as strategic assets	Overlooks institutional constraints and relational enablers
DCT	Firms adapt and reconfigure capabilities to respond to change	Captures SME agility in managing regulation, alliance shifts, and technology transitions	Assumes preexisting dynamic capabilities not always present in early-stage SMEs
ET	Firms coevolve within ecosystems of interdependent actors	Reveals how embeddedness in policy, funding, and innovation ecosystems facilitates scaling	May overlook firm-level agency and strategy

Each of the four theoretical perspectives rests on distinct foundational assumptions that confer explanatory power – and impose certain limits – when applied to SMEs in the NSE context. The NMI assumes that international expansion is fundamentally a relational, embedded process, driven by a firm's positions in inter-organisational networks. This perspective's strength lies in illuminating how SMEs gain market access and legitimacy through strategic ties and institutional linkages, which is

crucial in a domain where standalone entry is often unviable. However, the NMI's external focus can underplay firm-internal capabilities and resources. By contrast, the RBV posits that competitive advantage derives from firm-specific assets that are valuable, rare and inimitable. It directs attention to a company's proprietary technology, knowledge and other unique resources as key enablers of international growth. The RBV's limitation is that, on its own, it overlooks the institutional constraints and network enablers that condition how such resources can be deployed globally (Dyer & Singh, 1998; Lavie, 2006; Meyer et al., 2016; Peng et al., 2008).

DCT builds on the RBV by emphasizing a firm's capacity to continually adapt, reconfigure and renew its competences in response to change. This view captures the importance of agility for SMEs facing volatile regulations or rapid technological shifts in the NSE, yet it arguably presupposes that firms already possess such higher-order adaptive capabilities – an assumption that may not hold for many early-stage ventures. ET shifts the lens to the broader system of interdependent actors, assuming that firms evolve as participants in an interactive ecosystem rather than as isolated entities. The strength of this approach is its recognition that engaging with external platforms, policy frameworks and collaborative partners enables SME scaling in a highly institutionalised industry. At the same time, the ecosystem perspective's macro-level focus may risk overlooking individual firm agency and strategic choice. Taken together, these theories are complementary, each addressing different facets of SME internationalisation that the others might neglect. Yet their differing emphases also reveal potential tensions: a network- and ecosystem-oriented view prioritises external relationships and context, whereas an RBV/DCT lens prioritises internal assets and firm-driven processes. Rather than seeing these viewpoints as incompatible, this dissertation treats them as interlinked and mutually reinforcing – for instance, external networks serve as conduits for leveraging internal resources, while internal dynamic capabilities help firms capitalise on ecosystem opportunities.

The Uppsala model is included in Table 1 as a baseline reference, reflecting its foundational role in internationalisation theory. However, while it provides insights into incremental learning and commitment processes, its assumptions are misaligned with the accelerated, ecosystem-mediated trajectories of SMEs in the NSE. For this reason, the model is not adopted as part of the dissertation's integrated framework, which instead builds on NMI, RBV, DCT, and ET. In this sense, Uppsala serves as a useful point of contrast, underscoring the need for frameworks that capture rapid, institutionally embedded forms of internationalisation.

Notably, institutional theory is not included as a standalone framework in this model. This omission is a conscious and critical delimitation, not a denial of the importance of institutions. In fact, institutional influences are woven throughout the chosen

perspectives – for example, the NMI inherently accounts for institutional embeddedness via network ties, and ET explicitly encompasses the role of policy, regulation and other institutional structures in shaping firm behaviour. Including a separate institutional theory lens was deemed unnecessary because it would largely overlap with these integrated viewpoints and could diffuse the focus on SME-centric strategic mechanisms. Instead, institutional factors are acknowledged at every turn of the analysis without being formalised as an independent theory, ensuring that institutional effects are considered comprehensively even as the framework centres on NMI, RBV, DCT and ET.

Through this integrated lens, SME internationalisation in the NSE is understood as a capability-driven, institutionally embedded process that is both relational and adaptive. The framework acknowledges that firms do not expand merely by leveraging their own resources but by positioning themselves strategically within multiscalar systems shaped by policy, infrastructure, regulation, and technological regimes.

Figure 4 presents a visual overview of the integrated theoretical framework developed in this dissertation. It depicts the dynamic interplay between firm-level capabilities, institutional alignment, and network embeddedness—elements drawn from the combined application of the NMI, RBV, DCT, and ET. This framework is operationalised through the empirical analyses presented in Chapter 5 (Articles I–IV) and further synthesised and discussed in Chapters 6 and 7.

4 RESEARCH METHODOLOGY

This chapter introduces the methodological architecture of the dissertation and explains how the empirical and review components jointly support the development and testing of the integrated theoretical framework outlined in Chapter 3. The aim is to provide a concise roadmap that clarifies the logic of design choices, data foundations, and validation procedures before turning to a detailed exposition. With this orientation in place, Section 4.1 sets out the overall research design, data sources, and analytical strategies that guide the inquiry.

4.1 Introduction

This chapter outlines the methodological foundations of the dissertation, detailing the research design, data sources, and analytical strategies applied to examine SME internationalisation within the NSE. The study builds on three peer-reviewed articles and one manuscript presented in academic seminars, each contributing complementary empirical and theoretical insights. The objective is to establish a transparent, rigorous, and context-sensitive methodological structure rooted in case study research and a systematic literature review (Eisenhardt, 1989).

The methodological approach is shaped by the interdisciplinary and evolving nature of the space sector, where conventional linear models often fail to capture the complex interactions between firms, institutions, and regulatory architectures. The methods were selected to support the analysis of network-based internationalisation under conditions of regulatory uncertainty, technological dynamism, and institutional embeddedness (Dubois & Gadde, 2002; Welch et al., 2011).

This research draws on two primary methodological traditions. First, the qualitative case study methodology enables an in-depth, context-specific exploration of SME internationalisation dynamics. Second, the systematic literature review synthesises a fragmented and emergent academic field, offering a conceptual basis for empirical inquiry (Snyder, 2019; Tranfield et al., 2003).

The main case study focuses on the Kvarken Space Center and its role in facilitating SME internationalisation in the Nordic space sector. Data were collected through expert interviews, strategic documents, public procurement records, and institutional reports. This multisource approach allowed for empirical triangulation and a holistic understanding of how SMEs position themselves within regional and sectoral innovation ecosystems (Vissak, 2010).

The literature review article, serving as the second empirical pillar, systematically maps the existing knowledge base on the space economy and SME engagement. Following established review protocols (Snyder, 2019; Tranfield et al., 2003), it applies a keyword-driven search strategy, inclusion and exclusion criteria, and thematic coding to identify patterns, gaps, and emerging themes.

Together, these methodologies allow for the examination of both micro-level firm behaviour and macro-level institutional developments. Figure 4 illustrates the research process from theory development to data collection and analysis.

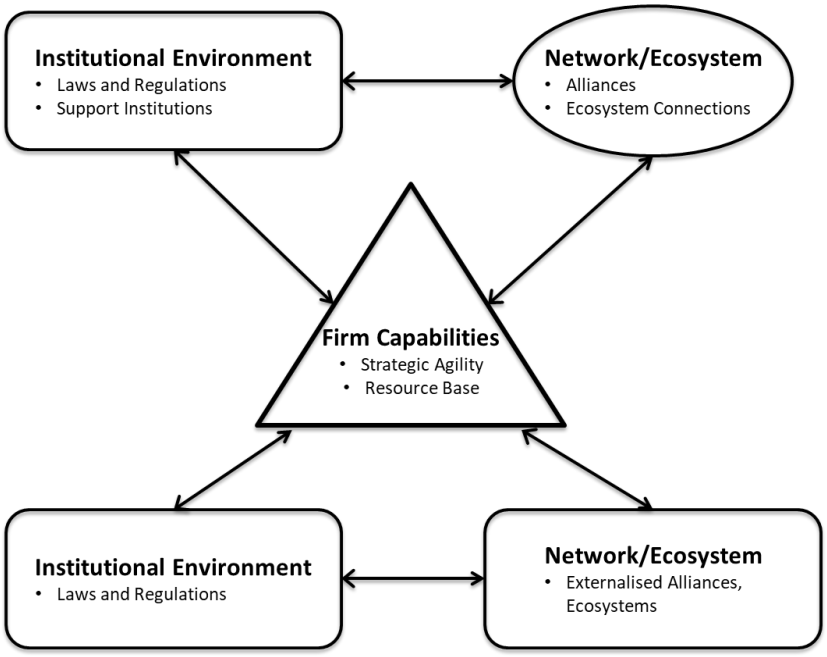

Figure 4. Integrated theoretical framework for SME internationalisation in the NSE.

Table 2 summarises the methodological characteristics of each article.

Table 2. Methodological overview of the dissertation articles.

Article	Authors	Title	Methodology	Contribution
I	Mikko Punnala, Jari Ratilainen	An emerging innovation ecosystem for New Space – Kvarken Space Center in Finland	Single case study; document analysis	Conceptual-isation of regional innovation ecosystems and PPP dynamics
II	Mikko Punnala, Santeri Punnala, Arto Ojala, Heidi Kuusniemi	The space economy: Review of the current status and future prospects	Systematic literature review; OECD-based framework synthesis	Mapping of conceptual terrain and identification of research gaps
III	Mikko Punnala, Santeri Punnala, Arto Ojala, Heidi Kuusniemi	Navigating the space frontier: Insights into the current state and future potential of the space economy	Systematic review; keyword protocol	Periodises the space economy's evolution into three phases and highlights the structural and institutional drivers of SME international-isation in the NSE
IV	Eldridge de Melo, Mikko Punnala, Arto Ojala	Small business international-isation in the Nordic space industry	Comparative multiple case study; expert interviews	Inductive theory-building on SME international-isation and ecosystem engagement

The methodological rigour of the study is reinforced through multiple validation strategies. Internal validity is ensured through source triangulation, including policy documents, interview data, and secondary reports. External validity is strengthened by contextualising the findings within the broader Nordic and European space sectors (Welch et al., 2011). Reliability is supported by the transparent documentation of coding procedures and data protocols (Vissak, 2010). Ethical approval was granted by the relevant university committee. All interview participants provided informed consent, and the collection and processing of personal data complied with the General Data Protection Regulation (GDPR)

governing the protection of natural persons with regard to the processing of personal data and the free movement of such data (Regulation (EU) 2016/679 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data (General Data Protection Regulation), 2016). Relevant safeguards were implemented to ensure the confidentiality, anonymity, and secure handling of all interview materials in accordance with applicable data protection standards.

Limitations include access constraints due to the strategic sensitivity of the space sector, and the relatively nascent nature of the commercial space economy, which results in limited longitudinal data. The case study offers contextual depth but is bounded in its generalisability. The literature review, while comprehensive, remains subject to publication lag inherent to emerging fields (Snyder, 2019). Nonetheless, the combined use of case study and literature review methodologies ensures conceptual coherence and empirical robustness and enables the dissertation to contribute new knowledge on SME internationalisation in the NSE.

4.2 Research Process and Positionality

The research process underpinning this dissertation has unfolded within a dynamic, multiactor, and security-sensitive context. Conducting qualitative, network-based research in the NSE has required careful navigation of methodological challenges, access constraints, and positional considerations that shape both the scope and depth of empirical inquiry.

One of the key methodological challenges concerned access to interviewees and institutional data within a sector characterised by restricted information flows, dual-use technologies, and non-disclosure norms. SMEs in the space industry often operate in close proximity to national security regimes, public procurement contracts, and commercially sensitive infrastructures. As a result, data collection required building trust over time, leveraging existing academic–industry networks, and adopting a flexible interview strategy that respected confidentiality while ensuring analytical rigour. Gaining access to key informants frequently depended on personal introductions and non-public contact pathways, underscoring the embedded nature of qualitative fieldwork in this sector.

The selection of case studies was influenced not only by analytical considerations, such as variations in governance structures and SME profiles, but also by pragmatic constraints related to data availability and linguistic or regional proximity. The emphasis on Nordic and European ecosystems reflects both the empirical richness of these contexts and the feasibility of sustained engagement. While this regional focus

offers analytical depth, it also limits the generalisability of findings to other institutional configurations, particularly in emerging economies or highly centralised governance environments.

From a positionality standpoint, the researcher's dual engagement with academic and policy-oriented communities shaped the framing and interpretation of the empirical material. Interaction with regional development agencies, ESA affiliates, and university-led innovation platforms contributed to a situated understanding of how SMEs experience and interpret institutional constraints. This positional embeddedness provided access to informal knowledge and practitioner perspectives while also necessitating ongoing reflexivity regarding potential biases in data interpretation. Throughout the research process, attention was paid to balancing the insider access afforded by these networks with the critical distance required for analytical independence.

The iterative nature of the research design also merits reflection. Early conceptual choices—particularly the adoption of the NMI as the foundational framework—were continuously reassessed in light of empirical observations. The incorporation of complementary perspectives, such as the RBV, DCT, and ET, emerged not from a predetermined theoretical architecture but from the need to account for the complexity encountered during data analysis. This abductive logic, aligned with the principles of the qualitative case study methodology, allowed the theoretical framework to evolve in dialogue with field data.

In sum, the research process has been shaped by context-specific constraints, relational dynamics, and epistemological openness. These experiences have informed both the empirical insights and the theoretical contributions of the dissertation, demonstrating that, in sectors such as the NSE, the researcher's positionality is not merely a background variable but an active element in shaping the knowledge produced.

5 SYNTHESIS OF THE ARTICLES: TOWARDS AN INTEGRATED UNDERSTANDING OF SME INTERNATIONALISATION IN THE NSE

This chapter synthesises the empirical findings and theoretical insights derived from three peer-reviewed articles and one manuscript presented in academic seminars that together constitute the core of this dissertation. Each article addresses a different level of analysis—ecosystemic, structural, strategic, and firm-level—contributing to a cumulative understanding of how SMEs internationalise within the NSE. The purpose of this synthesis is not to revisit each study in isolation but to draw out their interconnections, highlight cross-cutting mechanisms, and situate them within the integrative theoretical framework developed in Chapters 2 and 3.

Together, the articles challenge the assumption that SME internationalisation follows a uniform or incremental pathway. Instead, they reveal that in the NSE, internationalisation is shaped by multilevel interdependencies—technological, institutional, and relational—which require SMEs to act not only as strategic agents but also as embedded participants in evolving innovation ecosystems and governance structures. The findings contribute to the extension of the NMI by demonstrating how network embeddedness is conditioned by structural, regulatory, and capability-based factors unique to the space sector.

5.1 Article I – An Emerging Innovation Ecosystem for New Space – Kvarken Space Center in Finland

Authors: Mikko Punnala & Jari Ratilainen (2024)

Research Aim: To examine how a regional innovation hub (the Kvarken Space Center in Finland) facilitates SME internationalisation in the space sector.

Summary of Findings: This single-case study finds that the Kvarken Space Center acts as a critical platform for SMEs to integrate into global value chains. The ecosystem provides key resources—PPPs, institutional funding opportunities, and links to research institutions—which allow local space SMEs to overcome typical entry barriers (e.g. high capital requirements, lack of credibility, regulatory hurdles). Article I demonstrates that a regional space innovation ecosystem can substitute for international experience by embedding SMEs in networks that confer legitimacy and access to international projects. These findings support ET, showing that firm success in new industries often depends on systemic collaboration and specialisation. The results also extend the NMI's logic: embeddedness in a local cluster (with connections

to transnational bodies such as the ESA) can effectively serve as a springboard for internationalisation.

5.2 Article II – The Space Economy: Review of the Current Status and Future Prospects

Authors: Mikko Punnala, Santeri Punnala, Arto Ojala & Heidi Kuusniemi (2024)

Research Aim: To map the global space economy's development, identify emerging trends, and assess their implications for SME internationalisation.

Summary of Findings: This article conducts a structured literature review and policy analysis to examine the current structure and likely evolution of the NSE. It identifies several key enablers of space-sector expansion, including technological democratisation, miniaturisation, and increased VC activity. Simultaneously, it highlights persistent constraints—such as fragmented export control regimes, dual-use restrictions, and regulatory misalignments—that hinder SME participation in global markets. Article II contextualises SME activity within broader macroeconomic and policy frameworks, offering insights into the institutional and financial architectures that govern international access. Conceptually, the article lays a foundation for understanding SME challenges and opportunities in the NSE by linking empirical trends to internationalisation theory. It provides policy-relevant implications for regulatory harmonisation and strategic investment coordination, positioning the NSE as a structurally complex but increasingly permeable domain for SME international growth.

5.3 Article III – Navigating the Space Frontier: Current State and Future Potential of the Space Economy

Authors: Mikko Punnala, Santeri Punnala, Arto Ojala & Heidi Kuusniemi (2025)

Research Aim: To provide a comprehensive systematic review of the space economy's evolution, identifying key factors driving its past development and future growth, and examine how these macro-level shifts inform SME internationalisation theory.

Summary of Findings: Article III conceptualises the space economy as an emerging multiactor system and divides its development into three major phases: (1) a state-led phase, in which government agencies dominated and set the stage (e.g. the Cold War era of space exploration); (2) a cooperative/institutional phase, marked by

increased international collaboration and the gradual involvement of private actors alongside public initiatives; and (3) a commercially driven phase, characterised by entrepreneur-led New Space ventures and equity-funded innovation (the current era). Each phase created distinct opportunities and constraints for SME internationalisation. For example, in the cooperative phase, new institutional support mechanisms (such as international treaties and shared infrastructure) lowered barriers for SMEs, whereas in the current commercial phase, private investment and market-driven innovation are key drivers (but come with challenges such as regulatory lag).

The article's review reveals that SMEs' internationalisation trajectories in the space sector are heavily shaped by these structural conditions—a purely linear or incremental model (such as the classic Uppsala model) does not adequately explain SME behaviour across these phases. Thus, Article III argues for extending the NMI into a more comprehensive framework that accounts for institutional and technological context: SMEs are not just networked actors but are also constrained/enabled by the stage of industry evolution and governance regimes. This insight reinforces the dissertation's argument that successful SME internationalisation in the NSE hinges on both relational strategies and structural alignment (with policy, regulation, and ecosystem development).

5.4 Article IV – Small Business Internationalisation in the Nordic Space Industry

Authors: Eldridge de Melo, Mikko Punnala & Arto Ojala (2025)

Research Aim: To analyse how Nordic SMEs operating in the space sector develop internationalisation strategies under institutional and regulatory constraints.

Summary of Findings: Article IV uses a multiple-case study methodology to investigate how SMEs in Finland and other Nordic countries respond to the dual pressures of regulatory complexity and high technological entry thresholds. Drawing on expert interviews and firm-level data, the article identifies several strategic responses: early engagement with public–private intermediaries (e.g. ESA Business Incubation Centres), continuous adaptation of business models to align with procurement requirements, and deliberate development of dynamic capabilities to navigate geopolitical and legal asymmetries. The article demonstrates how firms operating in marginal or peripheral innovation environments can overcome structural disadvantages through ecosystem participation, institutional trust-building, and strategic alignment with international frameworks. These findings link macro-level dynamics—discussed in Articles II and III—to concrete micro-level

practices, showing how SME agency is exercised within structurally mediated environments. Article IV thus refines the applicability of the NMI by illustrating how relational embeddedness must be accompanied by institutional agility and capability reconfiguration in regulated, capital-intensive sectors.

5.5 Synthesis: Integrating the Contributions of the Articles

The four articles presented in this chapter offer complementary perspectives on the internationalisation of SMEs within the NSE. Together, they construct a cumulative analytical narrative that bridges structural, institutional, and strategic levels of analysis—advancing both theory and empirical understanding of how small firms operate in a sector defined by regulatory asymmetry, capital intensity, and multilevel governance.

Article I provides a micro-level case study demonstrating how a regional innovation ecosystem can serve as a launchpad for SME internationalisation. Through the Kvarken Space Center, the article illustrates that local embeddedness—when aligned with institutional platforms and public–private partnerships—can substitute for direct international experience. This empirical insight grounds the relevance of ET and enriches the NMI by highlighting the strategic function of regionally anchored intermediaries.

Article II moves to the macro level, mapping the global configuration of the NSE and its implications for SME participation. It identifies the structural enablers and persistent barriers that shape access to space-sector value chains, from VC flows to export control regimes. The article's policy-oriented synthesis positions the NSE as a complex but increasingly open institutional field, where SME success depends on the strategic navigation of both financial and regulatory infrastructures.

Article III builds on this structural foundation by theorising the space economy's evolution through a systematic literature review. It traces the sector's transition from state-led to commercially driven logics, proposing that SME internationalisation must be understood within multilayered institutional architectures. The article advances NMI by incorporating the notion of institutional embeddedness and reinforcing the role of systemic interdependence—key conditions often overlooked in classical models.

Finally, Article IV returns to the firm level to examine how Nordic SMEs respond to regulatory complexity and capability constraints. Through comparative case analysis, it reveals how SMEs mobilise dynamic capabilities, adapt business models, and

leverage ecosystem support to internationalise under structural pressure. This article operationalises theoretical constructs from the previous studies, showing how macro-level conditions manifest in concrete strategic practices.

In developing the integrative theoretical framework, the findings of the four articles were systematically compared to identify overarching themes across the different analytical levels. This synthesis process was iterative and abductive: insights from each study were cross-examined and clustered, which led to the recognition of four interdependent dimensions. By triangulating evidence from multiple cases and the literature, the researcher ensured that the emergent framework was not a mere aggregation of separate results, but a coherent construction grounded in all the empirical observations. This explicit analytical procedure strengthens the transparency of how the dissertation's theoretical contribution was derived from the article findings. These interdependent dimensions comprise network integration, which explains how SMEs embed within institutional, public–private, and ecosystemic networks to gain legitimacy and market access; business model adaptability, reflecting the ways in which firms reconfigure their value propositions in response to technological, regulatory, and market shifts; regulatory navigation, denoting the ability to manage complex and fragmented legal environments through compliance capabilities and institutional agility; and strategic resource mobilisation, highlighting how finance, infrastructure, and human capital are accessed and scaled, often through collective arrangements and ecosystem participation. Taken together, these dimensions provided the organising logic for synthesising the empirical findings into a coherent, multilevel framework.

Taken together, the four articles support the dissertation's central claim: that SME internationalisation in the NSE is not a linear or exclusively firm-driven process but a systemically embedded trajectory shaped by ecosystem alignment, institutional legitimacy, and adaptive strategic behaviour. The integrative framework developed across these studies extends existing internationalisation theory and offers empirically grounded insights for academics, policymakers, and practitioners operating in innovation-intensive and governance-dependent sectors.

6 DISCUSSION: SYNTHESIS AND IMPLICATIONS

This chapter synthesises the cumulative findings of three peer-reviewed articles and one manuscript presented in academic seminars and evaluates their broader implications for understanding SME internationalisation within the NSE. The analysis is situated within the dissertation's central objective: to develop an integrative theoretical framework that accounts for the structural, technological, and institutional specificities that define the international trajectories of space-sector SMEs. The findings confirm that the process of internationalisation in the NSE cannot be adequately understood through traditional models that emphasise gradual, market-by-market expansion. Instead, the process is better conceptualised as a dynamic and relational form of embeddedness, governed by access to networks, institutional alignment, and adaptive capability formation.

Drawing on the theoretical architecture developed in Chapters 2 and 3, this chapter brings together the empirical insights from the four articles and critically evaluates how these contribute to the extension and refinement of the NMI. The evidence confirms that successful SME internationalisation is contingent upon firms' ability to navigate not only commercial markets but also complex regulatory regimes, capital-intensive development cycles, and geopolitically mediated infrastructures of access and legitimacy. The synthesis supports a multidimensional understanding of internationalisation, in which firm agency is shaped—and often constrained—by relational asymmetries, institutional architectures, and strategic dependencies.

6.1 Theoretical and Empirical Synthesis

The empirical analysis conducted across the four articles identifies four interdependent dimensions that collectively shape the internationalisation trajectories of SMEs in the NSE: network integration, business model adaptability, regulatory navigation, and strategic resource mobilisation. These dimensions form the empirical foundation for the theoretical synthesis developed in this dissertation and enable a targeted response to the core research questions.

The first of these concerns the role of network integration. Articles I and IV provide compelling empirical evidence that strategic embeddedness in public–private partnerships, ESA incubation structures, and regional innovation platforms is not ancillary but central to SME success. The Kvarken Space Center, for example, functions as a structural gateway to global networks by offering access to infrastructure, funding instruments, and credibility-enhancing institutional alliances. These findings reinforce and extend the NMI by demonstrating that access to international markets is mediated less by sequential firm-driven expansion and more

by participation in structured ecosystems that blend public and private logic. In this sense, strategic insidership is not merely a function of relational initiative but a product of alignment with institutional rules, trust-based relational capital, and positioning within nested governance architectures.

Second, business model adaptability emerges as a critical capability for SMEs operating in the NSE. As shown in Article III, firms that succeed in commercialising space-based services typically adopt flexible and scalable models—such as satellite-as-a-service, hybrid data analytics, or platform-based EO products—that can be deployed across multiple sectors and jurisdictions. These models enable SMEs to overcome the high fixed costs and long development cycles characteristic of space-sector innovation while simultaneously enhancing responsiveness to regulatory and customer-side demands. While the RBV explains how internal assets—such as intellectual property and specialised knowledge—contribute to sustained advantage, the evidence also indicates that these capabilities must be reconfigured in response to shifting institutional, technological, and market conditions.

The third-dimension centres on the challenges posed by regulatory complexity. Articles II and IV document the extent to which internationalisation is constrained by export controls, technology transfer restrictions, and jurisdictional fragmentation. SMEs operating within or across U.S.-aligned regulatory systems, for example, face compliance burdens that are often disproportionate to their size and capacity. However, firms that engage proactively with supranational policy frameworks and institutional partners—such as ESA, ITU, and UNOOSA—are better positioned to mitigate regulatory risk through pre-emptive alignment and relational trust. These findings support the extension of DCT within this context, particularly in relation to the concept of institutional agility: the capacity of SMEs to adapt not only to technological change but also to evolving legal and political architectures. This dissertation introduces the concept of 'institutional agility', defined as the capacity of SMEs to adapt proactively and co-evolve with changing regulatory, political, and institutional environments. Unlike simple responsiveness, institutional agility involves anticipatory alignment with evolving governance structures and the ability to reposition strategically within shifting institutional architectures.

Finally, the role of strategic resource mobilisation—particularly in relation to finance—emerges as an enduring constraint and enabler. Article II outlines how the availability of VC, sovereign investment, and public innovation funding remains uneven across the sector. While early-stage seed funding is increasingly accessible, mid-stage capital for scale-up remains limited, especially for firms outside dominant national ecosystems. SMEs that succeed in navigating this environment do so by embedding themselves in funding-oriented consortia, aligning with public

procurement priorities, and signalling policy relevance to both private and institutional investors. These findings reinforce the importance of ecosystem theory in capturing how firms access not only material resources but also institutional scaffolding, credibility, and structural positioning.

In sum, the findings across all four articles provide a robust empirical basis for extending the NMI into a more context-sensitive and capability-enriched framework. They demonstrate that internationalisation in the NSE is not simply a matter of firm-level competence or relational initiative but a multiscalar process shaped by policy design, funding architectures, regulatory coherence, and institutional affiliation. The theoretical implications of this synthesis are further elaborated in the next section.

6.2 Assessing the Applicability of the NMI Framework

The NMI remains particularly well-suited for analysing SME international expansion strategies within the complex context of the NSE. In contrast to stage-based models, such as the Uppsala model, which assume incremental commitment through experiential learning, the NMI conceptualises internationalisation as an embedded process that is contingent upon interorganisational ties, institutional participation, and access to strategically governed networks. This perspective aligns closely with the realities of space-sector SMEs, which are often compelled to engage early and intensively with institutional and commercial partners due to the capital-intensive and regulatory-laden nature of the sector (Johanson & Mattsson, 1988; Peeters, 2021).

Nonetheless, while the NMI provides a strong relational foundation, it was originally developed in the context of relatively stable industrial environments. Its applicability to security-sensitive, politically contested, and rapidly evolving sectors—such as the NSE—requires theoretical augmentation. This dissertation addresses these limitations by integrating ecosystem theory, the RBV, and DCT, as articulated in Chapters 2 and 3, and supported by findings across all four research articles.

A key contribution of this integration is the recognition that relational embeddedness in the NSE is inseparable from institutional alignment. Empirical evidence from Articles I and IV confirms that SMEs succeed not merely by building horizontal partnerships but by embedding themselves within multiactor institutional frameworks—such as ESA's innovation ecosystem, PPP consortia, and transnational regulatory structures. These forms of embeddedness transcend transactional collaboration and involve long-term strategic coordination with state agencies, academic institutions, and regional innovation actors.

While the NMI explains how firms leverage external networks, the RBV introduces a necessary inward-facing dimension by highlighting how SMEs derive competitive advantage through firm-specific technological capabilities and proprietary assets, such as EO analytics or modular satellite systems (Barney, 1991; Wernerfelt, 1984). These capabilities are essential for differentiation and scale, but their real value is only unlocked when firms are able to connect them to relational and institutional infrastructures.

DCT complements this view by focusing on firms' capacity to reconfigure internal and external assets in response to dynamic institutional and technological change. In the NSE, such reconfiguration includes responding to dual-use compliance requirements, adapting to changes in International Traffic in Arms Regulations (ITAR) classification, or pivoting business models to align with evolving market norms (Teece et al., 1997). Articles II and IV offer clear evidence that SMEs that exhibit institutional agility—rather than simply technological responsiveness—are more likely to scale internationally.

ET further expands the NMI by conceptualising firms not as isolated agents within bilateral networks but as embedded participants in multilevel, coevolving systems of innovation and governance. This perspective is particularly visible in Article I's case study of the Kvarken Space Center and in the firm cases analysed in Article IV, which show that SMEs benefit from access to infrastructure, regulatory mentorship, and international procurement pipelines through structured regional ecosystems (Jacobides et al., 2018; Moore, 1993; Salenius et al., 2023).

Article III strengthens the theoretical foundation of this integration by providing macrostructural insights into the global space economy. It highlights how institutional arrangements—such as space law, export regimes, and geopolitical blocs—condition the very formation and accessibility of international networks. These dynamics necessitate a reconceptualisation of the NMI as a framework not solely for firm-level relational management but also for navigating vertically layered systems of institutional authority, risk regulation, and value creation (Johanson & Vahlne, 2009; Knight & Cavusgil, 2004; Meyer & Peng, 2016).

Moreover, Article III underscores the complementarity between ecosystem participation and capability development. SMEs are shown to rely not only on external networks but also on the internal consolidation of technology assets, organisational routines, and absorptive capacity. This dual dependency—on both inward strategic assets and outward institutional positioning—marks a critical refinement of the NMI and aligns it more closely with the realities of high-velocity, security-sensitive environments, such as the NSE.

Finally, the nonlinearity of SME internationalisation, as demonstrated across Articles II and IV, calls for an expanded logic within the NMI framework. Rather than moving sequentially through learning phases, SMEs in the space economy often internationalise immediately by embedding within incubators, innovation clusters, or procurement alliances from inception. This 'born embedded' logic resonates with insights from the international new venture literature (Knight & Cavusgil, 2004; Oviatt & McDougall, 1994) and supports a reframing of the NMI as a framework for multiscalar, ecosystem-mediated internationalisation.

In sum, while the NMI remains analytically central to this dissertation, its applicability is substantially enhanced through theoretical supplementation with RBV, DCT, and ET, as well as macro-structural evidence from Article III. These combined perspectives enable a more precise understanding of SME internationalisation in the NSE, not as a linear extension of firm behaviour but as a systemically embedded and capability-dependent process.

6.3 Strategic Resource Mobilisation in the Space Economy

One of the defining features of the NSE is the exceptional intensity of resource requirements—financial, technological, and human—associated with SME internationalisation. Unlike firms in more established sectors, SMEs in the space domain cannot rely on the incremental accumulation of capabilities. Instead, they must rapidly mobilise strategic resources, often through their embeddedness in institutional frameworks, innovation ecosystems, and multilateral partnerships. This resource mobilisation imperative is consistently emphasised in the empirical evidence presented across all four articles, particularly Articles II and III.

Financial mobilisation is the most immediate challenge. SMEs must secure capital to fund R&D, prototype testing, regulatory compliance, and international scale-up. Public mechanisms such as the ESA's ARTES programme, Horizon Europe, and national innovation grants from the foundational layer of space-sector financing. However, as documented in Article II, these mechanisms are increasingly complemented by private capital flows from VC funds, sovereign wealth vehicles, and PPP-driven innovation platforms (Weinzierl, 2018). The strategic use of blended finance and coinvestment structures enables SMEs to reduce risk exposure and signal credibility to downstream integrators and customers.

Technological resource access is no less critical. SMEs typically lack the in-house capacity to develop or scale advanced systems, such as microsatellite platforms, secure data transmission protocols, or orbital logistics software. Instead, they engage

in collaborative R&D with universities, research institutes, and space agencies. Articles I and III demonstrate how such partnerships facilitate technology transfer, accelerate time-to-market, and ensure compliance with evolving technical and legal standards (Thomas & Autio, 2020).

Human capital constraints also present a major barrier to internationalisation. Space-sector SMEs often operate with limited access to skilled professionals, particularly in fields such as orbital systems engineering, regulatory affairs, and mission design. To overcome this, firms engage in consortia-based training initiatives, cross-border recruitment via European mobility schemes, and talent codevelopment with academic institutions. Institutions such as the European Space Policy Institute (ESPI) have played a key role in building sector-specific capacity through policy-driven workforce development programmes (European Space Policy Institute, 2021; OECD, 2022).

The evidence confirms that resource mobilisation in the NSE is not a firm-internal process but one mediated by institutional architectures and network positioning. SMEs that succeed in internationalising are not necessarily those with the most advanced technology but those that are best positioned to leverage financing pipelines, technical partnerships, and capacity-building platforms. These findings support a revised interpretation of resource-based strategy in international business, one that integrates structural access, institutional legitimacy, and ecosystem alignment as codeterminants of competitive advantage.

On the human capital front, SMEs face a well-documented shortage of skilled professionals. To overcome this, they engage in joint talent development initiatives with academia, participate in regional training programmes, and recruit from international mobility schemes. Institutions such as the ESPI have been instrumental in building capacity within the SME workforce (European Space Policy Institute, 2021; OECD, 2022).

6.4 Navigating Institutional and Regulatory Complexity

Institutional and regulatory constraints persist as some of the most significant barriers to SME internationalisation in the NSE. The empirical findings presented across the four articles of this dissertation consistently highlight regulatory fragmentation, restrictive export regimes, and inconsistent national policies as major impediments to cross-border scalability and interorganisational collaboration (Jakhu et al., 2020; OECD, 2022; Profitiliotis & Loizidou, 2019). These challenges are particularly acute for SMEs, which often lack the internal legal expertise and financial

resilience required to absorb the transaction costs associated with navigating multiple, and at times conflicting, regulatory systems.

Article IV demonstrates that Nordic SMEs engaged in the space sector frequently operate under overlapping and jurisdictionally divergent regulatory regimes. This is especially evident in the handling of dual-use components sourced from the United States, where export control frameworks, such as the ITAR and Export Administration Regulations (EAR), impose complex compliance obligations (de Melo et al., 2025). The result is a legal environment in which firms are forced to devote disproportionate resources to risk mitigation, licensing, and contractual negotiation, thereby delaying or even deterring internationalisation initiatives.

Article II confirms that such challenges are not confined to transatlantic supply chains. Even within the European Union, national-level divergences in licensing, spectrum allocation, and satellite data governance undermine the supposed harmonisation of the internal market (European Commission, 2016; United Nations Office for Outer Space Affairs, 2024). These misalignments create legal uncertainty for SMEs attempting to enter or operate across multiple EU jurisdictions and complicate participation in pan-European procurement or research programmes.

Technological innovation often outpaces regulatory adaptation, as shown in Article III. Rapid advances in EO, artificial-intelligence-enabled analytics, and in-orbit servicing have exposed the inadequacy of existing legal frameworks. For SMEs, this regulatory lag translates into heightened legal exposure and unclear commercialisation pathways. The compliance costs associated with legal uncertainty—particularly for emerging applications—are disproportionately burdensome for firms lacking dedicated regulatory departments.

Despite these challenges, the findings also point to institutional mechanisms that mitigate regulatory complexity. As discussed in Article I, regional innovation ecosystems, such as the Kvarken Space Center, serve as intermediaries between SMEs and regulatory bodies. These ecosystems provide access to coordinated legal support, policy guidance, and shared infrastructures that facilitate compliance and reduce administrative friction (Punnala & Ratilainen, 2024; Salenius et al., 2023). Through their engagement in such ecosystems, SMEs are able to align more closely with prevailing standards and benefit from reputational spillovers associated with trusted institutional partnerships.

In light of this, SMEs must adopt a proactive and strategic posture towards institutional engagement. This includes embedding within regulatory networks, participating in prenormative standardisation initiatives, and codeveloping legal protocols with space agencies, industry consortia, and intergovernmental

organisations (Li & Shafait, 2025). The ability to navigate institutional complexity becomes not merely a compliance requirement but a strategic capability—an insight that aligns with the extended NMI and its emphasis on relational embeddedness as a conduit for legitimacy and access.

Table 3 summarises the key regulatory and institutional constraints identified in the empirical studies and presents the network-based mitigation strategies that SMEs have adopted or should pursue.

Table 3. Regulatory and institutional barriers and SME response strategies in the NSE.

Challenge	Impact on SMEs	Network-Based Solution
Regulatory fragmentation	Conflicting national laws impede international operations, especially for dual-use components	Engagement with ESA, UNOOSA, and national regulators, and alignment with export control norms
Capital intensity	High investment thresholds restrict early-stage scalability	Access to blended funding via PPPs, VC, Horizon Europe, and defence initiatives
Technological acceleration	Regulatory frameworks lag behind innovation in EO, AI, and in-orbit services	Collaboration with regulatory foresight units, R&D agencies, and legal innovation networks
Market access concentration	Dominance of large primes limits SME entry into key supply chains	Participation in industry consortia (e.g. ESABICs), joint tenders, and strategic alliances
Data and IP protection	Cross-border partnerships raise concerns over intellectual property and data sovereignty	Use of secure contractual frameworks, joint IP agreements, and trusted digital infrastructures
Workforce shortages	Difficulty in attracting legal and technical expertise affects scalability	Academic partnerships, talent mobility schemes, and regional upskilling initiatives
Geopolitical uncertainty	Export risks and diplomatic instability deter investment and slow expansion	Risk assessment capacity, multilateral engagement (e.g. Artemis Accords), policy advocacy

The cross-article synthesis makes clear that SMEs that are able to integrate into institutional networks—whether through ESA clusters, national innovation hubs, or multilateral regulatory platforms—gain more than operational efficiency. They acquire access to relational trust, tacit knowledge, and codeveloped policy trajectories, all of which function as indirect enablers of international market entry and scaling. These observations reinforce the argument that regulatory navigation must be viewed not only through the lens of risk mitigation but also as a form of strategic positioning within institutionally governed ecosystems.

In line with the NMI, this dissertation thus reframes regulatory complexity as a relational and structural condition—one that can be addressed through network embeddedness, institutional affiliation, and collective action. SMEs that internalise this logic and invest in trust-building, compliance foresight, and strategic alignment will be better positioned to thrive in the politically and legally mediated landscapes of the global space economy.

The implications are equally relevant for policymakers. Regulatory infrastructures must be designed not merely to prevent risk but also to enable participation. This includes the creation of clear, interoperable, and SME-inclusive legal frameworks, the promotion of standards convergence, and the strengthening of dialogue mechanisms between public authorities and emerging firms. In an increasingly complex and multipolar space economy, regulatory fluency and institutional navigation will define the next generation of globally competitive SMEs.

6.5 Innovation Ecosystems, Space Clusters, and Emerging Opportunities

Innovation ecosystems and regional space clusters constitute foundational infrastructures for enabling SME internationalisation in the NSE. As empirically evidenced in this dissertation, these ecosystems are not merely supportive environments for technological experimentation; they function as institutional intermediaries that bridge the divide between public policy frameworks and commercial strategies. They enable SMEs to access funding, mentorship, regulatory intelligence, and relational legitimacy—critical assets for firms navigating complex global markets. In this study, an '*innovation ecosystem*' denotes a network of interdependent actors organised around a focal platform or complementary assets, through which participants co-create and appropriate value via innovation and coordinated roles (Moore, 1993; Thomas & Autio, 2020).

Article I illustrates this dynamic through the case of the Kvarken Space Center, a regional platform that provides SMEs with access to institutional stakeholders,

academic collaborators, and transnational networks. This form of embedded intermediation reduces entry barriers and enhances the capacity of SMEs to engage meaningfully in international markets. The ecosystem does not merely accelerate innovation; it embeds firms within a shared infrastructure of governance, capability-building, and cross-border interaction (Punnala & Ratilainen, 2024).

This institutional embeddedness aligns with ecosystem theory, which emphasises interdependence, cospecialisation, and relational positioning as drivers of firm performance in dynamic industries (Jacobides et al., 2018). Innovation ecosystems operate at the intersection of market formation and policy orchestration, enabling SMEs to navigate legal regimes, access procurement programmes, and benefit from reputational spillovers linked to public legitimacy.

Article IV expands this argument by demonstrating how Nordic SMEs leverage regional cooperation mechanisms, policy support, and European-level instruments to overcome structural disadvantages, such as small domestic markets and geopolitical peripherality. These firms are able to access ESA funding, join PPP-led initiatives, and secure entry into international supply chains not despite their size or geography but because of the strategic positioning facilitated by their ecosystems (de Melo et al., 2025; OECD, 2022).

Article III reinforces this analysis by examining how business model innovation interacts with ecosystem engagement. Firms that develop software-defined satellites, AI-enhanced EO platforms, and modular service architectures are best able to capitalise on the infrastructure and institutional capital provided by innovation ecosystems. These firms do not merely create novel technologies—they embed them within scalable, commercially viable models that align with procurement logics, policy priorities, and evolving regulatory standards (Thomas & Autio, 2020).

Article II contributes a broader technological and policy perspective. Trends such as miniaturisation, standardisation, and modularisation are reshaping the global space economy and expanding the range of viable entry points for SMEs. Innovation ecosystems, in turn, serve as concentrators of the capabilities required to exploit these opportunities. They provide access to rapid prototyping, compliance testing, and coordinated go-to-market support—all essential for firms operating in the technologically intensive and risk-sensitive domains of the NSE.

Beyond technical capacity, ecosystems enable strategic responsiveness to geopolitical developments. As Articles III and IV suggest, frameworks such as the Artemis Accords and ESA-led initiatives create structured paths for international cooperation—but only for those firms that can signal compliance, alignment, and credibility. Ecosystem affiliation becomes a proxy for such attributes, embedding

SMEs in relational networks that function as validators of trust, security, and capability (United Nations Office for Outer Space Affairs, 2024).

Ecosystemic support is not limited to early-stage incubation. While entities such as the ESABICs provide crucial support for start-ups, consortia such as Kvarken and ESA Clusters extend assistance through later growth stages via infrastructure access, codevelopment projects, and policy advocacy. This continuity ensures that innovation does not stagnate at the proof-of-concept phase but is translated into commercially viable, internationally scalable solutions (European Space Agency, 2023; Salenius et al., 2023).

Digitalisation further amplifies the ecosystem advantage. Cloud-based satellite services, interoperable data platforms, and distributed analytics infrastructures allow SMEs to participate in global supply chains without needing to establish a physical presence in every market (Aloini et al., 2022). Ecosystems act as digital gateways, offering both technical integration and regulatory navigation—making them particularly valuable for firms pursuing 'born global' strategies (Thomas & Autio, 2020; Weinzierl, 2018).

Taken together, the findings across all four articles underscore that SME internationalisation in the NSE is not merely accelerated by ecosystem participation—it is, in many cases, dependent upon it. Innovation ecosystems concentrate resources, broker institutional access, and structure opportunity in ways that are uniquely suited to the high-velocity and high-risk environment of the space sector.

These insights reinforce the dissertation's central argument: that relational embeddedness, institutional trust, and ecosystem integration form the triadic foundation of successful SME internationalisation in the NSE. The combination of Articles I–IV demonstrates that innovation ecosystems are not passive contexts but active architectures of competitiveness. They enable SMEs to convert capabilities into scale, ideas into infrastructure, and networks into strategic positioning—thereby shaping not only firm trajectories but the evolution of the space economy itself.

6.6 Theoretical Contributions

This dissertation contributes to theory-building in international business by extending and reconfiguring the explanatory capacity of existing internationalisation models in light of the structural particularities of the NSE. The study engages with four major theoretical domains—namely the NMI, the RBV, DCT, and ET—and proposes a refined and integrated framework for understanding SME

internationalisation in sectors shaped by institutional interdependence, technological complexity, and regulatory volatility.

At its core, the NMI provides a relational understanding of how firms expand across borders through embeddedness in interorganisational networks. This dissertation confirms that in the NSE, such embeddedness is not optional but a structural necessity. SMEs must actively position themselves within complex institutional and ecosystemic networks—comprising public–private partnerships, innovation platforms, and transnational regulatory consortia—to gain legitimacy, access resources, and navigate uncertainty. However, the original NMI was developed in relatively stable industrial contexts and does not fully account for the institutional turbulence and geopolitical entanglement characteristic of the contemporary space economy. The findings of this study extend the NMI by incorporating institutional embeddedness and technological interdependence as core mechanisms of network formation and by highlighting how access to international networks is mediated through governance structures and geopolitical alignment.

In parallel, the RBV traditionally explains competitive advantage through firm-internal resources that are valuable, rare, inimitable, and non-substitutable. While this logic remains relevant, the empirical findings of this dissertation demonstrate that SMEs in the space sector achieve competitiveness not solely by leveraging internal assets but also through accessing complementary capabilities embedded in ecosystems. These include shared infrastructures, codeveloped knowledge, and reputational capital obtained via trusted institutional affiliations. The RBV is thus reframed through an ecosystemic lens in which competitive advantage stems from relationally and institutionally distributed resources. This reconceptualisation introduces the notions of 'borrowed scale' and 'shared capabilities', which are particularly salient for SMEs operating under resource constraints in emerging sectors.

DCT, which focuses on the firm's ability to sense, seize, and reconfigure assets in response to environmental change, also gains new interpretive depth when applied to the NSE. In this dissertation, dynamic capabilities are shown to extend beyond the internal processes of strategic renewal to include externally mediated adaptation. SMEs in the space sector do not merely react to change through internal flexibility but develop 'institutional agility' through their engagement with regulatory systems, policy platforms, and innovation alliances. This reframing shifts the unit of analysis from firm-internal dynamism to multiactor coordination and responsiveness. It highlights how adaptation is distributed across ecosystems and institutional networks rather than residing solely within the boundaries of the firm.

Finally, ET provides an overarching structural context that supports the reinterpretation of these established models. The empirical evidence illustrates that SME internationalisation in the NSE unfolds not within open markets but within structured, policy-enabled ecosystems that provide access to infrastructure, funding, compliance guidance, and relational legitimacy. Innovation ecosystems, such as ESA clusters or the Kvarken Space Center, are not just supportive environments but strategic infrastructures that shape opportunity, mitigate risk, and enable scale. These ecosystems orchestrate coevolution between firms, public agencies, research institutions, and regulatory bodies—embedding internationalisation within a broader architecture of strategic alignment and capability circulation.

Taken together, these theoretical extensions produce a multidimensional framework that moves beyond firm-centred and market-driven models of internationalisation. They allow for a more accurate interpretation of how SMEs behave in institutionally governed, technologically volatile, and geopolitically mediated sectors. This dissertation thus contributes to the field of international business by demonstrating that SME internationalisation in the NSE is not reducible to internal resource accumulation or bilateral network formation but is better understood as a systemic process shaped by structural access, relational asymmetries, and institutional alignment.

The theoretical model developed here offers a foundation for future research in comparable sectors—such as defence technology, cybersecurity, or dual-use AI—where internationalisation is similarly mediated by external systems of power, compliance, and collaborative infrastructure. It also informs theory–practice dialogue by providing a conceptual vocabulary to describe how SMEs achieve strategic positioning in environments where legitimacy, not just capability, determines the boundaries of opportunity.

6.7 Policy and Business Implications for the New Space Economy

The following sections outline the principal policy and business implications derived from the dissertation's findings. These implications are relevant to how policymakers design enabling institutional conditions for SMEs in the NSE and how firms and investors can develop strategies that align with regulatory, financial, and technological constraints.

6.7.1 Policy and Institutional Levers for SME Growth

The findings from this dissertation highlight that SME internationalisation in the NSE is critically dependent on the design and coordination of institutional frameworks. While entrepreneurial capabilities and firm-level strategies are essential, they are insufficient without enabling public infrastructures that address regulatory complexity, funding bottlenecks, and access asymmetries.

First, the research underscores the importance of regulatory coherence. The current landscape is fragmented, particularly in areas concerning export controls, dual-use technology classification, and national licensing regimes. Harmonising these frameworks—especially across the European Union—would significantly reduce transaction costs for SMEs and enhance their ability to participate in cross-border value chains. Multilateral alignment through organisations such as the ESA, the UNOOSA, and the ITU could serve as platforms for regulatory convergence.

Second, procurement policy emerges as a powerful instrument for SME development. Public contracts not only provide direct financial support but also act as validation mechanisms that increase firm legitimacy in the eyes of investors and international partners. Figure 5 visualises how procurement mechanisms and transnational infrastructures interact to support SME–industry integration under complex regulatory conditions.

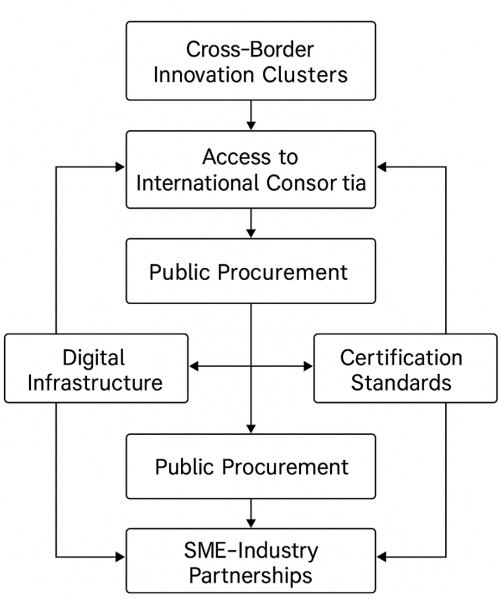

Figure 5. Institutional enablers and policy framework supporting SME internationalisation in the NSE. This figure presents the enabling institutional mechanisms derived from the empirical findings and policy synthesis in Section 6.4.

National and supranational procurement programmes should incorporate SME-targeted quotas, simplified application procedures, and evaluation criteria that recognise the innovation potential of smaller actors.

Third, institutional actors should reinforce blended financing models that combine public funds with private capital. ESA's ARTES programme and Horizon Europe already provide useful templates. However, additional coinvestment structures—such as PPPs, sovereign fund matching, and guarantee-backed credit instruments—are required to support SMEs through scale-up phases, particularly in high-risk segments, such as EO, satellite communications, and in-orbit servicing.

Fourth, spatially distributed innovation ecosystems, such as the Kvarken Space Center, should be further supported as decentralised nodes of internationalisation. These ecosystems play an intermediary role between SMEs and national or international institutions, offering regulatory guidance, infrastructure access, and ecosystem affiliation that confer legitimacy and facilitate trust-based integration into transnational networks.

Finally, digital infrastructure should be scaled to provide SMEs with real-time access to certification tools, procurement databases, and regulatory updates. A shared digital platform, managed in cooperation between the ESA, national agencies, and private consortia, would reduce the administrative burden on SMEs and allow them to respond dynamically to regulatory and market shifts.

In sum, institutional levers must be coordinated across governance levels to create an enabling environment for SME internationalisation. The success of space-sector SMEs will increasingly hinge on the coherence, accessibility, and responsiveness of the institutional systems within which they operate.

6.7.2 Business and Investment Strategies for Space SMEs

Alongside policy-level interventions, this dissertation identifies several strategic imperatives for SMEs and investors navigating the complex environment of the NSE.

First, SMEs should prioritise ecosystem alignment as a core internationalisation strategy. Embedding within ESA clusters, national space incubators, or regional innovation platforms enables access to infrastructure, expertise, and public funding. Such affiliation also provides relational credibility, which is essential in a sector marked by long lead times, regulatory sensitivity, and technological uncertainty.

Second, SMEs must proactively engage with institutional agendas. Firms that position their offerings in line with strategic priorities—such as environmental sustainability,

data sovereignty, or orbital safety—are more likely to attract support and investment. Policy alignment is not simply a matter of compliance but a mechanism of differentiation and competitive positioning in tendering, partnerships, and funding allocation.

Third, given the capital-intensive nature of space-sector operations, SMEs should design capital strategies that incorporate both equity and non-dilutive instruments. Early-stage funding can be accessed through angel networks and seed grants, but transition to growth stages often requires more structured approaches—such as convertible instruments, milestone-based grants, or strategic coinvestment with prime contractors. Firms should also engage with VCs who specialise in dual-use technologies, as these actors bring both capital and strategic insight.

Fourth, business model adaptability is key. The dissertation's empirical findings reveal that successful SMEs often deploy modular, scalable service architectures (e.g. satellite-as-a-service, EO data platforms) that can be tailored to multiple jurisdictions and use cases. Firms that can pivot or repurpose their technologies in response to changing legal regimes or client needs will be better positioned for sustained internationalisation.

Finally, SMEs must develop internal regulatory competence or secure access to external legal expertise. The capacity to interpret export rules, manage IP across jurisdictions, and respond to compliance requirements in real time is no longer a peripheral function—it is a strategic necessity. Investing in regulatory readiness not only de-risks operations but also enhances investor confidence and partnership eligibility.

For investors, the implications are equally salient. Due diligence frameworks must evolve to account for policy alignment, ecosystem affiliation, and regulatory adaptability—not merely technological novelty. Portfolio strategies should incorporate timelines, coinvestment mechanisms, and exit pathways that reflect the extended development cycles and public-sector dependencies of space ventures.

Together, these strategies reinforce the view—established throughout this dissertation—that SME success in the NSE depends not only on innovation or entrepreneurial agility but also on strategic integration into multilevel governance, capital, and ecosystem infrastructures.

7 CONCLUSIONS AND FUTURE RESEARCH

This concluding chapter synthesises the principal contributions of the dissertation and outlines key directions for future scholarly inquiry. Through a theoretically grounded and empirically rich investigation, the study has examined how SMEs navigate internationalisation processes in the context of the NSE. The analysis has demonstrated that SME success in this sector cannot be adequately understood through firm-centric models alone. Instead, it depends on firms' ability to position themselves within structured institutional ecosystems—networks that provide access to markets, legitimacy, financial capital, and regulatory support.

By integrating multiple levels of analysis and drawing on three peer-reviewed articles and one manuscript presented in academic seminars, the dissertation has produced a multidimensional account of SME internationalisation under conditions of regulatory complexity, technological uncertainty, and institutional constraint. It has shown that internationalisation in the NSE is not a linear process of market entry but a systemic outcome of embeddedness in coevolving public–private architectures.

7.1 Summary of Key Contributions

The dissertation makes five principal contributions to international business research and the emerging literature on space-sector entrepreneurship. First, it empirically validates the relevance of the NMI in explaining SME strategies in high-technology, institutionally governed environments. Unlike traditional incremental models of international expansion, the findings illustrate that SMEs in the NSE internationalise through immediate integration into institutional networks, strategic partnerships, and collaborative innovation ecosystems. This reinforces the NMI's relational logic while extending its applicability to sectors shaped by policy intermediation and geopolitical complexity.

Second, the research enriches the NMI by incorporating complementary theoretical perspectives—namely, the RBV, DCT, and ET. This multidimensional framework offers a more complete understanding of how SMEs acquire and deploy strategic resources, adapt to regulatory volatility, and position themselves within transnational value chains. The theoretical synthesis allows for a more context-sensitive application of the NMI, enhancing its explanatory capacity in sectors characterised by rapid innovation and institutional flux.

Third, the dissertation demonstrates the enabling role of PPPs in SME internationalisation. Empirical evidence from ESA's ARTES programme, the ESABIC incubators, and regional platforms such as the Kvarken Space Center confirms that

these initiatives serve not only as support mechanisms but also as institutional scaffolds. They reduce investment risk, increase visibility, and provide critical access to infrastructure and knowledge flows. PPPs thus emerge as strategic platforms for scale rather than passive support structures.

Fourth, the research identifies persistent institutional constraints—particularly fragmented export control regimes, dual-use restrictions, and inconsistencies in licensing systems—that disproportionately affect SMEs attempting to scale internationally. These regulatory barriers increase compliance costs and delay market entry. The findings support the case for enhanced policy coordination and adaptive legal frameworks that better reflect the commercial and technological realities of the contemporary space economy.

Fifth, the dissertation highlights the critical role of innovation ecosystems—especially regionally embedded clusters—in supporting SME globalisation. The case of the Kvarken Space Center illustrates how shared physical infrastructure, university–industry collaboration, and cross-border policy alignment serve as accelerators of international growth. These ecosystems not only support early-stage innovation but also offer continuity into later stages of market expansion and institutional integration.

Collectively, these contributions advance both theoretical and applied knowledge. They refine established models of internationalisation and offer empirically grounded insights into how SMEs can strategically navigate complex, policy-driven environments. Moreover, they inform policymaking by identifying the institutional conditions under which SMEs are most likely to thrive in global markets. The final section of this dissertation turns to the research opportunities that emerge from these findings, with particular attention to comparative studies, longitudinal approaches, and interdisciplinary extensions.

7.2 Limitations of the Study

While this dissertation offers a theoretically robust and empirically grounded analysis of SME internationalisation in the NSE, several limitations must be acknowledged. These relate both to methodological design and to the evolving nature of the empirical context.

From a methodological perspective, the study is primarily based on qualitative case research, which provides rich contextual insight but limits the extent to which findings can be generalised beyond the selected cases. The regional emphasis on Nordic and European space ecosystems further narrows the empirical scope. While

these regions offer instructive examples of institutional coordination and policy-driven innovation, the transferability of findings to other geopolitical or institutional contexts—particularly in emerging economies—remains constrained. Future research should therefore seek to replicate and test the presented framework in alternative regions, such as Southeast Asia, Latin America, or the Middle East.

Second, although the study conceptually engages with institutional theory and network-based internationalisation models, it does not incorporate quantitative methodologies, such as social network analysis or large-scale surveys. These methods could offer additional rigour by statistically validating the relational mechanisms and patterns of institutional embeddedness identified in the qualitative data. Incorporating such approaches in future studies would help triangulate findings and strengthen causal inferences.

A further limitation concerns the temporal specificity of the policy and regulatory environment analysed. The space sector is subject to rapid transformation, particularly in relation to export controls, security regimes, and international governance frameworks. While the dissertation reflects the prevailing landscape at the time of writing, it does not fully capture the impact of recent or forthcoming developments, such as the restructuring of global space treaties, the expansion of commercial activity into cislunar orbits, or the strategic realignment of access to orbital infrastructure and dual-use technologies. Longitudinal studies will be essential to understanding how such shifts affect the conditions under which SMEs internationalise.

Finally, although the role of digital platforms, data infrastructures, and AI-enabled analytics is acknowledged in the analysis, these elements are not explored in depth. Given their increasing centrality to space-sector entrepreneurship—particularly in relation to platform-based service delivery, machine-learning-driven Earth Observation, and algorithmic procurement—this represents an important area for future inquiry. Addressing this analytical gap would not only expand the empirical coverage of future studies but also enhance theoretical alignment with emerging debates on digital international business models.

7.3 Directions for Future Research

Building on the findings of this dissertation, a number of promising avenues for future research emerge that could extend, deepen, and test the conceptual and empirical insights presented here. One critical direction concerns the need for comparative institutional analysis across emerging space economies. While this study has focused primarily on the Nordic and European contexts, further work could explore how

varying governance structures shape SME strategies, regulatory exposure, and access to international markets in countries such as New Zealand, Japan, India, the United Arab Emirates, and Brazil. Such comparisons would offer valuable insight into how different political economies mediate the internationalisation pathways available to space-sector SMEs.

Longitudinal studies also present an important opportunity. As the space sector continues to commercialise and evolve, tracking SME growth trajectories, funding access, and regulatory adaptation over time will become increasingly important. Long-term datasets could illuminate how firms navigate institutional change, shift strategic alliances, or exit global markets. These analyses would provide a more dynamic understanding of the conditions under which SMEs sustain competitive advantage in high-velocity environments.

Further methodological innovation could also be pursued through network structure analysis. Employing tools such as social network analysis would allow researchers to explore how centrality, brokerage roles, and tie strength within innovation ecosystems affect SME scalability, legitimacy, and resilience. Such approaches could complement the qualitative findings presented in this dissertation and help quantify the structural benefits of ecosystem embeddedness.

Another underexplored area involves the role of digital infrastructures in shaping SME internationalisation. As digital coordination platforms, smart procurement systems, and blockchain-based licensing mechanisms become increasingly prominent in the global space economy, future research should examine how these tools facilitate trust-building, transaction efficiency, and compliance across borders. This line of inquiry is particularly relevant for SMEs lacking a physical presence in multiple jurisdictions and seeking to scale via virtual platforms.

PPP models also merit more targeted investigation. While this dissertation has demonstrated the enabling role of PPPs in reducing investment risk and enhancing access to infrastructure, further research could explore the governance design, equity distribution, and performance metrics of these arrangements. Comparative studies across different space market segments—such as EO services, satellite manufacturing, and in-orbit servicing—would shed light on the conditions under which PPPs succeed or fail in integrating SMEs.

Hybrid governance regimes represent another emergent topic of interest, particularly in domains such as lunar exploration and orbital maintenance where public and private mandates intersect in legally ambiguous environments. Understanding how SMEs operate within these regimes—where standards are nascent and responsibilities diffuse—requires new theoretical and methodological

approaches that can capture the complexity of institutional coevolution and strategic ambiguity.

Finally, the development of transnational institutional architectures is a subject of growing importance. Future research could explore how SMEs are affected by, and can shape, multilateral legal harmonisation processes—including those related to licensing, data governance, and spectrum coordination. In particular, comparative research could analyse how regulatory convergence and geopolitical shifts influence SME integration in emerging space economies, with specific reference to institutional frameworks in countries such as South Africa, India, and the UAE. These studies could also examine how SMEs navigate legal uncertainty and asymmetrical access to strategic resources in the context of accelerating commercialisation and geopolitical realignment.

Table 4. Research agenda for SME internationalisation in the NSE.

Research Theme	Focus Area	Research Objective	Suggested Methodology
Comparative institutional analysis	SME strategies in emerging space economies (India, UAE, Brazil)	Understand how governance structures shape market entry	Cross-country case studies
Longitudinal growth trajectories	SME performance over time	Capture changes in funding, partnerships, and regulations	Panel data or firm-level tracking
Network structure and integration	Ecosystem centrality, tie strength	Analyse how network embeddedness affects scale-up	Social network analysis
Digital infrastructures	Platforms, cloud services, blockchain	Identify how digital tools support internationalisation	Tech-oriented qualitative research
PPP models in hybrid governance	Public–private coordination in lunar or orbital regimes	Understand strategic collaboration in legally grey zones	Comparative policy and contract analysis

To support these directions, Table 4 presents a concise research agenda that maps the most salient themes that require further academic inquiry. It connects the theoretical, methodological, and empirical strands and demonstrates how each line of investigation builds on this dissertation's findings. In doing so, it offers a coherent

roadmap for advancing the study of SME internationalisation in the space economy across comparative, longitudinal, and interdisciplinary domains.

7.4 The Future of SME Internationalisation in the NSE

Looking ahead, the trajectory of SME internationalisation in the NSE will be shaped by the intersection of three enduring structural forces: the acceleration of commercial activity, the intensification of geopolitical competition, and the growing strategic role of institutional ecosystems. These forces will not only reconfigure the conditions under which SMEs engage in global markets but also redefine the capabilities required for sustained international success.

The emergence of cooperative governance frameworks, such as the Artemis Accords, along with the expansion of multinational space consortia and the proliferation of private investment vehicles focused on orbital technologies, suggests that SMEs will operate in an increasingly networked and regulated environment. Within this context, firms that develop modular, adaptable business models, engage in institutional codesign, and cultivate regulatory readiness will be best equipped to scale internationally. Their competitiveness will derive not solely from technological differentiation but also from their capacity to align with multilevel governance architectures that blend commercial objectives with public interest, legal coherence, and geopolitical awareness.

The findings of this dissertation also highlight the Nordic region as an instructive model for coordinated SME development in the space economy. Despite its relatively modest scale, the Nordic space ecosystem demonstrates that policy harmonisation, cross-border funding arrangements, and robust university–industry linkages can together produce a globally competitive environment for innovation. This regional configuration has enabled SMEs to internationalise rapidly and effectively while remaining integrated within shared infrastructures of trust, compliance, and strategic coordination.

As space becomes both a domain of commercial ambition and geopolitical rivalry, the ability of SMEs to position themselves as credible, compliant, and connected actors will define their future relevance. This dissertation has shown that such positioning is not a product of entrepreneurial capacity alone. Rather, it emerges through active integration into institutional ecosystems—those comprised of regulatory bodies, funding agencies, academic networks, and strategic industrial partnerships. Success in the NSE will increasingly depend on the ability of SMEs to operate as embedded agents within these ecosystems rather than as autonomous market entrants.

By advancing theoretical understanding, informing strategic practice, and proposing future lines of inquiry, this research contributes to the formation of an inclusive, innovation-driven, and institutionally coherent global space economy. In this vision, SMEs are no longer peripheral beneficiaries of space-sector expansion but central agents in shaping its technological frontiers, economic outcomes, and international integration.

8 AUTHOR CONTRIBUTIONS TO THE ARTICLES

For transparency, the following outlines the doctoral candidates and co-authors' contributions to the four articles included in this dissertation.

Article I: An Emerging Innovation Ecosystem for New Space—Kvarken Space Center in Finland (Punnala & Ratilainen, 2024).

- Mikko Punnala and Jari Ratilainen contributed equally to the research design, data collection, analysis, and manuscript preparation. Both authors were responsible for the development of the methodological framework, validation of findings, and iterative editing of the article.

Article II: The Space Economy: Review of the Current Status and Future Prospects (Punnala M, Punnala S, Ojala & Kuusniemi, 2024).

- Mikko Punnala led the research design, data management, analysis, methodology, project coordination, and manuscript drafting. Santeri Punnala contributed to data collection and analysis, methodology, and editing. Arto Ojala provided supervision and guidance in the research process. Heidi Kuusniemi contributed by securing research resources.

Article III: Navigating the Space Frontier: Insights into the Current State and Future Potential of the Space Economy (Punnala M, Punnala S, Ojala & Kuusniemi, 2025).

- Mikko Punnala was responsible for defining the research design, managing data collection, data analysis, methodology, project leadership, and manuscript drafting. Santeri Punnala shared responsibility for research design, data collection, and methodology. Arto Ojala provided supervision. Heidi Kuusniemi contributed research resources. Both Mikko and Santeri Punnala shared writing and editing responsibilities.

Article IV: Small Business Internationalization in the Nordic Space Industry (de Melo, Punnala & Ojala, 2025).

- Mikko Punnala contributed to data analysis, methodology development, verification of findings, visualisation of results, and editing. Eldrige de Melo was responsible for defining the research design, managing data collection, methodology, project management, and drafting the original manuscript. Arto Ojala supervised the research process and participated in editing.

This clarification demonstrates that the doctoral candidate has had a central role in the conception, execution, and reporting of most of the work, and that the co-authors'

contributions, while valuable, have been primarily supportive in nature. Such transparency makes explicit the doctoral researcher's independent contribution and ensures adherence to good scientific practice.

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An Emerging Innovation Ecosystem for New Space—Kvarken Space Center in Finland

Mikko Punnala and Jari Ratilainen

1 Introduction

Space, a source of inspiration for humanity, has been integral to our lives since the historic moment in 1969 when Neil Armstrong took mankind's first steps on the Moon. However, the pervasive influence of space on our daily lives may not be immediately apparent. From smartphone navigation to air travel, weather forecasting, and financial transactions, we are constantly utilizing space systems. In fact, the absence of these systems would render modern life, particularly in developed nations, virtually

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impossible (Jakhu et al., 2020). Space harbors immense untapped potential to address future crises, stimulate job creation, and foster innovation within the space industry (European Commission, 2016). In the coming years, space entrepreneurs, who provide cost-effective and affordable space solutions, will play a pivotal role in the evolution of the space economy (Peeters, 2021).

In developed economies, the intricacy of the space economy is on the rise, and distinguishing between space-related and unrelated activities is becoming progressively challenging. As the OECD Handbook on Measurement of the Space Economy (OECD, 2022) predicts, measuring the space economy will remain an evolving field as commercial space activities are changing rapidly. There is no explicit definition of space economy, nor is there a clear separation between different sub-areas.

The OECD Handbook on Measurement of the Space Economy defines the space economy as 'the full range of activities and the use of resources that create and provide value and benefits to human beings during exploring, understanding, managing and utilising space.' This includes all public and private actors involved in developing, providing, and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles, and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities (OECD, 2022). For comparison, the US Bureau of Economic Analysis (BEA) described the following definition when compiling their Space Economy Satellite Account: 'The space economy consists of space-related goods and services, both public and private. This includes goods and services that are used in space, or directly support those used in space, require direct input from space to function, or directly support those that do, and are associated with studying space' (OECD, 2022).

As Peeters (2021) and Weinzierl (2018) point out, the term New Space lacks a single, specific definition, reflecting its multidimensional nature that goes beyond mere commercial aspects. Various interpretations exist, ranging from the Space Frontier Foundation's view of New Space as a pathway to human settlement through economic development to Martin Sweeting's (Sweeting, 2018) emphasis on a fresh ethos that challenges traditional aerospace methods with entrepreneurial and agile approaches (Denis et al., 2020). Alternative terms such as Alt.space, entrepreneurial space, and commercial space have also been employed

(Pomeroy et al., 2019). These designations not only encapsulate technological innovations but also underscore new business models and organizational structures that focus on collaboration, agility, incremental deployment, and customer-centric design (Denis et al., 2020).

In essence, 'New Space' represents a paradigm shift, characterized by the inclusion of non-traditional actors such as private investors and hybrid public–private organizations, as well as a new approach to space utilization exploration, and commercialization (Peeters, 2021; Weinzierl, 2018). In the past decade, the space sector has seen a rise in initiatives providing open access to a wealth of space-derived data, enabling diverse entities in the field to utilize the rapidly increasing data volume (Aloini et al., 2022).

This chapter aims to provide an in-depth analysis of the emerging innovation ecosystem in the New Space sector, with a specific focus on the Kvarken Space Center. Recognizing the persistent challenges and opportunities in this rapidly evolving field, our purpose is to explore and articulate the key factors driving innovation and growth at the Kvarken Space Center. Through this exploration, we address critical questions such as: 'What are the specific challenges facing the New Space ecosystem?' and 'How is the Kvarken Space Center contributing to overcoming these challenges and fostering innovation?' This approach allows us to delve deeper into the role of the Kvarken Space Center as a pivotal player in shaping the future of the New Space Economy.

2 New Space Economy Ecosystem

2.1 Early-Stage Ecosystems Establishment

An innovation ecosystem can be defined as a network of interconnected actors, formed around a focal firm or a platform (a shared focal point or asset), incorporating production and use side participants, creating and appropriating new value through innovation (Thomas & Autio, 2020). Currently, there is only a limited body of literature and understanding around early-stage ecosystems in the New Space industry. Work more closely linking the nascent organizational processes of ecosystems to the different institutional and inter-organizational environments found in unsettled industry spaces, where the initial circumstances for ecosystem formation are asymmetric, distributed, and dynamic, is still missing (Salenius et al., 2023).

Business ecosystems develop through four life cycle phases: birth, expansion, leadership, and self-renewal (Moore, 1993). In the first stage, entrepreneurs focus on defining what customers want i.e., the value proposition of a new product or service. It is also often beneficial to cooperate during the first stage (Moore, 1993). As early-stage ecosystem collaboration lacks external trust and legitimacy, emerging ecosystems must engage legitimacy building, with agency and coordination to support interaction with the ecosystem participants and those looking to support or join it. Partner alignment, formation of a joint vision, core value proposition, and ecosystem identity are also critical. To pursue the ecosystem's intended value proposition, securing material and intellectual resources is required (Salenius et al., 2023).

The starting point of innovation ecosystems in literature can be defined as an empirically observed trend of non-hierarchical organization of the innovation process among actors that complement each other with non-generic collaboration (Salenius et al., 2023). The actor assuming the ecosystem leader role first engages in governance related actions such as designing the role of other actors and coordinating interactions and initiates, maintains, and develops ecosystem (Dedehayir et al., 2018). Ecosystems are composed of heterogeneous participants in various roles and facilitate an output that is more encompassing than any single participant can deliver alone. There is a great interdependence among its participants which is managed primarily by non-contractual mechanisms of system governance (Thomas & Autio, 2020). One of the most critical features in industry platforms is the potential of network effects (Gawer & Cusumano, 2014).

Innovation management in innovation ecosystems focuses mainly on two perspectives: analysis of innovation management strategies, and value creation and capture in innovation ecosystems (Li, 2019). Leveraging collaboration is the key to value creation through innovation. The innovation ecosystem approach examines the very nature of successful innovation systems and stresses that the system is greater than the sum of its parts. On the surface, many innovation systems contain all the right elements, but still fall short of expected outcome. Innovation ecology is dependent on the presence of several factors, such as talent, companies, institutions, and capital elements and to a great extent on identities, meaning, networking capabilities, culture of trust, and pragmatic cooperation. Smart development of a complex dynamic non-hierarchical system is of key importance. In addition to finding the right compositions of

elements, it is important to stimulate their relations and interactions in non-linear and non-hierarchical ways. For the development of innovation ecosystems, the definition of the system and its boundaries is not important but aiding the self-organization of its actors and facilitating the system's emergence from the multiple interactions are (Jucevičius & Grumadaitė, 2014).

2.2 Unveiling the Future: The Ascendance of the New Space Economy

The New Space Economy heralds a significant paradigm shift in the global space sector, increasingly characterized by the burgeoning role of private enterprises alongside groundbreaking technological innovations. This shift represents a departure from the era historically dominated by government agencies, marking the dawn of a new age where private companies are not only democratizing access to space but also pioneering novel business models and services. The term 'New Space' aptly encapsulates this evolution, denoting the emerging trend of innovative private space ventures that autonomously seek business opportunities, liberated from the confines traditionally imposed by governmental space missions (Profitiliotis & Loizidou, 2019).

Moreover, the sustainable growth and economic viability of the space economy are increasingly underpinned by 'New Space' initiatives. Such initiatives, propelled by technological advancements and innovative business models, aim to make space more accessible and beneficial for a wider array of applications. As the space economy continues to evolve, the distinction between governmental and commercial space activities becomes more nuanced, highlighting the critical role of public–private partnerships in advancing space technology and infrastructure (Peeters, 2021).

The current era is marked by a notable surge in commercial satellite launches, space tourism ventures, and private lunar exploration missions, fundamentally transforming the economic landscape of space activities. The comprehensive analysis provided by Greg Sadlier et al. (2019) further illuminates the economic impact of these activities, underscoring the strategic importance of nurturing this burgeoning field.

The narrative of the New Space Economy is one of profound transformation, characterized by the melding of entrepreneurial innovation with strategic economic growth. It is an era defined by the quest for sustainability, the expansion of access to space, and the enhancement of

global connectivity, all supported by a collaborative spirit among stakeholders. This narrative offers a multifaceted perspective on the ongoing evolution within the global space sector, showcasing its potential to drive future technological, economic, and societal advancements, enriched by the insights (Gonzalez, 2023; Paravano et al., 2023; Peeters, 2021; Profitiliotis & Loizidou, 2019; Sadlier et al., 2019).

The advent of reusable launch vehicles, SmallSats, and CubeSats has revolutionized space access, making it more cost-effective and inclusive. These innovations have precipitated a significant uptick in spacecraft launches, with SmallSats representing a substantial majority in recent years. Furthermore, the deployment of satellite constellations promises to extend global coverage, facilitating a range of applications from climate monitoring to broadband internet, marking a critical driver for the space market's future trajectory (Aloini et al., 2022; Deloitte Insights, 2023; Denis et al., 2020).

Venture capital and private equity firms have significantly increased their investment in space-related start-ups and technologies, fostering an environment ripe for innovation and competition. This influx of capital has enabled the emergence of new business models, such as mega constellations, and supported ambitious projects by leading companies like SpaceX and Blue Origin, thereby contributing to the sector's expansion and commercialization. The global space economy's growth trajectory underscores the sector's burgeoning strategic importance, with start-up equity investments reaching notable figures and a policy shift catalyzing the establishment of space start-ups, reflecting the entrepreneurial dynamism propelling the industry's growth (Deloitte Insights, 2023; Emen, 2020; McKinsey & Company, 2023).

An increasing reliance on space-based data by government agencies, private companies, and research institutions is driving the demand for space data and related services. This has led to the development of the space data-as-a-service market, where companies offer customized data sets for diverse applications, highlighting the critical role of space data in various industries (Deloitte Insights, 2023).

Projections indicate substantial growth in the sector's value and the number of active satellites, emphasizing the necessity for continued innovation, investment, and collaboration between public and private entities. Addressing emerging challenges, such as supply chain disruptions, regulatory hurdles, and environmental concerns, will be pivotal for the sector's sustained growth and long-term viability (Space Foundation, 2023).

The New Space Economy heralds a novel approach to space exploration and utilization, marked by the increasing role of non-traditional actors, the integration of space activities with ICT, and significant economic expansion. The sector's evolution presents exciting opportunities for interdisciplinary research, technological advancements, and economic development, underpinned by a collaborative spirit among all stakeholders (Aloini et al., 2022; Chavy-Macdonald et al., 2021; Deloitte Insights, 2023; Denis et al., 2020; Emen, 2020; McKinsey & Company, 2023; Pomeroy et al., 2019; Space Foundation, 2023; Weinzierl, 2018).

The European space sector is undergoing a transformative phase, shaped by global trends such as technological innovations, increased private sector investments, and a growing demand for space-based data and services. These trends are not only reshaping the space sector globally but are also manifesting uniquely in Europe, underpinned by strategic EU initiatives, investments, and the burgeoning role of commercial space activities.

Europe has embraced the technological advancements that are driving the New Space Economy forward. Innovations in reusable launch vehicles, SmallSats, and CubeSats, similar to global trends, are making space more accessible and cost-effective. This has led to an increase in spacecraft launches and the development of satellite constellations offering global coverage. European space endeavors are supported by strategic investments aimed at fostering technological advancements and commercial activities within the space sector. The European Union, recognizing the strategic importance of space, has allocated significant funds to its space programs, aiming to strengthen Europe's position in the global space economy and enhance its autonomy in space (Council of the European Union, 2020a, 2020b).

The European space sector is increasingly driven by commercial activities, aligning with the global shift toward a New Space Economy characterized by the involvement of private companies and entrepreneurs. This shift is facilitated by EU policies that encourage the commercialization of space and the success of European space companies in the global market. Initiatives to promote space and provide access to finance for start-ups, expanding businesses, and SMEs are crucial in developing a competitive European space industry (Council of the European Union, 2020a).

The EU's substantial space investments, particularly the €14.4 billion, earmarked for the European Space Programme for 2020–2022(24),

underscore its commitment to advancing satellite systems like Galileo, EGNOS, and Copernicus. These investments also aim to nurture space entrepreneurship and innovation, furthering the development of the European space sector. The EU's space policy is designed to meet increasing societal demands for space-based solutions and strengthen Europe's standing in the global space arena (Työ- ja elinkeinoministeriö, 2020).

While the European space sector benefits from the EU's strategic focus and investments, challenges remain in fully tapping into the potential of the New Space Economy. The integration of emerging space companies into significant space projects and the global market poses a formidable challenge. Nonetheless, the European space sector, with its rich history of technological innovation and strategic investments, is well-positioned to navigate these challenges and capitalize on the opportunities presented by the New Space Economy (Council of the European Union, 2020b).

The European Space Economy is at a pivotal juncture, with the EU's strategic initiatives and investments playing a critical role in shaping its future. The transition toward a more commercial and innovative space sector reflects Europe's response to global trends and its ambition to remain a key player in the New Space Economy.

In the evolving landscape of the New Space Economy, Finland's strategic approach and the initiatives at the Kvarken Space Center exemplify the nation's commitment to harnessing the potential of space for economic development, technological innovation, and societal benefits. Positioned within the broader European context, Finland's endeavors in space reflect a concerted effort to align with EU strategies, leverage investments, and capitalize on the burgeoning role of commercial space activities.

Finland has proactively embraced the shift toward a more commercial and private sector-driven space industry. This transition is marked by technological breakthroughs and a significant decrease in the costs associated with space exploration, enabling Finland to explore new business models and state-of-the-art technologies across various sectors (Harri et al., 2020; Piirainen et al., 2022). The Finnish government's reports and policy programs underscore the nation's vision to integrate space activities across sectors, translating space strategies into actionable goals and fostering government-led actions and investment programs to amplify space activities (Harri et al., 2020; Piirainen et al., 2022).

The New Space Economy program, spearheaded by the Finnish Ministry of Employment and the Economy, targets economic growth and employment through innovative business models. Coupled with Business Finland's New Space Economy program (2018–2022), these initiatives position Finland as a key player in the global space economy, emphasizing sustainable space utilization, climate change objectives, and security (Ranne, 2021).

At the heart of Finland's space endeavors lies the Kvarken Space Center, serving as an innovation hub and a beacon for Nordic cooperation in space. The center facilitates stakeholders in the Nordic region to explore new opportunities, enhance the use of satellite technology, data, and applications in various domains, thereby reinforcing Finland's pivotal role in space-related Nordic collaboration. The inception of the Kvarken Space Center, through the KvarkenSpaceEco project supported by the EU Interreg Botnia-Atlantica program, showcases a successful collaboration among universities and research institutions from Finland and Sweden (Kvarken Space Center, 2024).

Despite the promising trajectory, Finland faces regulatory challenges and hurdles related to the decentralized nature of its space sector. Overcoming these obstacles is paramount for Finland to fully leverage the opportunities presented by the New Space Economy (Harri et al., 2020). The Finnish space sector, characterized by a diverse array of companies and a highly educated workforce, stands testament to Finland's capabilities and ambitions in space (Piirainen et al., 2022).

In conclusion, Finland's strategic approach within the European context, bolstered by initiatives like the Kvarken Space Center, illustrates the nation's resolve to be at the forefront of the space revolution. As Finland navigates the complexities of the New Space Economy, its contributions to the global space industry and the Finnish economy's overall development are poised to make significant strides, contributing to the sustainable growth of the space sector.

3 Methodology

3.1 Emergence of a Sustainable Commercial Space Economy

The research was conducted within the framework of the EU Interreg Botnia-Atlantica Kvarken Space Economy project, spanning from 2019 to 2022, with the objective of establishing the Kvarken Space Center.

Situated in the Kvarken region (Fig. 1), which encompasses both Finland and Sweden, the center aims to serve as a catalyst for innovation in regional New Space activities. Its primary mission is to create a sustainable structure for regional economic development, focusing on space-based business and innovation. Additionally, the center seeks to bolster regional businesses by facilitating the development of new opportunities within the New Space Economy and aiding in the commercialization of existing space-based data through the establishment of a regional innovation ecosystem (Kvarken Space Center, 2019).

The concept of open innovation posits that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they advance their technology (Chesbrough, 2006).

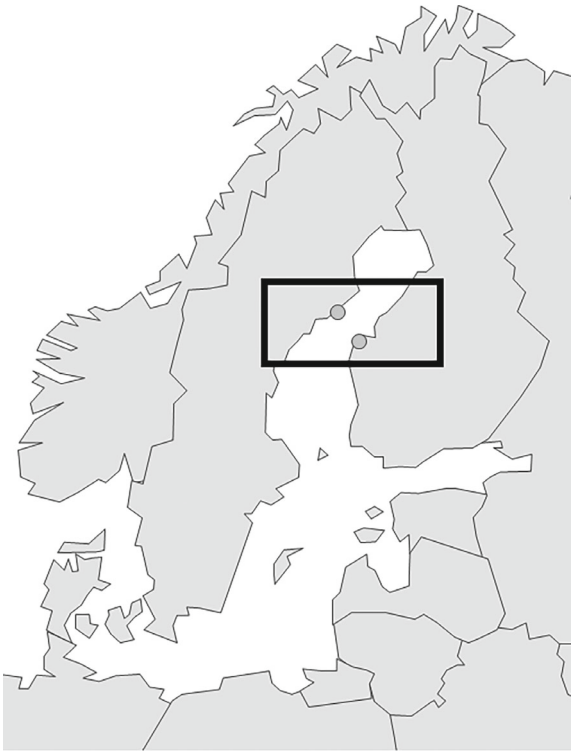

Fig. 1 The Kvarken region between Sweden and Finland

The current body of literature suggests that open innovation thrives under conditions of technological complexity and market uncertainty (Herskovits et al., 2013). This paper delves into the potential of New Space in the Kvarken region in Finland, by scrutinizing the critical aspects and demands for the regional innovation ecosystem landscape. It does so by leveraging insights from industry representatives and examining the manifestation of open innovation within these innovation ecosystems. Our objective is to elucidate the management of the open innovation process within an ecosystem involving multiple participants.

The study of an emerging ecosystem is inherently exploratory, necessitating the use of qualitative case study methods and in-depth interviews. The analysis of how ecosystems emerge is primarily anchored in empirical observation (Salenius et al., 2023). Semi-structured interviews with representatives from diverse sectors within the industry landscape were conducted, both in-person and via video conference calls. These sectors spanned energy, IT, maritime, logistics, land surveying, construction, security, forestry, and waste management. Additionally, subject matter experts involved in the KvarkenSpaceEco project were consulted. The research and establishment activities for the Kvarken Space Center ecosystem were conducted from January 2020 to September 2022, involved 30 interviews, 3 workshops, and several separate consultations and discussions. The aim was to map the landscape of the New Space Economy in the Kvarken region and identify potential opportunities for the innovation ecosystem. The current and potential utilization of space-based data for new product and service development and application for the development of internal business processes were also discussed. The authors of this chapter played a dual role as actor/observer, with the active goal of initiating and supporting the new space innovation ecosystem establishment in the Kvarken region. The research was designed to capture a snapshot of perspectives within a specific timeframe, focusing on the qualitative insights that inform the current state and potential future directions of the sector as related to the Kvarken Space Center in Finland.

The interviewees comprised entrepreneurs, technology and strategy managers, facilitators, coordinators from the business world, as well as experts from universities and research institutes. These individuals were either participating or aspiring to participate in the Kvarken region's space ecosystem. The interviews, which lasted from one to two hours, were

documented. An organized approach was employed to analyze the qualitative data gathered from interviews and reports to uncover underlying themes (Appendix: Thematic Culmination Points from the Interviews). Subsequently, we performed a detailed manual analysis to delve deeper into these themes. Additionally, to validate our findings and ensure robustness, we cross-referenced these themes with relevant literature in the field.

Five main questions were developed for the analysis:

1. What type of infrastructure would be needed to support innovation in the Kvarken region?
2. What type of competence, skills, products, or services would companies offer to the ecosystem either as individual offerings or connecting into a part of a value chain?
3. How can the decentralized nature of the space sector in the Kvarken region be effectively managed to enhance efficiency and foster a more coordinated approach?
4. Considering the global space economy, what are the potential areas for scalable business for companies in the Kvarken region, and how can these opportunities be maximized to support the growth of the local space economy ecosystem?
5. What strategies can be employed to improve the understanding and utilization of space-based data in the region?

Furthermore, the material concerning Finland's space economy has been primarily sourced from reports commissioned by the Prime Minister's Office. These reports, which scrutinize and aim to develop Finland's space strategy and space economy, serve as foundational references for the development of the national space economy, including in the Kvarken region. Based on this material, efforts have been made to utilize the nationally approved space strategy measures to ascertain and develop the state of the space economy in the Kvarken region.

4 Findings

In the establishment phase of the KvarkenSpaceEco project's ecosystem, we observe a harmonious alignment with foundational principles delineated in Sect. 2.1 of our literature review. This phase embodies the

essence of collaboration, value generation, ecosystem identity, and the strategic amalgamation of essential elements for ongoing development. These facets collectively mirror the theoretical underpinnings and practical examples cited in the scholarly discourse, thereby validating our research findings within the broader context of ecosystem evolution.

During the research and development of the Kvarken Space Center, observations of the New Space innovation ecosystem revealed that open development activities at the ecosystem level really mean finding new ideas together with innovation projects. The findings provide additional evidence that the formation of an innovation ecosystem for New Space is important and for companies that make people meet others and share a common interest in innovation cooperation. The actors emphasized interaction between members, as one company representative formulated: '*The goal of this New Space Economy ecosystem is to get people to talk, meet and know others, and find requirements of common interest*.'

A common platform must provide opportunities for brainstorming, advancing ideas into innovation projects, and creating a sustainable New Space Economy ecosystem. Creation of joint projects, from the bottom up by starting with brainstorming sessions, meetings, and workshops between organizations facilitate emergence of new ideas and incorporate the various views of different parties.

A broad level of interest can also be observed from the industry interviews for new technology, space-based data applications and opportunities utilizing new data layers to support day-to-day business and innovation. Business needs and interest areas of application range extensively. Only a few companies are already integrating space-based data into their processes. Proper understanding of data access, application, and possibilities for data utilization is still on a low level.

A major unanswered question is the viability of satellite remote sensing for local applications as the level of local infrastructure, easy utilization of drones and access to good quality aerial images and ready-made materials provided by public sector actors is commonly and often freely available for diverse applications. For many applications, openly available remote sensing data was considered to have insufficient spatial resolution for many industrial use cases and the cost of commercial imagery product remains expensive (especially for small companies). As a mitigating action cost sharing between several users of commercial imagery products acquisition was identified (e.g., via the Kvarken Space Center, shared project consortiums or actors in the value chains). The value of remote sensing

was especially observed for business activities, products, and services delivered to more remote geographical areas. The most utilized space data applications on the local level are connected to Positioning, Navigation, and Timing (PNT); in activities requiring PNT data, and were observed especially in the energy, maritime, security, logistics, and construction planning and engineering related discussions. Also, the value of PNT was identified in many new opportunities for product and service development, for example in combination of geographical information systems and supporting location-specific decision making in e.g., built and urban environments.

From the Business Development workshop (application to Waste Management) key identified issues included how to enhance traceability, developing pre-sorting, resource, and route optimization and how to make the waste value chain more transparent, identify origin and target actions on specific geolocations. In addition, special interest in applying space-based data to developing countries' needs was acknowledged. Current ESA funding calls were also reviewed as an opportunity to pursue further support for potential business applications.

During the Ecosystem Workshop 2022, several representatives of different companies pointed out that remote sensing, PNT data, and telecommunications support applications in the energy industry, logistics, shipping, improving the situational picture and awareness, agriculture, and forestry for change detection, connectivity, and forecasting. Often space-based data offers only a single part in a diverse value chain.

Several university and business representatives drew strong attention to the fact that education and know-how related to the utilization of space must be developed in Finland. The informants agreed that Finnish education is mostly insufficient to meet the challenges of the New Space Economy. One key requirement for the development of the space industry is to invest in the development of competence and know-how comprehensively in accordance with the needs of different sectors. Companies develop the ability to take advantage of emerging opportunities and participate in the New Space Economy as they create and acquire new skills and abilities.

In an interview with a manager of a start-up space data company, a comprehensive view on developing competencies from a business point of view was discussed. He emphasizes the critical need for understanding and effectively utilizing space-based satellite data, such as remote sensing

images, across various applications. The manager points out a significant gap in the general awareness and technical know-how among users, particularly in accessing, interpreting, and using raw image data and its associated metadata. This lack of understanding hinders the ability to extract valuable information from these images.

Furthermore, the manager stresses the importance of enhancing machine learning skills. He argues that analyzing satellite data without machine learning tools is too labor-intensive, highlighting the need for teaching the creation of machine learning models. Alongside this, there is a call for increasing data science education to enable structured big data analysis, requiring specialized data processing skills in programming languages like R or Python.

The discussion also extends to the teaching of artificial intelligence (AI) algorithms. The use of various AI models in the processing of space data is deemed crucial for analyzing the material effectively and preparing forecasts. This technical competence is complemented by a need for general business skills in start-ups within the New Space Economy. The manager enumerates roles such as front-end and back-end developers, designers, mobile application developers, and professionals in sales, marketing, partnerships, and fundraising. These roles are essential for a comprehensive understanding of the possibilities within the New Space Economy ecosystem and the interconnections between different actors.

A working model was also created that brings the relevant actors together to create solutions and consider possible project piloting and funding for Business Development Workshops. The proposed format was found to be an excellent approach from the point of view of developing a sustainable New Space Economy ecosystem in the Kvarken region. According to the model, existing funding tools or opportunities are combined with a real business challenge and a group of relevant industry players is ideal to strengthen the development of a New Space Economy ecosystem. The model can also serve as a blueprint for the development of future ecosystem networking opportunities.

Many aspects and needs of the innovation ecosystem were collected with the help of industry feedback:

1. Recognizing the value of the company/organization in the innovation ecosystem and creating added value to develop one's own

operations. As observed in the ecosystem literature, the key question was also, how can the developing innovation ecosystem create value for participating companies and organizations?

2. What kind of activity will the innovation ecosystem have for participating companies and organizations. Ease of use of business incubator services, regular ecosystem member meetings, organizing/providing various events (such as hackathons, webinars, learning opportunities, online courses, training, and short courses on space technology, data, and business), provision of a common online platform or group to share information, facilitating establishment of consortia and project groups for EU space searches were identified as the main needs, as well as the creation of a center for start-up activities to connect the designs of the different sectors interested in the area.
3. Infrastructure, business incubator services, open access to information resources, availability of laboratories also for research and training activities, the creation of collaboration platforms for information exchange, the acquisition of data and equipment required for training activities, the utilization of infrastructure funding and the combination of industry/business know-how, products and services in the region are also needed to support innovations, as well as the current manufacturing possibilities for New Space Economy applications are of paramount importance for the development of a sustainable space economy ecosystem in the Kvarken region.
4. Those who participated in the workshop were asked what kind of expertise, skills, products, or services they would offer to the ecosystem either as individual offers or as part of the value chain. The following components were identified; participation in system design, knowledge, and training of the latest technology, information science for environmental and climate applications, climate solutions utilizing satellite data to measure, monitor, and reduce the carbon footprint of companies, applications of real-time satellite data packages, satellite data application related to climate change, GNSS-controlled automation, application and management of ESA projects, implementation of mapping services, access to international contacts, access to industrial and agricultural information and possible end users of applications, knowledge of battery chemistry and mobile networks and the provision of satellite testing facilities

(vibration and RF) and opportunities to organize joint events with ESA BIC Finland.

5. Based on the discussions and presentations, the Kvarken Space Center should act as an umbrella that connects actors through events and activities as a form of Finnish-Swedish cross-border cooperation. Cooperation opportunities were seen as joint EU funding efforts, project consortia, matchmaking, customer and partner search, offering start-up events and organizing company and group visits, as well as direct promotion across the region.

Several development initiatives were identified across ecosystem actors, structures, activities, and support. The development of the space economy ecosystem will require increasing the awareness and commitment of stakeholders related to the New Space Economy. The establishment and support of a continuous innovation pipeline, the initiation of new space projects, participation in, supporting and promoting the establishment of new project consortiums were seen as important. Supporting industry in the introduction of New Space Economy applications, providing business incubation and mentoring for start-up and spin-off companies, identifying business and funding opportunities, establishing and developing local/regional innovation infrastructure for joint efforts in the New Space innovation ecosystem were identified. Organizing special events on business opportunities, new technology and networking, developing and promoting education in key subject areas (e.g., remote sensing, PNT, satellite communication, and New Space Business), and disseminating information to stakeholders were also recognized as important aspects of development. In Table 1, the key findings are presented categorized by their main themes.

The New Space Center plays a pivotal role in the evolution of the space ecosystem, serving as a linchpin across various key areas outlined in Table 1. Within the realms of education and skills development, the Center spearheads innovative programs and partnerships that bridge the gap between theoretical knowledge and practical application in space sciences. By collaborating with academic institutions and industry leaders, the Center engages in various activities to equip ecosystem members with the necessary expertise and insights. Through the ecosystem members, the Center's contribution extends beyond networking to

Table 1 Enhancing the New Space Economy: the role of the Kvarken Space Center in developing the space ecosystem

Category	*Key findings/insights*
Open development activities	– Open development signifies collaboratively finding new ideas within innovation projects – The significance of establishing an innovation ecosystem for new space – Emphasis on fostering dialogue, meetings, and shared interests
Industry interviews	– Widespread interest in new technology and space-based data applications – Few companies currently integrate space-based data – Limited comprehension of data access and its potential uses
Satellite remote sensing	– The feasibility of satellite remote sensing for local applications remains uncertain – Publicly available data often lacks the necessary resolution – Notable value in remote geographical areas and activities requiring PNT data
Business Development Workshop	– Focus on enhancing traceability in waste management – Interest in applying space-based data to developing nations – Exploration of current ESA funding opportunities
Ecosystem Workshop 2022	– Space-based data often plays a role in a multifaceted value chain – The importance of education and expertise in space utilization in Finland
Skill and competence development	– The need for understanding and utilizing space-based satellite data – The importance of advancing machine learning and data science education – Emphasis on mastering AI algorithms and general business acumen
Working model	– A model that amalgamates relevant stakeholders to devise solutions – Merging funding mechanisms with tangible business challenges

(continued)

Table 1 (continued)

Category	*Key findings/insights*
Industry feedback	– Recognizing a company's value within the ecosystem – The necessity for infrastructure and business incubator services – The expertise, skills, and services offered to the ecosystem
Kvarken Space Center role	– Serving as a nexus that connects various stakeholders – Promoting Finnish-Swedish cross-border collaboration
Development initiatives	– The need to heighten awareness and stakeholder commitment – Advocacy for the New Space Economy – Organizing events centered on business opportunities and novel technology

community engagement, fostering advancements in technology and business opportunities, thereby reinforcing its integral position within the space ecosystem's fabric.

5 Conclusion and Further Research Directions

Several significant empirical findings and implications for the development of a sustainable space innovation ecosystem in the Kvarken region have been identified and several key elements can be underscored. As discussed, coordination efforts to support early-stage ecosystem emergence and development are required, therefore the following should be considered:

1. **Continuous Innovation Pipeline**: Essential for generating new ideas and solutions, the establishment and nurturing of an innovation pipeline is a primary consideration.
2. **New Space Projects and Industry Support**: Crucial for applying theoretical concepts and realizing economic benefits, the introduction and industry support of New Space Economy applications is vital.

3. **Business Incubation and Mentoring**: Providing incubation and mentoring to start-ups and spin-offs is necessary to foster new business growth and entrepreneurial activities in the space economy.
4. **Identification of Business and Funding Opportunities**: This is vital for the financial sustainability of the space innovation ecosystem.
5. **Local/Regional Innovation Infrastructure**: Building and enhancing infrastructure is important for collaboration and resource sharing among different ecosystem actors.
6. **Event Organization**: Focusing events on business opportunities, new technology, and networking is important for knowledge sharing and value creation (e.g., Business Development Workshops).
7. **Stakeholder Awareness and Engagement**: Enhancing awareness, engagement, and commitment toward the New Space Economy is critical for fostering an innovation-supportive environment.

In addition to these elements, the collaborative Business Development Workshop model developed for encouraging involvement of relevant actors in solution creation, potential project piloting, and funding should be further explored. The model represents a practical approach to fostering collaboration and promoting collective efforts in the innovation ecosystem as seen in Fig. 2.

Some significant challenges were also uncovered around capabilities. There is a notable gap in the region regarding the necessary skills and educational opportunities for utilizing space data. Despite the presence of suitable capabilities across almost all areas of the space economy, these resources are not being optimally utilized. Furthermore, sustainable development regarding the new space innovation ecosystem has not been fully realized based on individual actors.

To address these challenges, the Kvarken Space Center has initiated several research, development, and innovation projects in collaboration with local universities and industry representatives. These projects aim to foster a sustainable New Space Economy ecosystem in the region. They have already enhanced awareness, understanding, and utilization of space-based information, leading to the creation of new innovations in the field.

In conclusion, the KvarkenSpaceEco project has established both an invaluable and robust foundation for the sustainable development and evolution of a space innovation ecosystem in the Kvarken region. The project's findings and initiatives serve as a strategic guide for future

Fig. 2 Innovation ecosystem potential overview in the Kvarken region in Finland. The Kvarken Space Center functions as the hub for local and regional activities and gives a single interface to Swedish and international collaboration

advancements in the New Space Economy, while also emphasizing the urgent need for further research. This is particularly salient in the context of early-stage ecosystems in the new space industry, an area currently characterized by a limited body of literature and empirical studies. The challenges and key elements identified by the project offer a fertile ground for future scholarly work in this underexplored domain. Moreover, the project's collaborative model, along with the research, development, and innovation projects it has initiated, represent promising approaches to addressing these challenges. As there is currently limited research available on early-stage ecosystems and their establishment, this paper offers a single case perspective for future research efforts into uncovering rationale and mechanisms for early-stage ecosystem development, especially in the new space industry. Therefore, there is a prevailing need for further

studies that delve into the complexities and nuances of early-stage space innovation ecosystems, thereby fostering a more sustainable and robust space innovation ecosystem in the Kvarken region and beyond.

To promote the development of space technology and harness the commercial potential of the emerging space industry, the following policy recommendations are presented:

1. **Facilitating Regional Networking and Collaboration**: Foster and deepen networking among regional stakeholders in the space industry. Encourage collaboration and knowledge exchange among local space-related organizations, universities, and businesses. This recommendation is based on points 1, 2, 3, 4, 5, 6, and 7 in the Conclusions.
2. **Enhancing Public–Private Partnerships**: Foster collaboration between government bodies and private enterprises in the space sector. Encourage joint ventures and public funding in private space initiatives to accelerate technological advancements and commercial viability. This recommendation is based on points 1, 2, 3, 4, and 5 in the Conclusions.
3. **Supporting Education and Workforce Development**: Invest in educational programs and training facilities focused on space technology and research. Promote STEM education to build a skilled workforce equipped to meet the demands of the growing space industry. This recommendation is based on points 1, 2, and 4 in the Conclusions.
4. **Encouraging International Collaboration**: Promote cross-border cooperation, particularly with Sweden, to jointly participate in the New Space Economy, proceed with economic steps toward a new space product and service industry, and to meet the capacity requirements of infrastructure, education, and innovation in the field of commercialization and utilization of space. This recommendation is based on points 2, 4, 5, 6, and 7 in the Conclusions.

Appendix

Thematic culmination points from the interviews:

Interviewee	*Theme*	*Related point to consider*	*Applicability to ecosystem elements*
Informant A: ICT Manager	Smart transport and data integration	Exploring IoT and location data for fleet management and asset tracking	1, 5
Informant B: Business Development Director	Integration of business in development projects	Need for engineers with natural sciences background and business understanding	2, 3
Informant C: Leading Specialist	Digital solutions for data management	Increasing importance of data science and GIS in product and service offerings	1, 2, 4
Informant D: CEO	Collaboration in the ecosystem	Learning about new data opportunities and integrating them into workflows	2, 6, 7
Informant E: Program Manager	The need for multi-talented individuals in future skills	Understanding the interplay between systems and the concept of time	1, 2, 7
Informant F: Area Manager	Solving customer challenges with technology	N/A	2, 3
Informant G: CEO	Interest in measuring technology and analytics in space	Potential in hardware and analytics for upstream and satellites	1, 2, 4
Informant H: Energy and Maritime Director	Material management and seafare optimization	Utilizing container tracking and positioning, voyage optimization challenges	2, 5
Informant I: Program Manager, Energy Distribution	Network monitoring and maritime data utilization	Time synchronization, utilization of wireless and satellite for backup, navigation, and vessel use optimization	1, 4

(continued)

(continued)

Interviewee	*Theme*	*Related point to consider*	*Applicability to ecosystem elements*
Informant J: Vice President	Data analytics and ecosystem engagement	Advise on active ecosystem establishment and engagement with companies and students	2, 6, 7
Informant K: Research and Development	Real-time information and infrastructure understanding	Application of satellite imagery in infrastructure and maintenance	2, 4
Informant L: ICT Director	Usability of open-source remote sensing data	Challenges in spatial resolution and data frequency	1, 5
Informant M: Project Manager	Utilization of GIS data and software	Contribution of development activities to commercial products	2, 4
Informant N: Vice President	Introduction to space-based data	Interest in ecosystem providing relevant application information	2, 7
Informant O: CCO	Openness to ecosystem cooperation	Interest in more available information and collaborative activities	1, 2, 7
Informant P: Associate Professor	Importance of start-ups and new ideas	Need for critical mass and collaboration among various stakeholders	1, 3, 4, 7
Informant Q: CEO	Facilitating concrete ecosystem activities	Strategies for creating sustainable business flows within the ecosystem	3, 4, 5
Informant R: Lecturer and Researcher	Trends, capabilities, and collaborative projects	Understanding technology trends, mapping capabilities, and analyzing opportunities for collaboration	1, 3, 5
Informant S: CEO	High-resolution imagery and skill development	Need for high-resolution data, machine learning, and data science skills	3, 4, 5

(continued)

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Interviewee	*Theme*	*Related point to consider*	*Applicability to ecosystem elements*
Informant T: Project Controller	Utilization of space-based data and blockchain	Systems development utilizing space-based data, drone inspections, and interest in hackathons	1, 6

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The Space Economy: Review of the Current Status and Future Prospects

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1 Introduction

Space, once the final frontier and a symbol of human aspiration, has transitioned from a realm of exploration to an indispensable backbone of our global infrastructure. Since Neil Armstrong's historic lunar step in 1969, our reliance on space has expanded exponentially, permeating every facet of modern life. From satellite-assisted navigation to global communication networks, space systems have become integral to both civilian and military operations. Beyond its immediate applications, the burgeoning space economy stands testament to the increasing commercial and strategic value of space. As we stand on the cusp of a new era, the development and growth of the space economy not only promise unprecedented opportunities but also underscore the need for sustainable

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and responsible utilization of the space domain. Space harbors immense untapped potential to address future crises, stimulate job creation, and foster innovation within the space industry (European Commission, 2016), and it is widely anticipated that, in the forthcoming years, space entrepreneurs offering economical and accessible space strategies will be instrumental in shaping the progression of the space economy (Peeters, 2021). Access to space is invariably viewed as a critical component of sovereignty and autonomy. The metamorphosis of the space sector into the contemporary space economy symbolizes a nascent industry, stemming from regulatory shifts, the influx of novel contenders, and the inception of space agencies partnering with businesses to foster space advancement (Denis et al., 2020; Weinzierl, 2018).

Academic analysis of the economic aspects of space activities has gradually matured into a specialized field, yet the task of comprehensively classifying and as such, understanding the space economy continues to present significant challenges (OECD, 2020, 2022; Weinzierl, 2018). In advanced economies, the complexity of the space economy is becoming ever more evident, and the distinction between activities related to space and those that aren't is progressively diminishing (Profitiliotis & Loizidou, 2019b).

While space economy research has rightfully begun to garner broader academic attention, it still remains fraught with ambiguities and misunderstandings. One of the most significant gaps is the absence of a comprehensive theoretical framework specifically tailored for understanding and classifying the activities of the space economy in terms of international business and their linkage to the broader economy. Existing theories in economics and business, while providing initial scaffolding, seem to not fully encapsulate the unique complexities and multidisciplinary nature of

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space activities. This absence not only hinders nuanced, targeted research but also limits our understanding of various business intricacies within the domain. Moreover, despite the growth in data availability and the maturation of the field, there is a conspicuous absence of standardized metrics and frameworks for assessing the space economy globally. This lack of standardization not only hampers cross-national comparisons but also poses challenges for policymakers and stakeholders in making informed decisions.

Furthermore, previous literature has not adequately addressed several pivotal questions. The establishment of international standards to ensure the comparability of space economy statistics across different countries remains an unresolved issue (OECD, 2022). The role of new entrants, such as business enterprises in space activities, is evolving, but the future industry dynamics are not yet fully understood (Denis et al., 2020; Profitiliotis & Loizidou, 2019b). Policymakers must contemplate how enhanced statistics on the space economy can guide policy decisions and investments in the space sector (Emen, 2020).

There seems to be an urgent need for a unified framework to comprehensively categorize the economic activities within the space economy, considering its multifaceted nature and diverse impacts on the broader economy. Such a framework should ideally integrate international business theories specific to the space economy, providing a structured perspective for examining this emerging field. As this area of study is novel and evolving, our study aims to act as a proof of concept, identifying foundational principles for developing such a framework. We propose using a modified version of the OECD approach as a basis for this framework. This approach, detailed in the OECD Handbook on Measuring the Space Economy, encompasses a broad spectrum of economic activities within the space domain (OECD, 2020).

Using the said approach, our aim for this chapter was to identify key enablers and areas of challenge within the space economy, so that we could gain a better understanding of the macro-level potential and challenges of the domain, while simultaneously testing the feasibility of the proposed framework for such research. In order to achieve a broad coverage of the economic activities within the space economy, we have conducted a systematic literature review meticulously selecting and examining a range of academic sources specifically focused on the space economy. Our approach proved fruitful as we were able to identify a significant number of macro-level trends that have played important

roles in the emergence of the space economy and those that may guide its development in the coming years. Ultimately, by providing such a common frame of reference, our goal is to ensure that the benefits of space exploration and commercialization are maximized and responsibly managed for the sustainable growth of the global economy.

2 Methodology

2.1 Selection of Relevant Articles

A systematic literature review was employed as our primary research method. This approach is renowned for its effectiveness in delivering a comprehensive and current understanding of specific themes. It enables an in-depth exploration of the research topic, allowing for a nuanced comparison and contrast of findings from previous studies (Paul & Rialp Criado, 2020). In identifying relevant literature, we adhered to a rigorous process that included systematic search strategies and evaluative criteria, as advocated by Littell et al. (2008) and Palmatier et al. (2018) (Littell et al., 2008; Palmatier et al., 2018; Paul & Rialp Criado, 2020). This method ensured a thorough and unbiased collection of pertinent studies, setting a solid foundation for our research. First, we applied search words to find relevant literature published between 2018 and 2022. The keywords (space economy, satellite account, new space economy, space economic, and space economics) were selected based on the aim of this study, and they should appear within titles, abstracts, or the entire content. The timeframe for the chosen articles is based on the 2nd edition of the OECD Handbook on measuring the space economy, which highlights that the most important space economy literature has been published after 2017. To find relevant literature, we utilized six main databases covering a wide range of publications across different disciplines in business, economics, information systems, engineering, and so on to ensure that we obtained all relevant articles on the topic. The databases employed were SAGE, SCOPUS, IEEE, ABI, EBSCO, and Taylor and Francis. The search was conducted between September 13, 2022, and September 19, 2022, and again between January 6, 2023, and January 8, 2023. To maintain academic quality of the study, we focused on peer-reviewed academic publications and excluded marketing and industry reports. Table 1 demonstrates the inclusion/exclusion criteria for articles found

Table 1 Selection process and criteria for accepted articles

Phase 1	*Phase 2*	*Phase 3*	*Phase 4*	*Phase 5*	*Phase 6*
Database query (13.9.—19.9.2022): SAGE, SCOPUS, IEEE, ABI, EBSCO (Academic Search Elite, Business Source Premier, eBook Collection and Regional Business News) and Taylor and Francis	Titles and abstracts were verified, and selection was made based on them	Only publications written in English were accepted	Articles were read and those that did not deal with the space economy were eliminated	New database query 6.1.-8.1.2023 (articles after the first query to 31.12.2022), phases 2 to 4	Articles were categorized based on the findings in an Excel table
3258 articles	121 articles	117 articles	57 articles	225 articles, from which 15 fulfilling the set criteria	72 articles

in the databases. Altogether, we found 72 articles that fulfilled selection criteria and were accepted for the ultimate analysis.

2.2 Selection of Relevant Articles

The articles found were published in a wide range of journals, varying from publications focused on space-related issues to more general outlets in the economics and management fields. The most relevant articles were found to be published in the core, leading research journals in space politics and policy, technical knowledge and information, international business, international economics, and international management literature.

There was also a great variation in the journals as the recognized articles were published in 45 different journals, of which seven journals have published more than one article examined in this chapter. The most publications were in Acta Astronautica (14), Space Policy (12), Astropolitics (9), and IEEE Access (3), representing 49% of the total number of selected articles. It is also important to note that space economy research has focused more on publications concentrating on space sciences than on those dealing directly with economic/financial/

commercial research. Based on the years of publication (2018, 11; 2019, 9; 2020, 15; 2021, 11 and 2022, 26), it can be argued that for 2022 a significant increase can be observed compared to earlier years. A total of 214 authors contributed to writing the selected articles, of which 8 authors (Almorad, Al-Naffour, Bowen, Dahrouj, Alouini, Li, Loizidou, Profitiliotis, and Saeed) contributed to two different articles. Based on this, it can be claimed that no single author can be identified as a definite leader in space economy research.

When examining the articles from both geographical and organizational perspectives, it is evident that the majority of the research is focused on the United States, followed by China and Europe (EU). In contrast, Russia's role is highlighted more for its historical achievements in space conquest than for its recent innovations in the development of the new space economy. When doing a similar comparison for organizations (companies) studied, the dominant role of SpaceX and other US companies in shaping the development and management of the new space economy is prominent.

In our research, we have adopted the classification of space activities into segments as outlined in the OECD Handbook on Measuring the Space Economy (OECD, 2020). This classification includes eight well-established segments; Satellite Communications, Positioning, Navigation and Timing (PNT), Earth Observation (EO), Space Transportation, Space Exploration, Science, Space Technologies, and Generic Technologies or Components that enable space capabilities. Like some organizations, we categorize "defense" as a distinct application within our framework to clearly differentiate between civilian and military activities in the space sector. Furthermore, our systematic literature review has identified three additional categories that are useful in the classification of economic activities within the space economy. These are:

1. **Co-operation:** This category emphasizes the importance of collaborative efforts and partnerships in the space sector. It includes international, intergovernmental, and commercial collaborations which are pivotal in advancing space exploration and technology.
2. **Legal:** The legal aspect covers the regulatory frameworks and legal considerations necessary for space activities. This includes space law, policies governing space exploration, and the use of outer space.
3. **Satellite Orbit/Constellation/Size:** This category delves into the technical specifics of satellite deployment, including considerations

of orbit types, satellite constellations for various applications, and the size and capabilities of different satellites.

By incorporating these additional categories derived from our literature review into the OECD's framework, our chapter offers a more comprehensive and nuanced understanding of the space economy, reflecting its evolving and multifaceted nature.

3 Findings

3.1 Emergence of a Sustainable Commercial Space Economy

The evolution of the space economy can be traced through three distinct phases: government-driven, industry-driven, and entrepreneur-driven. The first phase was characterized by government institutions such as NASA playing a central role in the sector, procuring from aerospace firms and undertaking major space missions driven by national prestige (Bowen, 2018b; Emen, 2020; Peeters, 2021; Tucker & Alewine, 2022). The launch of Russia's Sputnik I in 1957, which stimulated both the space race and the rapid development of international space law, was further shaped by the competitive dynamics of the Cold War, particularly the "Space Race" between the United States and the Soviet Union (Bashlakov-Nikolaev et al., 2022; Emen, 2020). That is, the ability to launch satellites and send humans to space was seen as a demonstration of technological prowess and economic strength, contributing to a nation's international standing and influence. This prestige factor continues to play a role in the space programs of both established and emerging spacefaring nations (Cvetkovic et al., 2022; Rementeria, 2022).

In the second phase, commercial space applications became prominent, transforming the dynamics of the space industry. Previously dominated by public actors and their prime business contractors, the industry began to attract new commercial entities. Decades of consistent public funding and government backing propelled this transition, allowing space technology to drive expansion in other segments with a more commercial orientation (Profitiliotis & Loizidou, 2019b). The growth of the space economy is mostly enabled by advancements in various space technologies, governmental support, and the strategic importance of these technologies for defense and military purposes. Governmental support has been a critical enabler for the growth of the space economy (Denis et al., 2020;

Lambakis, 2018; López et al., 2018). The ability to monitor and collect data about the Earth's surface and atmosphere from space provides a strategic advantage in terms of situational awareness and intelligence gathering. While space activities were largely state driven, they began to involve private companies as collaborators in space research activities (Emen, 2020).

A surge of entrepreneurial involvement, powered by equity funding, characterizes the third phase, new space. The emergence of disruptive innovations has created new markets and value networks, often initiated by outsiders and entrepreneurs. The space economy has experienced this disruption, leading to significant shifts in established market dynamics (Denis et al., 2020).

3.2 Enablers of a Sustainable Commercial Space Economy

Based on our literature review, we identified seven segments that seem to have acted as enablers for the emergence of a sustainable space economy. Those were defense, PNT, space exploration, space transportation, satellite communications, EO, and science. Among these, the need for defense, PNT, space exploration, and space transportation solutions stand out as the primary drivers for space-related economic activities in the emerging days of the space economy. These four main drivers are elaborated in detail next.

Firstly, defense emerged as a paramount consideration due to historical and sustained investments in space for defense purposes, as elaborated in 31 articles. These investments have led to technological breakthroughs and infrastructure developments fundamental to the growth of the space economy. The genesis and evolution of the space economy were significantly influenced by nations' defense and military imperatives. Discoveries about the vulnerability of space assets prompted a strategic shift toward the importance of space for national security and corresponding investments in space technologies (Bowen, 2018b; Lambakis, 2018). The military focus in space extended beyond merely protecting national interests, evolving into an instrument of geopolitical dominance and reshaping international relations. In this light, the launch of satellites and advanced space weaponry became symbols of global influence, not just military assets (Rementeria, 2022). The private sector's involvement in defense has spurred innovation through public–private partnerships, igniting debates

over the commercialization of national security. While these collaborations introduced dual-use solutions and cost efficiencies, they also underscored the need to balance innovation with control over essential military capabilities (Chavy-Macdonald et al., 2021; Lickfold & Jetter, 2019). International rivalries in space, exemplified by milestones like the moon race, intensified this drive, with nations investing heavily in space technology to assert supremacy (Rementeria, 2022; Szocik, 2019). Notably, while many space technologies are developed exclusively for civilian (peaceful) use, innovations such as PNT or satellite communications remain crucial for various defense and security agencies, and their development cannot always be easily categorized easily into strictly military or non-military solutions.

Secondly, PNT services played a central role in driving the growth of the space economy. This was indicated in 26 articles. The significance of these services, which play a key role in a wide variety of applications on Earth, from navigation and logistics to telecommunications and disaster management, is underlined. The demand for dependable PNT services has spurred investment and innovation in the space sector, thereby increasing its growth. The rapid expansion of the space economy is intricately tied to the advancement of PNT technologies, as clearly demonstrated by Global Navigation Satellite Systems (GNSS) such as the US GPS, Chinese Beidou, European Galileo, and Russian GLONASS. These technologies have catalyzed diverse applications, from precision weaponry to financial transactions and agricultural innovations (Bowen, 2018a; Lickfold & Jetter, 2019). The role of governments in the PNT sector has been pivotal as PNT has strategic importance in several domains such as national security, environmental management, and agriculture (Aloini et al., 2022; Bowen, 2018a, 2018b; Chavy-Macdonald et al., 2021; Lambakis, 2018; Oyewole, 2020). Further, PNT infrastructure greatly elevates a nation's international prestige and technological stature (Rementeria, 2022; Weinzierl, 2018).

Thirdly, based on 45 (24 + 21) articles, space exploration and space transportation have also had a crucial influence on the formation of a space economy (Alewine, 2020; Bi et al., 2022; Elvis & Milligan, 2019; Jakhu et al., 2020). These technologies, ranging from launching satellites into orbit to enabling human space travel, have revolutionized various sectors, including defense, finance, agriculture and maritime traffic management, becoming an integral part of our global, wireless, and mobile information infrastructure (Bi et al., 2022; Lambakis, 2018;

Weinzierl, 2018). Simultaneously, these advancements in space transportation systems have played a vital role in broadening access to space, thereby fostering the expansion of the space economy through cheaper and easier delivery methods for hardware, that is essential for providing other space economy-related services (Bi et al., 2022; Chavy-Macdonald et al., 2021; Kumar et al., 2020).

3.3 Present Status of the Space Economy and Its Most Essential Elements

Based on the reviewed literature, the present status of the space economy reflects significant growth, diversification, and commercialization of the industry. The commercial space sector is projected to reach a market value of $2.7 trillion by 2045 and encompasses a wide range of activities ranging from space manufacturing and asteroid mining to colonization efforts to other celestial bodies (Toivonen, 2022; Weinzierl, 2018). Governmental interventions have been pivotal in molding the space economy, as they orchestrate regulations that guide business practices and stimulate expansion across diverse domains, encompassing areas such as direct consumer applications and personal entertainment (Argentiero & Falcone, 2020; Toivonen, 2022). The heavy government interest toward the sector is also unlikely to disappear, due to its high weight in many critical fields. As Jakhu et al. (2020) put it, the space sector acts as a kind of linchpin for numerous industries, with an array of over 2200 satellites originating from more than 80 countries delivering several services across the globe. It could be said that organizations delivering services within the space economy context are primarily enablers for other segments. Next, we present eight key elements of space economy. Satellite orbit and constellation size has not been discussed as a unique theme, as it is covered within other satellite-related factors. Table 2 presents each of the segments in terms of how the analyzed literature sees the segment in terms of developments in the space economy. It is notable that many of the segments are seen both as slowing down the space economy development, while at the same time offering significant potential. This is logical, because if the challenges within the said segments can be overcome, it would offer huge future potential.

Satellite communications have become a cornerstone in the evolving space economy, with their applications permeating various sectors, from telecommunications and broadcasting to remote sensing and the Internet

Table 2 Amount of literature mentioning a specific space economy segment, grouped by narrative presented in the mentioning literature

Segment of the space economy	*Slowing down the development of the space economy*	*Created the basis for space economy growth*	*Requirement for the space economy to develop*	*Future potential for the space economy*
Co-operation			37	8
Defense		31		20
Earth Observation (EO)		16	3	38
Generic technologies or components that may enable space capabilities	18		42	51
Legal	18			
Positioning, navigation and timing (PNT)		26	3	26
Satellite communications		18	3	43
Satellite orbit/ constellation/size			22	55
Science	5	9	4	36
Space exploration		24		45
Space technologies	43		31	53
Space transportation	4	21	25	44
Grand total	**88**	**145**	**170**	**419**

of Things (IoT). As the global space economy approaches a valuation of over $350 billion, satellite services, particularly communications, are poised to account for a significant portion of this growth (Lauer, 2022). The ubiquity of these services, essential for internet connectivity, has expanded their reach to all nations (Lambakis, 2018). The integration of 5G and 6G technologies with satellite systems is heralding a new era in satellite-enabled services, promising reduced communication latencies and enhanced global internet service (Ho-Baillie et al., 2022; Hoyhtya et al., 2022; Jha et al., 2022; Saeed et al., 2021). Mega constellations, exemplified by initiatives like Starlink, are reshaping the satellite communications paradigm, offering ease of deployment and use.

PNT services, including GNSS, are foundational to, e.g., aviation, marine transportation, financial services, and military operations. They ensure precise navigation, timing, and efficient data transmission, highlighting their economic and strategic significance (Bowen, 2018a; Van Camp & Peeters, 2022). The rising demand for PNT services underscores their diverse applications, from aiding accurate navigation in aviation to ensuring transaction timestamp in finance or providing location-based mobile applications. Their military potential is also paramount, bolstered by satellite constellations and private investments, offering strategic advantages in operations and communication (Rementeria, 2022). The blend of governmental and commercial interests in PNT has spurred investments and advancements, but addressing challenges, such as orbital congestion and electromagnetic spectrum saturation, is essential for sustainable growth (Bowen, 2018a; Chavy-Macdonald et al., 2021).

Earth Observation (EO) technologies have become central to the space economy, expanding their capabilities from tracking military maneuvers to monitoring environmental changes. The commercial sector's access to advanced imagery underscores EO's indispensable role in modern society (Bowen, 2018a; Chavy-Macdonald et al., 2021). The pressing environmental challenges of today necessitate innovative satellites and sensors. Reduced costs, rapid technological advancements, and the rise of small satellite manufacturing are beginning to meet this demand. Emerging trends in EO, particularly in low earth orbit (LEO) constellations, are beginning to provide continuous video from space. This, coupled with the development of image analytics services, is opening new markets, and solidifying the importance of EO across traditional sectors such as climate monitoring and defense, but also pushing the services to new sectors such as finance. As technology advances, the role of EO-services continues to grow, promising innovative opportunities in both public and private sector (Denis et al., 2020; Rementeria, 2022).

Space transportation has, especially in the past few years emerged as a pivotal component in the burgeoning space economy, with its trajectory shaped by factors such as cost, delivery time, and technological risk acceptance (Denis et al., 2020; Rementeria, 2022). The influx of new entrants aiming to democratize access to space and reduce launch costs underscores the segment's significance (Friel, 2020). This trend is exemplified by companies such as SpaceX, which have revolutionized the industry with innovations such as reusable rockets and competitive launch

systems (Denis et al., 2020). Historically, space transportation was dominated by national entities, with orbital launchers primarily serving military objectives (Denis et al., 2020). However, the contemporary landscape is witnessing a shift characterized by the democratization of space and a burgeoning commercial sector. This is also opening significant opportunities for other parts of the space economy, as the cost of delivering essential payloads to orbit and beyond is dropping rapidly.

Space exploration began in 1957 and has since been a catalyst for technological revolutions culminating in human spaceflight. Historically dominated by state actors, the domain is now witnessing a transformative shift with the entry of commercial and private stakeholders, adding new dimensions to the exploration narrative (Kumar et al., 2020; Marzuki & Newell, 2021). The impetus provided by space exploration has spurred the inception of novel technologies and industries. Establishments such as lunar bases are potential testbeds for cutting-edge technologies that encompass energy generation, water processing, and space robotics. These innovations symbolize the profound knowledge generation intrinsic to the contemporary space sector (Argentiero & Falcone, 2020; Bi et al., 2022). Furthermore, the exploration of celestial bodies, such as Mars, has become a tangible reality, yielding a vast magnitude of data. The diminishing resources on Earth have pivoted attention toward the potential of extraterrestrial resource extraction, marking a transformative phase in space utilization (Bi et al., 2022; Jakhu et al., 2020).

Science encompassing human spaceflight is a pivotal component of the space economy. Such pursuits not only establish a distinct market but also catalyze the inception of innovative technologies, which subsequently find commercial applications. The escalating environmental challenges and the imperatives of climate change have accelerated the development of advanced satellites and sensors, delivering indispensable meteorological and climatic insights (Denis et al., 2020). The cost-effective "CubeSat" satellites are also pivotal for space exploration and scientific missions, aiming to augment our understanding of diverse scientific domains such as astronomy, heliophysics, and planetary science (Saeed et al., 2020). International collaboration in space science and research is intensifying, with nations combining their expertise and resources. The indispensable role of governments in nurturing the space industry cannot be understated. State patronage facilitates the realization of avant-garde space technology and research, subsequently bolstering national defense capabilities (Wu, 2018).

The evolution and proliferation of space technologies have been pivotal in augmenting our understanding of the cosmos and yielding myriad benefits for humanity. The International Space Station (ISS) epitomizes this, serving as a nexus for cutting-edge technology and research, enriching domains from human health to global education and the burgeoning space economy (Emen, 2020). The horizon for space technology applications is vast and ever-expanding. However, the rapid expansion of space technologies has ushered in challenges, notably concerning space sustainability. For instance, the quandary of space debris has emerged as a focal point, with an estimated 300,000 potential satellite-destroying debris fragments in orbit (Emen, 2020). Addressing this conundrum necessitates concerted efforts, encompassing national and international regulations, and innovative solutions such as insurance incentives for debris mitigation (Harrington, 2020). In sum, space technologies, while offering a plethora of opportunities and benefits, also introduce challenges that mandate astute navigation.

The integration of generic technologies and components has been a game changer in the space sector, ushering in unprecedented capabilities and prompting even faster innovation. The incorporation of commercial off-the-shelf (COTS) technologies in satellite production epitomizes this shift, offering a blend of cost-efficiency and streamlined operations (Denis et al., 2020; Weinzierl, 2018). The rise of CubeSats underpinned by COTS components, and the advent of specialized suppliers focusing on cost curtailment through bulk production further accentuate this paradigm shift (Bi et al., 2022; Weinzierl, 2018). Another transformative approach is vertical integration, which combines service operation with satellite manufacturing, bypassing cumbersome contracting and procurement processes, thereby ensuring a seamless supply chain (Weinzierl, 2018). Concurrently, innovative manufacturing methodologies, such as additive manufacturing, are bolstering space capabilities (Bi et al., 2022; Weinzierl, 2018). However, the proliferation of these generic technologies and components is not devoid of challenges. Cybersecurity has emerged as a paramount concern in this context. Addressing these cyber vulnerabilities is imperative to safeguard the integrity and security of space systems (Bi et al., 2022).

3.4 Future Potential and Key Success Factors of the New Space Economy

The space economy is undeniably vast and comprises diverse segments, each with its unique potential for growth and impact. Navigating the intricate boundaries that sometimes delineate these segments can be a formidable task. In the following section, we will outline the most promising segments, drawing from our review of the existing literature.

Our analysis reveals that satellite constellations represent pivotal arenas for future growth, underpinned by technological evolution and the mounting demand for satellite services. The proliferation of satellite constellations, the inclination toward compact satellite missions, and the integration of these advancements with terrestrial networks set the stage for transformative economic growth. The management and optimization of satellite deployment in various orbits is a critical aspect of space operations. The future of this segment is tied to the advancement of technologies that enable a more efficient use of orbits and the development of smaller, more capable satellites. Growth in this segment will likely be driven by the increasing demand for satellite services, from communication to Earth Observation (Barry & Alfaro, 2021; Lambakis, 2018). The recent surge in proposed constellations—over a hundred in 2020—signals both the growth and unpredictability of this segment (Letellier & Lizy-Destrez, 2022). While high-orbit satellites predominantly hail from industry giants, LEO constellations expand their reach, catering to diverse environments, including the Arctic (Hoyhtya et al., 2022). The global trend leans toward smaller satellite missions epitomized by projects such as Starlink, which boasts over 2000 satellites. Moreover, the pursuit of small satellite launchers stems from increasing satellite counts and the blossoming of large constellations, which generated $1.2 billion investment between 2000 and 2016 (Ali et al., 2020; Denis et al., 2020). Enhanced electronics miniaturization which reduces satellite size and launch costs, augments this progression without compromising performance. In summary, the future of the space economy seems to hinge on LEO innovations, vast constellations, and compact satellite technologies, promising transformational growth and integration between satellites and terrestrial technologies.

Space technologies encompass a broad range of systems and applications. From satellite technologies to space-based sensors and instruments,

these technologies underpin the capabilities of the space economy. Technological advancements and the increasing demand for space-based capabilities will shape the future of this segment (He, 2022; Jakhu et al., 2020). Space technologies are poised for extensive and multifaceted advancements. The industry is transitioning toward more interconnected, decentralized systems of systems (SoS), fueled by the imperative of efficient information integration, which is crucial for mission success (Bi et al., 2022). Industry leaders notably advocate for the integration of space and terrestrial networks, especially for applications like remote 5G backhauling (Denis et al., 2020). With milestones such as SpaceX's Crew-1, the paradigm of space travel is shifting, urging NASA (and other governmental institutions) to adapt its strategies to foster public–private collaborations (McCaffrey, 2021). The US Department of Defense (DoD) continues to leverage commercial procurement, anticipating that this trend will intensify. Private ventures are also eyeing innovative space segments, from Martian research to space tourism, with potential planetary protection implications (Profitiliotis & Loizidou, 2019a, 2019b). Simultaneously, a significant proportion of individuals within the high-income bracket express interest in space tourism (Pásková et al., 2021). Conclusively, as the space sector evolves, it will likely become more interconnected and complex, amplifying the roles of private enterprises, and emphasizing public–private collaborations.

The space economy is poised for considerable growth, fueled by generic technologies that enhance space capabilities. Recent strides in democratizing space access, exemplified by SpaceX's reusable rockets, align with the miniaturization trend seen in satellites such as CubeSats, which are pivotal for global IoT connectivity (Bi et al., 2022; Denis et al., 2020). This transformation integrates space and terrestrial networks, heralding a new era of broadband access, especially in remote areas (Denis et al., 2020). The industry's pivot to satellite constellations demands novel, cost-effective manufacturing methods, championing standardized designs and expedited development (Eugeni et al., 2022; Rementeria, 2022). As lunar bases emerge as testing hubs for nascent technologies, from power generation to waste management, sensing technologies also rise in prominence for both terrestrial and space object tracking applications. With further space explorations, the surging data is bound to underscore the importance of continual space tech innovations (Bi et al., 2022). Fundamentally, propulsion systems, communication modalities, and advancements in materials science serve as the foundation

of this booming space economy, driving unparalleled economic growth and fostering innovation (Barry & Alfaro, 2021; Lambakis, 2018).

Space exploration, which encompasses, e.g., human spaceflight, robotic studies, and potential colonization, is a key driver of the future space economy. Companies like Blue Origin and SpaceX, with their ambitious plans, catalyze investments and technological advancements in this domain (Barry & Alfaro, 2021). There is growing attention toward mining resources from celestial bodies such as asteroids and the Moon, underlined by significant private and governmental interest (Feichtner, 2019; Marçal Sanmartí, 2020; Vergaaij et al., 2021). However, under the current framework of international and domestic law, considerable ambiguity exists regarding the legal parameters and guidelines for lunar and asteroid mining activities (Anderson et al., 2019; Steffen, 2022). Satellite technologies play an instrumental role in enabling such ventures, although their economic feasibility remains a subject of debate (Jakhu et al., 2020). The trajectory of this segment is influenced by scientific intrigue, evolving technology, and aspirations to broaden human activities in space (He, 2022; Szocik, 2019). Asteroids could soon bolster astronaut missions in multiple ways. They could serve as resource hubs for deep-space settlements, act as testing grounds for pioneering technologies, and even function as depots or transit vehicles for interstellar journeys (Krolikowski & Elvis, 2019).

Space transportation, which is pivotal to the burgeoning space economy, is driven by cost, delivery time, and technological risks (Denis et al., 2020; Rementeria, 2022). New entrants are reducing launch expenses, and SpaceX's reusable rockets exemplify these advancements. The increasing presence of specialized launch services, such as the deployment of small satellites from the ISS, further underscores this transition (Denis et al., 2020). Countries such as the United States and China have fortified their positions through a blend of government policies and private ventures. The push for commercial launches shows expansive growth in this realm (Pomeroy et al., 2019; Rementeria, 2022). However, despite varied solutions, space transportation remains under significant governmental influence, emphasizing the importance of domestic upstream capabilities. Ultimately, as the segment serves defense, communication and exploration needs, the urgency to advance technology and ensure security grows, underscoring its role in shaping the space economy's future trajectory.

Satellite communications are a segment that has already demonstrated its economic value and is poised for further growth. The demand for reliable and readily available high-speed communication services is growing, and satellite technology is uniquely positioned to meet this demand. The future of this segment will likely be shaped by the development of new technologies and the expansion of services to underserved areas (Jakhu et al., 2020; Lambakis, 2018). Essential to our digital era, these services foster global connectivity, are indispensable to defense, security, and commercial ventures (Lambakis, 2018). Both commercial and defense sectors are increasingly reliant on satellite capabilities (Budning et al., 2021; Lambakis, 2018). The incorporation of 5G/6G into satellite systems signals is a transformative change, offering the benefits of decreased communication delays and an edge over conventional geostationary orbit (GEO) systems (Hoyhtya et al., 2022; Jha et al., 2022; Saeed et al., 2021). Mega constellations such as Starlink further redefine this landscape, complemented by shared ground station networks such as Amazon AWS that centralize data from numerous satellites (Jha et al., 2022). While the potential is immense, this burgeoning reliance calls for heightened security and resilience. Efforts encompass space debris mitigation, secure connectivity systems, and strategies to counteract satellite interference (Hoyhtya et al., 2022; Jha et al., 2022; Lambakis, 2018). The future of satellite communications includes governmental satellite communication solutions, which integrate 5G/6G technologies with security features and quantum solutions (Hoyhtya et al., 2022). Satellite communication's future is vibrant, central to the expanding space economy. Embracing novel technologies, fortifying security, and championing sustainability and regulations will cater to the escalating needs of diverse sectors.

Earth Observation (EO) is a segment with significant future potential. The ability to monitor and collect data on the Earth's physical, chemical, and biological systems have wide-ranging applications, from climate monitoring to disaster management. The growth of this segment is expected to be driven by the increasing demand for data and the advancement of satellite technologies (Argentiero & Falcone, 2020; Budning et al., 2021). The analysis underscores the importance of EO satellites for providing valuable data for various Earth applications, from environmental monitoring to urban planning. Similarly, scientific research in space will continue to lead to numerous technological and scientific advancements, contributing to the growth of the space economy.

4 Conclusion and Further Research Directions

Based on the analyzed literature, it can be noted that the emergence and phenomenal growth of the space economy cannot be attributed to a single or even a few factors. It is rather a complex, multifaceted phenomenon, intricately woven by technological advancements, governmental patronage, and the strategic imperatives of defense applications, that at a later stage have been supported more and more through purely civilian commercial projects. The governmental backbone has been instrumental, providing not only financial but also infrastructural and moral support, catalyzing the sector's growth and ensuring its sustainability. The space economy functions like a self-sustaining reaction, where the demands of one field catalyze the substantial development of others. This interconnectedness makes it challenging to pinpoint a singular cornerstone of the space economy.

In this study, we observed from the literature that defense imperatives, technological advancements, and burgeoning commercial interests are the main catalysts for growth. Historically, the quest for enhanced surveillance, reconnaissance, and communication capabilities has driven nations to invest significantly in space technology and exploration. These early investments, initially spurred by pioneering aspirations and technological curiosity, have matured over time into indispensable tools for national security. This evolution underscores the strategic importance of space within the broader canvas of global geopolitics. At the same time, we are seeing an unprecedented democratization of space, through purely private and civilian initiatives. These mainly commercial activities are taking the previously defense-centric space economy toward new horizons and leading to a transformative evolution of the space economy. However, this journey is interspersed with challenges. The increasing militarization of space, the looming threat of its potential weaponization, and the ever-present concern of space debris necessitate a framework of robust governance, stringent regulation, and international collaboration.

The commercialization of space emerges as a transformative theme in this study. Based on the reviewed literature, transitioning from traditionally government-led initiatives to a more commercial-centric paradigm, the space sector is witnessing a reshaping of its very fabric. At the heart of this commercialization, and the ensuing democratization of space, is the development and proliferation of space-centric products and services tailored for diverse commercial markets, usually entirely outside of the

space domain. This evolution is not only reshaping the industry but is also anticipated to ignite competition, foster unparalleled innovation, reduce operational and entry costs, and unveil novel economic growth avenues. The ripple effects of this transformation are profound, with expectations of substantial job creation, a surge in innovation, and a plethora of opportunities for both established businesses and budding entrepreneurs.

Moreover, the space sector is witnessing a technological renaissance. The fusion of space-specific technologies with generic, terrestrial technologies is expanding the realm of possibilities in space. Pioneering innovations, such as the development and deployment of LEO constellations and the rise of small, versatile satellites, are revolutionizing traditional communication and surveillance capabilities. The democratization of space, further propelled by commercialization, promises to catalyze innovation, broaden participation, and amplify the collective benefits of space activities, setting the stage for an era of inclusive, global space exploration.

In light of these developments, the absence of a dedicated theoretical framework for the space economy becomes increasingly conspicuous. While existing theories provide initial scaffolding, they fall short in addressing the unique complexities of space activities, such as technological challenges, ethical considerations, and international regulations. The development of a bespoke theoretical framework is imperative for targeted research and effective policy formulation. This would not only deepen our understanding of business dynamics in the space economy but also facilitate more robust strategies and cross-border collaboration.

As we stand at the crossroads of the future of the space economy, the landscape offers a rich tapestry of opportunities, intricately woven with challenges. As we navigate this multifaceted landscape, a harmonized, collaborative approach is paramount. This approach, which balances both the potential and inherent complexities of space endeavors, co-operation will be instrumental in ensuring the holistic, sustainable, and beneficial evolution of the global space economy.

4.1 Further Research Implications

The space economy, with its vast opportunities contrasted against inherent challenges, offers a fertile domain for both academic and practical exploration. The analysis of the literature reveals a predominant alignment with the definitions presented in the 2nd edition of the OECD

Handbook on measuring the space economy. The importance of understanding the present state and prospects of national space economies, as delineated in the OECD Handbook, cannot be overstated, as it provides a comprehensive overview of a nation's space economy potential.

This article consistently underscores the strategic significance of defense in space. Historically, investments in space, driven by defense imperatives, have been catalysts for technological and infrastructural advancements that have shaped the trajectory of the space economy. Nations' defense and military priorities have deeply influenced the evolution and growth of the space economy. At the same time academic literature seems to see the future potential more in other segments of the space economy, suggesting that a change might be upon us in this regard, and understanding this shift might prove to be crucial. It is notable, that the segments that have defined the space economy since its beginning days, such as defense, PNT or space exploration are not at the forefront of future expectations, even though their importance and potential remain high.

The literature that we have referenced seems to highlight the increasing role of the private sector in space activities. Their involvement has yielded innovative approaches, increased financial commitments, and initiated a shift in the conceptualization and realization of space missions. While, e.g., the domains of space tourism and space mining are not exhaustively explored in this article, the growing engagement of the private sector advocates a promising trajectory for these and other areas. The innumerable benefits that space exploration offers, from scientific advancements to potential space habitation, further highlight the potential of these new kinds of ventures.

While potential avenues for future research are endless, based on our findings the following areas of research seem to be the most urgent for understanding the whole potential and challenges of the space economy:

- What are the foundational principles and theories that can be developed to understand international business in the context of the space economy?
- How has the OECD Handbook on measuring the space economy been implemented in statistical reporting, and are there discernible differences between countries in terms of space industry development and internationalization opportunities?

- What specific barriers to market entry do companies encounter when expanding into various national space economies, and how do these barriers differ across countries?
- How can a multidisciplinary approach, incorporating international economics, provide a more nuanced understanding of the complexities inherent in the space economy?
- What insights can case studies offer into the economic strategies employed by different countries and companies in the space sector?
- How do different national policies and economic strategies in the space sector compare in terms of effectiveness and impact on the global space economy?
- How is the dynamic between defense and security in space, particularly in the context of increasing commercialization developing?
- What is the role and influence of start-ups in driving innovation and competition within the space sector?
- What challenges and opportunities are presented by LEO constellations and the emergence of small satellites?
- How does the integration of terrestrial technologies into space applications affect the broader technology sector?
- What strategies can be developed to enhance international collaboration and ensure the sustainable and collaborative use of space resources?

Moreover, the imperative for research in international economics as it pertains to the space economy is increasingly evident. Topics such as market entry strategies across different national space economies, the implications of international space law on global trade, and the role of international taxation and financing mechanisms are becoming ever more important when assessing the viability and holistic impact of future space endeavors. These economic considerations are integral to understanding how the space economy interfaces with global, non-space-related markets, and regulatory frameworks, thus likewise affecting how space capabilities are developed. A multidisciplinary approach, incorporating especially international economics, is therefore indispensable for a nuanced understanding of the space economy. This focus on international economics not only enriches existing research agendas but also serves as a critical lens through which to explore the complex interplay between space activities and global economic systems.

At a broader scale our findings also emphasize the need for robust regulatory frameworks to ensure sustainable and equitable access to outer space while addressing potential conflicts and resource conservation. The rising prominence of the private sector, the extensive benefits of space exploration, and the imperative for international collaboration are other key themes that resonate throughout the article's narrative.

4.2 Limitations

As this study operates at the cutting edge of economics-focused new space research, we recognize the potential for imperfections in our selection methodology. Our analysis should be perceived more as a broad exploration and synopsis of the factors shaping the growth of a sustainable (new) space economy and its future, rather than a comprehensive listing of all related works. However, the 72 international academic papers ultimately chosen for our literature review epitomize the most pivotal contributions in this academic domain. While our selection was not entirely exhaustive, it encompasses a substantial and highly indicative collection of scholarly efforts, underscoring the growing attention and significance this subject now commands within the global academic sphere.

We also wish to acknowledge the subject's complexity and novelty and emphasize that the framework we have used in this paper to classify activities within the new space domain is not fully exhaustive. Thus, we see an urgent need for developing a framework that better describes the different levels and relationships of activities not only within the space economy, but also the linkages to the broader, global economy. We also acknowledge that a large amount of the used literature was US-based, though this was also to be expected due to the prominence of the US in the space domain and was not an active choice from the authors. Due to the factors mentioned above, it was quite challenging to construct a comprehensive categorization for "new space" activities.

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Navigating the space frontier: Insights into the current state and future potential of the space economy

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1. Introduction

Space, once a symbol of human aspiration and the final frontier, has evolved into an indispensable part of our global infrastructure, marking a significant transition from a mere destination for exploration to an economic backbone [1]. This paper sets the stage for a comprehensive exploration of the modern space economy, a field characterised by its rapid evolution, immense economic potential, and a shift from defence-driven government initiatives to commercial pursuits. Since Neil Armstrong's historic lunar landing in 1969, our reliance on space has intensified, now influencing every aspect of modern life, from satellite-assisted navigation to global communication networks. The economic significance of space is evident in numerous sectors, with satellite infrastructure playing a crucial role in telecommunications, finance, weather forecasting, and defence. For instance, positioning navigation and timing (PNT) services, originally developed for military applications, now underpin global financial transactions, transportation logistics, and emergency response systems. Without these space-based systems, disruptions in supply chains, telecommunications, and critical infrastructures would be inevitable. As highlighted by Van Camp and Peeters [2], a large-scale failure of satellite networks could severely impact global economies, demonstrating the indispensable nature of space-based capabilities. The burgeoning space economy, which is driven by the increasing commercial and strategic value of space, is on the brink of a new era—one that promises unprecedented opportunities but also highlights the imperative for the sustainable and responsible utilisation of space [3,4].

The space economy has become a rapidly expanding and strategically important domain, influencing industries and economies worldwide. The space economy can be defined as *'the economic space that encompasses all economic activities related to the development, production, operation, and commercialisation of space-based infrastructure, technologies, and services'*. It includes contributions from both the public and private sectors, spanning the manufacturing of satellites, launch vehicles, ground stations, and space platforms as well as the downstream industries that utilise space-enabled capabilities, such as satellite communications, Earth observation (EO), navigation, and scientific research [4,5]. The evolution of the space economy has been significantly shaped by the emergence of New Space, a paradigm shift from a government-dominated model to a market-driven ecosystem. This transformation has been fuelled by private investment, venture capital, and cost-efficient technological innovations, accelerating the commercialisation and democratisation of space activities [1,6]. The New Space economy is characterised by increased competition, modular production techniques, and service-oriented business models, making space-based technologies more accessible, scalable, and integrated across global industries.

The motivation for conducting this literature review stems from the pressing need to understand the economic dimensions of space activities, which have significant implications for both research and practical applications. From a research perspective, the space economy represents a dynamic and rapidly growing field that demands comprehensive analysis to grasp its complexities and potential [3,7]. As space activities transition from government-led initiatives to commercial ventures, it is crucial to examine the factors driving this shift and their impact on economic growth, technological innovation, and international collaboration. In terms of practical applications, the findings of this review provide valuable insights for policymakers, industry leaders, and stakeholders involved in the space economy. Understanding the economic drivers and challenges associated with space activities will enable better decision making and foster innovation, investment, and sustainable growth. Additionally, this review highlights the need for international cooperation to address the regulatory, legal, and ethical issues associated with space activities. By providing a new point of view for the classification of economic activities within the New Space economy, this review will support the development of policies and strategies that

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maximise the benefits of space activities and mitigate potential risks.

Our research addresses the following key questions.

- What are the key factors affecting the future development potential of the overall space economy?
- How have the key development factors changed since the early days of the space economy?

These questions are crucial to investigate because a deeper understanding of these factors can significantly enhance academic research, as well as having important practical impacts on the space economy. For example, identifying economic drivers and barriers helps pinpoint what stimulates growth and what obstacles must be addressed, thus facilitating more effective policy and strategic decisions. Recognising the role of new entrants can shed light on how innovation and competition transform the industry, and establishing robust measurement standards and economic models ensures accurate analysis and sound investment decisions. This improved understanding can drive technological advancements, foster international collaboration, and ultimately contribute to solving global challenges, such as climate change, through enhanced space capabilities.

2. Methodological review and approach

We aimed to address critical aspects of the space economy through our research questions, examining the foundational factors and historical context that led to its emergence, the technological innovations and market dynamics driving its growth, and the status of commercial and governmental activities in space. Additionally, we identified barriers to the development of the space economy—such as regulatory challenges, high costs, and technical risks—and explored the technological, financial, and policy-related requirements for sustainable growth. We also assessed future development potential, focusing on emerging opportunities and the key drivers of the space economy's trajectory.

In taking this approach, we concentrated on various factors influencing the origins and evolution of the New Space economy, with a focus on key drivers such as innovative business models and their impact on global competition [8]. We used an amended version of the framework presented in the *Organisation for Economic Co-operation and Development (OECD) Handbook on Measuring the Space Economy,* 2nd *edition* [4] to classify our findings in an economic context. We focused our literature search on the period 2018–2023, as this period marked a notable surge in relevant research, particularly in the sphere of commercial space applications [3,4]. Our systematic literature review encompassed an extensive search across multiple databases, including SAGE, Scopus, IEEE Xplore, ABI/INFORM, EBSCO (Academic Search Elite, Business Source Premier, eBook Collection, and Regional Business News), and Taylor & Francis. The last database queries were conducted on 9 April 2024, covering literature published up to 31 December 2023.

We employed 'space economy', 'satellite account', 'new space economy', 'space economic', and 'space economics' as keywords to identify and retrieve pertinent articles. However, our methodological approach extended beyond keyword-based analysis to a systematic qualitative review of full texts. Articles were assessed in their entirety to ensure that the identified themes were contextually accurate rather than based solely on the presence of specific terms.

To enhance the rigour of our findings, we applied a structured contextual analysis framework to determine whether key terms were used in reference to historical, contemporary, or future developments [9,10]. This ensured that interpretations of economic drivers and trends were temporally accurate. Additionally, thematic coding was employed to differentiate between incidental mentions of terms and substantive discussions relevant to our research questions [9,10]. Our analytical process involved a two-step approach: (i) quantitative occurrence analysis—mapping the frequency of relevant terms across the dataset to establish broad thematic trends, and (ii) qualitative impact assessment—evaluating how key terms were used within each article, ensuring that terms were not overemphasised based purely on frequency [9,11].

This approach mitigated the risk of disproportionately weighing frequently mentioned but contextually marginal topics while ensuring that critical but less frequently mentioned themes received appropriate attention. In our analysis, term frequency was not assumed to be directly proportional to impact; the significance of a given theme was determined through qualitative evaluation, considering factors such as policy relevance, economic implications, and cross-sectoral linkages [9,11]. This methodological structure allowed us to distinguish systematically between casual mentions of key terms and in-depth discussions pertinent to our research questions. In general, it should be noted that while the tables and graphs displayed throughout this article primarily reference quantitative occurrence, these findings are in line with our qualitative findings. The decision to present the data from a quantitative occurrence point of view was made to provide readers with tangible, easy-to-understand numeric values.

Furthermore, to strengthen the validity of our conclusions, we analysed how each article addressed the identified themes, ensuring that our findings accurately reflected content rather than merely the presence of specific terminology. While this literature review provides a broad view of prevailing discussions in the literature, we acknowledge that it differs from empirical studies using surveys or direct interviews in which researchers' perspectives are explicitly gathered. Future research could complement this literature review with empirical methodologies to further validate and refine our findings [10,11].

We initially identified 4,619 papers through our database search. A multi-phase screening process was then applied (Table 1). After title and abstract screening, we narrowed the scope to 226 papers. We excluded non-English publications, yielding 221 papers, and then conducted thorough full-text reviews. Ultimately, 98 articles were selected for detailed analysis, as they best epitomise the core themes of business model innovation, technological advancement, and the impact of public policy on the space economy [9–11].

To ensure accurate temporal classification, we categorised the findings into three primary historical periods.

1. **Early state-driven phase (1950s–1990s):** Characterised by Cold War era government-led investments, where military applications and national prestige were dominant factors.
2. **Transition phase (1990s–2010s):** Marked by the gradual commercialisation of space activities, including the expansion of satellite services and increasing private-sector involvement, largely through government contracts.
3. **New Space phase (2010s–present):** Defined by venture-capital-driven commercialisation, disruptive innovation, and increased autonomy of private space enterprises from traditional government-funding structures.

This classification allowed us to track how economic drivers evolved

Table 1
Selection criteria for accepted articles.

Phase	Description	Count of Articles
Phase 1	Database query: SAGE, SCOPUS, IEEE, ABI, EBSCO (Academic Search Elite, Business Source Premier, eBook Collection, and Regional Business News), and Taylor & Francis	4,619 articles meeting the set criteria.
Phase 2	The title and abstract were verified, and selections were made based on that information.	226 articles meeting the set criteria.
Phase 3	Publications in languages other than English were excluded.	221 articles meeting the set criteria.
Phase 4	Articles were read and analysed thoroughly. Those that did not fully meet the selection criteria were excluded.	98 articles meeting the set criteria.

over time and to ensure that historical, present, and projected future developments were appropriately contextualised.

The identified articles were published across 49 journals, and the distribution of publications by year (2018–11; 2019–9; 2020–15; 2021–11; 2022–26; 2023–26) shows a notable increase in publication quantity since 2022. In terms of the number of articles published, the top publishing journals for the examined articles were *Space Policy* (17), *Acta Astronautica* (12), *Astropolitics* (9), and *New Space* (5), which accounted for about 44 % of the examined articles. Most other journals identified in this research published only one of the examined articles.

We aimed to identify key factors related to the origins, present status, and future potential of the space economy, focusing on both state and private actor roles. Our review covered a range of journals, emphasising diverse contributions within space politics, policy, and international business. The findings indicate a substantial focus on US companies within the articles (Fig. 1), with particular emphasis being placed on the pivotal role of SpaceX (Fig. 2) in the emerging space economy, especially its entrepreneurial strategies and public–private partnerships.

As we conduct our research at the forefront of economics-focused New Space research, we recognise the potential for imperfections in our selection methodology. Therefore, our analysis should be perceived primarily as a broad exploration and synopsis of the factors shaping the growth of a sustainable (new) space economy and its future rather than a complete listing of all related works. The 98 international academic papers chosen for our literature review nevertheless epitomise the most pivotal contributions in this academic domain. We wish to acknowledge that our aim is to provide the academic community with a foundation for the examination and classification of these activities. Due to the factors mentioned above, it is challenging to construct a comprehensive categorisation system for 'New Space' activities, which is why we have taken the first steps in that regard in this paper.

3. Quantifying the multidimensional space economy: challenges, governance, and evolving segments

When defining the space economy, particularly within developed economies, we encounter the significant challenge of distinguishing space-related activities from other economic activities. In this systematic literature review, we explored various theoretical frameworks and models intended to clarify the economic dynamics of space activities [1,4,12]. This encompassed economic theories related to technological innovation, market expansion, and regulatory impacts. By examining the broader context of the space economy, including geopolitical influences, technological advancements, and market trends, we identified and categorised the specific characteristics of various segments of the space economy [4]. This approach enabled us to understand the unique attributes and economic contributions of each segment. Our methodology involved sourcing data from multiple databases and academic journals, screening articles using relevant keywords, and synthesising the findings of the selected studies.

According to the OECD [8], the rapid evolution of commercial space activities necessitates a dynamic and nuanced understanding of the space economy. This evolving landscape is further complicated by the lack of a uniform definition of the space economy, leading to inconsistencies in the literature. To address these inconsistencies, our research employs the framework provided by the *OECD Handbook on Measuring the Space Economy* [4] as a baseline. The OECD framework classifies the space economy into the following key segments: (1) satellite communications, (2) PNT, (3) EO, (4) space transportation, (5) space exploration, (6) science, (7) space technologies, (8) generic technologies or components that may enable space capabilities, and (9) defence.

In addition to these established segments, our literature review identified three emerging structural factors that frequently appear in contemporary research: cooperation, regulation, and satellite constellations. These elements did not originate from the OECD classification but were derived directly from our systematic literature review, representing an original contribution of this study. Their inclusion reflects a clear empirical emergence from the analysed corpus of articles rather than an arbitrary addition. The selection of these three specific categories was based on a systematic content analysis, wherein they repeatedly appeared across multiple sources as key determinants shaping space-related economic activities.

The criteria for inclusion were.

- Recurrence in scholarly discourse: These themes were consistently referenced as pivotal influences on the space economy across numerous studies.

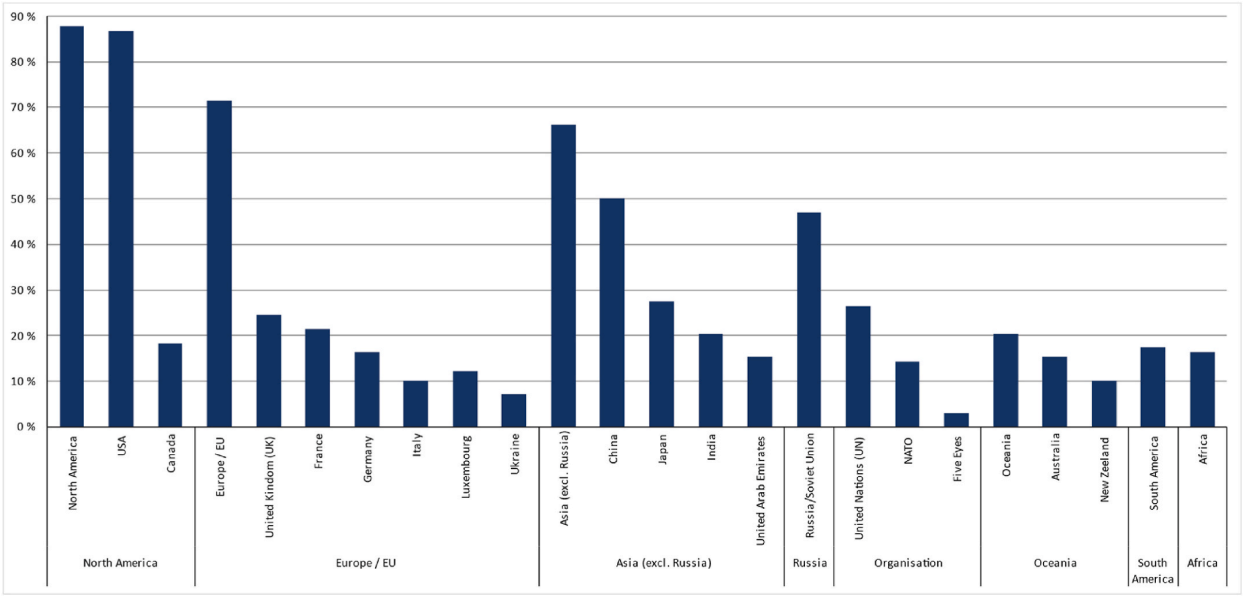

Fig. 1. Share of articles featuring selected geographic areas or governmental organisations.

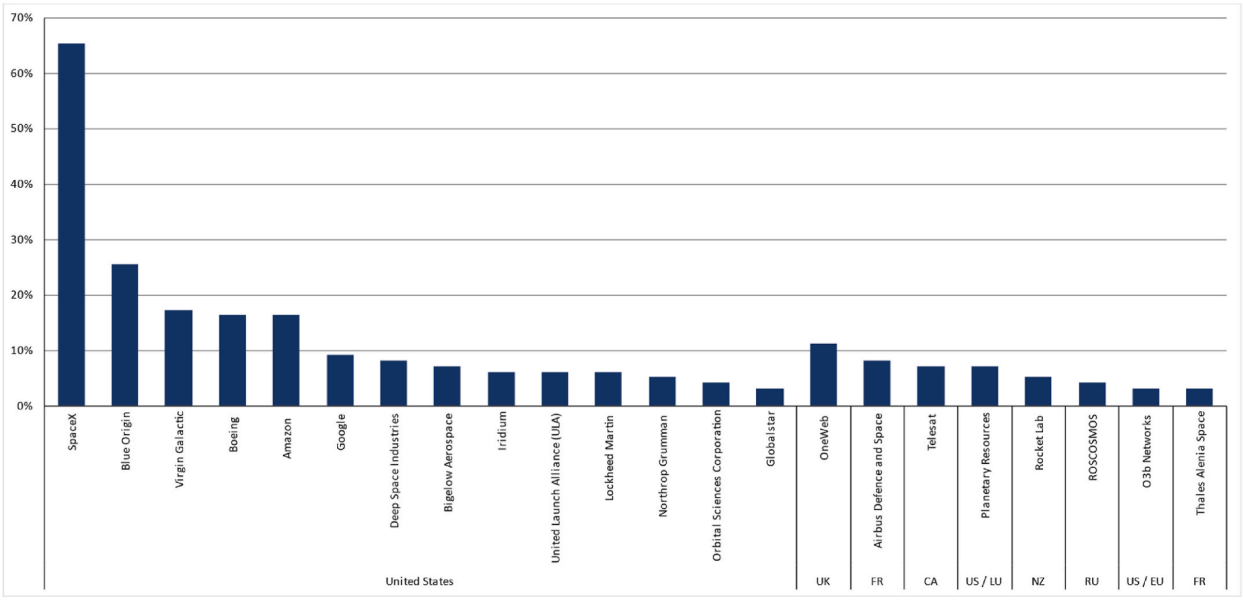

Fig. 2. Share of articles mentioning a certain company (where N > 1).

- Distinct economic and strategic impact: Unlike many general themes, these categories demonstrated a direct and traceable influence on space-sector investment, policy formation, and market structuring.
- Interconnection with OECD-defined segments: While the OECD classification categorises economic activities, these three elements function as cross-cutting structural determinants of growth, shaping the development and expansion of those activities.

It is important to clarify that these categories do not compete with or attempt to replace the OECD segmentation. Instead, they complement and enhance it by addressing key external drivers that influence the development of OECD-defined space activities. The OECD classification delineates space-related industries (such as PNT services, space transportation, and satellite communications) by their economic function. In contrast, cooperation, regulation, and satellite constellations are systemic factors that influence the evolution of these industries rather than constituting distinct economic activities themselves [4].

To illustrate this distinction.

- Cooperation (e.g. international partnerships, joint ventures, public–private collaborations) is a governance and economic enabler, shaping how OECD-classified activities are conducted.
- Regulation (e.g. legal frameworks, compliance standards, national space policies) defines the operational environment in which space activities take place.
- Satellite constellations and miniaturisation (e.g. Starlink, OneWeb) represent a disruptive technological shift impacting multiple OECD-classified segments, such as telecommunications, EO, and PNT [4].

By integrating these elements, our research extends the analytical depth of the OECD framework, providing a holistic perspective that captures both the activities themselves and the structural factors shaping their development. This distinction eliminates potential confusion between economic segments and their underlying drivers.

The governance and legislation of space activities are crucial for the space economy's development, ensuring stability in space operations. However, ambiguity remains regarding the specific laws and norms applicable to many space economy activities [3,13]. The 1967 Outer Space Treaty, despite being the principal framework for international cooperation, occupies an ambiguous position regarding space resource use [13,14]. The growing reliance on space systems across civilian markets and military uses has amplified the importance of space politics and economics in global relations [15,16]. As space activities evolve, so does the demand for comprehensive and adaptable space law, emphasising the need for consistent national and international regulatory frameworks to navigate the complexities of space activities.

By adopting the OECD framework and expanding it to include the new categories identified in our literature review, we provide a more comprehensive analysis of the space economy. This approach not only facilitates a clearer understanding of current trends and challenges but also supports the development of targeted policies and strategies that can foster growth in this dynamic sector. Our research highlights the need for continuous refinement of measurement frameworks to keep pace with rapid developments in space activities. As the space economy continues to evolve, incorporating emerging categories and trends into established frameworks will be crucial for maintaining an accurate and actionable understanding of this multifaceted domain.

4. The dawn of the space economy: How it all came to be

The evolution of the space economy has traditionally been segmented into three phases. Initially, space exploration was a state-driven affair, with agencies such as NASA championing endeavours propelled by the quest for national prestige and seminal space missions [12,17–23]. This period was characterised by monumental events such as the launch of Sputnik I, igniting the Cold War's 'Space Race' and shaping the foundation of international space law [20,21,24]. As superpower competition in space began to wane, the landscape shifted, with private enterprises progressively becoming pivotal in this new market, driving technological innovation and heralding a new era in the sustainable development of the space economy [25].

The transition from a government-led space sector to a market-driven, innovation-centric space economy was fundamentally driven by digitalisation. The integration of big data analytics, cloud computing, and AI-driven automation transformed space-based infrastructure into a scalable commercial sector. By reducing operational costs, improving accessibility, and enabling real-time decision making, digital technologies significantly accelerated the commercialisation of satellite services.

Following the Apollo programme, the space industry faced the challenge of sustaining its workforce and industrial capabilities, prompting governments to support early commercial applications such as satellite telecommunications, weather monitoring, and EO. The integration of digital technologies into space-based infrastructure played a crucial role in this shift, enabling real-time data analytics, software-defined satellites, and AI-driven automation to optimise operations and expand commercial opportunities. During this period, companies such as Hughes, Intelsat, and Boeing were key in developing the commercial satellite market, initially relying on government contracts before gradually shifting towards independent revenue models. The development of geostationary satellite communications in the 1970s and 1980s exemplifies this transitional phase, as space infrastructure became increasingly integrated with private-sector interests. The widespread adoption of digital platforms further facilitated the commercialisation of space-based services, providing a foundation for data-driven applications in various industries.

The New Space economy, as it is understood today, emerged much later, shaped by venture capital investments, technological innovation, and a more risk-tolerant entrepreneurial approach. Unlike the earlier phase of commercialisation, New Space companies such as SpaceX, Blue Origin, and Planet Labs leveraged private financing, cost-efficient production methods, and rapid iteration cycles to challenge established aerospace incumbents. SpaceX's first successful orbital launch in 2008 symbolised this shift, underscoring the growing role of private entities and marking the beginning of a new era in space entrepreneurship. The increasing reliance on digitalisation, including cloud-based satellite data processing, automated EO analytics, and AI-driven mission planning, further enabled this transformation by making space services more scalable and accessible.

Simultaneously, the United Nations Office for Outer Space Affairs (UNOOSA) was instrumental in cultivating an inclusive and developmental space economy, emphasising essential pillars such as economy, society, accessibility, and diplomacy [21,26]. Additionally, the strategic importance of space extended beyond exploration, as space assets became integral to the global power structure and defence, marking the beginning of a 'Second Space Age' characterised by the intermingling of private initiative and public enterprise in space ventures [21]. The focus during this era was on economic and strategic gains, including the development of *cis*-lunar economies and resources for cost-effective operations [19]. These developments reflected a shift in the geopolitical dynamics of space, with the major powers again contesting for space leadership [27].

In the third, industry-driven phase, commercial space applications further reshaped the industry. New commercial entities, supported by public funding and government initiatives, began to play a significant role, indicating a move towards more diversified and commercially oriented business models [20,28–30]. This entrepreneur-driven phase represents the current state of the space economy, characterised by equity-funded ventures that introduce disruptive innovations and alter market dynamics. It demonstrates a significant paradigm shift in business models [3] and a more pronounced role for private funding and entrepreneurship, diverging from prior government-led initiatives and reflecting a dynamic, evolving space economy.

4.1. The search for hegemony and national prestige as the starting point

The emergence of the space economy was closely tied to the Cold War era's geopolitical dynamics. The race to the moon, motivated by national prestige and hegemony, was a crucial catalyst in space technology development. The United States and the Soviet Union, as the leading superpowers, channelled substantial investments into their space programmes, as the blocs perceived space dominance as a symbol of national power and technological superiority [16,18,19,31–36]. This rivalry not only advanced space technology but also laid the foundation for the space economy.

The quest for space exploration, which was primarily driven by the pursuit of national prestige, significantly influenced international relations and global power dynamics [16,37]. The militarisation of space during this period extended beyond national security, reflecting a broader strategy for asserting dominance in space [18]. Governments recognised the strategic importance of space for defence and intelligence, leading to a direct public role in the management of space technology and resources. These Cold War dynamics shaped public policies and business models in the space sector, with governmental control being prevalent in terms of technology, infrastructure, and finance. The role of space assets in military operations and strategic planning further highlighted their importance for national security [29,31,38,39].

Therefore, the emergence of the space economy can be attributed to the Cold War quest for national prestige and technological superiority. The US–Soviet rivalry accelerated space technology advancements, symbolising national power and paving the way for the evolving space economy. The ongoing influence of this era's legacy is evident in the space programmes of both established and emerging spacefaring nations, in which the pursuit of space achievements continues to shape business models, international relations, and public policies.

4.2. Determinants of space economy growth

The development of the space economy has been driven by a set of fundamental economic, technological, and policy determinants, rather than by industrial sectors alone. While traditional classifications categorise space activities into industries such as defence, PNT, satellite communications, and EO, these sectors emerged in response to key enabling factors rather than acting as independent drivers of growth.

Through our analysis, we identified eight primary **determinants of space economy growth**.

- **Technological innovation** – Advances in satellite miniaturisation, reusable launch vehicles, and automation have expanded market accessibility.
- **Economic investment** – Government funding, venture capital, and commercial financing models have supported industry expansion.
- **International collaboration** – Multilateral agreements, public–private partnerships, and global cooperative missions have facilitated growth.
- **Regulatory frameworks** – Legal structures governing spectrum allocation, commercial licensing, and sustainability policies shape industry dynamics.
- **Scientific research** – Innovations in aerospace engineering, materials science, and computational modelling enable new applications.
- **Market demand** – Increased reliance on satellite-based services, including broadband and navigation, has driven commercial activity.
- **Infrastructure development** – The expansion of launch sites, satellite constellations, and data processing centres enables large-scale operations.
- **Geopolitical strategies** – National security concerns, competition for orbital resources, and space policy influence market structures.

These determinants interact to shape the evolution of space-based industries. For instance, the rise of satellite communications was enabled by regulatory liberalisation, telecommunications investment, and technological improvements in geostationary relay systems. Similarly, EO services expanded due to scientific advances in remote sensing, increased governmental funding, and open data policies that encouraged commercial applications.

Understanding these determinants is essential for analysing how and why different space sectors have emerged. The following sections explore key space economy industries, illustrating how their development has been influenced by these fundamental growth drivers.

4.3. The emergence and growth of the new space economy through growth determinants rather than segment growth

The development of the space economy is driven by fundamental economic and technological determinants of growth, rather than by specific industrial sectors [39–41]. While defence, PNT, space exploration, space transportation, satellite communications, EO, and science represent core application areas of the space economy, they are not, in themselves, the forces that generate economic expansion. Instead, our analysis identified a set of underlying growth drivers that enable and shape the evolution of these industrial segments [32,42,43].

These determinants of growth include technological innovation, which continuously lowers costs and expands space-based applications, and financial investment, where public funding from agencies such as NASA and ESA, along with private capital from venture funds, acts as a key catalyst [3,44,45]. International collaboration enhances research capabilities and market access, while regulatory frameworks provide the legal and institutional foundation for sustainable and competitive space activities [17,29,46]. Infrastructure development, including launch capabilities, satellite constellations, and ground-based assets, further enables large-scale commercialisation [47]. Market demand for services such as broadband, EO, and navigation fuels continuous economic activity, while scientific research contributes to long-term innovation and technological spin-offs [32,40]. Finally, security and geopolitical interests influence investment flows and policy decisions, reinforcing the strategic importance of space activities [39,48].

It is essential to distinguish these growth determinants from the economic segments they influence. The OECD classification provides a structured segmentation of space-related industrial activities, categorising them into areas such as satellite communications, space transportation, and PNT services. However, this classification does not explicitly address the forces that drive economic growth within these segments. Our framework complements the OECD approach by introducing a distinction between the industrial domains of the space economy and the fundamental drivers that enable their expansion [40,41] (Fig. 3).

Defence has been a vital component in the formation of the space economy, with investments in military purposes catalysing significant technological advancements [18,39,49]. The military applications of space technologies, ranging from satellite reconnaissance to secure communication systems, are crucial for modern defence strategies and national security. Early developments, such as the NAVSTAR programme, laid the foundation for what would later become the Global Positioning System (GPS), demonstrating the strategic importance of satellite-based navigation. Similarly, MILSTAR, a secure satellite communications system, exemplifies the role of defence-driven innovation in advancing global communication infrastructure. This focus has not only enhanced military capabilities but also spurred innovations in various space technologies, which extend beyond defence to impact other sectors of the space economy [48,50,51]. This crossover has created new market opportunities and business models, showing the interconnectedness between defence and commercial space activities. As a result, the defence sector's role in the space economy has extended beyond national security, stimulating broader technological innovation and contributing to the sector's growth.

Positioning, navigation, and timing (PNT) services have emerged as a cornerstone in the growth of the space economy, being essential for a broad range of applications, including navigation, logistics, telecommunications, and disaster management. The development and diversification of systems such as GPS, Beidou, Galileo, and the Global Navigation Satellite System (GLONASS) exemplify the segment's significant advancements and investments, with applications extending from tracking for precision weaponry to timestamping for financial transactions and guidance for agricultural practices [40,48,49]. Governmental support has been pivotal in advancing PNT technologies, with governments recognising their strategic value in areas such as national security and environmental management [39]. This has led to the integration of PNT with satellite communication technologies, revolutionising numerous sectors and significantly contributing to the global space economy [33,50]. While initially focused on defence applications, PNT services have expanded their reach, especially through mobile applications, as seen in major civilian infrastructure initiatives

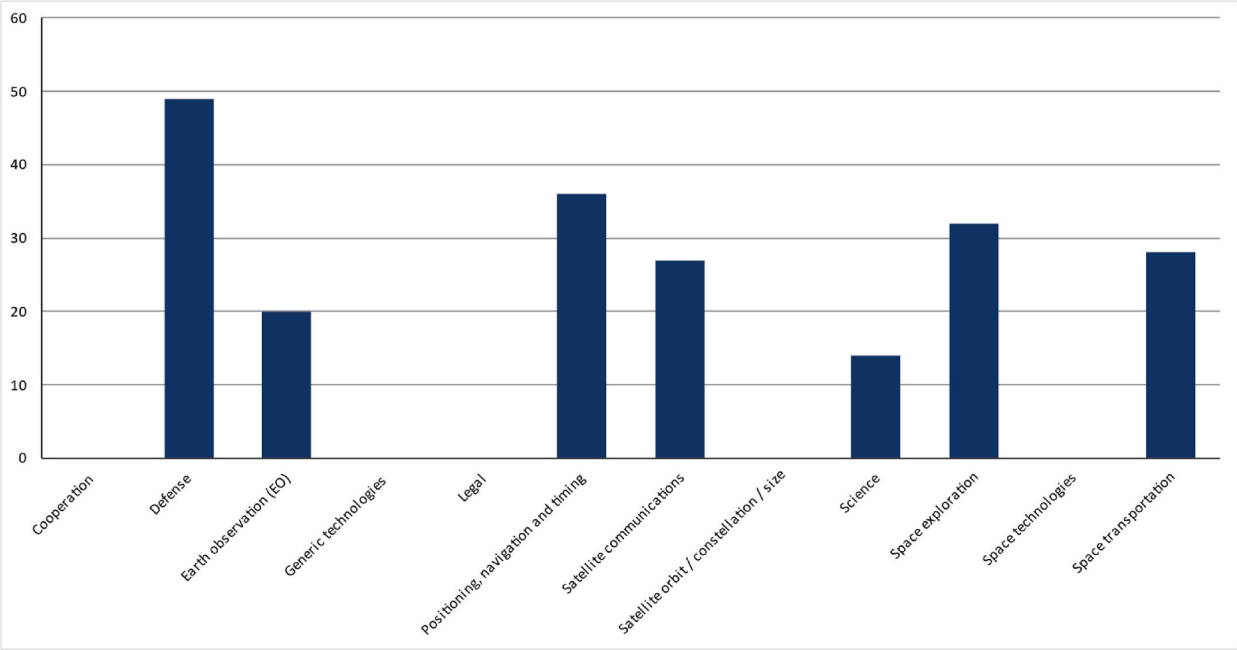

Fig. 3. Attribution of growth determinants explaining past growth by space economy segment – number of articles mentioning the identified growth determinants in relation to specific segment.

such as the European Galileo system, demonstrating the broadening scope of and high demand for applications. Now indispensable in industries from transportation to finance, PNT services have achieved foundational status in the space economy, having evolved from their defence-oriented beginnings into versatile, cross-sectoral applications [16,42].

Space exploration and space transportation have also had a crucial influence on the formation of the space economy. These technologies, which involve launching satellites into orbit and enabling human space travel, have revolutionised various sectors, including defence, finance, agriculture, and maritime traffic management, becoming an integral part of our global, wireless, and mobile information infrastructure [18,52]. Simultaneously, these advancements in space transportation systems have played a vital role in broadening access to space, thereby fostering the expansion of the space economy.

The growth of the space economy has been significantly propelled by advancements in satellite communication technologies, which are essential for applications from military operations to global information transfer. Government support has played a critical role, particularly in defence and national security, regarding which satellite communications provide strategic advantages in intelligence and situational awareness [18,39,48]. Additionally, the development of these technologies contributes to national prestige and international influence while simultaneously fostering innovation in various scientific fields [1,16,42,53].

Earth observation (EO) technologies have become closely linked to the growth of the space economy, revolutionising data gathering about Earth's systems through satellites. These advancements have led to new applications in scientific research and commercial ventures and have been supported by significant governmental backing because of their strategic value in terms of defence and environmental monitoring [39,48–50]. The strategic importance of EO technologies in defence has also driven substantial military investments, enhancing global situational awareness [40,42]. Furthermore, the development of EO technologies contributes to national prestige and scientific progress, underscoring their key role in advancing the space economy [1,16,53].

The expansion of the space economy has also largely been driven by advancements in scientific research, particularly that devoted to the earth sciences and understanding the universe overall. Governmental support has been vital and has focused on the strategic importance of space science in areas such as defence and environmental management [34,39]. This focus, coupled with military investments in space-based research on intelligence and situational awareness, has propelled economic growth in the sector [16,40]. Moreover, the prestige and technological advancements associated with space exploration have furthered governmental influence and innovation in various scientific fields [1,16,53]. The continued evolution of the space economy is thus shaped by these scientific advancements, which are supported by both governmental and private-sector initiatives.

The expansion of the space economy is the result of a complex interplay between technological innovation, government support, and strategic defence priorities. Governmental involvement has been pivotal, providing financial, infrastructural, and moral backing, which has fuelled development and ensured the long-term viability of the space economy. Initially driven by the defence sector's need for advanced situational awareness, global communication, and intelligence, the space economy evolved as advancements in one area spurred growth in others. Significant technological advancements, such as reusable rockets and miniaturised satellites, have drastically reduced the cost of space activities, driving substantial investments. The increasing demand for satellite-based services, combined with government initiatives and funding for defence and scientific research, drove the creation of the initial infrastructure for commercial space activities. Thus, the growth of the space economy has been driven by a synergy between technological advancements, reduced operational costs, and robust government support, highlighting the critical role of both the governmental and private sectors in its evolution.

5. The overarching role of digitalisation in the space economy

Digitalisation has emerged as a transformative force reshaping the global economy, with profound implications for the space sector. As a key enabler of the transition from phase 2 (government-driven commercialisation) to phase 3 (market-driven expansion) of the space economy, digitalisation has facilitated new business models, enhanced service scalability, and lowered entry barriers for private actors [12,42]. The increasing integration of digital platforms, data processing, artificial intelligence (AI), cloud computing, and big data analytics into space-related activities has accelerated the commercialisation of space applications and expanded their economic impact across various industries [52].

The widespread adoption of digital connectivity and cloud-based infrastructures has enhanced the efficiency, accessibility, and automation of space services [8,52]. Satellite infrastructure now functions as a critical component of the digital economy, generating vast amounts of data that can be rapidly processed and monetised through cloud computing and AI-driven analytics [25]. This development has enabled the rise of data-*as*-a-service (DaaS) and platform-based business models, allowing space-derived information to be seamlessly integrated into diverse sectors such as agriculture, logistics, finance, and urban planning [49].

The digital revolution has also played a pivotal role in reducing operational costs and improving market accessibility for emerging space companies. The proliferation of software-defined satellites, AI-powered mission planning, and real-time geospatial analytics has allowed private players to optimise satellite utilisation, enhance service precision, and introduce scalable solutions tailored to commercial demands [54,55]. Furthermore, edge computing capabilities on satellites are minimising the need for extensive ground processing, enabling faster decision making and more autonomous satellite operations [56].

Beyond data-driven applications, digitalisation has also facilitated collaborative innovation and global market integration. The convergence of machine learning algorithms, blockchain technology, and Internet of Things (IoT) networks with space-based infrastructure has unlocked new commercial frontiers, including real-time asset tracking, automated EO analytics, and space-based financial instruments [17,57].

By accelerating the transition towards a fully digital, interconnected space economy, these advancements have significantly lowered the barriers to entry for non-traditional space actors, fostering the growth of the New Space industry [3,57]. The next phase of space economy expansion will likely be shaped by the increasing reliance on AI-driven decision making, enhanced cybersecurity frameworks, and the integration of terrestrial and space-based digital ecosystems [49,58].

This evolution underscores the necessity of incorporating digitalisation as a core determinant of space economy growth rather than as a secondary technological advancement. As the industry continues to expand, future policies and investments must ensure that regulatory frameworks, cybersecurity standards, and digital infrastructure support the sustainable integration of digital technologies within the space economy [4,42].

6. Present status of the space economy

The space economy is undergoing significant growth, diversification, and commercialisation. It encompasses a wide range of activities, from space manufacturing and satellite communications to asteroid mining and prospective future colonisation efforts [1,59]. Governmental roles remain crucial in shaping this economy through regulatory guidance and the stimulation of expansion in various domains, including consumer applications and entertainment [29,59,60]. In today's interconnected world, the space sector—hosting over 12,000 satellites from more than 80 countries—is integral to numerous industries, providing a

broad array of global services [61]. The resurgence of human space travel for tourism, scientific experimentation, and satellite deployment is further propelling the industry's growth.

While private enterprise has gained substantial traction in the space sector, global state powers still dominate, with only a few key actors truly shaping the industry's future [1,31]. As the questions emerging in the sector are complex and multidisciplinary, scholars from fields including economics, industrial organisation, and public finance play central roles in understanding and shaping the development of the space economy [27,31,42,62]. As power balances in the space domain evolve, the implementation of New Space concepts can alter existing hierarchies—particularly in market economies with competitive private offerings. However, nation-states will almost certainly strive to preserve their positions at the top of the space power hierarchy, leveraging public space agencies and regulation to maintain their advantages. Novel funding schemes and collaborations with the private sector are crucial for harnessing the economic potential of space [16,31].

Valued at over $350 billion annually, satellite communications are a cornerstone of the expanding space economy and are experiencing transformative technological advancements [27]. These services, vital for global connectivity, play diverse roles—from commercial telecommunications to defence operations—highlighting their versatility [39]. The adoption of novel technologies, including 5G and 6G in satellite systems, signifies a major leap forward, ushering in an era of lower communication latency and improved global internet coverage [54, 63–65]. Furthermore, the rise of extensive low Earth orbit (LEO) satellite networks, exemplified by SpaceX's Starlink, is revolutionising the field by enhancing deployment scales and accessibility. The societal and economic impact of satellite communications is profound; however, challenges such as managing space debris and ensuring secure connectivity are critical considerations for sustainable advancement in this domain [54,64].

Positioning, navigation, and timing services are now indispensable across various sectors, including aviation, maritime transport, finance, and military operations [2,40]. Modern activities increasingly rely on PNT services, and defence-related investments in this segment remain significant [16]. However, the expansion of PNT services to new applications presents challenges such as orbital congestion and the need for enhanced space traffic management and cybersecurity measures [40, 50].

Earth orbit technologies—particularly EO satellites—have expanded from military reconnaissance to vital tools for environmental monitoring [40,50]. Innovations in satellites and sensor technology, aided by cost reductions, are addressing today's environmental challenges. The European Commission's Copernicus programme, in partnership with the European Space Agency (ESA), demonstrates EO's global impact by fostering businesses and new services [1,3]. Trends in EO, especially the deployment of constellations in LEO, now offer continuous imaging and video analytics, expanding EO's relevance to sectors such as finance. The evolving role of EO promises new opportunities in both the public and private sectors [3,16].

Space transportation, which is crucial for expanding the space economy, is shaped by factors such as cost, launch frequency, and technological risks [3,16,31,66]. Innovations by new players—most prominently SpaceX's development of reusable rockets—have revolutionised the launch sector, enabling it to transition from exclusive military dominance to widespread commercial and civil use, including the routine deployment of small satellites [3,21,31,67]. This shift is also evident in major spacefaring nations such as the US and China, where government and private ventures are increasingly intertwined [3,68]. The rise in commercial launch services and the nascent space tourism industry exemplify the sector's growth [69–71].

Space exploration, a significant technological catalyst since 1957, has transitioned from being state driven to involving commercial and private competitors [72–74]. The Cold War era's US–Soviet rivalry accelerated human spaceflight and captivated global attention, setting the stage for today's primarily peaceful space utilisation and efforts at conflict prevention [75]. Space exploration continues to drive technological and industrial advancements; for instance, proposed lunar bases serve as testbeds for innovations in energy and robotics [52,60]. The prospect of extraterrestrial resource extraction (e.g. mining asteroids or the Moon) is gaining momentum, attracting both private companies and government interest [52,75].

Science—particularly human-spaceflight-related science—plays an integral role in the space economy by fostering innovation and creating markets for technologies with broad commercial applications. Environmental challenges and climate change have hastened the development of sophisticated satellites and sensors that are critical for meteorological and climate data collection [3]. The proliferation of CubeSats (compact 10 cm-class satellites), pursued by academic and industrial actors, has improved global connectivity and lowered the cost of space exploration, benefitting fields such as astronomy and planetary science [76]. Notably, advances in CubeSat antenna technology have enhanced communication capabilities, which are vital for both research and commercial uses [77]. Government support remains essential for space science initiatives, contributing to advanced space technology and national defence [78].

The growing interest in space technologies has significantly deepened our understanding of the cosmos and has delivered numerous benefits to humanity. The International Space Station (ISS) exemplifies these advancements: it serves as a hub for cutting-edge research and technology demonstration while also benefitting areas such as human health and global education, thereby contributing to the space economy [20]. Space research has improved climate models and recycling processes on Earth. However, the rapid expansion of space activities presents serious challenges, particularly in terms of space sustainability. A major issue is orbital debris: an estimated 300,000 fragments pose collision risks to satellites [20]. Addressing this issue requires global cooperation and innovative approaches, including regulatory measures and incentives for debris mitigation [79].

The integration of generic and commercial off-the-shelf (COTS) technologies into satellite production has revolutionised the space sector by enhancing capabilities, reducing costs, and driving innovation [1,3]. The rise of CubeSats, supported by COTS components, along with specialised suppliers enabling bulk production, exemplifies the shift towards cost efficiency [1,52]. Vertical integration—merging service operations with manufacturing—has streamlined supply chains by eliminating complex contracting [1]. Additionally, advanced methods such as additive manufacturing (3D printing) are pushing space capabilities forward [1,52]. However, reliance on generic technologies raises cybersecurity and quality concerns, necessitating robust protection measures [52].

The space economy is rapidly maturing while continuing to experience significant growth and diversification. Key sectors—such as satellite communications, PNT services, EO technologies, space transportation, and space science—are at the forefront, increasingly adopting generic technologies to drive down costs and enhance service availability. The current state of the space economy is characterised by a dynamic environment, rapid development, and growth driven largely by commercial activities and motives. The integration of advanced technologies and the entry of private companies have revolutionised these segments, making space more accessible and economically viable. Innovations in satellite technology, the development of reusable launch vehicles, and competitive markets encouraging cost reduction and efficiency have facilitated the shift from government-led initiatives to commercial enterprises. The democratisation of space—with contributions from pioneers such as SpaceX—is creating new opportunities. However, reliance on a limited number of innovative players concentrated in specific regions carries a risk of systemic bottlenecks or failures if these actors' capabilities are not realised or diversified. Collaboration between governments, the private sector, and academia is essential to navigate these challenges and harness the full potential of the space

economy.

6.1. Factors slowing down the development of the space economy

While the space economy has experienced rapid and continuous growth in recent decades, we identified several major challenges that hinder its expansion. Three primary factors and two secondary ones emerged as potential impediments based on our review.

- **Complexity and cost of space technologies** – The advanced technologies driving the space economy also present significant barriers. Their complexity, the necessity for global cooperation, and the inherent risks of space activities can slow development. High costs and large risks associated with activities such as human spaceflight and deep-space exploration can impede progress if not managed [16].
- **Inadequate and ambiguous legal frameworks** – Gaps and uncertainties in space law and regulation create an environment of uncertainty that can affect business investments and slow industry development. The UNOOSA has outlined four pillars for future space activities—economy, society, accessibility, and diplomacy—as guiding principles, but effectively navigating the complex legal landscape remains vital for continued growth [3].
- **Integration of generic technologies and cybersecurity** – The increasing use of generic and COTS technologies introduces variability in availability and risk. Lower launch costs, increased capital, and improved capabilities of small satellites broaden access to space but come with challenges, such as cybersecurity threats, that complicate the adoption of innovations from outside the traditional space sector [3].
- **Insufficient scientific advancement** – Slower-than-anticipated progress in certain areas of space science and technology can subtly hinder growth. Complex scientific challenges and the need for international cooperation in projects, such as large space telescopes or deep-space probes, create difficulties [80]. A lack of breakthroughs or sustained investment in fundamental space science might limit long-term innovation.
- **Constraints in space transportation development** – Despite recent improvements, high launch costs and significant risks remain barriers. The interplay between factors such as cost-effective satellite delivery and launch frequency highlights the importance of affordable, reliable space transportation. New competitors are innovating with SmallSat launchers and other solutions [3,16,81], but overcoming the remaining cost and risk hurdles is essential for further growth.

Space technologies thus serve a dual role in the space economy—driving growth but also presenting potential barriers. Their complexity and the need for global cooperation shape the pace of development. The quest for innovative technologies to overcome these challenges is critical, yet high costs and large risks can impede progress [3,16]. International cooperation, while vital for space exploration and large projects, also introduces complexities that can slow advancement [3].

The legal and regulatory framework plays a crucial role in shaping the space economy. Inadequacies and ambiguities in current space law create uncertainty, affecting business investment and slowing industry development [3]. The United Nations and other bodies stress the importance of globally consistent regulations and norms. Navigating this legal landscape effectively is vital for the continuous growth and expansion of the space economy.

Progress in the space economy is closely linked to innovation in generic technologies and components that enhance space capabilities. While access to space is broadening due to lower launch costs, increased capital, and improved small-satellite capabilities, the varying availability of and risks associated with these generic technologies pose substantial challenges to sustainable growth [3]. Additionally, threats such as cyberattacks underscore the need for secure technologies, complicating the incorporation of innovations from outside the traditional space sector.

A lack of scientific advancement and slower development in space transportation also subtly hinder the space economy's growth. Complexities in space science and the need for international collaboration can create difficulties in pushing the boundaries of knowledge [80]. Similarly, high costs and significant risks in space transportation mirror barriers in other sectors and continue to constrain growth [82]. A focus on cost efficiency and risk reduction has led new competitors to innovate in launch systems and satellite development [3,16,81], indicating that solutions to these interconnected challenges are actively being pursued.

In conclusion, the growth of the space economy is intricately linked to various factors, each presenting unique challenges and opportunities. Despite tremendous advancements, the space economy still faces barriers such as high capital requirements, regulatory hurdles, and technical risks. The complexity of space technology, long development cycles, and substantial upfront investments pose challenges for both new entrants and established companies. Regulatory issues—including the need for international coordination and compliance with diverse laws—further complicate the landscape. While space technologies and innovations offer significant growth opportunities, their complexity and cost, along with legal challenges, can impede progress if not properly managed [3,74]. Scientific advancements and improvements in space transportation capabilities are crucial for industry growth, yet they face hurdles such as the need for international collaboration and high exploration costs [80,82]. Overcoming these challenges will require coordinated efforts by policymakers, businesses, scientists, and other stakeholders to harmonise their actions, surmount barriers, and fully realise the potential of space exploration and utilisation [3,16].

6.2. Requirements for the space economy to develop

A myriad of determinants essential for the space economy's future also shape its growth trajectory. Fig. 4 presents a structured framework differentiating between space-related economic activities and the underlying factors that influence their growth. While activities such as satellite communications, EO, and space transportation define key industrial segments of the space economy, their expansion is contingent upon determinants of growth such as public and private investment, regulatory frameworks, and technological advancements. Conversely, barriers such as high costs, regulatory constraints, and limited infrastructure development can inhibit market growth [3,74]. This distinction allows for a more precise understanding of how structural factors shape the evolution of space-based industries.

The evolution of the space economy is driven by technological innovation, government policies, and private-sector investment. As the field matures, diverse investors—including venture capitalists and research institutions—are increasingly funding space-related projects. This influx of capital is advancing technologies such as reusable rockets, miniaturised satellites, and advanced propulsion, reducing the costs of access to space and creating new commercial and scientific opportunities [3,74]. The space economy also offers an interdisciplinary platform for scholars: engineers and scientists develop new materials and propulsion technologies, economists and policy analysts assess economic impacts and regulatory needs, and social scientists explore societal implications such as space tourism [3,16]. Integrating these diverse insights can shape the space economy to maximise benefits and address challenges.

The space economy's growth is propelled by the adoption of generic technologies to enhance space exploration and commerce. This growth hinges on utilising high-quality components supported by innovative resource optimisation strategies [74]. Efficiency gains are achieved through disruptive innovations and streamlined supply chains focused on mass production and system integration [3]. Trends towards standardisation and miniaturisation are critical, enabling cost-effective

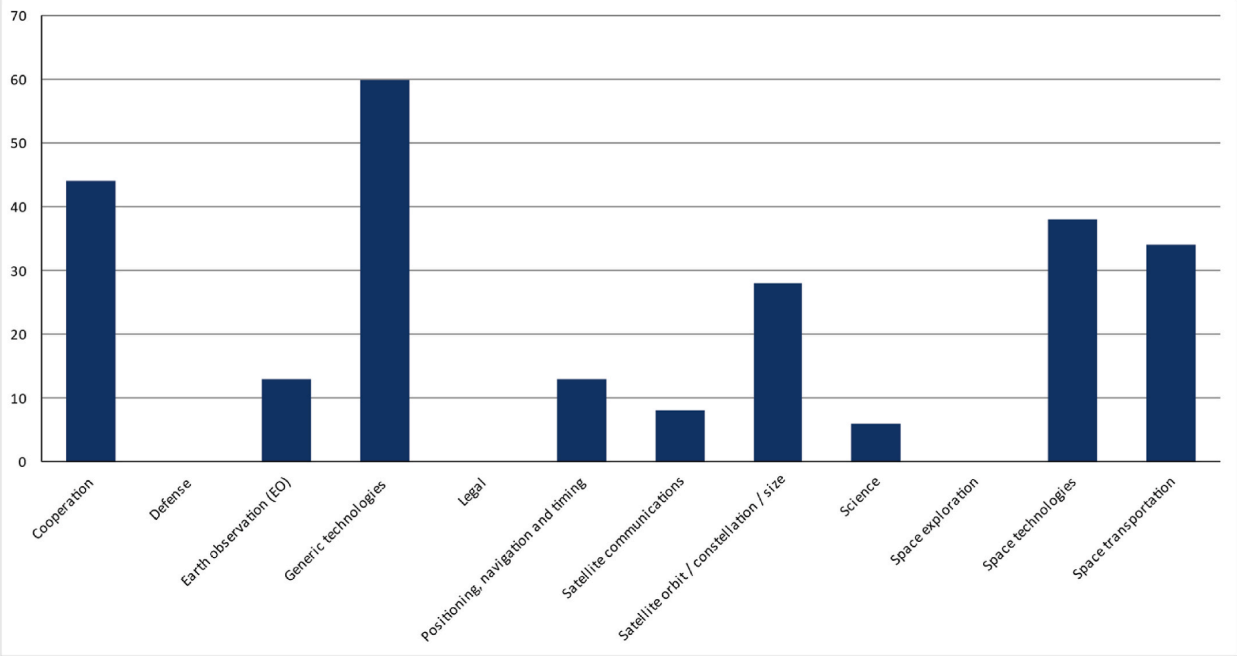

Fig. 4. Development requirements per space economy segment – number of articles mentioning development requirements for a specific segment as the basis for a broader expansion of the New Space economy.

satellite manufacturing. The industry's commitment to excellence is reflected in its shift to design-centric production and advanced data analytics. Innovations such as augmented reality, 3D printing, AI, and the IoT are pivotal in the evolution of space operations, especially in integration and automation [3,16,83].

Disruptive innovations across products, processes, and services are initiating a new phase of space exploration and commercialisation. The trend towards standardisation, coupled with miniaturisation, is revolutionising satellite production, making it both cost effective and efficient [3,16]. Collaboration is key, as demonstrated by organisations such as UNOOSA that emphasise the global benefits of space technologies, especially for developing nations [3]. Moreover, the commercialisation of space transportation—driven by leading industry players and government support—is democratising space access and marking a pivotal shift in the industry [3,16]. These developments collectively provide an optimistic view of the space economy's future trajectory, underscoring its potential and the vast opportunities it offers.

International cooperation involving both the public and private sectors is becoming increasingly vital for space commerce. The United Nations Office for Outer Space Affairs emphasises the need to make space technologies accessible to all, especially developing countries, highlighting space's role in the economy, society, and diplomacy [3]. Such global collaboration is essential for advancing technology and improving economic efficiency. Partnerships between governments, industry, and academia are crucial for sharing resources, knowledge, and expertise, leading to effective public–private ventures. These collaborations range from private companies utilising government infrastructure to joint ventures blending state and private investments. Despite the benefits, challenges such as the lack of a comprehensive legal framework and political or economic risks pose barriers to the full potential of cooperative space initiatives [3,16].

Space technologies play a crucial role in shaping modern society—for example, by advancing satellite communications and integrating satellites with terrestrial networks [54]. These improvements enrich various domains, including civil aviation, climate monitoring, and space exploration. They address immediate societal needs (such as remote education and telemedicine) while also contributing to long-term objectives such as sustainable space operations [52]. The development of space transportation is fundamental to the growing space economy [84]. Initially limited to highly trained astronauts, spaceflight is becoming more accessible thanks to companies such as SpaceX, Virgin Galactic, and Blue Origin [84]. This democratisation of space access is supported by agencies such as NASA, which endorses commercial crew and cargo flights to the ISS [57,85]. The commercialisation of space transportation, including space tourism and lunar missions, relies on technological advances and new business models that reduce costs for both satellites and launch vehicles [22,49,67,84]. The deployment of large satellite constellations and the potential for rocket-based point-to-point travel on Earth are transforming space operations [85]. However, as the sector grows, addressing issues such as space debris will be vital to maintaining space as a sustainable resource [55,84,86].

The space economy is increasingly influenced by the strategic utilisation of LEO, the deployment of new satellite constellations, and the growing demand for small satellites. LEO's low latency is ideal for real-time communications and EO, enhancing global connectivity and offering cost-effective solutions [16,39]. Satellite constellations in LEO are set to transform global communication networks and continuous EO, providing near-real-time coverage [36,76,87]. The trend towards miniaturisation has popularised smaller satellites such as CubeSats, which are more affordable and efficient—appealing particularly to start-ups and New Space ventures due to their ability to be mass produced and deployed in large numbers [3,88]. The future of the space economy is closely linked to the effective application of these technologies, which are crucial for sustainable growth and indicative of the sector's direction.

In addition to the primary growth factors, traditional space economy segments such as satellite communications, EO, PNT, and science continue to play significant roles in the space economy's development. Although these fields did not emerge in our literature review as drivers

of growth per se, they benefit from and support the overall growth factors through co-innovation and synergies. For the space economy to continue developing, several requirements must be met. These include continuous technological advancement, increased private and public investment, and the development of standardised measurement frameworks. International cooperation and collaboration are also essential in addressing regulatory and legal challenges, ensuring that space activities are conducted responsibly and sustainably [3,16]. Developing robust economic models to assess the return on investments in space exploration and related activities is crucial for informed decision making and fostering future growth [3,74].

7. The shift towards commercialisation and private-sector involvement in the space economy

Fig. 5 The shift towards commercialisation and greater private-sector involvement in the New Space economy is clear. The space economy is projected to reach a total valuation of $2.7 trillion by 2045, indicating not only economic but also political significance for numerous nations, as the commercial space sector is expected to grow exponentially [59, 75,89]. The rapid expansion of the space industry is propelled by the emergence of global internet constellations, currently its fastest-growing segment. This development exemplifies the technological advancements that are ushering the space economy into unprecedented realms of possibility [2]. Overall, the space economy will not become any simpler in the future—each of its segments will influence its growth and trajectory. Separating these sectors from each other is challenging, but focusing on the underlying growth determinants provides clarity. It is crucial to differentiate between economic activities (e.g. satellite communications, EO, space transportation) and the structural determinants that shape their growth.

While topics such as ‘legal’ and ‘cooperation’ may be categorised separately in some analyses, they should not be interpreted as standalone economic activities. Instead, these factors serve as cross-cutting determinants of growth that influence multiple sectors of the space economy. For instance, space regulations impact defence, PNT services, satellite communications, and scientific research alike, and cooperation shapes the development of commercial space markets, international missions, and space governance.

To improve conceptual clarity, our analysis focuses on the true determinants of space economy growth, aligning with the eight key factors identified in conclusion: technological innovation, international collaboration, economic investment, regulatory frameworks, scientific research, market demand, infrastructure development, and geopolitical strategies.

Advancements in space technology have significantly reduced costs and expanded the scope of viable space activities [6]. The development of reusable launch vehicles, for example, has dramatically cut launch expenses and increased launch frequency, allowing far greater access to space [34]. Small satellites and software-defined spacecraft have introduced greater flexibility, enabling commercial actors to scale operations efficiently [4]. Emerging capabilities such as in-space manufacturing, robotic assembly, and AI-assisted mission operations are expected to further expand economic opportunities [12]. These innovations not only enhance existing applications—such as EO and satellite communications—but also enable entirely new sectors, including space resource extraction and interplanetary logistics [90].

Digitalisation plays a transformative role in the space economy by integrating AI, cloud computing, and big data analytics into space-based services [15]. The proliferation of digital platforms has enabled real-time geospatial intelligence, automated satellite operations, and predictive maintenance for spacecraft [1]. The expansion of cloud-based satellite data analytics has lowered barriers to entry, allowing new players to provide data-driven solutions across various industries, including agriculture, finance, and logistics [4].

Additionally, the convergence of edge computing with satellite networks has enhanced data processing capabilities, reducing latency and improving service efficiency [71]. As digital infrastructure extends further into space, developments such as blockchains and decentralised ledgers are emerging to ensure secure data transactions, particularly in

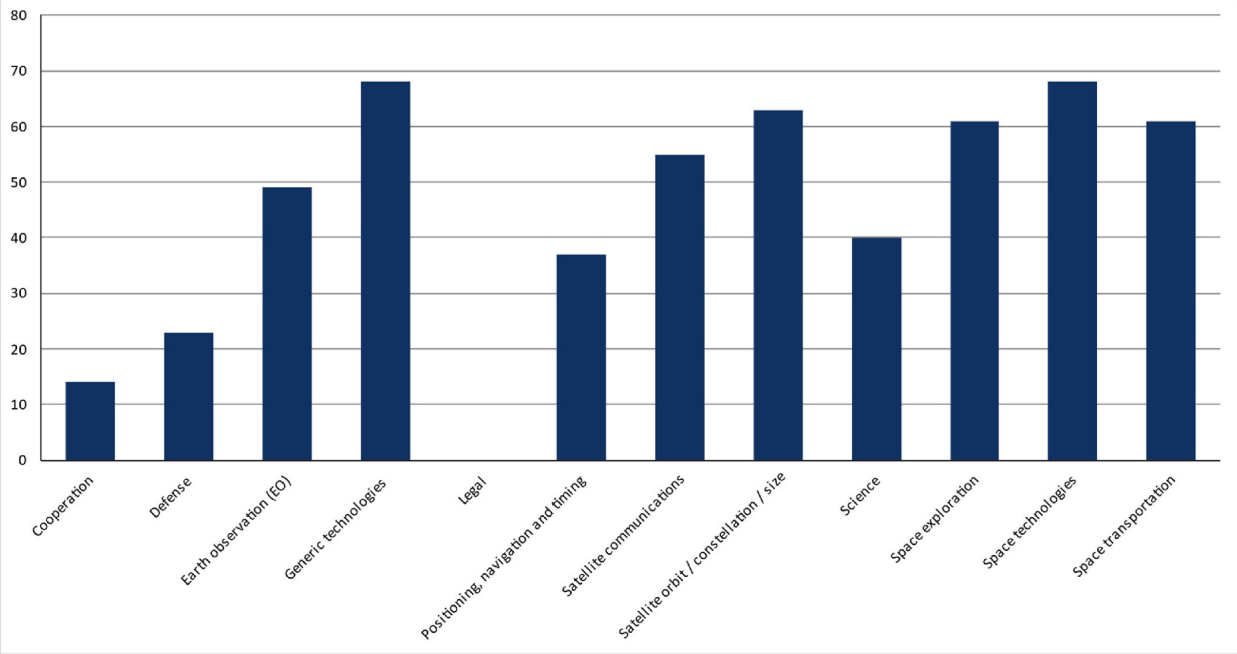

Fig. 5. Attribution of growth determinants’ future potential per space economy segment – number of articles mentioning potential for the identified growth determinants in relation to a specific segment.

satellite asset management and space commerce [12].

The growth of the space economy is strongly linked to investment trends, with both public- and private-sector funding playing crucial roles [4]. Historically, space activities were largely government funded, but there has been an increasing influx of private capital from venture capital firms, institutional investors, and sovereign wealth funds [90].

Public–private partnerships have become essential in supporting large-scale projects, such as global satellite constellations, lunar exploration missions, and in-orbit servicing industries [1]. Market demand for space-based services (including broadband connectivity and precision navigation) continues to drive investment in downstream applications [15]. Future developments such as space-based solar power and deep-space resource extraction will depend on sustained financial backing and evolving business models [59].

Regulatory frameworks play a crucial role in shaping the commercial space sector [4]. Governments and international bodies are responsible for establishing laws and policies governing spectrum allocation, space traffic management, and commercial space activities [1].

As private actors take on a larger role, regulators must strike a balance between encouraging innovation and ensuring safety, sustainability, and fair competition [15]. The regulatory landscape must also address emerging challenges such as space debris mitigation, satellite cybersecurity, and intellectual property rights for space-based manufacturing [71]. Standardisation efforts led by organisations such as the UNOOSA and the International Telecommunication Union (ITU) are vital in fostering global cooperation and stability in space activities [12].

The expansion of space-related infrastructure is critical for the sustainable growth of the space economy [4]. The increasing number of launch facilities, ground stations, and inter-satellite communication networks has enhanced global connectivity and accessibility [90]. Mega-constellations developed by companies such as Starlink and OneWeb have transformed satellite-based internet services, although they also introduce new challenges such as orbital congestion and sustainability [1]. Meanwhile, modular spacecraft design, additive manufacturing, and COTS components are reducing costs and increasing production scalability [71]. The ability to manufacture key space components in orbit will further reduce reliance on Earth-based logistics and open new frontiers for industrialisation in space [12].

National governments view space as a strategic economic and security asset, leading to increased investment in defence-related space programmes and competition for leadership in space-based markets [4]. Government-backed initiatives such as the US Artemis Accords, China's Belt and Road Space Information Corridor, and Europe's Secure Connectivity Programme are shaping the landscape of international space policy [1]. As the commercial space sector continues to expand, global competition for market dominance will intensify [15]. However, geopolitical tensions must be managed through strategic alliances, cooperative agreements, and resource governance frameworks to ensure that the benefits of space exploration and commercialisation are equitably distributed [71].

International partnerships have played a significant role in shaping the space economy, from cooperative research projects to multinational exploration programmes [4]. The ISS is a prime example of successful collaboration between space agencies of multiple nations [1]. Future projects—such as lunar bases and deep-space missions—will require continued cooperation between governments, commercial enterprises, and international organisations [15]. Establishing global norms for space governance and fostering sustainable economic practices will be essential to ensuring long-term growth in the space economy [12].

8. Conclusion

Our research highlights that the expansion of the space economy is not solely the result of sectoral growth but is fundamentally shaped by underlying economic, technological, and policy determinants. While traditional classifications (such as those used by the OECD) segment the space economy into industries such as satellite communications, EO, space transportation, and defence, our analysis demonstrates that these sectors have emerged because of structural, linked determinants of growth rather than acting as independent drivers of economic development.

Through a systematic literature review, we identified eight key determinants that influence the development of space-related industries: technological innovation, international collaboration, economic investment, regulatory frameworks, scientific research, market demand, infrastructure development, and geopolitical strategies. These factors collectively shape the pace and direction of the space economy by influencing capital allocation, regulatory conditions, technological feasibility, and strategic priorities. Among these, digitalisation has emerged as a fundamental enabler that accelerates commercialisation, enhances data-driven decision making, and expands market accessibility.

The integration of AI, cloud computing, and big data analytics into satellite infrastructures has transformed how space-based services are delivered and utilised across multiple industries. Cloud-based satellite data analytics, automated Earth observation processing, and AI-driven mission planning have significantly reduced operational costs and increased service scalability. As a result, digitalisation has lowered barriers to entry, enabling a more competitive and diverse space economy. Furthermore, the growing convergence between terrestrial and space-based digital infrastructures is unlocking new commercial opportunities, reinforcing the role of space as a key enabler of the broader digital economy.

Rather than treating economic growth in the space sector as a linear expansion of predefined industrial categories, this study emphasises the dynamic interaction between enabling factors and industrial outcomes. For example, while satellite communication has grown into a dominant sector, its expansion has been contingent on advancements in telecommunications infrastructure, launch services, deregulation, digital networking capabilities, and sustained public–private investments. Similarly, the growth of space transportation has been driven by cost reductions in launch systems, reusable rocket technology, and policy support for commercial spaceflight, rather than being an inherent enabler of the space economy itself.

Furthermore, the increasing role of New Space actors and private-sector investments has fundamentally altered the structure of the space economy, shifting it from a government-driven model to a market-oriented ecosystem. The rise of venture-backed firms, digital platform-based services, and scalable business models has enhanced competition and innovation across space-based industries. However, this shift has also introduced new challenges, including regulatory adaptation, digital security risks, sustainability concerns, and geopolitical competition, which will shape the trajectory of the space economy in the coming decades.

To provide a more accurate conceptual framework, future studies should focus on the determinants driving economic activity in space rather than relying solely on industrial classifications. Additionally, policymakers should prioritise investment mechanisms, regulatory stability, digital infrastructure, and technological advancements to ensure sustainable growth. As the space economy progresses, digitalisation will remain a key driver of innovation, market expansion, and industry transformation. By shifting the analytical approach from sectoral segmentation to economic enablers, this study offers a clearer understanding of how space-based industries evolve and what factors will define their future development.

CRediT authorship contribution statement

Mikko Punnala: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Santeri Punnala:** Writing – review & editing,

Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Arto Ojala:** Supervision, Methodology. **Heidi Kuusniemi:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Small Business Internationalization in the Nordic Space Industry

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Abstract

The Nordic region has the potential to become a hub for space innovation in Europe, with an ecosystem of startups and established companies pushing the boundaries of satellite technology, space exploration, and space-based applications. This region has a long tradition for space research and exploration, dating back to the 1960's with Denmark and Sweden. However, small space firms in this region face various challenges to internationalize. Strict regulations, international and national laws covering technology development, satellite launches and operations, pose challenges for small firms to expand globally beyond the startup phase. Additionally, the high capital and technology costs makes it difficult for these firms to internationalize. Despite these challenges, there are promising opportunities for these firms to grow and internationalize. The goal of this study is to understand the internationalization process for these space firms and present a model of the internationalization processes. This paper employs qualitative research methodology, combining interviews, case studies, and literature analysis.

Keywords:

Internationalization; Space Firms; Nordics; Markets; SME; International New Ventures

Introduction

Internationalization has been identified to have an important role for SMEs, including better survival prospects, growth revenue, innovative capability, and upgraded productivity than non-internationalized small firms (Lakshman et al., 2023). Successful entry into foreign markets can be often challenging for small firms regardless of the industry they operate. However, the industry where a firm operate, can also play an important role in the firm's internationalization (Grøgaard et al., 2013). In this study, we are especially interested in internationalization of small firms operating in space industry. Space industry forms an interesting area of study, as even the global economy is decreasing, the space economy as boomed in the last decade and is expected to grow to $1 trillion by 2030 (McKinsey & Company, 2024).

Space industry is very networked globally (Hassinen et al., 2024), making internationalization rather mandatory for these firms in order to establish and remain in business, regardless of where in the world the firm is located. Traditionally, internationalization can be defined as the process of

business activities across home country borders with an increasing degree in operations (Welch & Luostarinen, 1988) as well as the process of adapting firm's operations (strategy, structure, and resources) on international environments (Calof & Beamisht, 1995; Koch, 2018) by utilizing and organizing global resources. The definition of internationalization can vary depending on the literature analyzed, however, it is uniform that internationalization is an important phenomenon for firms to scale up and compete in an increasingly globalized economic landscape (Tippmann et al., 2023).

The space industry is increasingly competitive (Brennan & Utrero-González, 2024); for survival, it is imperative that firms develop a clear internationalization strategy and differentiated value proposition because, in most of the cases, the domestic markets are not able to commercially sustain space firms. Given the rapid evolution of the space industry and the paradigm shift from being the sole domain of government agencies and large aerospace defense companies to the commercialization of space, entrepreneurship activities have expanded (Baber & Ojala, 2024b; Punnala et al., 2024). In this context, where the risks of commercial endeavors are shared among private business organizations (Punnala et al., 2024), the internationalization of small space firms is becoming increasingly relevant.

In the context of this study, we are especially interested in the Nordic region (including Finland, Denmark, Iceland, Norway, and Sweden) that is characterized by research pioneering, technological innovation, and entrepreneurial spirit (Isaksen & Onsager, 2010; Kalinina & Kondratov, 2018). In the last 10 years, small Nordic space firms have emerged as key players in the space industry, leveraging their expertise in areas such as Synthetic Aperture Radar Satellites (SAR), Ground Stations, and Earth observation (Muff et al., 2022). Even small Nordic space firms have always been known as innovative firms, these firms easily face a variety of challenges that hinder their activities to scale up and enter global markets. By better understanding how these firms internationalize their businesses and the challenges they face is key to their success and for the greater good and growth of the Nordic space sector.

To explore the internationalization strategies of small space firms in this region, it is necessary to analyze the approaches adopted within this context. Research indicates that small and medium sized enterprises (SMEs) often utilize different strategies compared to larger enterprises when breaking into international markets (Child et al., 2022). The goal of this research is to present a model of the internationalization processes for space firms in the Nordics region by understanding and answering: 1) *How do small Nordic space firms internationalize their business?* And *2) What are the challenges these small Nordic space firms face in their efforts to internationalize their business?*

Literature Review

Small business internationalization is a thorough researched area in international business literature. Researchers have been studying the internationalization of SMEs since the end of the last century (Buckley & Casson, 2021), but as small firms operating in space industry presents rather new phenomenon, the holistic understanding of internationalization of these firms is meager.

One of the earliest models of internationalization, the Uppsala model (Johanson & Vahlne, 1977) advocates that firms normally start their expansion in a physically and culturally nearby market (Arvidsson & Arvidsson, 2019), and then gradually expand to more different or distant markets as they gain experience and knowledge (Johanson & Vahlne, 1977). The Uppsala model also predicts that firms are more likely to take an incremental approach to their internationalization process starting with markets that share a greater degree of similarity with the home market (Otomo et al., 2023).

The second internationalization model, that has been widely applied to study internationalization of SMEs (Ojala, 2009), is the network theory of internationalization (Johanson & Mattsson, 1988). This model argues that an international company should form network relationships with other firms rather than aiming to act in isolation from other actors within industry. A network is defined as a set of two or more firms allowing interconnected exchanges (Roque et al., 2019) which includes the exchange of resources between its different members (Kenny & Fahy, 2006). Firms that adopt this model aim at achieving higher performance and profitability by developing relationships that allow them to access resources, technical and economic knowledge, and even the collective assumption of costs and risks to sell their products and services (Gulati et al., 2000; Johanson & Mattsson, 1988).

Many studies have also focused on what have been designated as the “born globals” (Knight & Cavusgil, 1996; Madsen & Servais, 1997) “international new ventures” (Oviatt & Phillips Mcdougall, 1994), “instant inter-nationals” (Preece et al., 1999), or “global start-ups” (Oviatt & Phillips Mcdougall, 1994). These studies focused on studying firms that are international from inception or very soon after the establishment. The firms can be found globally and in high concentration in several countries with Norway and Denmark being amongst those with high concentration of such firms (Moen et al., 2002, 2019; Sharma & Blomstermo, 2003).

The "space economy" and "space industry" represent interconnected yet distinct aspects of economic and industrial activities related to outer space exploration and utilization. Space Economy encompasses the comprehensive scope of activities and utilization of resources that generate value and benefits for humans within the context of space exploration, understanding, management, and use (Baber & Ojala, 2024b; Punnala et al., 2024). It goes beyond mere space missions or satellite launches to include downstream applications of space technology, such as satellite communication, Earth observation, and global navigation systems, impacting various

sectors like agriculture, urban development, and telecommunications. Essentially, the space economy covers all economic activities linked to space, transcending commercial, governmental, or scientific boundaries, and incorporates the broader economic impact of space on society (OECD, 2022).

Space Industry is more specifically concerned with the companies and organizations engaged in space-related endeavors, including the development, manufacturing, and operation of spacecraft, satellites, and associated ground support infrastructure. This sector is a component of the larger space economy, focusing more on production and technological elements.

It can be summarized that Space Economy is an umbrella term for all space-related economic activities, integrating both the direct and indirect contributions to the economy at large. In contrast, the space industry zeroes in on the direct involvement in space activities, centering on the manufacturing, launching, and operational facets of space technology and services (OECD, 2022). There is also a term "Space business" that can be defined as commercial activities encompassing the exploration, development, establishment, and execution of operations in and related to outer space" (Baber & Ojala, 2024b).

Each Nordic country has developed distinctive strategies, contributing uniquely to the global space sector. From Norway's comprehensive application of space technologies to Finland's leadership in space electronics and educational initiatives, these national strategies underscore a collective Nordic ambition for sustainable development and technological progress (Norwegian Space Agency, 2020; Työ- ja elinkeinoministeriö / Liikenne- ja viestintäministeriö, 2018). As commercialization progresses, Nordic small space firms face challenges and opportunities. Adjusting to regulatory changes, embracing technological advancements, and developing the workforce are key challenges. Conversely, the expanding space economy and the rise of new space-faring nations present significant opportunities for Nordic firms to engage globally and contribute to the international space landscape (Del Canto Viterale, 2023; Europea Space Agency, 2021; Harridon et al., 2021; Lei et al., 2023; Mani et al., 2023; Ministry for Higher Education and Science, 2021; OECD, 2023; Weinzierl, 2023).

Over the past few years, the space sector has experienced a significant transformation, from government-dominated space endeavors towards more entrepreneurial and commercial "New Space" era (Baber & Ojala, 2024a; Punnala et al., 2024). This transition has also created opportunities to establish new types of space firms which operate globally. However, we have very limited understanding how these firms internationalize their business what type of challenges they might face in their internationalization efforts.

Research Methodology

The study was designed to be qualitative and multiple case-method was selected for this study due to the exploratory nature of the research questions. Case study research is a very useful method as it allows expanding and generalizing theories by combining the existing theoretical knowledge with new empirical insights (Yin, 1981, 1994).This is especially important in studying topics that have not attracted much previous research attention such as internationalization of space firms. The case study research method is also particularly useful for theory-building even if little is known about the phenomenon (Vissak, 2010). This method better enabled us to utilize empirically rich and detailed data belonging to an understudied phenomenon (Edmondson & Mcmanus, 2007; Yin, 1994). In-depth interviews with representatives of Nordics space firms helped to acquire detailed, and many cases silent data that enabled form a better understanding of their internationalization processes.

The data collection involved semi-structured interviews with representatives of space firms from the Nordics region, the firms have operations in different market segments of the space industry and have been established on different periods. This was to allow us to collect data from a wider pool. The firms selected fit within the following criteria; they (a) were incepted and have their headquarters in the Nordics region, (b) provide a space technology-based product/service, (c) fit the definition of an SME when they officially initiated their internationalization efforts, (d) be continuously involved with internationalization activities for the past year. The firms meeting these criteria have been identified through the website of Euroconsult, Nordic Space, Swedish Space Corporation, Space Norway, European Space Agency Business Incubator database and Business Finland. A total of fifteen firms were identified based on these sources. These fifteen firms were contacted through e-mail with a request to participate on this research. Seven out of 15 responded positively and were willing to share their knowledge. Table 1 summarizes key information of these firms as well as the internationalization mode.

Company	A	B	C	D	E	F	G
Market Segment	Earth Observation	Manufacturing	Earth Observation	Ground Station	Manufacturing	Manufacturing	Infrastructure
Established	2014	2019	2016	2002	2018	2011	1995
Internationalization Model	Sales Distribution Channel	Partnership	Expansion (Subsidiary)	Network	Sales	Joint Venture	Joint Venture
Main Reason for Internationalization	Revenue	Revenue	Revenue	Revenue	Revenue	Revenue	Revenue
Country of Origin	Finland	Sweden	Finland	Norway	Finland	Sweden	Norway
Number of Employees	500	47	32	333	20	119	59

Table 1. Key information on the case firms

The firms selected, fulfilled the criteria of either, currently being an SME or of being an SME at the moment the firm internationalized. The European Commission defines an SME as a firm that has less than 250 employees and less than or equal to €50 million euros turnover (OECD, 2022). For this study, the Nordic region was chosen. Despite its smaller size compared to other major global regions, it consists of countries with a high level of innovation (***).

The interviews were conducted either face-to-face or via video conferencing software. The reason for this approach is because due to the nature of these organizations being distributed throughout the Nordics and management teams travelling constantly it was more convenient to conduct them remotely. For each interview, we scheduled 45 minutes, but the duration varied as can be seen in Table 2.

Firm	Interview Method	Duration (m)
A	Video Conference	55
B	Video Conference	45
C	Video Conference	45
D	Face-to-face	60
E	Video Conference	35
F	Video Conference	60
G	Face-to-face	25

Table 2. Information about the interviews.

The variation of the duration occurred because respondents were free to take their time to answer the questions. Some questions also resulted in the need for follow-up questions depending on the response received to either clarify or provide more information. The interviewees were all higher-level management (CEO, Business Development Director, Vice President, CTO, Sales Director) and their participation was voluntary and anonymous. All the interviewees had in-depth knowledge of their firms' operations and international markets entry processes.

For the interviews, we prepared an interview scrip with a list of 22 questions to help us obtain information regarding these firms. These questions were grouped into 10 different groups as can be seen on table 3. Zoom platform was utilized for the 25 – 60 minutes long interviews, these interviews were then transcribed verbatim through the transcription feature of the Zoom platform and a second listening was conducted to ensure that the transcription is in accordance with the recordings. For the live meetings, voice recordings were recorded and at the same time notes were taken. After each live interview, the recordings were transcribed and ensured that the transcriptions matched the voice recordings. Complete interview reports were sent to the interviews for data validity and in case of inaccuracies on the text, corrections were made based on the comments

provided. The collected data of the case firms was also compared to industry reports, company websites and other sources.

Group	Questions
Introduction	1. Introduce yourself and your role in the company.
	2. Briefly explain the purpose of the interview: to gain insights into your company's internationalization strategies within the space industry.
Company Background	3. Can you provide an overview of your company's history and core operations within the space industry?
	4. What are the key products or services your company offers in this industry?
Internationalization Experience	5. Has your company engaged in any internationalization efforts? If yes, could you please describe these initiatives?
	6. What were the primary motivations for your company to internationalize its operations?
	7. What defined internationalization for your company?
	8. Could you share any challenges or barriers your company encountered during the internationalization process?
	9. How did your company overcome these challenges?
Market Selection	10. How did your company select the target international markets?
	11. What criteria did your company consider when choosing these markets?
Entry Modes & Strategies	12. What entry modes did your company utilize when entering international markets (e.g., exporting, joint ventures, subsidiaries, direct sales, suppliers (importing)?
	13. Could you elaborate on the strategic approach your company adopted to establish a presence in these markets?
Product Adaptation	14. How did your company adapt its products, services, or business model to suit the needs of international markets?
	15. Did your company employ any localization strategies to align with local cultures, regulations, or market preferences?
Partnership/Collaborations	16. Did your company form any partnerships or collaborations with local or international entities to support its internationalization?
	17. What were the key objectives behind these partnerships or collaborations?
Outcomes/Performance	18. How would you evaluate the success of your company's internationalization?
	19. What key performance indicators (KPIs) does your company use to measure the effectiveness of its internationalization strategies?
Future Plans/Challenges	20. What are your company's future plans regarding international expansion within the space industry?
	21. Are there any anticipated challenges or opportunities your company foresees in its internationalization journey?

Conclusion	22. Is there any additional information or insights you would like to share regarding your company's internationalization experiences within the space industry?

Table 3. Interview questions

In accordance with GDPR regulation and research ethics, any information that could disclose their identity has been omitted. Firms and respondents have been labeled with letters. An interview guide was created to ensure that the same questions were asked of all subjects. The interviews have been conducted from November 2023 to March 2024. Data analysis was conducted from November 2023 to April 2024 at which patterns were analyzed for each firm on their internationalization journey.

Research Findings

Internationalization of Nordic space firms

The findings of this study reveals that the main reason why the case firms opted for internationalization was to increase the revenue. A common theme expressed by the interviewees is that the Nordics regions and its domestic markets are too small for these companies to be able to have healthy streams of revenue. For instance, Firm A which manufactures, launches and operates its own satellites in order to be able to serve their EO market, argumented that the only means to be competitive against the bigger, more traditional firms in their market segment was to increase the operational expenses (OPEX). However, on average, OPEX is way too high for space firms that operate any sort of ground and space infrastructure, thus being imperative that they internationalize early on after inception.

More than half of the case firms reported that once they had a product that was ready to be commercialized, the time period between inception and the first international export, international hire, international partnership and international contract was less than one year. In terms of export intensity and revenue streams, the case firms that internationalized earlier were able to outperform those that took longer to internationalize. The general consensus for this claim from the interviewed firms is that if a firm take too long to internationalize, they miss the opportunity to secure contracts from foreign governments that played an important role. As the interviewee from Firm A stated “Currently, over 50% of revenues in our market segment are from government contracts”.

In general, the interviews reveal that internationalization of space firms can occur in various forms, including: (a) Signature of Memorandums of Understanding (MoU); (b) Partnership agreements such as reseller agreements; (c) Hiring personnel in foreign countries; (d) Direct export/sell; (5)

Tendering; (e) Direct Investment; (f) Funding through public initiatives. The findings also shows that space firms from the Nordics region, with time are getting increasingly strategic and systematic. The CEO of firm C stated that "from an early stage, Nordic space firms design an "export strategy" which is a term that is interchanged with "internationalization". This indicates that there is a slight difference between how larger firms internationalize compared to smaller firms. Furthermore, the case interviewers also pointed towards a four-stage internationalization approach:

1. Once the firm has a Minimum Viable Product (MVP), they start by exporting their products/services sporadically without established resellers/distributors. This allows the firm to acquire a better understanding of the different markets, customer needs, target customers, refine the value proposition and achieve a product-market fit. Firms B, C and E are currently on this stage.
2. The second step is when firms have already defined their target markets and have established distribution channels within that market by establishing partnerships or signing agreements with local or regional resellers/distributors. Firms D and F are currently on this stage.
3. The third step happens when the firm officially sets up their own entity/subsidiary for sales. Firm G is currently in this stage.
4. The fourth and last step is when the firm increases its international commitment by manufacturing and selling the product in the same market they previously exported. Firm A is the only firm out of all the interviewed firms to have reached this stage. All the other interviewed firms with the exception of Firm G have stated that they intend to achieve this stage in their internationalization efforts.

Firm A and Firm D formed a network of connections early on to share operational risks and costs. These risks and costs included the deployment of ground infrastructure globally, which allowed for faster and more competitive satellite data downlinking. This was critical for Firm A, as it enabled the company to secure larger contracts in foreign markets.

Internationalization challenges encountered by small Nordic space firms

When attempting to break into foreign markets, Nordics space firms face several challenges. In terms of challenges, there is a discrepancy between the expertise needed to internationalize space firms and the expertise available from the human capital pool in the Nordics. Funding is another challenge that Nordics space firms face when compared to competitor firms of the same size in other regions such as North America and Western Europe. Venture capital culture is more advanced in the U.S than Europe as a whole. Due to lower returns when compared to the U.S., Nordics VC firms have a harder time raising capital for small space firms and therefore invest less money in Nordics space firms.

These challenges that includes; regulatory hurdles, funding constraints, and competition from larger players in the global market pose obstacles for small businesses seeking to internationalize in the space industry.

1. **Regulatory hurdles** - The regulatory frameworks for space technology development, satellite launches, and space operations are often complex and challenging for small businesses. As these companies seek internationalization, they have to comply with international standards, obtain necessary permits and licenses, and be able to navigate bureaucratic processes.

2. **Funding constraints** - Case firms often faced difficulties in securing adequate financing to support their growth and expansion initiatives, particularly during the early stages of their operations which hinders the ability for these firms to compete effectively in the global space market. Access to capital for research, development, and commercialization of space technologies is a major challenge for space firms in the Nordic region, as there are limited public funding initiatives.

3. **Competition from larger players** - Case firms also face competition from larger players in the global market, including well established aerospace corporations such as Airbus Defense and Space, Boeing, Lockheed Martin and Maxar as an example. These larger players often have greater financial resources, technical capabilities, legacy products that have been well embedded into different global systems and a great market reach often fueled by government support based on national interest, allowing them to dominate key segments of the space industry.

4. **Technology development** - Technology development is a very important aspect of the space industry, requiring continuous innovation and investment in research and development (R&D)(Aglietti, 2020; Ben-Itzhak, 2022; Corrado et al., 2023). During the case interview, it has become clear that these firms have to overcome challenges that are related to technology development. Often, developing space technologies requires substantial expertise, infrastructure, and resources, which often is beyond the capabilities of smaller firms.

5. **Satellite launches** - This is one of the most important components of the space industry value chain, because it enables firms to deploy their technology into orbit and deliver services to customers. The case firms interviewed have reported that for those companies that have to deploy technology in space this is a major budget and time challenge due to the fact that there are currently no launch facilities in the Nordics region, thus their technology has to be shipped to a foreign launch site which increases costs and also adds regulatory hurdles that they might have to deal with.

6. **Customer selectivity** - The case firms also revealed that customers are increasingly selective, and sales cycles are usually taking longer, specifically for government contracts. Branding plays a huge role when attempting to internationalize and from an early stage, space firms from the Nordics region have to dedicate resources on foresting partnerships with potential Proof of Concept (POC) customers/partners in order to get the product out in the market and gain credibility.

Discussion and conclusions

The objective of this study was to investigate the phenomenon of firm's internationalization contextualized to the space industry and the Nordics region. In order to obtain a thorough understanding of this phenomenon, this paper analyzed which processes the case firms undertook to internationalize. The case studies and the literature review have shown common philosophies and internationalization patterns for space firms.

The first contribution of this study is that it analyzes space firms within an international business context to enhance our understand of how firms in space industry undertakes internationalization efforts. This study applies traditional internationalization theories (Johanson & Vahlne, 1977; Johanson & Mattsson, 1988) and compares them with the internationalization strategies of space firms. Different studies have investigated the case of internationalization from different angles, industries, geographical region and market segments. However, we expand these studies for new industry sector.

Based on the case studies, there are strong evidence that these firms are incepted with the goal to internationalize, for some of these firms, their first sales/customer is from an international market. It is also true that the smaller the domestic market, the more urgent it is to internationalize or that firms are already incepted in an international context. In another words, they are "Born Globals" (Knight & Cavusgil, 1996; Madsen & Servais, 1997).

As a limitation, the firms studied were from the Nordics region that has its own characteristics. Therefore, firms originating from countries from this region may choose different ways of internationalization. Consequently, the results of this studies might not be generalized. Especially, space firms from larger domestic markets might internationalize in different manner or their internationalization process may vary from the findings of this study.

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