



## Research Article

# Standing on the Shoulders of Giants: The Evolution of the Irish Space Sector from an Institutional Perspective

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## ABSTRACT

This article focuses on Ireland's potential as a space actor and the role that the space sector can play in contributing to Ireland's future development. By embracing the metaphor of 'standing on the shoulders of giants' and by reconciling an institutional perspective of entrepreneurship with the triple/quadruple helix model, the article describes the journey of the Irish space sector that has capitalised on the experience of the major space players already established in the space arena in order to successfully carve its own niche.

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## 1. Introduction

Despite its economic and political importance, academically the space industry has been relatively overlooked by entrepreneurship scholars. This research examines how entrepreneurship in the space industry is shaped by institutions. We investigate this question in relation to the Irish space context. Empirical explorations of the role of the interrelationships among university–industry–government–society in regional entrepreneurial activities are rather rare. To address this gap, this article focuses on the Irish space sector by coupling an institutional perspective of entrepreneurship with the triple and quadruple helix models that have been widely adopted by regional studies. Accordingly, this article seeks to provide cohesiveness to an array of international business topics such as innovation and international competitiveness that traditionally would have been dealt by the literature in isolation.

Countries invest in space capabilities to fulfil national strategic objectives, including military considerations and defense strategy, leadership and prestige, development and resource management, economic growth and diversification. Economic growth and diversification are increasingly important as drivers of government space activity. Capturing a larger share of the global space economy is a desirable goal for several reasons. Space is a reliable growth industry that has proven resilient in the face of economic

downturns, while space-enabled services boost productivity in other adjacent sectors of the national economy.

However, beside the strategic economic and political importance of the space sector, addressing the question of how entrepreneurship is shaped by institution is rather crucial for a variety of reasons that are linked to some of the peculiar features of the industry. First, the range of actors participating in space related activity has expanded considerably since the days of the original space race of the 1960s involving only the Soviet Union and the US. As well as now involving a growing number of private sector actors, today over seventy countries have space programmes with China emerging fast as a space power and potentially rivalling the pre-eminence of the US in space in the future. Today's space state actors are not only the large economies such as the US, Russia, China, Japan, and India, they also include some smaller economies. Ireland is among those smaller economies with national aspirations to being a player in the space sector and a driver of its economic growth in the future.

Second, the space industry is perceived as very innovative, leading us to expect to find this industry flourishing in an environment that is conducive to entrepreneurship. Yet, the space industry is highly regulated by institutions [1]. There is little research examining how institutions impact on entrepreneurship at an industry level [2]. However, there is a well-established consensus that institutions tend to shape the rules of the innovation game [3]. Focusing on entrepreneurship in the context of the space industry offers the opportunity to deepen our understanding of industry-specific conditions that shape the rules of the game for

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innovation – not only how the game is played, but also the size of the playing field [4].

Third, Ireland is a particularly interesting setting. Ireland's space industry is relatively young, with its inception in the mid to late 1970's. Ireland's neutrality during WWII and in the succeeding Cold War discouraged national investment in space era, effectively excluding it from the first generation of global space activity in the 1950s and 1960s [5]. In contrast, Ireland's modern space industry boasts over 70 companies nationwide whose combined turnover was forecast at €500 mn in 2020. Enabled by Ireland's membership of the European Space Agency (ESA), Ireland's ambition in space is directed towards the peaceful application of space technologies to the benefit of its economy and society [6].

In the light of the abovementioned reasons, this article focuses on Ireland's potential as a space actor and the role that the space sector can play in contributing to Ireland's future development. By relying on the metaphor of 'standing on the shoulders of giants', the article describes the journey of the Irish space sector that has capitalised on its collaboration experience with major space players already established in the space arena in order to successfully carve its own niche.

The article considers Ireland's history in space up to the present. It assesses the country's competitive strengths and weaknesses and the extent to which it can position itself to competitive advantage within the global space sector. The assessment is performed at three inter-related levels – macro (i.e., international), meso (i.e., national) and micro (i.e., enterprise) levels. At macro level, Ireland's relationships with international space actors particularly ESA are assessed. At meso level, the government's national space strategy produced in 2019 is critically evaluated as is the role of state institutions principally the national enterprise agency – Enterprise Ireland. At micro level, the resources, capabilities and strategies of firms are critically examined. The link-in and link-out collaboration strategies of firms are described and illustrated with concrete examples. Their potential for driving growth in the sector is assessed. Drawing on the triple/quadruple helix model [7,8], it emerges that a very strong collaboration ethos permeates all three levels of analysis considered thus distinctively characterising the industrial fabric of the space sector across all its layers. The article contributes to several areas of enquiry such as entrepreneurship, innovation and international business by bridging them together within the overarching institutional perspective, thus delivering a more cohesive body of knowledge to a range of topics that otherwise would have been rather sparse.

The paper consists of five sections. The next section introduces the relevant theoretical foundations that have informed the article. The third section outlines the methodology adopted. The fourth section describes the case study and provides a discussion of the findings. The final section outlines the original contribution of the work, the implications stemming from the findings, their limitations along with directions for future research.

## 2. Theoretical foundations

### 2.1. An institutional perspective of entrepreneurship

In the literature, there is a long-standing discourse on the role of institutions in national and regional economic development [9–13]. Despite the ambiguity about the role and nature of institutions, there seems to be a consensus that institutions matter for regional development because they shape the institutional context of regional and national economies and condition processes related to economic growth such as innovation and entrepreneurship [10,14].

The concept of institutions offers a concrete, tangible way to capture the structures that form the industrial context in which firms operate. North [15,16] showed how regulations, law and the like can be understood as formal institutions. In contrast, cultures, values and practices can be seen as informal institutions. Together, formal and informal institutions offer a structural map of the space industry territory, the context that firms encounter and negotiate, as well as the policies, rules and norms that influence the ways in which they behave.

Institutions encompass notions of culture, legal environment, tradition and history and economic incentives, which frame social interaction by hindering and enabling activities and decisions [17]. Within this context, political freedom, corruption and education would have all a significant impact either enabling or hindering entrepreneurship. The main premise of the institutional embeddedness of entrepreneurial activities is that prevailing values, rules, expectations and infrastructure in countries often shape entrepreneurial activities [18]. Institutional theory applied to entrepreneurship suggests that entrepreneurs must conform to existing institutions in order to gain endorsement, legitimacy and resources from the relevant stakeholders [19]. Entrepreneurs aim to gather the necessary human and financial resources by convincing the relevant stakeholders of the legitimacy, appropriateness and desirability of their proposed activities in relation to the prevailing socially constructed system of evaluation [20].

Common institutional factors that shape entrepreneurial activities are market conditions and property rights [21], family structure [22], formal policy [23] and the availability of capital [24]. Urbano and Alvarez [25] for instance demonstrate that a favourable regulative dimension (fewer procedures to start a business), normative dimension (higher media attention for new business) and cultural-cognitive dimension (better entrepreneurial skills, less fear of business failure and better knowing of entrepreneurs) increase the probability of being an entrepreneur. Conversely, inadequate institutional development can hinder new venture development [26] while a more developed institutional environment with overly restrictive regulation can hamper entrepreneurial activities [27].

Research has found that informal relationships may help to fill in the 'institutional voids' resulting from an inadequate development of formal institutional infrastructure [28]. Accordingly, a focus on institutionally embedded entrepreneurial action allows scholars to appreciate the relationships between entrepreneurship and the institutional settings in which it comes about [29].

### 2.2. The triple helix model

Potential determinants of entrepreneurship that have been presented in the literature include population (e.g., size), income, number and type of R&D, employees, educational degrees, university R&D, creativity, foreign population, political structure, land costs, taxes, natural amenities and others [30]. As far as factors influencing entrepreneurship, the triple helix model of university–industry–government relationships has been developed to study the knowledge infrastructure in networks of bonds among the institutional constituents of a regional innovation system [31,32]. Specifically, the model provides important insights into understanding innovation in the context of the mutually supportive relationships among university–industry–government players [8].

In recent years, several authors [7,33,34] have been using the triple or quadruple helix model to explain innovation and economic development in many countries or regions.

The triple helix model was created by Etzkowitz and Leydesdorff [8] to explain the relationships between university, government

and industry. Etzkowitz et al. [31] states that the triple helix is increasingly responsible for innovation. Although this is not a linear model, it is based on the relationships between these three groups of stakeholders. Industry acts as a source of production, while government provides regulations, stability and rules, and universities provide technology and new knowledge. According to some authors [35], the long-term growth of innovation and the importance of integrating the citizens' perspective based on media and culture has led to the development of the quadruple helix model, adding one more helix to the original one. Thus, some authors [7,36] argue that the structure of an economy is divided into four helixes consisting of universities, industry, government and civil society, in which their relationships generate innovation and economic development.

However, despite their valuable contributions to understanding entrepreneurship, comprehensive empirical explorations of the role of the triple and quadruple helix models and the interrelationships among university–industry–government–society in regional entrepreneurial activities are rather rare. To address this lacuna, by relying on an institutional perspective of entrepreneurship we investigate the determinants of entrepreneurial activity using the triple/quadruple helix model to assess the impact of institutions on entrepreneurship within the peculiarities of the Irish space sector. The article embraces the view that coupling an institutional perspective of entrepreneurship with the triple and quadruple helix models that have been widely adopted in regional studies is instrumental to providing cohesiveness to an array of international business topics such as innovation and international competitiveness that traditionally would have been compartmentalised as if they were silos. Such cohesiveness allows for a finer grained picture of the more specific institutional dynamics that enable the space industry to flourish.

### 3. Methods

We want to understand how entrepreneurship in the Irish space industry is enabled and constrained by institutions. Our deductive, interpretative and qualitative approach aimed to broaden understanding of this industrial context and the impact its institutional environment has on entrepreneurial practices [37]. Our qualitative approach generated a grounded understanding about how this industry, and interactions within and outside it, works with and against new business creation and entrepreneurship. Qualitative case study methodology enables researchers to conduct an in-depth exploration of intricate phenomena within some specific context [38]. Case study research consists of a detailed investigation, often with empirical material collected over a period of time from a well-defined case to provide an analysis of the context and processes involved in the phenomenon. The phenomenon is not isolated from its context but rather is of interest precisely because of its relation with the context.

Given the nature of the research and limited body of knowledge of how entrepreneurship in the Irish space industry is shaped by institutions, the case study approach is the most suitable methodology for the empirical investigation. The case study is appropriate when investigating a poorly researched phenomenon and where data required for formulating hypotheses have not yet been obtained [39,40]. Exploratory case studies typically address how and why questions [40] concerning the dynamics present within a particularly contextual setting to develop initial understandings [39,40]. Specifically, the single case study is appropriate if the case under scrutiny is critical, extreme, unique and revelatory [41]. The single case study allows for analytic generalisation of the results that could inform the development of theoretical propositions which can be tested in future studies [40].

As for the case selection, we consider the case of the Irish space sector as a revelatory case study [41] for several reasons. First, Ireland has a long-established history of astronomy and space research. In recent years, Ireland has developed a thriving space industry and research community, facilitated primarily through Ireland's membership of the European Space Agency (ESA). Second, Ireland is a relatively small country, both in terms of size and population. Third, differently from most countries, Ireland's political stance of neutrality has significantly shaped its industrial fabric. More precisely, given that stance, Ireland did not experience the evolution of any indigenous defence industry to encompass outer space and pushed its emergent space sector to capitalise on the benefits mainly presented by the emerging commercial landscape in space [42]. Fourth, Ireland enjoys a competitive position in the fields of material science, nanotechnology, software development, software engineering, pharmaceuticals, and med-tech. These sectors provide a very fertile ground on which the space sector can flourish. Finally, Ireland ranks high on third-level education amongst the OECD countries, the number of young people in Ireland attending third-level education is significantly above the OECD average [43]. As such, due to these peculiarities that make the Irish space sector rather unique, it was deemed as a potentially very fruitful setting in which seeking to understand the determinants of entrepreneurial activity in the space industry are enabled and constrained by the institutional dynamics.

As for the data collection, we preliminarily relied on desk research by assembling a very vast array of secondary data (65) as depicted in Table A1 in the Appendix. Various arguments in favour of developing secondary analysis of qualitative studies have been put forward ([44–46]; Thorne 1994). It has been contended that the approach can be used to generate new knowledge, new hypotheses, or support for existing theories; that it reduces the burden placed on respondents by negating the need to recruit further subjects; and that it allows wider use of data from rare or inaccessible respondents as in the case of the Irish space industry. The secondary sources ranged from European institutional sources (13), international sources (6), Irish governmental sources (16), consulting companies (2), Irish company websites (10) and web articles (18).

Concerning the data analysis, we performed thematic analysis [47]. Thematic analysis is an accessible, flexible, and increasingly popular method of qualitative data analysis. Thematic analysis is a method for systematically identifying, organising, and offering insight into patterns of themes across a data set. It was performed independently by the two researchers to minimise the emergence of possible biases. More precisely, this research uses thematic analysis to analyse the content of secondary sources, which is a method for identifying, analysing, and reporting themes through reading and rereading the data [48]. Thematic analysis combines and integrates components or fragments from data, which are often meaningless when viewed alone [49]. In this study, thematic analysis is carried out following six steps proposed by Braun and Clarke [47]. The first step is to organise and prepare the data for analysis and become familiar with the dataset. In this research, we sorted and arranged the documents into different types by classifying them by source (i.e., European Institutional sources, international sources, Irish governmental source, consulting companies, company websites). Both the researchers read the documents several times to gain a good understanding of the data before moving to the coding stage. Step two is generating initial codes. In this phase, we organised our data in a meaningful and systematic way. Instead of line-by-line coding, we encoded the data segments associated with our research problem. In this stage, we carefully studied the content of text materials for the analysis of naming and classification, through the process of analysing, examining and

conceptualising and comparing the data. Step three is searching for emerging themes. A theme is characterised by its significance. There are hundreds of themes in the process of open coding, so we classified similar concepts and clustered them together. At this stage, the categories are temporary and may be subject to change at any time due to new discoveries. At the end of this phase, each code was organised into broader themes that illustrated the specifics of the research question. Step four is reviewing themes. At this stage, we read the data associated with every theme and considered whether or not the data really supported each theme and worked in the context of the entire dataset. We also checked whether those themes were coherent and distinct from each other. Step five involved defining and labeling the themes. This is the final refinement of the themes, and the aim is to identify the ‘essence’ of what each theme is about [49]. At this stage, we made the relationship between the theme and the sub-themes clear. We used the meaning or image evoked by the data to name the theme. Step six involved writing-up. Writing is an integral part of the analytical process in thematic analysis, which includes analytical narrative and data extraction. The authors of the study acted as the two coders for the data analysis processes. Both coders have published several articles on the space industry and have extensively used thematic analysis in their previous work. To improve the accuracy of thematic analysis, a sample of 65 sources was assigned for check-coding. Two coders independently analysed these 65 sources. We use Index of Inter-coder Agreement  $\pi$  [50] to report the proportion of agreement between the coders.

As a result of this process several themes emerged from the extensive data collected. These were namely – *the evolution of the Irish space sector, the importance of the international collaboration, national policy and governance, education and research, financing of the Irish space sector and the Irish space enterprise sector*. Each of these themes will be discussed in detail in the next section.

#### 4. Findings

##### 4.1. The evolution of the Irish space sector

Fig. 1 below provides a timeline of the major events that have shaped Ireland’s participation in space.

Ireland’s commercial involvement in the global space economy formally began with its membership of the ESA in 1975. This followed Ireland’s participation in the European Space Conference in 1974 and various representations at the European Space Research Organisation in the 1960s. The principal argument for the country’s

membership centred around the desire to develop an emerging industry in scientific research and information technology.

Despite possessing sufficient expertise within its growing engineering sector, Ireland lacked public investment in national defence and security, owing to its strict policy of neutrality. This prevented the evolution of any indigenous defence industry to encompass outer space [5]. However, joining the ESA complemented Ireland’s defence policy position, given the organisation’s overarching aim of promoting cooperation and collaboration among European States on space research and the application of space technologies for purely peaceful outcomes. For this reason, Ireland is primarily concerned with the industrial possibilities provided by space technologies. Ireland’s national airline, Aer Lingus, was the first to capitalise on the opportunities presented by the emerging commercial landscape in space. In 1982, the company founded Devtec to manufacture specialised mechanical components for ESA-Ariane launch vehicles. In addition, Space Technology Ireland Limited was established to utilise the experience gained by Irish scientists in producing both hardware and software for ESA programmes. Irish telecommunications progressed rapidly alongside these developments. The public provider Telecom Eireann became a signatory to the Eutelsat organisation in the 1980s, and Atlantic Satellites Ltd were granted access to the direct broadcast satellite system in Ireland in 1985 [5].

Nowadays Ireland’s positioning in space is underpinned by public and private cooperation at a national level, and membership of the ESA and the EU internationally. The government’s commitment to supporting Ireland’s space industry has been confirmed with the launch of the National Strategy for Space Enterprise (NSEE), and its ongoing investment in space companies through Enterprise Ireland. The importance of education to the current and future success of the industry is visible in developments at primary, secondary and tertiary levels. Higher education remains the most important channel through which scientific research in space becomes commercial reality.

Globally, Ireland’s commercial involvement in space can be compared to states at similar levels of economic development and with similar population sizes. Small, open economies such as Singapore and Luxembourg have joined Ireland as new participants in Space 4.0, with both countries publishing national space policies to lure private investment and increase government contracts. Conversely, Ireland’s space industry includes both the manufacture of space technologies and the provision of services that use those same technologies. Furthermore, the rapid technological change that has lowered the costs of entry into the global space economy

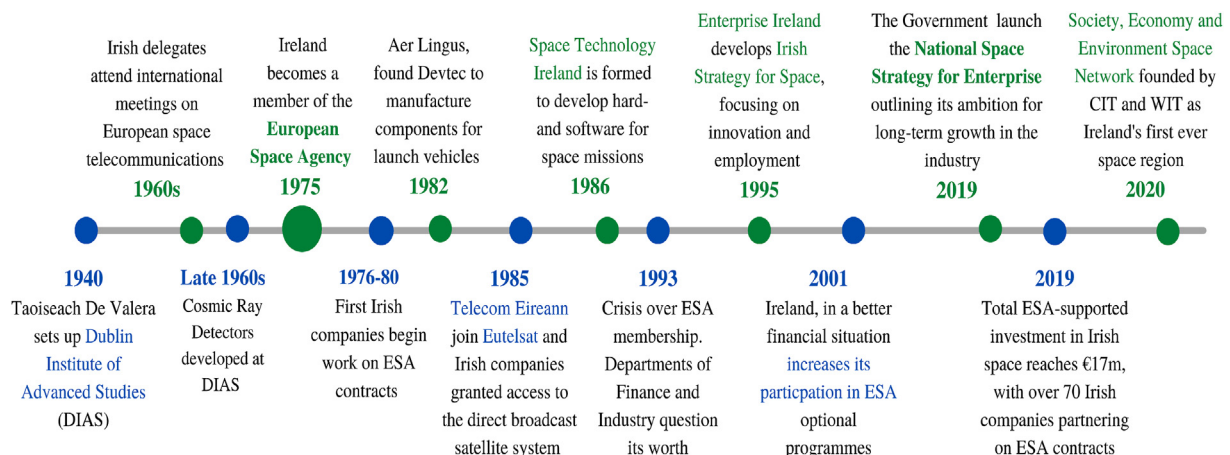


Fig. 1. Timeline of events in the development of Ireland’s space industry.

has brought states such as Denmark into the fold. An EU member state like Ireland, Denmark is part of the ESA and participates in both the Copernicus and Galileo programmes (ESA, 2018). Ireland's contribution of €3.60 per capita to the ESA's annual budget is significantly lower than that of Denmark's at €5.47 per capita. Both Denmark and New Zealand channel their engagement with space through a government agency or ministry that has other, non-space related priorities, much like Ireland.

Smaller countries can be niche players in the global space economy; utilising their small populations, world-class education systems, and their industrialised economies allow them to become leaders in their respective fields [1]. Luxembourg which has done so through funding ventures independent of a space agency and, despite an insignificant space budget, is home to the world's leading GEO satellite operators: Intelsat and SAS. While the opportunities are vast, some areas of the space industry, such as large-scale rocket manufacturing, are likely outside of Ireland's reach. In Ireland's case, Enterprise Ireland and IDA Ireland, amongst others, have stressed the importance of Irish companies in this industry finding their niche. Ireland has a global reputation in the fields of material science and nanotechnology and is also advanced in areas such as software development, software engineering, pharmaceuticals and med-tech. These have contributed to Ireland's success in downstream activities catching the attention of key players in the global space industry.

#### 4.2. The importance of international collaboration

As a member of the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the EU space programmes, and more recently, the European Southern Observatory (ESO), Ireland's engagement in the space sector has been increasing. Ireland seeks to benefit from these memberships, integrating Irish space technologies and innovations into the wider international space industry and contributing to the new era of space, Space 4.0.

The ESA's core activities are facilitated through mandatory programmes that all constituent members are obliged to participate in (ibid.). Ireland's involvement in these activities span a wide variety of products and services, from the production of advanced satellite components and the development of satellite launchers to educational software procurement and technical engineering processes. The ESA's budget stood at €6.68bn in 2020, with Ireland contributing €97.8 m during the period 2016–2020 (ibid.). Financing of ESA contracts has been primarily enabled by Enterprise Ireland (EI), Ireland's national agency charged with monitoring the operations of Irish industry collaborating on ESA programmes. The total contract value of ESA-supported investment in Irish space rose to over €17 m in 2019, with 70 companies partnering with the ESA on space activities, including five new entrants. EI maintains a permanent delegation of three representatives at the ESA's governing council. However, the agency is not solely dedicated to the development of Irish space; its core purpose is to promote export-led growth in all aspects of the Irish economy.

Despite its growing international footprint in space, Ireland is not a member of the UN's Office for Outer Space Affairs. This leaves the Space Generation Advisory Council (SGAC) as the country's only form of representation for its space industry at the UN. SGAC is a global non-profit organisation that convenes university students and young professionals working in space to promote the creation, discussion and adoption of ideas for space by young people that can advance the causes of humanity. The Irish delegation of SGAC has acted as an interlocutor between the ESA and Irish university-based start-ups such as Enbio and Innalabs, both of which have won ESA contracts worth over €500,000 in 2017.

International collaboration and partnership form the principal foundation of Ireland's success in space. Ireland's participation in multilateral institutions such as the ESA has provided the demand for Irish space products and services, allowing an ecosystem of space companies to thrive. The ESA allocates the funding for Irish space projects and promotes technological transfer and knowledge sharing between member states. Ireland's membership of the European Union underpins this supportive environment, with the single market and customs union facilitating the free movement of goods, services, capital and labour into and out of Ireland. This enables it to more readily fill skills gaps in the space sector. Thus, Ireland has benefitted more from regional growth in the global space industry, rather than from the globalisation of space. This reflects the historical view of space as a strategic resource and a vehicle to promote national security. Therefore, Ireland's space industry has progressed on a regional, rather than on a global basis. Irish space companies, many of whom are start-ups, tend to act locally with regional strategies. The EU has sought to secure its own strategic autonomy by publishing its first space policy, with the aim of positioning the bloc for the technological shifts and intensifying competition inherent in the new space race, strengthening EU space supply chains, of which Ireland forms a part.

#### 4.3. National policy and governance

The Irish government's National Space Strategy for Enterprise 2019–2025 (NSSE) is a commercialisation plan and strategy for Irish enterprises in the space industry. It outlines a vision for the space-active enterprise sector in Ireland to develop 'an economically sustainable and expanding space-active industry, delivering quality jobs for the economy of tomorrow' (ibid.). With the launch in 2019 of the NSSE, the Irish Government outlined its ambition to support long-term, sustainable employment in Ireland's growing space-active industry (ibid.). Revenue and contract value targets, raising awareness among the public and building expertise with domestic and international talent all feature as strategic goals to secure Ireland's place in this new global space race. The strategy aims to deliver a number of outcomes by 2025. These include – doubling space related revenue and employment, supporting companies involved with the ESA, increasing awareness of Ireland's activities in space, developing and attracting talent for space industries, and developing a sustainable Earth Observation services sector based on advanced data analytics capability (ibid.). The Government wants Irish employment in the industry to be high-value skilled roles where skills developed for use in the space sector can be applied to the wider economy in areas such as software development, communications and nanotechnologies or to contribute to tackling global challenges such as climate change (ibid.). Within the national policy arena, the key players are namely the *Space Enterprise Coordination Group* and *Enterprise Ireland*.

The *Space Enterprise Coordination Group* was established in 2019 by the Irish Government to oversee the implementation of the initiatives outlined by the National Space Strategy. While Enterprise Ireland plays an important role in enterprise development and growth, it was recognised that there was a need for wider coordination to thoroughly exploit the opportunities and benefits offered by EU and ESA space programmes (ibid.). It is an interdepartmental group, combining key stakeholders to better utilise investments in space, contribute to climate change solutions and to make more informed decisions with regard to Ireland's space industry (ibid.).

Much of the work done by *Enterprise Ireland* (EI) revolves around helping companies on their development cycles. For companies with prospective technology for space, EI aids them in accessing finance through venture capital and equity funding. For companies

who have already developed their technology, it helps them to bring it up to a certain level of maturity based on the Technology Readiness Level scale developed by NASA. EI provides a source of expertise for Irish companies in initialising, developing and executing space strategies. From there they assist these companies in bidding for ESA contracts and tenders to develop space technologies, services and business applications. It also acts as a point of reference for the international space industry in identifying space related technology and expertise in Ireland (ibid.) as well as new market opportunities for technology transfer into and out of the space sector. They support Irish space-active companies on applicable trade missions and support Ireland's industrial interests in the various European space-related organisations: EUMETSAT, ESA, ESO, etc.

#### 4.4. Education and research

At primary level, children are exposed to creative learning through a suite of new programmes that include ESB Science Blast, Maths Week and the Primary Science Fair. The educational materials employed at these events are produced by organisations such as the Irish Rocketry Society and Astronomy Ireland. At second level, total enrolment in STEM subjects at senior cycle rose by 5% between 2016 and 2019, with enrolment for female students in STEM at junior cycle rising by 12%. Blackrock Castle Observatory in Cork has developed space education resources for teachers that allow students to easily access STEM learning. At third level, Ireland had the highest rate of STEM graduates out of any EU member state in 2017, at 32.7 per 1,000 of people between the ages of 20 and 29. Irish involvement in International Space Week brings conversations led by industry experts about the latest developments in space to university audiences. Promoting STEM including space learning and research is the result of a collaborative environment consisting of academic institutions and private enterprises that co-fund research and co-sponsor scholarship.

Professional training and executive education can further improve Irish companies' understanding of the opportunities that exist in the global space economy. Space Industry Skillnet (SIS) is a State-sponsored enterprise network that encourages the sharing of knowledge and the development of technical expertise, both of which enable the fulfilment of ESA contracts. Unveiled in 2006 at an initial cost of €400,000, SIS is a collaborative effort between Skillnet Ireland (a government agency) and 30 private companies. In providing education to employees at all levels of space companies, SIS builds competence and know-how across the industry. In addition, SIS advises 'pure-play' or space-only businesses to consider the spin-out possibilities of their products and services for ground applications. Furthermore, SIS provides outreach to non-space companies to assess the commercial viability of spin-in operations in space, with the objective of procuring more ESA contracts and increasing the number of space-active businesses.

The founding of the Society, Economy and Environment Space Network (SEESN) in 2020 as Ireland's first ever space region by Cork and Waterford Institutes of Technology (IoT) exemplifies the necessity of cooperation in space. SEESN aims to establish an Irish Space Coast and attract inward investment from at home and abroad. In addition, University College Dublin has launched C-Space, Ireland's first dedicated hub for space research and innovation. C-Space's priorities include fostering links to industry through consultancy and access to research facilities, as well as expanding the skill set of Irish graduates through the introduction of a master's programme in space technology. Crucially, C-Space is home to EIRSAT-1, the first Irish-built satellite. EIRSAT-1 was developed in partnership with students from Trinity College Dublin, Dublin Institute of Technology and Maynooth University.

Within the EU, Ireland is a member of the Copernicus Academy, which connects universities, research facilities and business schools to enable cross-institutional cooperation and the development of common frameworks for teaching disciplines. The EU's PRODEX programme also provides exposure of Irish scientists to ESA experiments, including at the European Southern Observatory and the International LOFAR project. In 2010, the ESA in collaboration with the Irish government announced the go-ahead for the creation of an Irish branch of the European Space Education Resource Office (ESERO) (ESA, 2010). Additionally, investments in International Research Organisations such as the International LOFAR telescope and the European Southern Observatory have created opportunities for Irish students' involvement in current research.

#### 4.5. Financing of the Irish space sector

The Irish government has financed promising space research through Enterprise Ireland (EI). EI's 'Commercialisation' Fund provides €15,000 in research grants, and additional funding if the research is commercially feasible. Two additional funds were established as part of the NSSE initiative. These are the Disruptive Technology Innovation Fund (DTIF) and the Climate Action Fund. The DTIF was a €500 million fund in which successful applicants were to be granted a minimum funding of €1.5 million. Meanwhile, the 'Agile Innovation' fund provided 50% funding for commercial projects under €300,000. This financed space-related start-ups, facilitating research, and the commercialisation of space technology. Pilot Photonics, a Dublin City University start-up, developed a 'Photonic Integrated Comb Laser' with financial support from EI. This college start-up has used its technology for space applications including satellite communication, high-frequency optical metrology and high-performance gravimeters. Pilot Photonics success underscores the importance of financing bright ideas.

ESA reinforce EI's space initiatives by providing additional funding and access to space technologies. ESA's 'Business Incubation Centre' (BIC) offers up to €50,000 in funding to space start-ups with some 67 Irish companies benefitting from ESA funding in 2018, stimulating industry growth and development. To build on this success, the Irish government is increasing its contributions by 50% before 2025, charting a bright future for Ireland's space industry. As a result, Irish SMEs such as Treemetrics have established a firmer positioning in the sector. Underpinning the success of both EI and ESA funding initiatives is one of the most competitive tax systems in the world. However, it has yet to be exploited by the international space industry.

Research and Development (R&D) grants are the preferred source of public funding in the space industry. Ireland's tax system encourages R&D, by allowing companies to avail of a 25% tax credit on R&D expenditure, in addition to a 12.5% tax deduction. Effectively Irish companies are refunded €37.50 for every €100 of qualifying R&D expenditure. This encourages and supports organisations to invest in new product R&D and innovation. For example, Varadis developed a radiation detection chip called 'RADFET', which is used on the International Space Station, using medical resources at the Tyndall Institute. This is a perfect win-win outcome. Tyndall supports world-class product innovation, while benefiting from a financially attractive tax credit.

Ireland has offered stellar financial incentives to space companies in the past. However, the role of states is changing and countries can no longer necessarily depend on state-sponsored space activity alone, as markets and private capital have changed the game [1]. Thus, there is an opportunity for Ireland to further adapt its financial supports infrastructure to best engage in this new space investment landscape.

#### 4.6. The Irish space enterprise sector

In 2018, the Irish space industry's turnover was estimated to reach €500 mn by 2020, with direct employment in space enterprises rising to 4,500 (Horn, 2019). There has been a growing participation of Irish companies in space over the past decade. This can be divided between upstream and downstream segments of the space value chain.

The former relates to the manufacture, launch and maintenance of space technologies, and the latter focuses on harnessing the application of such technology to deliver space-centred products and services. Contracts involving upstream investment by the ESA include mBryonics, an indigenous start-up located in Galway that utilises complex optical technologies to channel data communications to and from satellites (O'Regan, 2021). Downstream developments include contracts with companies such as Techworks Marine, which provides collection of and access to data on coast water measurements.

Ireland has predominantly been focused on and specialised in the downward segment with the primary focus currently being earth observation data. This focus and specialisation is further emphasised in the Irish government's National Space Strategy for Enterprise 2019–2025 (NSSE). Earth Observation (EO) is the gathering of information about the Earth's environment using space-based technologies, usually from satellites with imaging capabilities. Ireland has access to the data EO provides through its membership of the ESA, the EU's Copernicus Programme and EUMETSAT, the European satellite agency that observes the atmosphere, ocean and land surfaces. Data from Sentinel-1, -2, -3 and -5P satellites can be accessed freely through the Copernicus Open Access Hub, yet the challenge is to find ways to apply the data to benefit society. The commercial application of satellite data in Ireland is especially relevant to sectors in which Ireland specialises, such as marine and agriculture. This aligns with the Government's aim of cultivating sustainable space-related economic development in industries previously unengaged with Ireland's space-active companies. In 2021, EI planned to advertise a call for private entities interested in collaborating with the public sector to identify further commercial uses for EO data.

Space manufacturing supply chains are extremely complex and divided into 'Tiers' with many players often involved in several segments at the same time. At the top are 'Primes', responsible for the overall design and assembly of complete space systems. Tiers 1 and 2 contribute to the design and assemble of major equipment and subsystem parts. Traditionally, most Irish companies were likely to be found below Tier 2 and specialised in the production of expert components and materials. However, in recent years the industry has seen the emergence of new players at every level of the supply chain. New innovations and increased collaboration are also aiding the development of supply chains within the industry.

Collaboration is key in establishing a thriving ecosystem. The ability of Irish space-active companies to exchange technologies between space and non-space sectors, where technology synergies exist, is seen as key in the development of a sustainable and agile industry. Already, Irish companies from related technology sectors are engaging with the space sector to develop technologies with uses both in space and in other high reliability sectors such as automotive and aerospace. In addition, the goal is to support the emergence of enterprises using satellite-derived data to develop high value services, which can support policy making decisions, enterprise development and address global challenges.

A central focus of the NSSE is the potential for 'spin-in' involvement of non-space enterprises in the space sector, such as Pilot Photonics, which has adapted its laser technology used in data centre networking for extra-terrestrial use. Similarly, the 'spin-out'

participation of space companies into other areas of the economy is also envisaged, like start-up Arralis in Limerick, which has marketed its Ka-band communications antenna (initially designed for an ESA Space Antenna mission) to support 5G applications.

Evidence of successful technology transfer can be seen in Dublin-based SME ENBIO which has its roots in the medical device industry, and which has contributed to the ESA's Solar Orbiter mission. ENBIO has moved from producing synthetic coatings for implants to providing ESA with material to protect satellites from extreme temperatures while orbiting the sun.

These synergies between the space and non-space industries, and the capability of Irish companies to exchange technologies between these industries, has been identified as a key goal of the Irish Government in their 'National Space Strategy for Enterprise 2019–2025'. To this effect, Enterprise Ireland has been actively engaging with Irish companies, such as ENBIO, in helping them realise their full potential and contributing to the growth of Ireland's Space Industry.

Ireland lacks the presence of a European Large Space System Integrator, such as Airbus in France or OHB in Germany, to complement the growing ecosystem of Irish space start-ups. These integrators (also known as 'Primes') allow for economies of scale and scope by bringing multiple components of the upstream and downstream value chain under centrally coordinated control. To counter this deficiency, EI hosted several Primes and emerging Irish space enterprises in 2019 to promote collaboration and identify opportunities for investment. The event resulted in over 70 business-to-business meetings.

Notwithstanding the disruptive impact of the global pandemic, new ESA contracts are being signed, with companies like ÉireComposites securing the right to design and manufacture equipment in Connemara for the Altiuss satellite. The NSSE target of attracting five to ten new entrants to the space industry each year has not been revised and is expected to be achieved despite COVID-19.

COVID-19 has highlighted ways in which space can solve world problems. A range of space technologies were deployed to help in the fight against Covid-19. In Ireland, Skytek, a Dublin-based space software company, developed a satellite-enabled platform to support the country's emergency response. With links to Ireland's Computerised Infectious Disease Reporting system, it generates alerts when suspected cases rise. PMD Solutions, a Cork-based company, in partnership with Beaumont Hospital, developed the world's first space-enabled 5G wearable medical device to monitor respiratory-compromised patients in the community. This innovation is yet another example of the spin-out potential for flexible space-active companies in Ireland, adapting space products and services for unrelated markets.

Broadening access to the internet has been pioneered by companies such as Elon Musk's SpaceX (Lucey, 2021). 40% of the world's population still had no internet access in 2021 [51]. This inaccessibility acts as a barrier to economic growth and social mobility. In the southern Irish county of Kerry, only two-thirds of households have access to high-speed broadband). SpaceX's Starlink aims to address this shortage by providing low-cost, high-speed broadband beamed from low-orbit satellites. The company has partnered with the National Space Centre (NSC) in Cork to supply internet to the Black Valley, one of Kerry's most rural areas. The collective efforts of SpaceX and the NSC herald the first direct investment of a Prime in Ireland's space industry.

Domestic strengths in areas of material science and nanotechnology have put Ireland in a strategic position to take advantage of the rapid shrinking in size of both satellites and propulsion units. These transfers of technology not only benefit the space industry but can also serve as a testbed for applications in other sectors. The 2017

International Space Universities Space Studies Program (SSP17) report underscored these positive spillovers from the space sector into Ireland's domestic pharmaceutical and biomedical industries. This is seen in ENBIO's vision to become 'the multi-industry standard for sustainable, metal surface technology solutions'.

Some of the most high-profile collaborations involving Irish space firms in recent times showcase just how far the Irish space sector has come. For example, on 20th February 2021, Réaltra's Payload Data Router (PLDR) system, which was both designed and manufactured here in Ireland, was launched onboard the SS Katherine Johnson spacecraft from a NASA facility in Virginia. This marked the first project whereby an Irish firm was the prime contractor in the delivery of a complete space system, from start to finish.

Ireland's space industry is characterised by strong stakeholder engagement between the public and private sectors, both of which are driven by value optimization rather than profit maximisation. Irish space companies are committed to supporting secure, high-paying employment, and the Irish Government is dedicated to funding the commercial success of space-active businesses. There is an understanding between both actors that the benefits of space to both business and society complement rather than compete with one another. Ireland's space sector is committed to realising long-term, sustainable growth that also promotes job creation and environmental protection. The European Investment Bank has forecasted the space commercialisation industry to grow by €2.3 trillion by 2030 (European Investment Bank, 2019), and Ireland is keen to claim its piece of the pie. Collaboration is seen as a notable strength across many of the Irish firms operating in the industry.

Overall, recent developments have put Ireland in a very promising position. With the presence of well-established software, telecommunications, and nanotechnology industries, Ireland's industrial capabilities and strong talent base have made considerable contributions to the global collaborative space race.

The NSSE highlights that as a small and diverse industry, Irish enterprise must remain responsive to opportunities in a range of sectors in order to successfully grow. Accordingly, Enterprise Ireland is charged with supporting the development of an agile space-active enterprise sector by pursuing an open innovation model, including technology spin-in and spin-out; supporting space qualification and Technology Readiness Level (TRL) progression for the commercial space market; building supply-chain relationships with space systems integrators and ensuring non-dependency on agency and institutional support. However, Irish firms and individuals hoping to make a name for themselves in the global space economy have been met with their fair share of obstacles. Government oversight of structural arrangements in the industry can constrain the long-term development of the sector. This was outlined in the SSP17 report that called for greater priority to be placed on establishing a national space agency, stating that a space agency would help the industry to grow while aiding the government in areas of education, outreach and investment. In 2017, a Roadmap for Emerging Space States (ARESS) was produced by the UN Committee on the Peaceful Uses of Outer Space (COPUOS). This report also recommended that Ireland establish its own space agency, to incentivise more space-active private industry (International Space University, 2018). The absence of an Irish chairperson in the United Nations Office of Outer Space Affairs (UNOOSA) has left the Irish space industry with no party to represent national interests. This has also left Ireland at a disadvantage as firms are legally unprotected in commercial operations in space which has resulted in start-ups moving and/or setting up

in nearby member states such as the UK. Calls for a national space agency have been echoed by actors in the industry. The formation of the Irish Space Industry Group (ISIG) in 2015, has provided a platform to promote the collective interests of companies in the sector with the aim to 'preserve and grow a vibrant and sustainable space industry sector in Ireland'.

An additional recommendation of ARESS was to increase investment in space-related STEM education (ibid.). However, other voices in the industry have maintained that efforts must be made to provide more routes into the industry apart from the traditional degree paths in STEM. The provision of apprenticeship routes into the industry in Ireland as is the norm in the likes of Airbus and Surrey Space Centre in the UK can assist in promoting the growth of the Irish Space Sector.

## 5. Discussion: a critical assessment of Ireland's space sector

By means of the triple/quadruple helix model, the following table frames the emerging themes that were identified as a result of the thematic analysis and that were thoroughly described in the previous section.

*The government* played a pivotal role in shaping *the evolution of the industry*. The fact that Ireland lacked public investment in national defence and security, owing to its strict policy of neutrality, prevented the evolution of any indigenous defence industry to encompass outer space. However, joining the ESA complemented Ireland's defence policy position, given the organisation's overarching aim of promoting cooperation and collaboration among European States on space research for purely peaceful outcomes. For this reason, the Irish space industry is still primarily concerned with the industrial possibilities provided by space technologies. The government's commitment to supporting Ireland's space industry has been confirmed with the launch of NSEE and its ongoing investment in space companies through Enterprise Ireland. The Irish government has financed promising space research through EI. This financed space-related start-ups, facilitating research, and the commercialisation of space technology.

Nowadays Ireland's positioning in space is underpinned by public and private cooperation at a national level, and membership of the ESA and the EU internationally. Ireland's participation in the ESA has provided the demand for Irish space products and services, allowing an ecosystem of space companies to thrive. EI aids companies in accessing finance through venture capital and equity funding, it helps them to attain a certain level of maturity and provides a source of expertise for Irish companies in initialising, developing and executing space strategies.

Overall, from the evidence presented it can be inferred that the government has played a pivotal role in the establishment and ongoing development of the Irish space industry. This pivotal role has entailed a wide array of complementary initiatives ranging from initiating international collaboration, setting an adequate industrial policy strategically targeting the sector, direct financing (i.e., space research, space-related start-ups, commercialisation of space technology), the provision of incentives through a very competitive corporate tax regime along with substantial investment in higher education.

The importance of *education* to the current and future success of the industry is visible in developments at primary, secondary and tertiary levels. However, higher education remains the most important channel through which scientific research in space becomes commercial reality. C-Space, Ireland's first dedicated hub for space research and innovation fosters links to industry through



consultancy and access to research facilities, as well as expanding the skill set of Irish graduates through the introduction of a master's programme in space technology. Crucially, University College Dublin's C-Space is home to EIRSAT-1, that was developed in partnership with students from Trinity College Dublin, Dublin Institute of Technology and Maynooth University. Ireland membership of the Copernicus Academy, which connects universities, research facilities and business schools to enable cross-institutional cooperation and the development of common frameworks for teaching disciplines.

*Civil society* has been also instrumental in shaping the industrial fabric of the Irish space industry—the same openness to internationalisation has brought remarkable benefits at national level with non-profit organisations such as SGAC playing a pivotal role as an interlocutor between the ESA and Irish university-based start-ups such as Enbio and Innalabs which have won ESA contracts.

*The Irish space industry* developed in parallel as a result of the government initiatives. In 1982, for instance following the Irish membership of ESA, Aerlingus founded Devtec to manufacture specialised mechanical components for ESA-Ariane launch vehicles. Similarly, Space Technology Ireland Limited was established to utilise the experience gained by Irish scientists in producing both hardware and software for ESA programmes. As soon as Telecom Eireann became a signatory to Eutelsat, Atlantic Satellites Ltd were granted access to the direct broadcast satellite system. The strong ethos of policy neutrality has brought Ireland to predominantly focus and specialise in the downward segment, especially on earth observation data. The openness of the institutional environment is significantly visible in the synergies between the space and non-

space industries, and the capability of Irish companies to exchange technologies between these industries.

Overall, the experience of the Irish space sector demonstrates that the institutional perspective of entrepreneurship is apt to explain both the evolution and the dynamics of the industry. Within this context, the explanatory power of the triple/quadruple helix model is particularly evident as highlighted in Table 1. The interactions of the players of the triple/quadruple helix have proven to be highly conducive to the growth of entrepreneurship within the Irish space sector. Those interactions have been enabled by an institutional environment that enables the forging of frictionless connections and engagements among the players of the helix.

Additionally, from the application of the helix to the Irish space industry a rather important finer grained nuance tends to emerge. There is a widespread acknowledgement that informal institutions play a key role in shaping the regional development [9–13] and to great extent expectations foster entrepreneurial activities [19,20]. As depicted in Fig. 2, our findings highlight the pivotal importance of *openness to collaboration* and of *international orientation* that both take place at the institutional level and that by osmosis similarly foster the entrepreneurial ethos of the space industry.

Furthermore, the case study provides emblematic evidence that by engaging in fruitful collaborations at large with more established players (i.e., Ireland closely collaborating with ESA internationally and Irish space firms collaborating with well-established non-space firms domestically), smaller countries can indeed become niche players in the global space economy. Likewise, by making efficient use of their distinctive resources (i.e., their small populations, world-class education systems, and their

**Table 1**  
Framing the emerging themes utilising the triple/quadruple helix model.

Emerging themes	Triple/quadruple helix model
The evolution of the Irish space sector	The evolution of the Irish space sector has clearly stemmed from the remarkable close <b>interplay between government, the university sector, industry and civil society</b> . <b>The government</b> has provided the institutional framework – both at macro level internationally, and at meso level nationally – for the sector to be established and flourish. <b>The university</b> has greatly benefited from adequate long-sighted national policies that have led to the provision of the necessary skills and expertise that were needed by the industry. At micro level, <b>the enterprise sector</b> has been able to fully capitalise from the synergies stemming from the interplay between these layers. It had a remarkable impact on the sector across the three levels of analysis. At macro level, the international activities pursued by <b>the government</b> have allowed the Irish space sector to become globally competitive in a relatively short timeframe. Ireland's participation in multilateral institutions such as the ESA has provided the demand for Irish space products and services, allowing an <b>ecosystem of space companies</b> to thrive. Its membership of the ESA forms the basis of Ireland's place in space and has given Irish space companies an international platform from which to operate. ESA funding is central to the industry's growth. However, at the same time, Ireland is neither a member of UNOOSA nor the UN's Committee on the Peaceful uses of Outer Space. This detracts from Ireland's ability to collaborate with international partners, whether public or private, and leaves the industry vulnerable, considering recent increased global competition. Additionally, the increasing trade protectionism by the US and China poses a significant risk to the growth of Ireland's space industry. Free trade is essential to the development of Irish space companies, and tariffs on goods or services destined for foreign markets would damage their competitiveness. At meso level, the same openness to internationalization has brought remarkable benefits at national level with <b>non-profit organisations</b> such as SGAC acting a pivotal role as an interlocutor between the ESA and <b>Irish university-based start-ups</b> such as Enbio and Innalabs which have won ESA contracts. Additionally, a key new opportunity for Ireland has recently emerged on foot of a 2017 agreement between Enterprise Ireland and ESA. The agreement allows access to an unprecedented volume of near real-time data about planet Earth and its environment captured by the EU's Copernicus programme. It has estimated that the Copernicus programme could generate a financial benefit of approximately €30 billion, in addition to over 50,000 new jobs, by 2030. Ireland is ideally positioned, given its strong heritage in ICT, to seize this opportunity and develop Copernicus data to respond to opportunities. In order to facilitate the use of this resource, <b>Enterprise Ireland, working with Government departments and agencies</b> , industry and research institutions will establish a Space Data Hub, allowing users to access and process data from European and other 3rd party space missions. This hub will form the core around which a vibrant internationally traded services sector, based on converting Earth Observation data into commercially valuable information, will be built. These services will be delivered through advanced ICT expertise, including among others, automated processing and deep learning. The Space Data Hub will drive the development of skills which can be applied to other industrial applications such as Industry 4.0. and will stimulate the creation of a vibrant, sustainable Earth Observation services sector, bringing value to industry and the community through the creation of commercial value from space derived data.
The importance of international collaboration	At micro level, international collaboration amongst the <b>Irish domestic firms</b> has led to the establishment of high-

(continued on next page)

Table 1 (continued)

Emerging themes	Triple/quadruple helix model
National policy and governance	<p>profile initiatives such as the adoption by NASA of the PLDR system - the first project where an Irish firm was the prime contractor in the delivery of a complete space system, from start to finish. Furthermore, SpaceX's Starlink allying with the NSC should spur further investment and partnership between Irish space companies and Primes abroad. More business-to-business meetings and government involvement are needed in this regard.</p> <p>Despite possessing sufficient expertise Ireland <b>lacked public investment in national defense and security</b>, owing to its strict policy of neutrality. This traditional policy of military neutrality has significantly hindered the development of any indigenous defense industry to encompass outer space. However, at the same time it has <b>pushed the sector into primarily exploring the industrial possibilities provided by space technologies for peaceful purposes</b>. This reflects the historical view of space as a strategic resource and a vehicle to promote national security.</p> <p>Ireland <b>lacks a dedicated government agency</b> for space. EI is the government agency charged with developing Irish enterprise in world markets (Enterprise Ireland, 2021a). Consequently, EI works to promote all industries, meaning space companies are competing with other unrelated start-ups/SMEs for resources.</p>
Education and research	<p>Ireland's investment in STEM education has developed highly skilled knowledge workers who can effectively realise the opportunities present in the industry.</p> <p>The NSSE highlights that the size of the emergent space-active industry in Ireland means that the critical mass is not yet achieved to require a broad range of dedicated space related third level educational programmes. The absence of a Large System Integrator (LSI) or 'Prime' company in Ireland, and the size and variety of disciplines active in the sector mean that much of the training for the individual needs of enterprise is carried out in-house or co-operatively within small groups of enterprises through the Space Industry Skillnet, which provides a dedicated training network for the space sector.</p> <p>Female participation in STEM education can be increased and more space-related undergraduate courses can be offered at <b>universities</b>. Business concepts such as finance and marketing for space companies could be incorporated into existing space-related degrees.</p>
Financing of the Irish space sector	<p>In relation to the economic incentives, the success of both ESA and EI funding initiatives is supported by one of the most <b>competitive tax systems</b> in the world where a corporation tax rate of 12.5% on trading profits is substantially lower than in competing countries. This gives Irish based companies a significant competitive advantage and is nurturing a vibrant space ecosystem where the entrepreneurial attitude of its stakeholders is bound to pave the way to business success.</p> <p><b>Ireland's stellar financial infrastructure</b> provides a competitive advantage for both space start-ups and incumbents through the commercialisation fund, Agile Fund and Ireland's attractive tax regime including its low corporation tax and 25% tax credit on R&amp;D.</p>
The Irish space enterprise sector	<p>In line with the open and collaborative nature that characterize Ireland's national culture, the sector has been thriving out of its active and dynamic participation in multilateral institutions such as the ESA which has provided the demand for Irish space products and services, allowing an ecosystem of space companies to blossom.</p> <p>Furthermore, by capitalizing on its global reputation in the fields of material science, nanotechnology, software development, software engineering, pharmaceuticals and med-tech, Irish firms were successfully able to establish themselves in downstream activities.</p> <p>At meso level, the ability of Irish <b>space-active companies to exchange technologies between space and non-space sectors</b>, where technology synergies exist, is seen as key in the development of a sustainable and agile industry where spin-in and spin-out mechanisms play a pivotal role.</p> <p>At micro level, Irish firms have shown remarkable dynamic capabilities [52] where ambidexterity [53] has been instrumental in allowing them to fully exploit their core competences in order to explore new opportunities.</p>

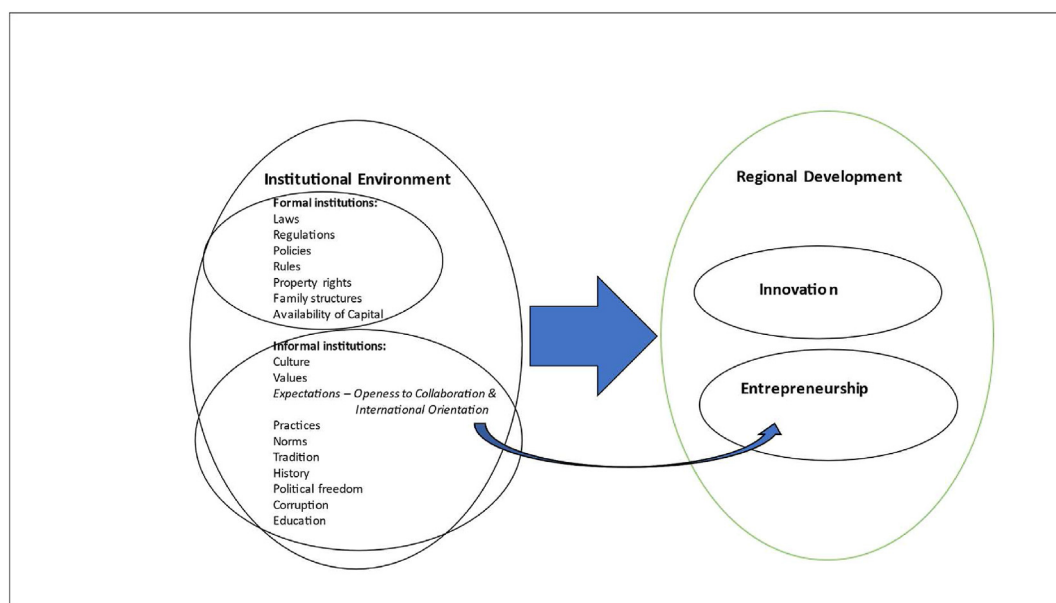


Fig. 2. The impact of collaboration and international orientation on entrepreneurship.

thriving ecosystems), they can become leaders in the space arena. Ireland is positioned to play a role in the growing global space sector. As collaboration in the space sector becomes more important into the future, Ireland's established prowess in terms of collaborative leadership capabilities can also work to its advantage.

## 6. Conclusion

The contribution of the study is twofold.

First, at a theoretical level our findings demonstrate the explanatory value of the institutional perspective of entrepreneurship and it does so in relation to the specific context of the Irish space industry. Historically, the resource-based theory of the firm [54] has been one of the key theories in entrepreneurship because access to resources is central to the success of a new venture. While resources are certainly crucial, it has increasingly become clear that both formal and informal institutions [15,16] play a pivotal role in fostering entrepreneurship. This is particularly evident in relation to the Irish space industry. Our analysis offers a comprehensive empirical exploration of the role of the triple and quadruple helix models and the interrelationships among university–industry–government–society constituents within the Irish space sector. Issues such as the institutional environment, tradition and history in an industry, the national culture, and economic incentives all can impact the evolution of a sector and, in turn, greatly influence entrepreneurial success [55]. Within this context, institutional theory provides a theoretical lens through which these issues can be identified and examined [56] and the Irish space sector is indeed the ideal setting for doing so. This is particularly evident if we look at the distinctive evolution of the Irish space sector, whereby these key stakeholders have played a pivotal role. More precisely, within the Irish space sector by coupling an institutional perspective of entrepreneurship with the triple and quadruple helix models that have been widely adopted by regional studies this study has provided cohesiveness to an array of international business topics such as innovation and international competitiveness whose interplay tend to be overlooked by overlooked by extant scholarly work (e.g., the study by Lamine et al. [4]). In particular, such a cohesiveness allows a finer grained picture of the institutional dynamics that have enabled the Irish space industry to flourish to be gained. The application of the helix to the case study ultimately highlights the pivotal importance of *openness to collaboration* and of *international orientation* that characterise the institutional fabric and that significantly shape the entrepreneurial attitude within the space industry.

Second, the study makes an important methodological contribution by developing a robust and compelling single case study by relying on systematic thematic analysis of secondary data. Until recently, thematic analysis was a widely used yet poorly defined method of qualitative data analysis. Thematic analysis is rapidly becoming widely recognised as a unique and valuable method in its own right, alongside other more established qualitative approaches like grounded theory, narrative analysis, or discourse analysis. While most extant studies adopting thematic analysis have largely relied on primary data, this article adopts a single case study approach whose explorative qualitative ethos can equally provide rich granular insights into several key themes. These are namely *the distinctive evolution of the Irish space sector*, *the importance of the international collaboration*, *national policy and governance*, *education*

*and research*, *financing of the Irish space sector* and *the Irish space enterprise sector*.

The policy implications stemming from the case study are also significant. In relation to the specific case of the Irish space sector, our results suggest that the roles of government, university, industry, and civil society vary in the promotion of entrepreneurial activity across the different level of analysis. For instance, the role of civil society seems to be particularly important only in relation to the macro level concerning the international collaboration. In addition, the heterogeneous effects of interaction among the players of the triple/quadruple helix on entrepreneurship suggest that systematic policy approaches are required in making effective entrepreneurship policy. The role of the university sector is especially important, in that it mediates the interaction among the players in the triplex helix system and can yield to valuable synergies in sectoral entrepreneurial activity. In addition, the positive and significant effect of higher educational attainment within the Irish context on entrepreneurial activity further emphasises the important role of the university sector in entrepreneurial development.

Our study contributes to the entrepreneurship policy literature by demonstrating the value of a more structural entrepreneurship policy emphasising the co-evolutionary relationship among university, industry, and government, as well as civil society, in promoting sectoral entrepreneurial activity.

The research provides richer and granular insights into the relevant institutional dynamics that have allowed the Irish space industry to be established and to flourish. Although these insights could not have been achieved by employing a different methodology, our methodology would have benefited from the inclusion of some primary data collection by means of in-depth interviews with the relevant players of the Irish space sectors.

There are opportunities for more research on the topic of the Irish space sector. A survey of the population of sector firms addressing the findings from this study would make a further contribution to our understanding of entrepreneurship in relation to the specific motives, strategies and challenges associated with their establishment. Similarly, the rising political tensions in Europe due to the occupation of Ukraine by Russia may call Ireland's position of neutrality into question. Its space industry may be forced to work only with certain countries or suppliers, undermining the potential for global expansion. Furthermore, the complexity of global supply chains means that any disruption to manufacturing upstream can impact upon services downstream. This could result in a 'butterfly defect' within the global space industry, where a negative shock to one sector or country destabilises the whole global economy [57]. These latest developments warrant further investigation.

## 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

No data was used for the research described in the article.

## Appendix

**Table A1**  
Secondary data.

How	Who and what	Where and when
European institutional source	Clancy, P. (2008) A Brief History of Irish Space Activities. Noordwijk, The Netherlands: ESA Communication Production Office.	Available at: < <a href="https://esamultimedia.esa.int/multimedia/publications/HSR-40/HSR-40.pdf">https://esamultimedia.esa.int/multimedia/publications/HSR-40/HSR-40.pdf</a> > [Accessed 12 April 2022].
	European Commission (2017) Big Data in Earth Observation	Available: <a href="https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Big%20Data%20in%20Earth%20Observation%20v1.pdf">https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Big%20Data%20in%20Earth%20Observation%20v1.pdf</a> [Accessed 12 April 2022].
	European Investment Bank (2019) How to leverage Europe's technological leadership and boost investments for space ventures. The Future of the European Space Sector.	Available at: <a href="https://www.eib.org/en/publications/the-future-of-the-european-space-sector-report">https://www.eib.org/en/publications/the-future-of-the-european-space-sector-report</a> [Accessed 12 April 2022].
	EU Science Hub - European Commission (2021) Earth observation - EU Science Hub.	Available at: < <a href="https://ec.europa.eu/jrc/en/research-topic/earth-observation">https://ec.europa.eu/jrc/en/research-topic/earth-observation</a> > [Accessed 10 March 2021].
	European Space Agency (2018) Denmark.	Available at: < <a href="https://www.esa.int/About_Us/ECSL_-_European_Centre_for_Space_Law/Denmark">https://www.esa.int/About_Us/ECSL_-_European_Centre_for_Space_Law/Denmark</a> > [Accessed 12 April 2022].
	European Space Agency (2020) Solar Orbiter: Operating in extreme environments.	Available at: <a href="https://www.esa.int/Science_Exploration/Solar_Orbiter">https://www.esa.int/Science_Exploration/Solar_Orbiter</a> [Accessed 12 April 2022].
	European Space Agency (2021a). This Is ESA.	Available at: < <a href="https://esamultimedia.esa.int/docs/corporate/This_is_ESA_EN_LR.pdf">https://esamultimedia.esa.int/docs/corporate/This_is_ESA_EN_LR.pdf</a> > [Accessed 10 April 2022].
	European Space Agency (2021b) Funding.	Available at: < <a href="https://www.esa.int/About_Us/Corporate_news/Funding">https://www.esa.int/About_Us/Corporate_news/Funding</a> > [Accessed 12 April 2022].
	European Space Agency (2021c) Large System Integrators.	Available at: < <a href="https://www.esa.int/About_Us/Business_with_ESA/Large_System_Integrators">https://www.esa.int/About_Us/Business_with_ESA/Large_System_Integrators</a> > [Accessed 12 April 2022].
	European Space Agency (2021d) €400,000 training initiative launched by space industry.	Available at: < <a href="https://www.esa.int/Space_in_Member_States/Ireland/400_000_training_initiative_launched_by_space_industry">https://www.esa.int/Space_in_Member_States/Ireland/400_000_training_initiative_launched_by_space_industry</a> > [Accessed 12 April 2022].
	European Space Agency (2021e) PRODEX.	Available at: < <a href="https://www.esa.int/About_Us/Corporate_news/PRODEX">https://www.esa.int/About_Us/Corporate_news/PRODEX</a> > [Accessed 12 April 2022].
	European Space Agency (2021f) ESA- What is Space 4.0.	Available at: < <a href="https://www.esa.int/About_Us/Ministerial_Council_2016/What_is_space_4.0">https://www.esa.int/About_Us/Ministerial_Council_2016/What_is_space_4.0</a> > [Accessed 12 April 2022].
	International source	Copernicus.eu. (2021) Copernicus Academy   Copernicus.
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