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Aerospace technologies and civil spillovers

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INTRODUCTION

From the beginning of the new millennium, a new framework has emerged for the aerospace industry. Until this moment, the space government agencies made mainly the sector, dominating in terms of investments and technologies development. A larger number of players in the industry instead characterizes the new setting, including many start-ups and small-medium enterprises. Other typical features of the new aerospace environment are the private investments as primary founding, aspect that allows also to entrepreneurs and venture capitalists to enter the market, and the process innovation alongside the technology one: making process less costly and more efficient could grant an important cost advantage. The new framework makes interesting to investigate the relationships between the aerospace industry and following civilian applications.

This thesis focuses on the analysis of spillovers coming from aerospace technologies through the analysis of patents data and citation pattern. Analyzing these data, it's a method to understand where the knowledge generated by an industry could spread: this research thesis focuses specifically on the attempt to understand if aerospace spillovers spread through other industries or mainly remain inside the boundaries of the sector. This analysis approach is quite straightforward, even if it has some drawbacks: not all the innovations could be tracked, for example many firms or institutions could decide not to patent some innovations for several reasons, maybe they want to keep secret their R&D efforts or they do not need to protect their innovations.

The thesis builds a companies' sample through the *dealroom.co* platform, which includes many startups and small-medium enterprises operating within the aerospace sector or at least working with data coming from this sector. With this assumption in the sample's construction, the thesis does not have the ambition to cover entirely the aerospace domain, since many important players, like space government agencies and very large companies operating in several industries, have been left out. After the identification of the companies, the following step consists of creating a patents' sample with several data related to each occurrence. These data allow to create several statistics to understand the nature of the patents gathered and of the selected companies.

In order to understand where the spillovers of the aerospace industry are mainly directed, the thesis shows the computation of an index called *SPACE_tech:* this index allows to understand the characteristics of the spillovers generated by the aerospace innovations and to classify the starting patents, according to some criteria applied on the citing patents. Results show that aerospace spillovers tend to spread more easily outside of the edges of the industry. This is because of many reasons discussed extensively in the thesis, for example, the fact that aerospace technologies are important for many industrial domains.

The thesis investigates also which are the variables that affect the likelihood of being cited by citing patents classified as *"space",* according to the criteria presented in the chapter, and the probability of being cited by patents out-of-space. Some *logit* models have been tested in different sample sizes. Results show that the likelihood depends mostly on some patents features like the wideness of the IPC classification and the fact of being classified strictly as *"space"* (at least one space IPC code is present among the industrial classification). These results are noteworthy since they suggest that the probability of citation is more related to patents characteristics, like the IPC classification, than to some assignees features.

Before going into the details of the research that has been conducted, the thesis briefly describes in chapter 1 the aerospace industry, highlighting the main differences between the so-called *New Space* environment and the traditional sector. Following in chapter 2, spillovers are defined and then contextualized in the aerospace environment. While in chapter 3, the data-gathering process and the method applied for the analysis are depicted. Moreover, the linear regression analysis is described. Finally, in the last chapter, the main conclusions and takeaways of the thesis are reported.

1. ECONOMIC CONTEXT: RELEVANCE OF THE AEROSPACE INDUSTRY

To fully explain the aim of the analysis provided by the thesis is essential to describe the main characteristic of the aerospace industry and the innovation flows that characterize this sector. The space industry, which has reached a global value around 423.8 billion USD in 2019 (Statista, 2022), can include many activities related to the research, exploration, and utilization of the space.
Before listing the primary features of the current aerospace industry, a small review of the history of this industry is provided to also explain the differences between the traditional aerospace industry and the so-called *New Space*.

1.1 Traditional aerospace industry

Aerospace industry's origins can be traced back to the 1960s, when the Soviet Union launched the first satellite Sputnik I, inaugurating the so-called *Space Race,* a period of very strong competition for supremacy on space technology, mainly between the United States and the Soviet Union. A large quantity of costs and risks characterized the first years of space technologies that no individuals or private companies would ever consider sustaining and so the only investors in the industry were the governments of powerful countries (NATO, 2018).
In Europe, instead, the origins of the largest and most important institution, the *European Space Agency* (ESA), can be traced back to 1975 when two existing organizations, *European Launch Development Organization* (ELDO) and *European Space Research Organization* (ESRO), merged. Ten countries took part immediately in the project: Belgium, Germany, Denmark, France, the United Kingdom, Italy, the Netherlands, Sweden, Switzerland, and Spain, while Ireland joined slightly later (ESA).
The first scientific mission was a satellite able to monitor the gamma-ray emissions in the Universe and, operating for many years, it was immediately a great success (ESA).
After a few years, ESA, NASA, and the UK joined a common project, launching in the space the first ever high-orbit telescope, which was able to operate for eighteen years (ESA).

The role of governments has been crucial for the aerospace industry for many years, since private investors considered the commercial opportunities of the space industry as very risky, costly, and characterized by long payback periods. (NATO, 2018).
Despite the very high costs and risks, the space industry provided some benefits to society already in the first years of explorations contributing to advances in many fields like computing, small electronics, telecommunications, and GPS technologies.
Governments' approach towards the space industry, particularly that of the United States, changed in 1984 with the Commercial Space Launch Act that aims at speeding up innovations

and driving costs down, through the expansion of the role of commercial space companies (Whealan, 2019).
In Figure 1 below the NASA's budget throughout the years is plotted. From the chart it's clear that, starting from the peak at the end of the Sixties, the NASA budget has been decreasing. This trend can be due to several explanations, but it is surely in line with a greater participation of commercial space companies in the industry.
This shift of the US policy, which will be followed also by Europe countries, contributed, alongside many other factors, to the *New Space* era after the beginning of the 2000.

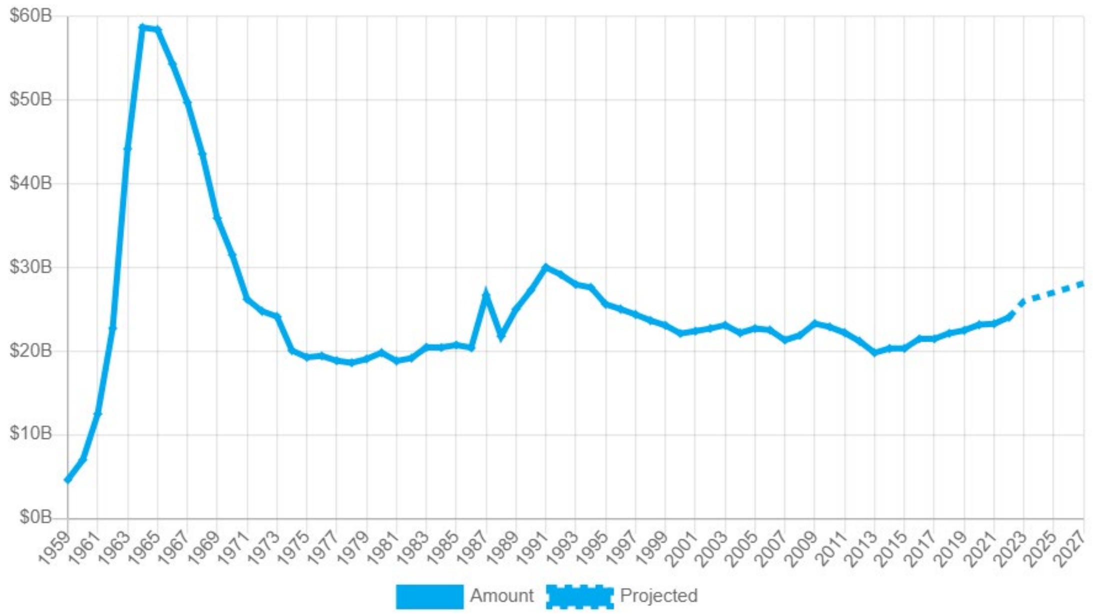

Figure 1. Trend of NASA's budget throughout the years. Peak was in the sixties (Source: The Planetary Society).

1.2 New Space era

This second paragraph focuses on the aerospace industry after the beginning of the second millennium, with the beginning of the so-called *New Space* era. This period has been characterized since from the start of different features with respect to the typical setting of this industry, traditionally dominated by space government agencies and institutional research centers.
This paragraph presents the main features of the modern space industry, from the supply chain point of view. Then, the industry key sectors are presented, describing which they are and what their value is. Finally, a brief summary of some future trends will be shown.

1.2.1 New Space key features

The term *New Space* can be used to refer to a visible and defined private spaceflight industry. The term refers to a set of mainly recent space companies, working independently of governments and their major contractors, developing faster and cheaper space solutions and technologies (Martin, 2017). Private firms are no more simply operating as contractors to governments or institutions, but they are becoming themselves key characters in the industry. The key features of the companies belonging to the *New Space* can be summed up in three meaningful aspects: an innovative industrial approach, the definition of new space markets and supply chain schemes and private/commercial funding as primary source (Moranta and Donati, 2018). Figure 2 depicts the main trend of the *New Space* era (Moranta and Donati, 2018).

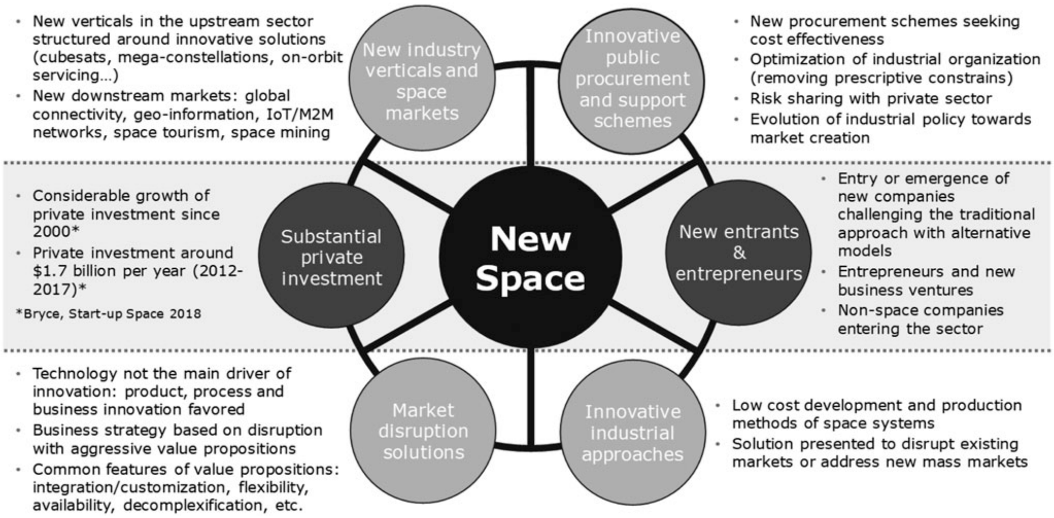

Figure 2. Key trends describing the *New Space* dynamics.

The first aspect refers to the fact that in companies belonging to the *New Space era*, innovation does not focus only on technology, but also process and business innovation are important: lower costs development process and production methods are pleasant solutions to enlarge the existing markets or to address the space solutions to new mass markets (Moranta and Donati, 2018).

Talking about new space markets, space companies recently have tried to widen their markets both upstream and downstream: upstream solutions are for example *cubesats* or on-orbit servicing, while downstream markets comprise global connectivity, space mining and space tourism (Moranda and Donati, 2018). *Cubesats* are the perfect example of the effort of making the access to space less costly: they are small satellites, weighing from few grams to hundreds of kilograms, able to make the same operations of traditional ones (Focus, 2020).

However, the most noteworthy characteristic of the *New Space* ecosystem is related to the number of private investments, which have a central role, and the entrance of new players in the market: many entrepreneurs and ventures enter the market challenging the traditional approach with alternative models (Moranda and Donati, 2018). All these players have an entrepreneurial approach, more agile and flexible than the traditional, hierarchical, and bureaucratic state agencies, with an open and decentralized innovation process (Rementeria, 2021).

Another important difference between the traditional space industry and the so-called *New Space* era regards the technological innovations life cycles. As seen in Figure 3, in the traditional space industry, R&D and product development phase can be very lengthy, since they require large upfront investments. Product development phase can last 5-15 years, much longer also compared to other ICT technologies. (1-5 years). Thanks to the business model of the companies belonging to the *New Space*, the product development life cycle and the need for large initial investments have been reduced. In the meantime, these changes have led to faster commercialization of space technologies. All these aspects have contributed to shift the s-curve of new space companies towards left and this progress it's likely to keep going in the future.

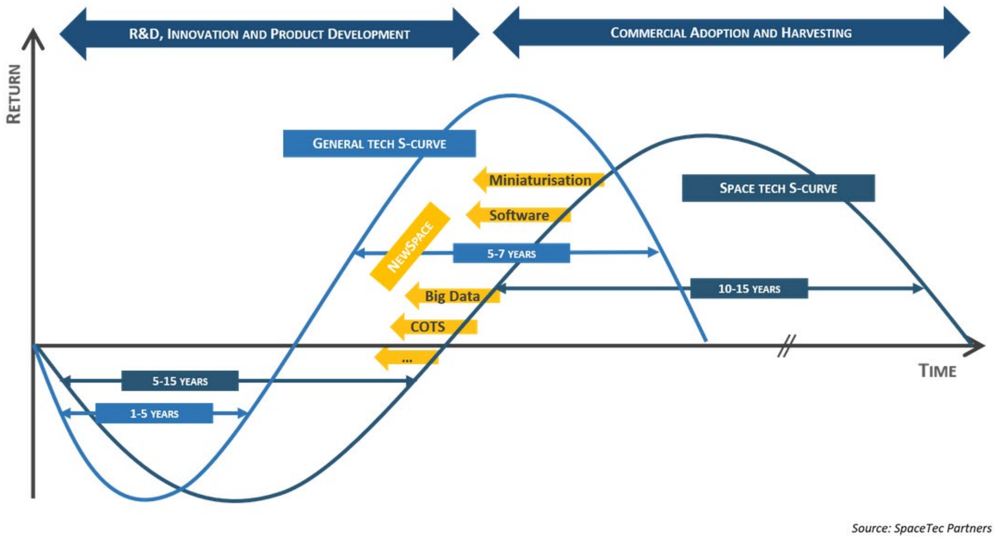

Figure 3. S-curve of technological innovation for space industry.

1.2.2 Core sectors

It's possible to divide the current space industry into three main core sectors: Satellites, Launch Services and Ground Equipment (NATO, 2018).
Satellites make up the most developed sector of the space industry since they have a very important place in the global economy. One explanation for this important role is that the know-how requested for satellites involved spillovers into other commercial sectors beyond the ones directly involved in the production. In recent years, the number of satellites in orbit is increasing, since they serve a broad range of functions: the main sub-sectors are manufacturing and services. Production and maintenance costs are very high, but they are

declining thanks to the upcoming of small satellites, also known as “minisats”, which are lighter and can carry out certain tasks in place of the traditional ones (NATO, 2018).
Satellites service is a very broad field which extends also beyond telecommunications. Specifically, the data generated from the Earth observations can provide a wide range of services, from tracking criminal activities to predict disaster (like tornados or tsunami) or monitoring weather. Obviously, satellites have huge applications also in the military field.
In 2019, there were around 2500 satellites in orbit, 53% belonging to the United States (Statista, 2022).
In Figure 4, it is possible to see the trend of revenues generated by the satellite sector during the last fifteen years.

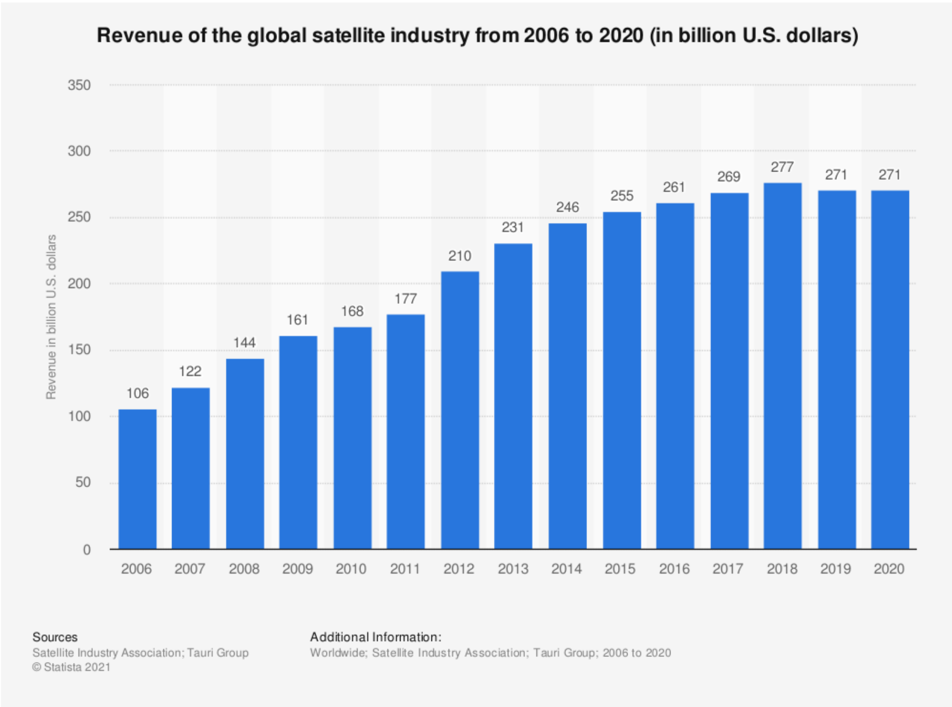

Figure 4. Revenues generated by satellite sector in the last fifteen years.

To remark the predominance of the satellite sector among the several space sub-domains, some studies forecast that satellites will count for 50% of the global space economy by 2040: increasing the number of satellites will allow to provide better Internet service, in particular the cost of managing very large dataset will be lowered (Morgan & Stanley, 2020).

Launch services sector makes up a more niche role than satellites and in recent years is estimated to be worth USD 5.4 billion (Statista, 2022). The innovation that affects more this sector is the use of reusable rockets, which represent a promising advance for reducing costs and launch turnaround time. However, these rockets will be characterized by a higher unit price.

The final notable component of the space industry is ground equipment, which refers to the Earth-based infrastructure that directs the information transmitted from satellites to proper transmitters and receivers. This infrastructure includes antennas that allow for transmission and reception of different communications signals, such as satellite radio and television.

Figure 5 shows the contributions of the several sub sectors that characterize the aerospace industry. The results are forecasted until 2040: it is clear how the impacts of this industry on other sectors able to create value will be larger and larger.

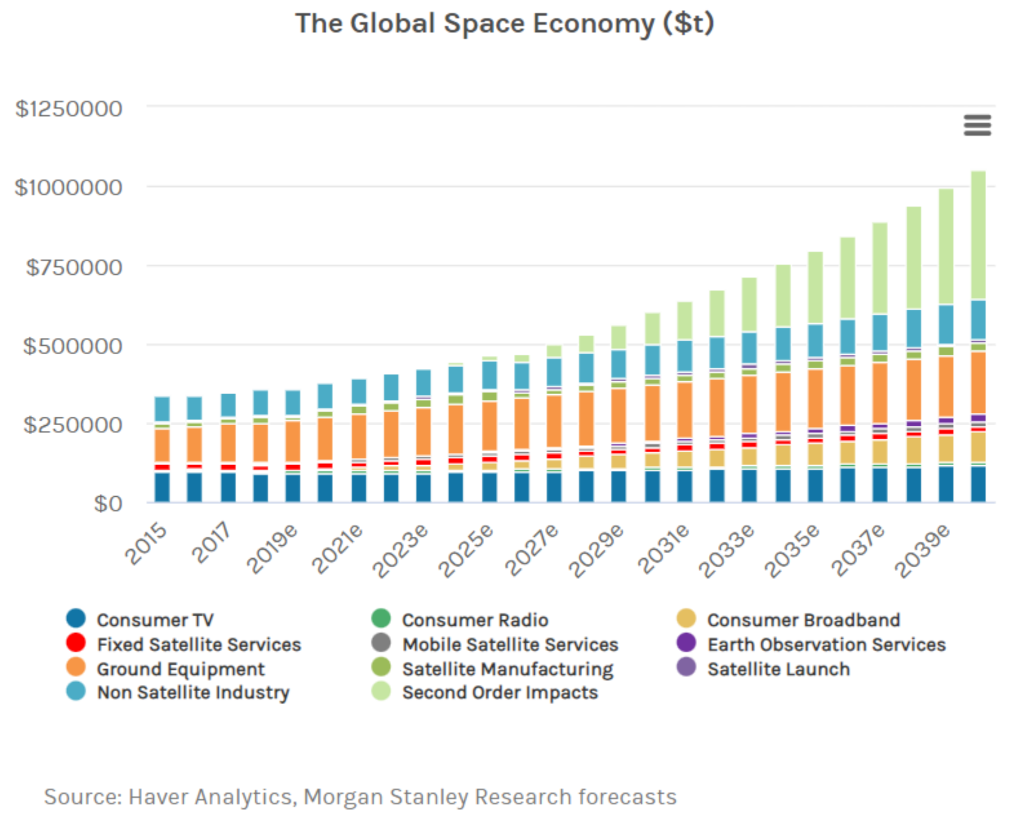

Figure 5. Contributions to global space economy of the different core sectors (Source: Morgan & Stanley, 2020).

1.2.3 Government spending comparisons

In the last years, government spending comprised around 20% of the total global space economy, with an amount of 87 billion USD. United States governments is the largest spender, since NASA's budget was over 25 billion USD in 2021 (Statista, 2022). The other major players in the market are the European Space Agency and China government, respectively, with a 6 billion USD and 11 billion USD expenditure. In the Figure on the following page, the government expenditure on space programs can be seen. Figure 6 depicts some of the largest countries in the world, like US, China, Japan, and other European countries. Even if it's clear how the US remains the leader in the industry, it's important to point out that more and more

nations are entering the market: nowadays 70 countries have established national space and, with the foundation of the new Latin American and Caribbean Space Agency (ALCE), every region of the world in action (McKinesy & Company, 2022).
From the chart depicted in Figure 6, it's possible to notice how the government expenditure worldwide increases of 10.7% with respect 2020, despite COVID-19 pandemic.

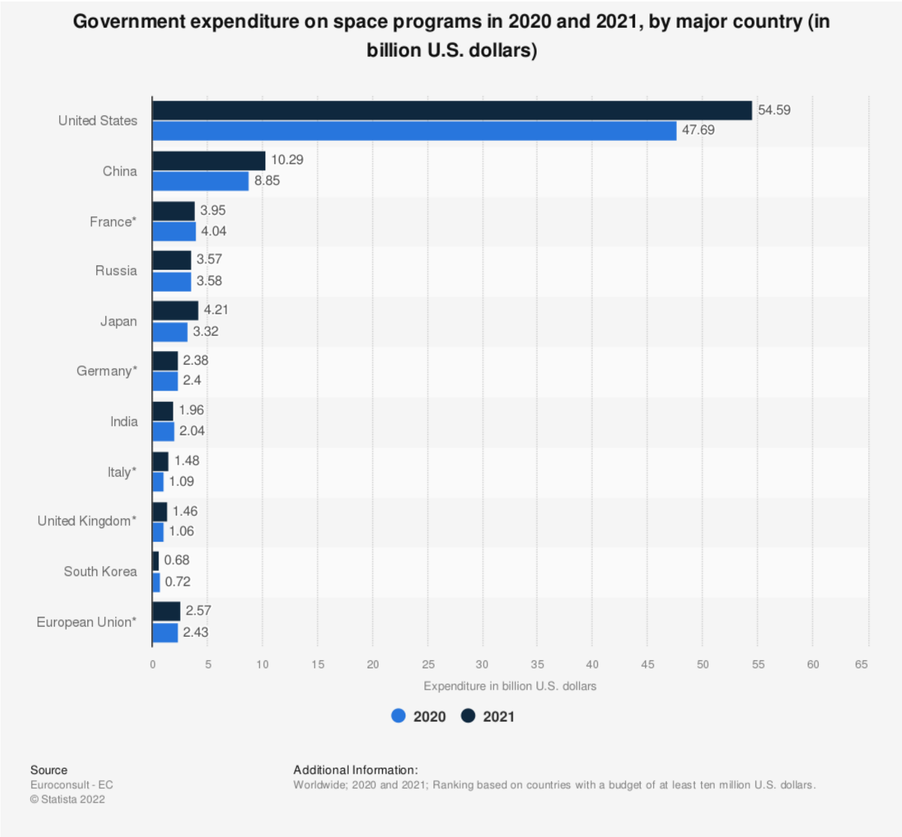

Figure 6. Comparison of government expenditure on space programs between 2020 and 2021.

1.3 Future trends

The last paragraph of the chapter provides a brief hint of some forecasted trends, both in financial and operational terms.
About financials, the space industry is expected to grow at a CAGR of 5.97% until 2026, reaching a global value of more than $500 billion (Statista, 2022). Market growth will be driven by high levels of private funding. In fact, they have supplanted many operations of government space agencies, advances in technology, and a growing public-sector interest in the space industry.
An emerging concept in the market is the space tourism, which is becoming attractive to more and more people. Many companies are involving themselves in these activities to make the concept an accessible reality to many people. Nowadays, space tourism stays accessible just for very wealthy people, since the required investments for civilians are huge.
Space tourism includes different flights, like orbital, suborbital or parabolic ones: this whole sector will account for 555 million U.S. dollars by 2030, according to some forecasting (Statista, 2022).
From Figure 7 below, it is possible to see the increasing trend expected for the space tourism worldwide.

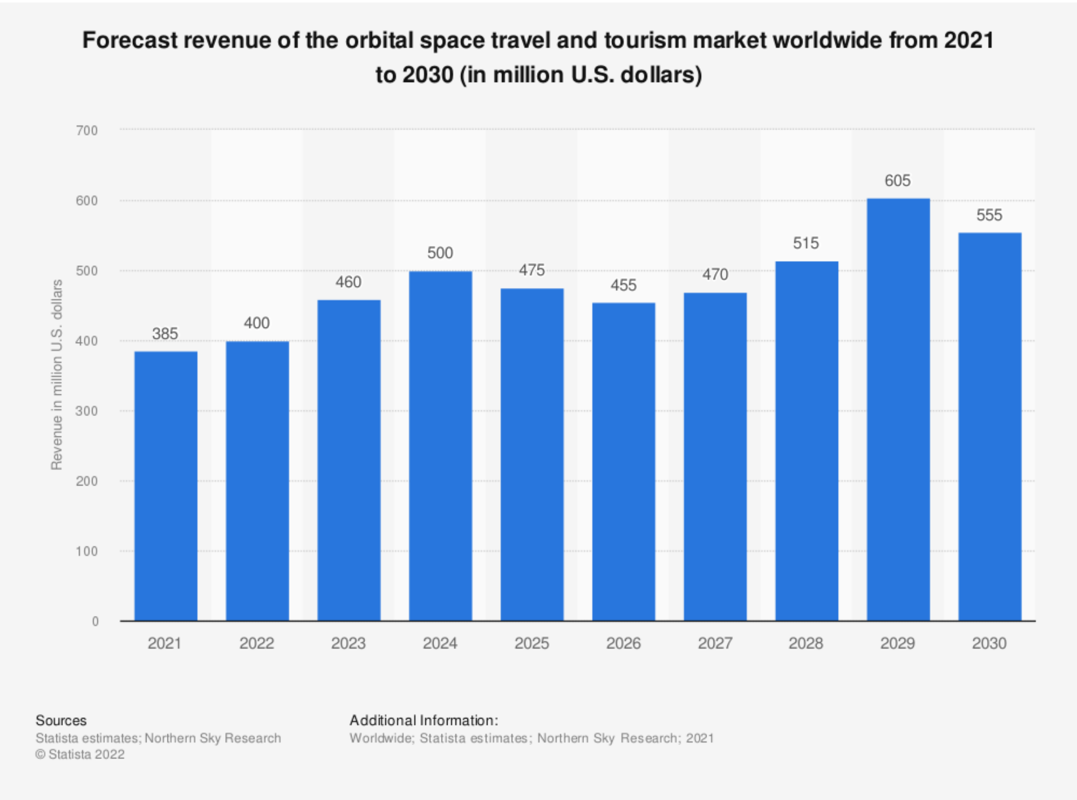

Figure 7. Forecasting of space travel and tourism revenues until 2030.

Another concept which is gaining credibility in the market is the possibility of utilizing space resources, through mining of asteroids. They can contain a significant quantity of natural resources, metals like nickel, platinum, and cobalt. The main challenge to overcome are the huge costs of this mining, that for now does not make these operations economically feasible (NATO, 2018).

2. KNOWLEDGE SPILLOVERS AROUND AEROSPACE INDUSTRY

This chapter focuses on the concept of spillovers and on its relevance related to R&D expenditure. Then, a short summary on how space spillovers have been studied in the literature is presented, showing some examples of technology transfers from space industry to civil applications (spin-out).

2.1 What is a "spillover"?

In an economic context, the term "spillover" is used to describe any effect arising from an activity which is not reflected in the cost paid by those involved in the transaction (London Economics, 2018). For this reason, usually a spillover is also referred to as an "externality". Externalities arise because firms cannot capture all the benefits coming from their R&D expenditure, so there is also a problem related to the appropriateness of inventions, that can be controlled through patents legislation, trade secrecy and other intellectual property protection mechanisms (Nadiri, 1993). Another term to identify spillovers is *technology transfers*, which describe the transfer of knowledge from the innovator to another organization (London Economics, 2018).

The room and potential for spillovers is particularly high where the investments in R&D are essential to generate new knowledge, goods, and services (London Economics, 2018). Literature focuses a lot on the presence of knowledge spillovers between R&D cooperation firms: in the absence of cooperation, knowledge spillovers to competing firms must be considered involuntary, since they may end up strengthening market position of a competitor and making R&D efforts less effective (Belderbos et al., 2004). Recent studies, instead, have shown how firms cooperating in R&D expenditure can increase the knowledge transfers: they try maximizing incoming spillovers through R&D collaboration and in the meantime minimizing outgoing spillovers through IP protection (Belderbos et al., 2004). So, it's clear how the effects of spillovers can be either positive or negative.

R&D spillovers can be effectively categorized into three main types (London Economics, 2018):

- *Knowledge* spillovers are the primary focus of literature and refer to a technology which is generated by an organization and used by another. These spillovers can occur through different channels, including the mobility of labor and the publication of papers or technical documents.
- *Market* spillovers occur through market mechanisms when the innovation has been fully commercialized. In this case, the innovating organization cannot capture all the benefits coming from the new technology. The difference can be captured either by other firms in the supply chain (producer surplus) or by consumers (consumer surplus).

- *Network* spillovers occur when an innovation increases the value of other innovations: consumers will adopt the innovation only if other providers develop other systems that make the innovation sufficiently attractive. This concept explains that a critical mass is required for the innovation to work properly can be widely adopted.

One common result is that companies tend to underinvest in R&D since the private returns are lower than the public ones (Aerospace Technology Institute, 2019). This is also because of the absorptive capacity of the firms. For these reasons, public investments in R&D remains important, since they can sustain the knowledge flow, which benefits to society (London Economics, 2018).
Talking about the aerospace industry, in a study of the *Aerospace Technology Institute* (ATI) the social return to space R&D investments was found to be over four times as large as private return (Figure 8 sums up the results) (Aerospace Technology Institute, 2019). This explains why governments should support investment in aerospace R&D.

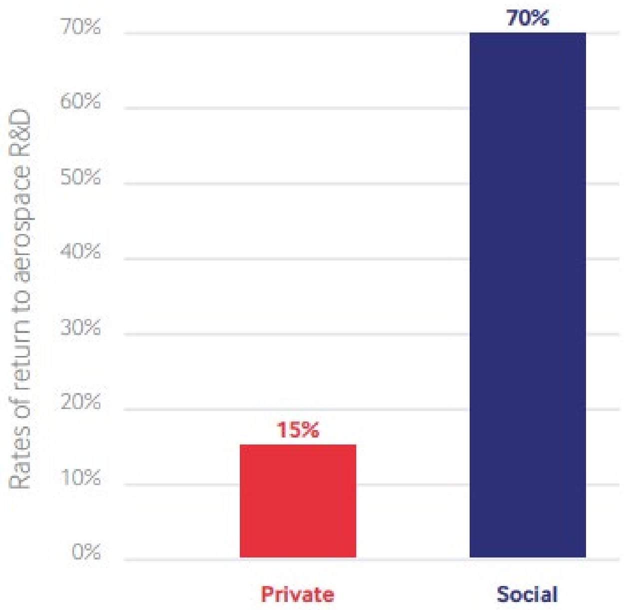

Figure 8. Returns to aerospace R&D for social and private investments are depicted.

Another way for classifying knowledge spillovers is dividing them into vertical and horizontal (Lukach and Plasmans, 2002): the first ones mainly occur between competitors, while vertical spillovers can be observed between firms belonging to different industries. Different economic variables, like competition and specialization (they are going to be described more in detail in 2.1.2), can affect these spillovers (Lukach and Plasmans, 2002).

Other than for R&D expenditures, spillovers effect is quite clear also related to firms' productivity, considering the role of multinational companies (MNCs). For example, when a multinational company establishes abroad, local firms can benefit from increasing their productivity (Blomström and Kokko, 1998). Such spillovers can contribute to increase local firms' productivity in different ways: the simplest one is when the local firm is able to copy some technologies used by the big corporation (Blomström and Kokko, 1998). Another example of productivity increased by spillovers is when the entry of an affiliate leads to more severe competition in the local setting and so firms are forced to use more efficient technologies (Blomström and Kokko, 1998).

How to effectively measure spillovers is a great challenge, since they are an unexpected outcome of an economic activity, like an investment in R&D. Many studies provide different econometrics model based on different critical indexes that try to measure the number of spillovers, however they exempt from the main object of this thesis and will not be treated.

2.1.1 Mechanisms of transmission

Spillovers can be transmitted via different mechanisms (London Economics, 2018):

- *Labor mobility*. One way of transmitting knowledge can be through the mobility of workers who can acquire knowledge in one organization and then take it into a new one when they change job.
- *Worker interaction.* Knowledge can be shared via formal exchanges between organizations, like publications, meetings, or other events. This kind of mechanism can occur when firms are engaged in R&D cooperation.
- *International exchange.* This mechanism refers to how foreign R&D expenditures can affect domestic productivity. It is possible to identify three main mechanisms: international trade (domestic firms can benefit from purchase of foreign products), foreign direct investment (FDI), direct learning.
- *Commercialization.* Knowledge embodies in products, or processes can reveal some aspects of the new knowledge to buyers and users. Successful commercialization and diffusion can signal that the innovative technology is productive.

It is essential to highlight how the physical proximity can affect the efficiency of these channels, bringing to the creation of industrial clusters. According to many studies, localized clusters can facilitate knowledge spillovers and increase the exchange of information. One of the main argument underlines how a cluster industrial environment, in which many firms are competing or collaborating across different research project, creates not only a larger dynamism but also increases the learning transfer process (Malmberg and Maskell, 2002).
Geographical proximity is particularly affecting the efficiency of transmission channels when dealing with tacit knowledge. Unlike codified knowledge, which can be transmitted also

through market interactions like imitation, the tacit one is more complex, and its transmission is more related to geographical proximity (London Economics, 2018). Since tacit knowledge is quite hard to formally transmit, it requires many face-to-face interactions, so it is considered to being geographically bounded (London Economics, 2018). Unlike tacit knowledge, codified one is easier to be transmitted via formal channel, like papers, technical documents or even patents. So, it is considered to being not geographically bounded, since the physical distance does not affect the ability or inability to spread the knowledge (London Economics, 2018).

2.1.2 Factors affecting spillovers

Many studies have tried to list the different variables that can affect, positively or negatively, spillovers from an industry towards other markets. Such factors can be categorized into four main classes (London Economics, 2018):

- *Funding characteristics*. Funding involves the amount of R&D expenditure, the sources of such investments, and channels through which they are delivered. Results related to the size of investments are inconclusive, meaning that it is not clear how the returns change with respect to the amount invested. The source of funding does not influence how the returns can change, even if private investments are characterized by a shorter return time. Some theoretical evidence seems to suggest that private funding may realize greater spillovers, but this can be because these investments are inclined to fund R&D project with a higher probability of success and so it's easier for them to spread in near markets (London Economics, 2018). Talking about the channels, evidence show that public investments made through research institution generate higher benefits than investments made by government departments (London Economics, 2018).
- *Technological characteristics*. This class includes different features of the technology that can influence in many ways the number of spillovers. About stage of innovation, there is no clear evidence that shows that a more developed innovation is related to higher spillovers (London Economics, 2018). Generic and multi-object technologies are associated with higher spillovers, mainly when considering large period of analysis: this is because the versatility of an innovation means broader set of applications (London Economics, 2018 and ATI, 2019). When dealing with FDI spillovers, another massive factors to consider are the absorptive capacity of the firm and the technological gap: many evidence shows that the size of spillovers increase with the technological gap, since local firms may benefit more from the imitation of efficient technology from foreign firms and from their R&D investments (Crespo and Fontoura, 2007).
- *Market and industrial sector*. This class refers to some aspects, like the type of markets under analysis, the level of competition, and the age of the sector. From many studies (London Economics, 2018 and ATI, 2019), it is quite clear that higher value-added sectors, like space one, which are characterized by a constant innovation process, are

associated with higher spillovers with respect to lower value-added industries, like food and drinks. Being a nascent or emerging industry can be a positive factor for generating larger spillovers, since there is a lot of room for improvements and the possibilities of the industry are still much unknown (ATI, 2019). Outcomes related to the level of competition are instead quite unclear: according to some theories, like Marshall spillovers, competition is detrimental for spillovers, since it decreases the incentive for firms to innovate (fewer benefits), while other theories, like Porter spillovers, suggest that competition is beneficial since it forces firms to keep innovating (London Economics, 2018).

- *Environmental factor*s. The analysis of the variables affecting spillovers, it's incomplete without mentioning that the place where the investment or the innovation process take place is fundamental to understand the effect on the creation of spillovers. Patent protection, which obviously can differ from one country to another, can have very ambiguous impacts on the potential for spillovers, because on one hand it is an incentive for firms to innovate, but on the other, a strict patent law limits collaboration (London Economics, 2018 and ATI, 2019). As mentioned also in the 2.1, role of government is essential for spillovers potential, specifically when dealing with highly innovative market sectors like the aerospace one: if government policies are employed correctly, they can increase the potential for spillovers (London Economics, 2018).

  To conclude the analysis of the environmental variables, it is necessary to highlight how the types of interaction between the actors in the industry affect the potential for spillovers. According to many results, it is clear how involving universities and research institutes in the technology development process and make them work actively in the innovation process, is a positive factor for increasing spillovers potential (London Economics, 2018 and ATI, 2019). As already mentioned in 2.1, the creation of industrial networks and cooperative R&D efforts surely increases the potential for spillovers, since there is a strict relationship that allows easier knowledge flows (Belderbos et al., 2004 and ATI, 2019).

  When dealing with environmental factors, it is important to mention the creation of industrial clusters, which can surely increase the room for spillovers: the participation in a cluster allows creating many strategic interactions and alliances between all the players belonging to the clusters (London Economics, 2018, ATI, 2019 and Malmberg and Maskell, 2002). As already mentioned in 2.1.1, the role of clusters is affecting particularly the transmission of tacit knowledge, since it increases the number of informal meetings that are quite necessary to transfer knowledge which is not so easily accessible (London Economics, 2018).

2.2 Spillovers in the space sector

This paragraph focuses on the concept of aerospace spillovers, presenting the phenomenon and its main features, and pointing out some examples of civil objects with a space origin.

2.2.1 General framework

Spillovers arising from the space sector are often related to technology transfers, meaning that the knowledge, embodied in a patent or product, is transferred from one organization to another (London Economics, 2018).
It's possible to identify a common and general transfer pathway regarding the space domain: technology transfer often follows the Earth-Space-Earth pathway (London Economics, 2018). This basically means that technologies flow from terrestrial industries to the space sector, where they are developed deeply to reach higher performances required for this sector; then innovations can be applicable for civil applications, even if it translates in a sort of downgraded from space application (London Economics, 2018). From this evidence, one general statement that can be derived is that the space sector has a role of integrator and improver of terrestrial technologies (London Economics, 2018).

Important research by ATI (2019) tried to quantify the sector in which aerospace spillovers are significant. The results are summed up in Table 1.

Industry sector	**Percentage**
Automotive	22%
Ships, rail, other transport	3%
Rubber and plastics	9%
Machinery and equipment	19%
Scientific R&D	37%
Other non-aerospace	10%
Overall	100%

Table 1. Estimation of aerospace spillovers in other industries. (ATI, 2019)

From the figures, it's possible to see how 25% of the total spillovers from aerospace affects automotive and other transportation sectors: this can be because these industries have similar product requirements and apply almost the same manufacturing methods (ATI, 2019).

The aerospace industry has always innovated a lot for creating new composite materials with very peculiar properties that have been used also in many other sectors, like the plastics one.

The greatest part of space spillover goes to scientific R&D, in fact, many research centers, universities or other institutions are involved in aerospace R&D activity.
In the statistics, some sectors that are not so statistically relevant are excluded, but they can benefit a lot from aerospace spillovers: an example can be the one of aviation fuels and repair and maintenance (ATI, 2019).

Talking about spin-in toward the aerospace sector, it is important to mention the electronics/electrical sector. In fact, probably aerospace benefit from innovation in these sectors, rather than the opposite, since the production and design cycles in the space sector are much longer than the ones of civil applications (ATI, 2019).

All different spillovers mentioned in 2.1 are present in space industry (ATI, 2019). Often space research can be commercialized by other industries, before that an aerospace activity effectively applies it, benefiting other players in the supply chain. As mentioned above, R&D project may involve people from universities, research centers or other players that can increase their knowledge and skills, collaborating from aerospace companies. This mechanism is often underestimated, instead 50% of space R&D expenditure is associated with forming people and creating different skills. The last kind of spillover can be observed when aerospace firms make available common data or different platform, like open-access software where other firms or businesses can access, creating a network.

2.2.2 Examples of spillovers from the aerospace industry

To conclude the description of the spillover concept related to the aerospace industry, it is interesting to introduce some objects which are nowadays common for the society, with a broad set of civil applications, but in principle are invented for a space purpose. For example, NASA created a *Tech Transfer* program in 1962 and since then, it makes many technologies available to research institutions and to industry, impacting the creation of products that have affected the life of billions of people (Nakahodo and Gonzalez, 2020).

The first example to be described is the material known as polyimide foam, also known as *memory foam.* In the 1970s, NASA started a project for finding a material which was fire resistant to be used in airplane cabins, since most of the deaths in airplane crashes were because of explosions of fire. Thanks to the work on some materials already done for the *Apollo Program*, NASA collaborating with some companies wanted to optimize a polyimide foam for seat cushioning, for building low-density wall panels and high-strength floor panels and for thermally and acoustically insulation (NASA, 2020). The technology transfer process was possible since NASA waived its patents on the material, allowing the companies to produce commercially the new composite material (NASA, 2020). In a few years, many commercial airlines used the new material, but also in satellites, spacecraft, many industrial applications and for Navy's ships and submarines (NASA, 2020). Thanks to its properties, like

durability, acoustic and thermal insulation, easiness of handling and lightweight, now it is used for a great number of applications like railcars, medical devices, solar energy systems, electronics, and missile guidance systems (NASA, 2020).
Another example of NASA's spinoffs are the so-called space blankets, used for insulating spacesuits and spacecraft. The material is composed of several layers of thin, durable plastic, each one is coated with a metal film. Nowadays one of the most interesting applications of this material are jackets realized using *Ultraflect*, a material based on radiant barrier insulation invented by NASA in the 1960s (NASA, 2022). These jackets are produced by a startup called *13-One*. The jackets (one example is visible in Figure 9 below) are very warm, water- and wind-resistant and weigh less than 450 g (NASA, 2022).

Figure 9. Jacket designed by *13-One* using *Ultraflect* fabric (Source: NASA, 2022).

The last example of NASA's spinoffs into civil applications regards the development of LED technologies. NASA funded some studies to understand how light affects humans, since when astronauts are in orbit, their biological clock tends to be in the wrong time. In 2011, NASA started looking into the field of solid-state light-emitting diodes, in which light is created without any physical reaction (NASA, 2022). Thanks to the studies at NASA's Kennedy Space Center in Florida, the new lamp modules have been developed. Starting from space studies, many companies have developed light bulbs, designed for keeping circadian rhythms in check and for helping people resting better (NASA, 2022). Nowadays, this technology is used for decontaminating and filtrating air, which is possible thanks to the ultraviolet light, and for helping plants grow.

One of the most successful examples of technological transfer to startups is the program *Creating startup with NASA technologies*, launched by the *New York Space Alliances* (NYSA) and supported by NASA (Nakahodo and Gonzalez, 2020). The aim of the program is to make possible for companies in the New York ecosystem to license NASA technologies and develop some commercial applications. To involve the industrial community, the program facilitates the access to NASA technologies for qualified entrepreneurs, provides a quite fast process in creating a collaboration with companies and tries to reduce the distance between the technological developers of the technologies and startups (Nakahodo and Gonzalez, 2020).
The players involved in the program are depicted in Figure 10 below (Nakahodo and Gonzalez, 2020).

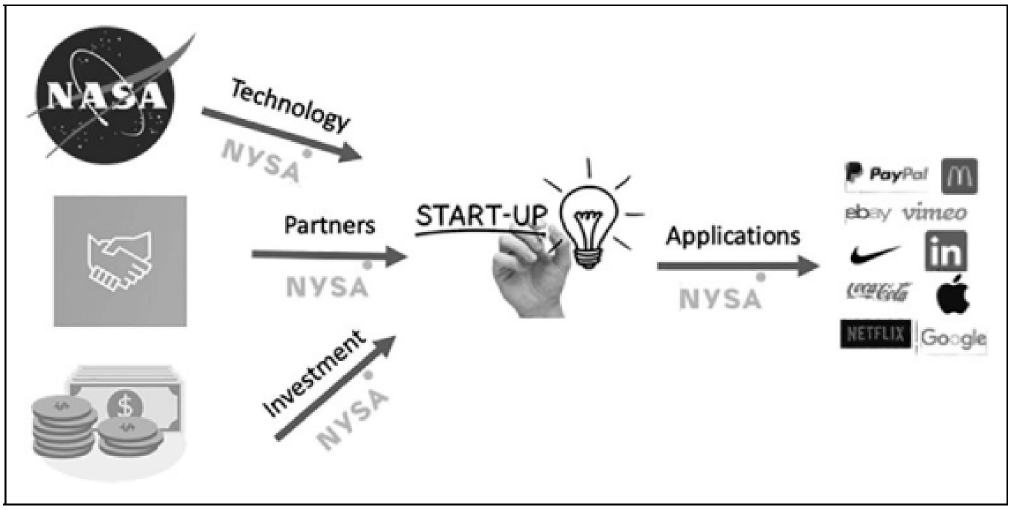

Figure 10. Structure of the *Creating startups with NASA technologies* program.

3. DESCRIPTION OF THE RESEARCH

In this chapter, the research will be presented, starting from which are the objectives of the analysis, explaining how the sample of patents has been selected and focusing on how companies have been included or not. After that, the sample of companies and the one of patents will be described, showing some descriptive statistics, and explaining how the citing patents have been gathered. The last sample to be analyzed is the one of the citing patents, which is presented by computing and commenting some general statistics.
Then the last two paragraphs of the chapter focus on understanding where the spillovers generated by the aerospace industry are directed. This analysis has been done through the computation and interpretation of an index called *SPACE_tech* which allows to understand if the aerospace innovations remain in the industry or spread across different sectors.
The last paragraph consists, instead, of a linear regression analysis in which four models are presented. The aim of this analysis is to understand if there are some characteristics of the patents, or of the assignees, which affect the possibility of diffusion inside or outside the edges of the aerospace sector.

3.1 Object of the research

This thesis aims to identify and analyze the characteristics of the spillover from space industry to civil applications. Using both patents published by space companies and citation data, it is possible to identify which are the factors that increase the likelihood of observing a space-civil spillover and to estimate the industries in which space innovations fall back. It is important to remark that the thesis does not expect to cover the whole aerospace environment, but the focus of the study is mainly on small and medium enterprises (SMEs). The criteria adopted during the selection of the companies will be described in the following paragraphs.

The thesis is based on the concept of patents, as "strategic decision": patents can have an importance which far exceeds the simple legal document. However, the thesis does not consider all the innovations which are not patented: it's correct to consider this approach a good approximation, since different studies adopt it (Lukach and Plasmans, 2002 and Jaffe et al., 1993). In fact, if a firm decides to apply for a patent, it means that the innovation has a great economic potential and that the company wants to also protect the investor behind the invention (this is particularly true when the inventions sustained by investments increased over time) (Lukach and Plasmans, 2002).

The identification of the spillovers from the aerospace industry is done through patent citations: in this way it is possible to understand which companies cite patents belonging to the space industry and in which industry sector the aerospace innovations fall back.
The examiner or the Patent Office use patents citations to determine which are the technological antecedents of the innovation described in the patents (Jaffe et al., 1993).

Citations are identified in different ways: the applicant has a legal duty to disclose any potential knowledge of prior technologies that he might have, moreover the examiner is usually quite an expert in the technical field where the application is required (Jaffe et al., 1993).
When tracing spillovers using patents citation, it is necessary to remark the limitations: it's clear that this thesis is not going to detect all the spillovers that are not associated with any citations. However, this is a phenomenon typical of the basic research (Jaffe et al., 1993), while the focus of the thesis is related to applied research for developing industrial innovations. Moreover, spillovers related to basic research, at least at the beginning, are associated with a lower economic value, since the innovations have not been patented yet: this consideration confirms even more why tracing spillovers through citation pattern can be a good estimation.

3.2 Data collection

For properly explaining the data collection process, it's better to divide it into two main stages: it starts with the identification of the companies and then the gathering of the patents filed by each one of them.

The selection of the companies was done on the *dealroom.co* platform, which has been fundamental to identify the firms belonging to the space sector that have filed some patents. However, the list of the company identified by *dealroom.co*, which, at the time of the research included 270 firms, was filtered again adopting some criteria:

- *Big Corporation*. If a firm is very large and operates in various markets, it has been excluded, since the aim of the thesis is to consider only companies with pure space application. Doing so, all the firms which have an important business related to the space industry, but are known to operate also in other industries, have been excluded. Otherwise, including also firms operating in other sectors, it would be impossible to distinguish the spillovers coming from aerospace to civil applications.
- *Different core business*. Like the previous criterion, it has been chosen to exclude firms which have clearly as the main business a sector which is not aerospace, regardless of the dimension.

The second stage of the data collection consists of gathering the patents filed by each organization. This step was done using the software *Derwent Innovation*, in which it's possible to look for patents by entering queries. Once a firm has been selected, patents have been searched by introducing, as query, the name of the company, which corresponds to the assignee/applicant of the patents. After finding the patents filed by a firm, they were exported in a single file for creating a big data set. *Derwent Innovation* allows to search for large number of information related to patents. For each patent, the following information have been recovered:

- *Publication Number.* The publication number is a code that identifies uniquely a published patent. The first letters of the code allow to identify which is the office that has published the patent and the kind code at the end indicates the application stage. Kind code does not have a univocal meaning, since it depends upon what standard classification has been applied (WIPO, 2015).
- *Assignee/Applicant.* The assignee/applicant is commonly the owner of the patent and who or which owns the property rights associated with the invention (WIPO, 2015). These names could change over the patent's application if the rights associated with the invention are transferred (WIPO, 2015).
- *Application year.* It can be defined as the year date on which the assignee or the applicant filed an application in a particular country or territory (WIPO, 2015). It is important to remark that each legislation can differ in how application or filing procedure are managed, so it's not possible to draw a more precise definition.
- *IPC codes.* These codes are a classification system coined by International Patent Classification (IPC), that want to establish to which industrial field, based on its technical nature, the innovation belongs (WIPO, 2015). These codes are four-digit codes that refer univocally to an industrial sector. This classification structure is regularly updated and revised to include the latest technologies or to split already existing sectors in many subunits that have a more precise scope (WIPO, 2015). IPC decided to structure a new classification system able to overcome the many differences originated from a country basis classification.
- *Citing patents.* Along with each patent, also the citing ones have been reported. As already mentioned in 3.1, during a patent application, it is mandatory to disclose any references to prior innovation, and these documents will be cited in the references section of the patent. It is possible to identify both backward and forward citations (WIPO, 2015): the thesis searches for forward citations, since the patents filed by the selected aerospace companies are considered the root ones. Analyzing statistically the patents that cite the ones belonging to the aerospace companies, allows to determine to which sector the space innovative solutions fall back.

  Backward citations have been ignored since they can be useful when trying to establish which are some sources used by aerospace companies during the innovation process. However, since this approach exceeds the scope of the thesis, they have been ignored.

While performing the patents collection, other firms have been excluded from the sample. This was mainly because of two causes:

- *Disambiguation.* Finding patents just with the name of the firm was too complex, since results included different sources other than the firm searched. The name was not enough for disambiguate the assignee and find the patents, belonging to the right assignee. To find the patents belonging to these companies, it would have been necessary to write complex queries, combining different information related to the single assignee.

- *No patents found.* For some firms it was not possible to find any patents on the *Derwent Innovation* software. According to *Derwent* those firms did not apply for any patents. For keeping consistency between the sources consulted, they have been excluded: no patents have been searched through other procedures or consulting other sources.

The following paragraphs will present the statistics related to the samples that have been collected following the procedures and the selection criteria listed above.

3.3 Description of the companies' sample

The starting point for selecting the companies was the *dealroom.co* portal. During the identification of the preliminary sample, two filters were applied to get the firms belonging to the space sector that have already applied for some patents. As already pointed out, the thesis focuses on start-ups or small-medium enterprises, excluding large corporations that operate in several industries which would make quite difficult to track eventual spillover through the method of patents citation. In addition, also government space agencies have been excluded and the reason for this choice is that these agencies can have a different attitude towards the patenting process compared to common companies. They can decide not to patent their innovations to not disclose publicly on which matter their R&D efforts are focused, or simply they do not need to patent innovations which are complex and difficult to reverse engineered from outside. For these reasons, they have been left out from the sample, keeping companies that have a quite similar attitude towards the patenting process and the industrial domain.

With this preliminary selection, the starting sample was composed of 270 companies, at the time of the analysis. Then, following the criteria that have been explained in 3.2, each single company has been analyzed, and at the end, 197 companies have been considered eligible for entering the final sample. The percentage of starting companies that have been selected corresponded to the 72,96%.

The companies that were excluded counted for 27,04%. More in detail, 40 firms were excluded since they were classified as big corporations, counting for 54,79% of the excluded firms. Some examples of this type of companies are *Michelin, Nokia Corporation* or *Volvo Cars*.
Talking about the other criteria adopted:

- 17 firms were excluded for ambiguity, since it was too difficult to differentiate their names (23,29%), like *Airborne, Spoon* and *ETS.*

- 8 firms were excluded for operating mainly in a clearly different core business (10,96%), like *Eni, Olivetti* and *EasyMile*.
- 7 firms were excluded since no patents have been found on *Derwent Innovation* (9,59%), like *Decentriq.*
- *Institute of Physics* was excluded since it is a different kind of organization, not comparable with the other companies in the sample and not so illustrative for the aim of the thesis (1,37%).

The results related to the reasons why some companies have been excluded are summed up in Table 2.

<table>
<tr><th></th><th colspan="3">Percentage</th></tr>
<tr><td>Companies included in the sample</td><td>72,96%</td><td colspan="2"></td></tr>
<tr><td rowspan="5">Companies excluded from the sample</td><td rowspan="5">27,04%</td><td>Big corporation</td><td>54,79%</td></tr>
<tr><td>Disambiguate</td><td>23,29%</td></tr>
<tr><td>Different core business</td><td>10,96%</td></tr>
<tr><td>No patents found</td><td>9,59%</td></tr>
<tr><td>Institute of Physics</td><td>1,37%</td></tr>
</table>

Table 2. Summary of the occurrence of each exclusion factor.

To describe the companies' sample can be useful to compute some descriptive statistics to derive different information. Table 3 shows some basic statistics related to the number of patents per company. The fact that the largest number of patents per company is 633 confirms how the thesis does not include large companies. In fact, the first indicator to look at when establishing the dimension of a firm has been the number of patents. All the firms with more than one thousand patents have been excluded since considered too large for the aim of the thesis. Obviously, for the companies below the generic threshold of one thousand patents, the other selecting criteria have been applied.
The standard deviation value, which is quite high, confirms how the firms included in the sample are SMEs of different sizes: from recently founded and small start-ups to medium corporations well known in the aerospace sector.

	# of patents per company
MAX	633
MIN	1
AVG	70,208
STANDARD DEV.	122,6274528

Table 3. Basic statistics related to the number of patents per firm.

The sample can be divided into different classes according to the dimensions of patents' portfolio. In Table 4, some classes have been identified, according to different sizes, and the occurrences of each of these have been computed. From the values in Table 4, it's possible to notice how the most common class was the one between 10 and 50 patents, with 38,6% of the total sample. Large corporations, with more than 500 patents, are just the 3% of the sample and this is in line with the choice of building a sample of small and medium enterprises. The firms belonging to this class are quite large and established corporation, like *Inmarsat*, whose business is strictly related to the aerospace operations and so, for evaluating potential spillovers, their role is quite important. However, over 54% of the selected companies have between fifty and one hundred patents filed.

CLASSES FOR DIFFERENT PORTFOLIO DIMENSIONS		
Size	**Occurence**	**% of total**
1	3	**1,5%**
<=5	22	**11,2%**
<=10	33	**16,8%**
<=50	76	**38,6%**
<=100	31	**15,7%**
<=500	26	**13,2%**
>500	6	**3,0%**
Total	197	**1**

Table 4. Occurrence for each portfolio size.

Other information that can be interesting to observe from the companies' sample are the geographical distribution around the globe and the "age" of the firms, looking at the founding year.

The data related to the geographical distribution report the founding country or the nation in which the headquarter is currently located, according to the information that are reported on *dealroom.co*. From the chart depicted in Figure 11, it's clear how the companies' sample includes several countries. The most represented nations are however UK and France, respectively with 39 and 37 companies.

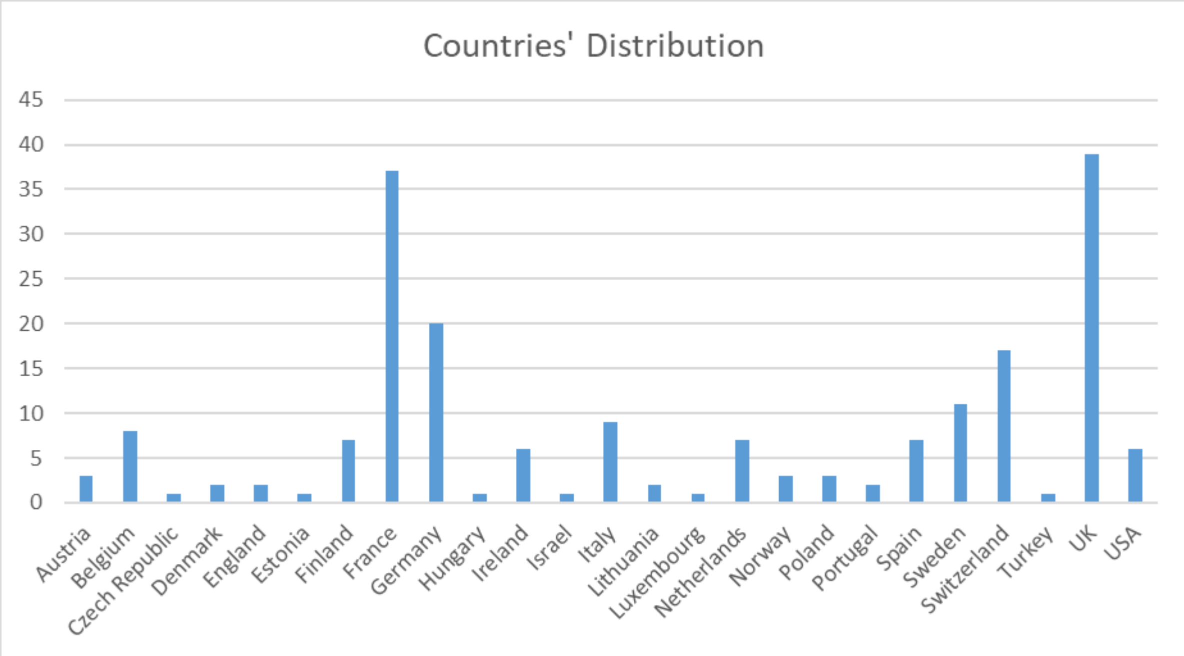

Figure 11. Countries that make up the sample.

Table 5 sums up the distribution of the different countries. Almost 40% of the selected companies have been founded or have currently the headquarter in UK or France.

	# of firms	Percentage
UK	39	19,80%
France	37	18,78%
Germany	20	10,15%
Switzerland	17	8,63%
Sweden	11	5,58%
Others	73	37,06%

Table 5. Countries' distribution is summed up.

Finally Figure 12 depicts the foundation years of the selected companies in the sample. It's clear that in the last twenty years many aerospace companies have been founded: looking at the sample, the number of companies founded per year it's clearly increasing since the beginning of the second millennium. Specifically, over 76% of the companies have been founded after the beginning of the second millennium.

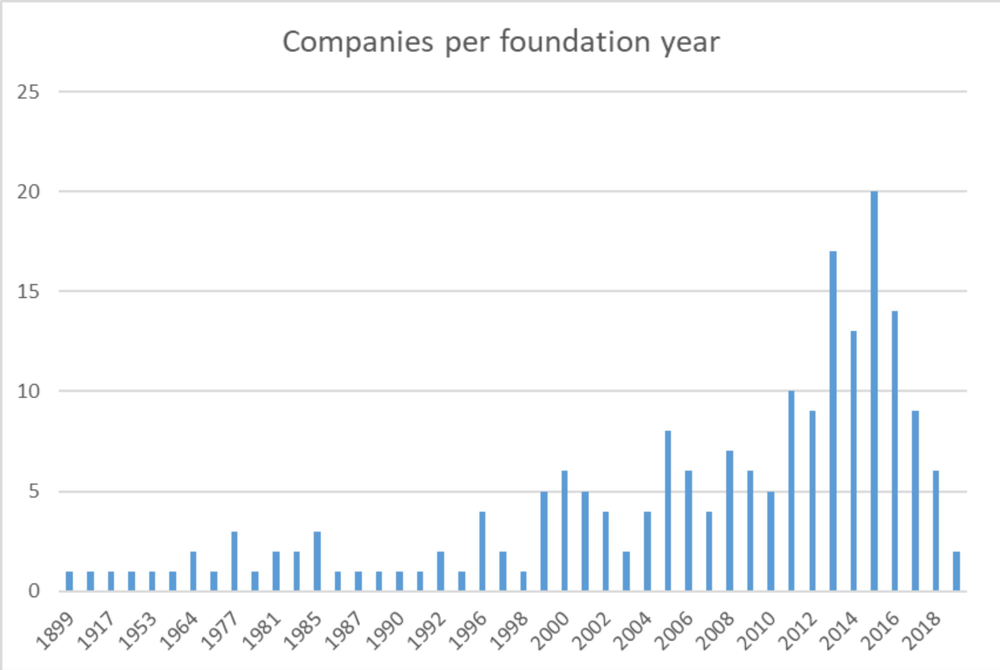

Figure 12. Number of companies per foundation year.

Statistics about foundation years are aligned with the *New Space* phenomenon. In fact, space industry is no longer a pure public sector, but private investments have become very common. The data above confirms this trend, that show how many firms operating in the sector are recently founded.

The decreasing trend visible in the last few years can depend simply upon a common delay in the procedure to update the electronic databases: in this way, it’s likely that the data of the most recent years are quite underestimated.

3.4 Description of the patents' sample

This paragraph focuses on the description of the patents' sample and the analysis, made through some statistics, of the IPC codes.
As pointed out in 3.2, the patents have been gathered by entering the assignee names that correspond to the company's name in the software *Derwent Innovation*. Through this procedure, which was iterate for each selected company, 13828 patents have been collected. Then, to build a proper data set, all the patents, along with the other information got from the software, were put together.

The most interesting statistic that can be derived from the patents' sample refers to the IPC codes: analyzing them makes possible to understand in which industries companies patent their innovations.
Before showing the results, it is important to remark that the same patent can belong to different technical sector, and so to be associated with different IPC codes, according to the classification performed by the examiner. Another relevant aspect refers to the legislation in which the patent has been applied: in fact, if in a country the patent has been associated to some technical fields, when other Patent Offices examine the filed application, if appropriate, other IPC codes can be added (WIPO, 2015).
So, to count the occurrence of each IPC code, it's necessary to structure the database with a univocal correspondence between the patent publication number and each IPC code. Said that, the patents gathered are associated with 22374 IPC codes, divided into 371 different codes.
Table 6 below depicts the occurrences of the most present IPC codes as percentages.

IPC codes	Denomination	Percentage
H01Q	Antennas, radio aerials	7,61%
H04B	Transmission	7,10%
H04L	Transmission of digital information	6,02%
H04W	Wireless communication networks	5,08%
G06F	Electric digital data processing	5,00%
G01S	Radio direction-finding; radio navigation	4,54%
B64C	Aeroplanes/helicopters	2,70%
H04N	Pictorial communication	2,51%
H01L	Semiconductor devices	2,43%
F16J	Pistons; cylinders; pressure vessels; sealings	2,11%
No code	-	3,07%
Others	-	51,85%

Table 6. Summary of the most present IPC codes.

Before commenting on the values shown in Table 6, it is necessary to remark that the percentage have been computed using as denominator the total number of patents associated with a single IPC code: this means that a patent which was associated to over one IPC code was counted how many times the IPC codes reported.
Looking at the figures in Table 6, it is clear how six of the first ten most represented IPC codes belong to the same class code: the one named as *Electricity* (H as first letter). Specifically, the first four IPC codes are related to the transmission and receipt of an electric signal: these specifications are fundamental for the proper working of a satellite. So, the aerospace companies filing so many patents in these technical fields seems to confirm how the most valuable sub-sector of the space industry is the one of satellite, particularly related to the transmission of electric signal.
The other codes shown in Table 6 belong to different class code: G06F and G01S belong to the class of *Physics,* B64C to the one of *Operations/Transporting*, while F16J to the class related to *Mechanical engineering*.

In Table 6 it is reported that around 3,07% of the sample (considering the one which associates to a patent a single IPC code) it's not associated to any code: the reasons no IPC codes are reported can be because of some missing data on the *Derwent Innovations* database, or to many design patents (mainly from the US).

Another interesting aspect to investigate is how the number of patents applied per year has changed in the past. From Figure 13 below, it is easy to spot an increasing trend starting with around the beginning of the millennium. This increasing number of patents is perfectly aligned with the beginning of the *New Space* era: the larger and larger number of private firms operating in the space industry corresponds to a greater number of patents' application. However, the number of patents applied is increasing at an even steeper trend, mainly from the 2010 to the 2018, when it bounces back and starts decreasing.

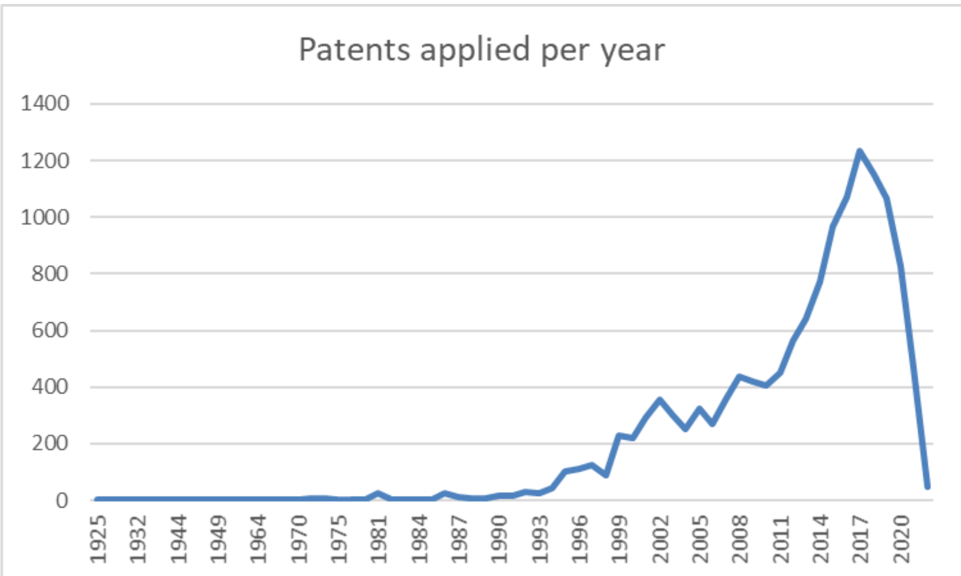

Figure 13. Number of patents per year. Increasing trend is visible.

The explanations behind the decreasing trend in the number of patents in the last few years can be different: it's important to remind that patents have a non-disclosure period of 18 months and that the procedure to create the electronic database can be long. Considering these aspects, it's likely that the number of patents of the last few years is underestimated (for example, application demands of 2021 are not tracked). It is possible that also the peak in the number of patents around 2018 is underestimated.

For the analysis of potential spillovers can be useful to know where the aerospace companies tend to patent their innovations. Table 7 sums up the most frequent institutions identified in the sample.

Country	**# of patents**	**Percentage**
US	3064	22,16%
EP	2691	19,46%
WO	1415	10,23%
CN	1138	8,23%
GB	1027	7,43%
Others	4493	32,49%
Total	13828	100,00%

Table 7. Patents publication country.

Over 22% of the patents gathered have been patented in the US. Among the first publishing entities, there are also two important patents institutions: the acronym EP refers to the *European Patent Office*, while *WO* is the abbreviation for *World Intellectual Property Organization* (WIPO). The last two countries depicted in the table are China, counting for 8,23% of the total, and the UK, counting for 7,43% of the total.
These digits are quite predictable since they are a consequence of the US being the most important technological market, in terms of players active in the industry and of investors interested in the innovations.
Companies apply firstly in the US market to establish the innovation in the most important market and after they spread the new technologies in the different local markets, like Europe, China, and Japan. For an innovation or technology to be global, it is necessary to be established in these major markets, for being known by many investors and have to possibility to enjoy knowledge spillovers from other industries.
Companies can decide also to patent their innovations under the Patent Cooperation Treaty (PCT), for seeking protection simultaneously in numerous countries: these patents are defined by the acronym *WO* in Table 7.

3.5 Description of the citing patents

This paragraph focuses on the analysis of the citing patents, derived from the patents' sample presented in 3.4, and the description of some related statistics. The aim of analyzing the list of citing patents is to find out which are the assignee/applicants that cite more the collected space patents and to understand to which industrial domain they belong.

The process of identification of the citing patents was performed by using the software *Derwent Innovation*: the publication number of the citing patents was derived already when building the dataset of the root patents. Obviously, each root patent can be cited by none, by a single patent, or by more than one. To extract the information related to the citing patents, it was necessary to build a dataset based on a univocal correspondence between the publication number of the root patent and the publication number of each citing patent. The procedure ended identifying 29997 citing patents.
Then the list of the publication number of the citing patents was entered into the software Derwent Innovation to derive additional information: the name of the assignee/applicant, the year of application and the IPC codes associated with each citing patent.
When performing this operation, two publication numbers were not found on *Derwent Innovation*: they can be considered as small noises in the data, but since they counted for 0,0067% of the total number of citing patents, it is an acceptable outcome.

The first important outcome that can be determined from the analysis of the citing patents is the identity of the assignee/applicant. The list of the top ten assignees is shown in Figure 14 below.

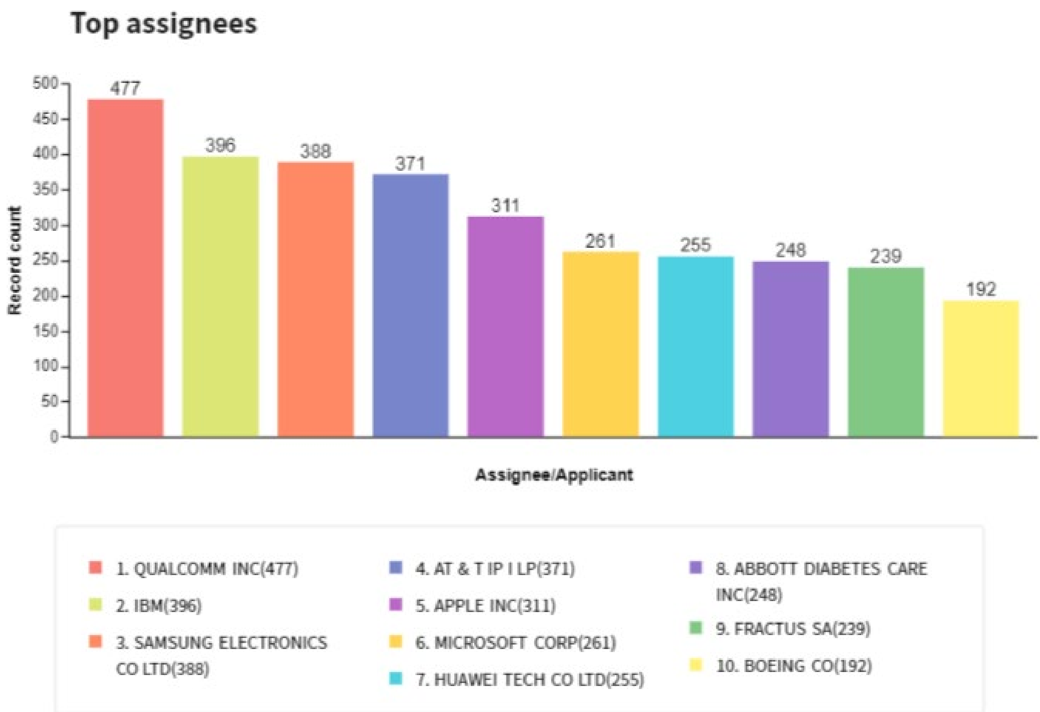

Figure 14. List of Top 10 assignees.

As shown in Figure 14, many companies among the top ten assignees have their core business in telecommunication: *Qualcomm Inc*, for example, is one of the leading wireless tech innovators, providing different solutions for developing the potentials of wireless connectivity. It's interesting how, the first company commonly known for operating also in the space sector is *Boeing CO,* that is only the tenth top assignee among the citing patents.
Among the commonly known companies in Figure 14, there are also some firms whose operations are not so known: *Fractus SA* and *Abbott Diabetes Care Inc*. The first one is a Spanish firm specialized in the development of internal antennas for smartphones, tablets, and Internet of Things devices, while the second is a very interesting case: *Abbott Diabetes* is a firm specialized in the manufacturing of products for people with diabetes, in particular innovative systems for monitoring of blood glucose.
The presence of big corporations operating in the telecommunication and mobile device sector between the first top ten assignees, seems in line with the IPC codes identified in 3.4: in fact, the top IPC codes found in the patents' sample are related to the industry of telecommunication.

To confirm the outcome of the first chart, it's necessary to look also at the IPC codes of the citing patents: from the top assignees identified previously, it's presumable that the most present IPC codes will be related to the telecommunications and wireless connectivity sectors. Figure 15 shows the occurrences of the top 10 IPC codes.

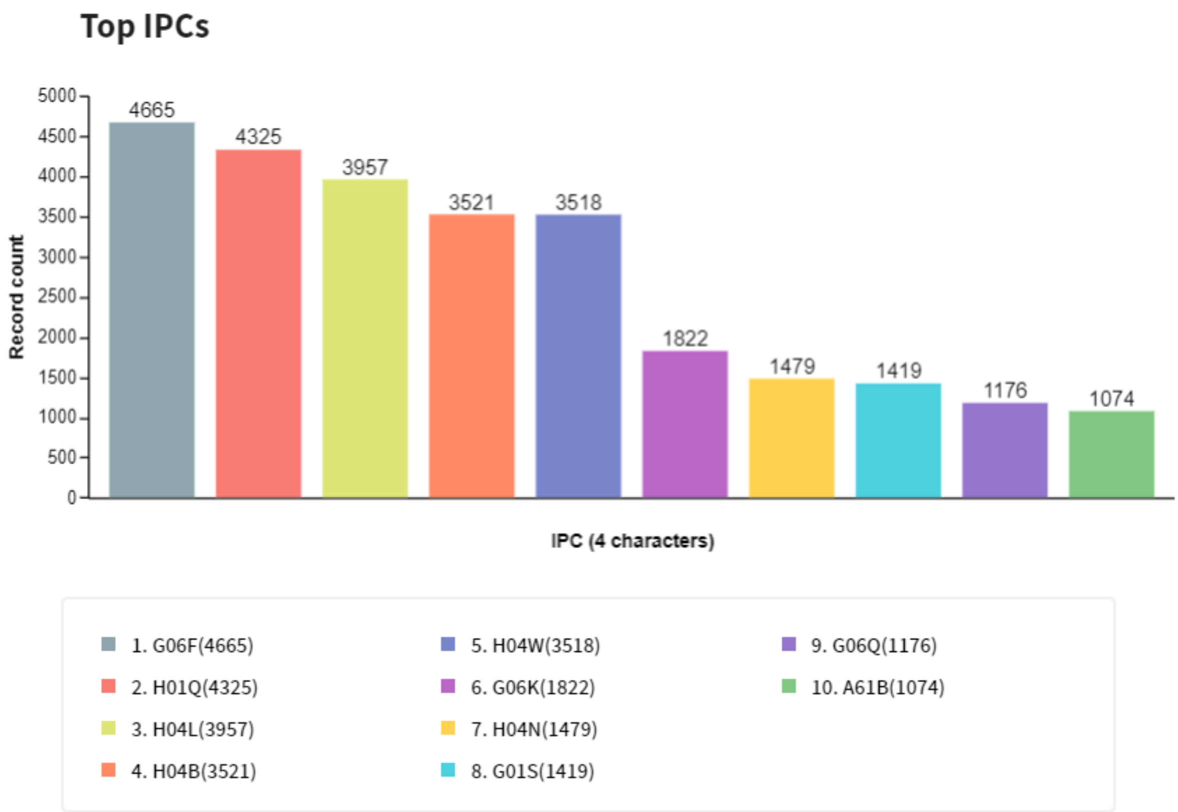

Figure 15. Top 10 IPC codes among citing patents.

The chart depicted in Figure 15 seems to confirm the results observed in Figure 14. The greatest part of the most present IPC codes is related to the managing and transmission of data. Specifically, the denominations of the top ten IPC codes are the following:

- G06F: *Electric digital processing.*
- H01Q: *Antennas, Radio aerials.*
- H04L: *Transmission of digital information.*
- H04B: *Transmission.*
- H04W: *Wireless communication networks.*
- G06K: *Graphical data reading; Presentation of data.*
- H04N: *Pictorial communication.*
- G01S: *Radio direction-finding; Radio navigation.*
- G06Q: *Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes.*
- A61B: *Diagnosis; Surgery; Identification.*

It is interesting also to remark that looking at the IPC codes in their extended form, five of the top ten most present codes belong to the H01Q sector. Specifically, their denominations are the following:

- H01Q 1/24: *Details of, arrangements associated with receiving set.*
- H01Q 1/38: *Details of antennas formed by a conductive layer on an insulating support.*
- H01Q 9/04: *Resonant antennas*.
- H01Q 1/36: *Structural form of radiating elements.*
- H01Q 1/48: *Earthing means; Earth screens; Counterpoises.*
-

It is important to remark that all the definitions reported above are the ones provided by the *World Intellectual Property Organization* (WIPO, 2016 and 2019).

Reading the denominations of the top ten most present IPC codes explains the chart of the top ten assignees. The sectors of the assignees of the citing patents are mainly related to the management and transmission of signals for very different purposes, from telecommunications to radio signals.

Another interesting data that can be extracted from the sample of citing patents is the country of application (at least for the top assignees). As depicted in Figure 16, the country in which the top assignees have applied the most is the US. This is predictable since the US is the largest technological market in the world, so it is common for large companies to start applying in this market and consequently spreading the innovations in the local markets.

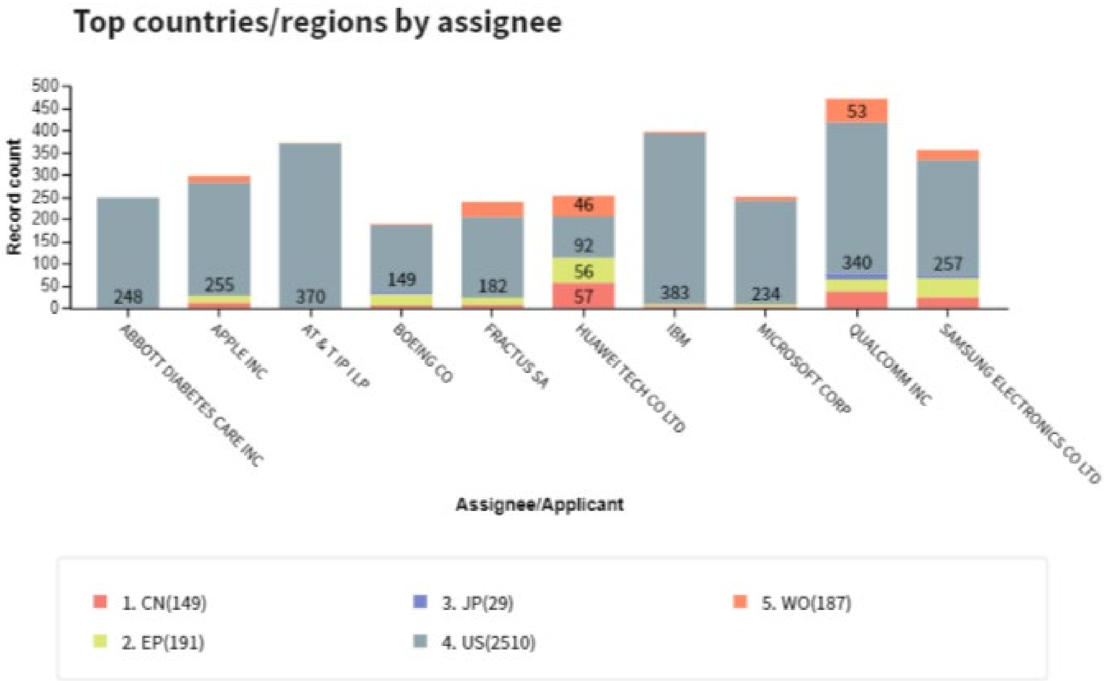

Figure 16. Country of applications for the top assignees.

3.6 Analyzing spillovers direction

This paragraph focuses on the analysis of the spillovers generated by the aerospace sector. The first subparagraphs deal with the creation and computation of the *SPACE_tech* index. This index has been computed to understand by which industrial sector the root patents are cited. Looking at the statistics of this index is possible to derive some hints on the spillovers direction and understand for which industrial sector the aerospace technology is meaningful. The index has been created on the sample of citing patents, but the statistics that will be shown are referred to the root patents, since the direction of the spillover is a characteristic of these ones.

3.6.1 Creation of the SPACE_tech index

The first task is to develop properly an index by looking at the sample of citing patents. It's important to define some criteria to adopt, for establishing if the citing patent can be classified as belonging to the space sector or not. If the patent satisfies one or more of the following conditions, the index will have a value different from null:

- the citing patent is associated to IPC codes related to the space sector:
    - B64G (*Cosmonautics; Vehicles or equipment therefor)*
    - H04B 7/185 *(Space-based or airborne stations)*
    - H01Q 1/48 (*Earthing means; Earth screens; Counterpoises*)
    - BG4C (*Airplanes; Helicopters*)

- the assignee of the citing patent is among the following government space agencies:
    - Agenzia Spaziale Italiana (ASI)
    - Canadian Space Agency
    - Department of Space (DoS), Government of India
    - European Space Agency (ESA)
    - German Aerospace Centre. Deutsche Zentrum für Luft und Raumfahrt (DLR)
    - Ministry of Science, Technology and Space (MOST), Israel
    - National Aeronautics and Space Administration (NASA)
    - Space Telescope Science Institute
    - Swedish Space Corporation (SSC)
    - National Centre for Space Studies – Centre National d'Études Spatiales (CNES)
    - China National Space Administration (CNSA)
    - Japan Aerospace Exploration Agency (JAXA)

- the publication number of the citing patent is also among the space patents identified in the first sample, as described in 3.4.

- the assignee of the citing patents is among the companies excluded from the sample recovered from *dealroom.co* (in this case the citing patents are classified anyway as belonging to the space sector, following the clustering made by the *dealroom.co* platform).

- the assignee of the citing patents is classified as a company mainly operating in the space sector.

In Table 8 the percentage of each case is reported. It's obvious, since the explanation provided above, how the last line of Table 8 is not simply the sum of the other contributions. In fact, a single citing patent can belong at the same time to over one of the categories described above.

	Percentage
Patents with "space" IPC codes	8,05%
Patents of govt agencies	0,17%
Patents in the root sample	5,31%
Assignees from the root sample	3,64%
Assignees related to the "space" sector	1,53%
SPACE_tech patents	16,29%

Table 8. Percentages of citing patents belonging to *"space"* are reported.

Looking at the data in Table 8, it's clear how the largest part of the citing patents belongs to the "space" sector because of their IPC codes (8,05%). These IPC codes, related to the "space" sector, have been identified according to their definition on the WIPO classification. Specifically, the top twenty most present four digits IPC codes have been checked and the four listed above have been selected.
Among the citing patents, the ones whose assignee is one of the government agencies mentioned above are a tiny percentage (0,17%). This is because of different reasons that will be described in 3.6.1.1, where also some examples will be presented.
Moreover, also the citing patents which was already identified among the root ones have been included in this selection: the percentage that was found (5,31%) is not very high.
The 3,64% of the citing patents have been classified as "space" since their assignees belong to those companies that have been excluded in the selection of the firms from *dealroom.co*, according to the procedure described in 3.3. In most cases, these companies are big

corporations, with operations in many fields, among which also the space sector is present. Some examples are *The Boeing Company* and *HP Enterprise*.
Amongst the twenty most present assignees of the citing patents, some have been identified as operating mainly in the aerospace sector, meaning that their most valuable operations are related to the “space” field: 1,53% of the citing patents have been classified as belonging to the space sector because of their assignees. Examples of these companies are *Honeywell* or *The Boeing Corporation*.

The most interesting information provided by the digits in Table 8 is that just a small quota of the citing patents (16,29%) belong to the “space” sector. This can be because of many reasons: for example, it means that space technologies are relevant for several sectors.
Other explanations must be found among the selection criteria of *dealroom.co* platform. The fact that just the 16,29% of the citing patents belongs to the “space” suggests that probably the companies identified by *dealroom.co* are already at the edge of the aerospace industry: they can be considered as downstream, in the sense that, for their operations, data coming from the aerospace sector are meaningful, but the outputs of their work are already partially out of the pure space boundaries.

3.6.1.1 Citing patents of government space agencies

As shown in Table 8, the number of citing patents belonging to space government agencies is small with respect to the other contributions: the magnitude of this number can be due again to different reasons that deserve a depth-in analysis.
The first reason that must be highlighted regards the companies’ sample: as explained in 3.3, not the whole aerospace sector has been included. For example, big corporations and other space agencies have been intentionally left out of the analysis. Maybe space agencies monitor in a more detailed way the innovations coming from big corporations or other space agencies and excluding them from the selection, obviously lowers the percentage of finding citing patents belonging to government space agencies.

For better understanding other reasons for the magnitude of this percentage (0,17%), it can be useful to look at some examples of these patents.
First, it is interesting to look at Table 9 and noting the differences with the most present IPC codes of all citing patents shown in Figure 13. The five most present IPC codes in this small sample of citing patents are extremely different from the ones of the entire sample. Field of application of these technologies differs hugely from the ones of the whole sample of citing patents.

IPC codes	Denomination	Percentage
G01S	Radio direction-finding; Radio navigation	15,94%
B64G	Cosmonautics; Vehicle or equipment therefor	14,49%
H04N	Pictorial communication	7,25%
H04B	Transmission	6,52%
F17C	Vessels for containing or storing compressed, liquified or solified gases	6,52%

Table 9. Five most present IPC codes related to the space agencies' citing patents.

Second, it is interesting to look at some citing patents, analyzing their field of application and tracing back which patents of the root sample they cite. The patents shown as examples are the following:

- US20160023783A1. This patent has been applied by the National Aeronautics and Space Administration (NASA) in 2015 and its title is: *System for removing Orbital debris in low earth orbit (LEO), has single launch vehicle that contains payload which includes vehicles such that each vehicle is oriented upside down on payload.* The IPC codes belong all to the class of B64G (Cosmonautics; Vehicle or equipment therefor), confirming that this sub-sector of the space industry does not have a large diffusion among the civil applications. Among the patents cited, there is also a patent of the root sample described in 3.4: US7905453B2, whose assignee is *Intelsat,* an intergovernmental agency founded for the management and development of the telecommunications via satellite.

- EP3518003B1. This patent has been applied by *Centre National d'Etudes Spatiales* in 2018 and its title is the following: *Device for calculating position, velocity, and time (PVT) measurements from global navigation satellite system (GNSS) signals in which grid size of code phase delays and Doppler frequency shift values is adapted using second PVT measurement.* The IPC code of this patent is G01S (Radio direction-finding; Radio navigation), and, among the others, it cites one patent belonging to the root sample described in 3.4: EP2530488A1. *U-blox*, which is a Swiss company specialized in semiconductors and wireless modules for the industrial and automotive sector have applied the root patent.

The reason these two examples have been presented is to show just a hint of a trend that can be identified by looking at this small sample of citing patents. Space agencies adopt technologies coming from the aerospace sector in a very limited way (always keeping in mind that the selected companies are not the whole aerospace industry). Some reasons for this can be that space agencies do not monitor the innovations coming from SMEs or start-ups of the space sector, since they believe their inventions are not noteworthy for agencies' operations. Looking at Table 8 in 3.6.1 it appears that innovations coming from space companies find a wide diffusion among non-space companies, or at least are monitored by companies belonging to different sectors: for these innovations, being already spread in different civil sectors, lowers the incentives for space agencies to adopt them.

The last reason behind the small number of citing patents applied by government space agencies should be related to the trade secret and reverse engineering: most times, innovations related to the aerospace industry do not need to be patented. The amount of sunk costs and specific knowledge required are so large that can be very difficult to imitate an invention in an economically valuable span of time.
At the same time, space government agencies can decide not to patent their innovations in order not to disclose publicly their R&D efforts or to keep secret ongoing research studies.
These are the same reasons, already disclosed in 3.3, for which the companies' sample do not include space government agencies.

3.6.2 Space spillovers direction

After having explained in 3.6.1 how the index has been computed, this should be transferred to the root samples to track the technology transfer and understand if the spillovers generated remain within the aerospace sector or spread towards different industries. This a very important step and one of the most important aims of the whole thesis.
In order to track this technology transfer, the procedure adopted comprises computing the number of citing patents, the number of *"space"* citing patents and the number of *"no space"* citing patents for each root sample. The criteria used to define if a citing patent is classified as belonging to space sector are the ones presented in 3.6.1. The number of *"space"* citing patents can be calculated by looking at each single patent and understand if their status is equal to one or null according to the *SPACE_tech* index. On the other hand, the number of citing patents not belonging to the space sector is computed as the difference between the number of citing patents and the number of *"space"* citing patents.
It is important to remark that the data described above are calculated for each single root patent, since it's necessary for understanding the spillovers direction of each single patent.
After doing that, it is possible to categorize the root patents according to their chances to be cited and the type of companies that cite them.

After computing the data about the citing patents for each root patent, some descriptive statistics have been calculated. In Table 10, it is possible to see the statistics related to the number of citing patents for each root patent. The standard deviation (14,28) related to the variable of the number of citing patents is quite large and this can be explained by the inclusion in the sample of companies of very different size. Many patents applied by small start-ups or companies can have very few, or even none, citations, while the ones applied by medium and large firms are more likely to be cited and known.

GENERAL STATISTICS ON THE # OF CITING PATENTS	
AVERAGE	2,83
MAX	575
MIN	0
ST.DEV	14,28

Table 10. Descriptive statistics about the number of citing patents.

As already done for analyzing the companies' sample, it is useful to cluster the root patents in different classes for understanding how they distribute according to the number of citing patents. In Figure 17 below, the related histogram is depicted.

Over 88% of the patents' sample belongs to the first two classes, since they include patents cited by less than five different citing patents. It's important to point out that the contribution of the patents with no citing one is the largest among all the classes computed. These outcomes are perfectly consistent and predictable considering the type and the size of the firm included in the analysis. As already said, excluding from the companies' sample large firms, that maybe are known for operating in many sectors, inevitably lowers the number of citing patents for each patent analyzed.

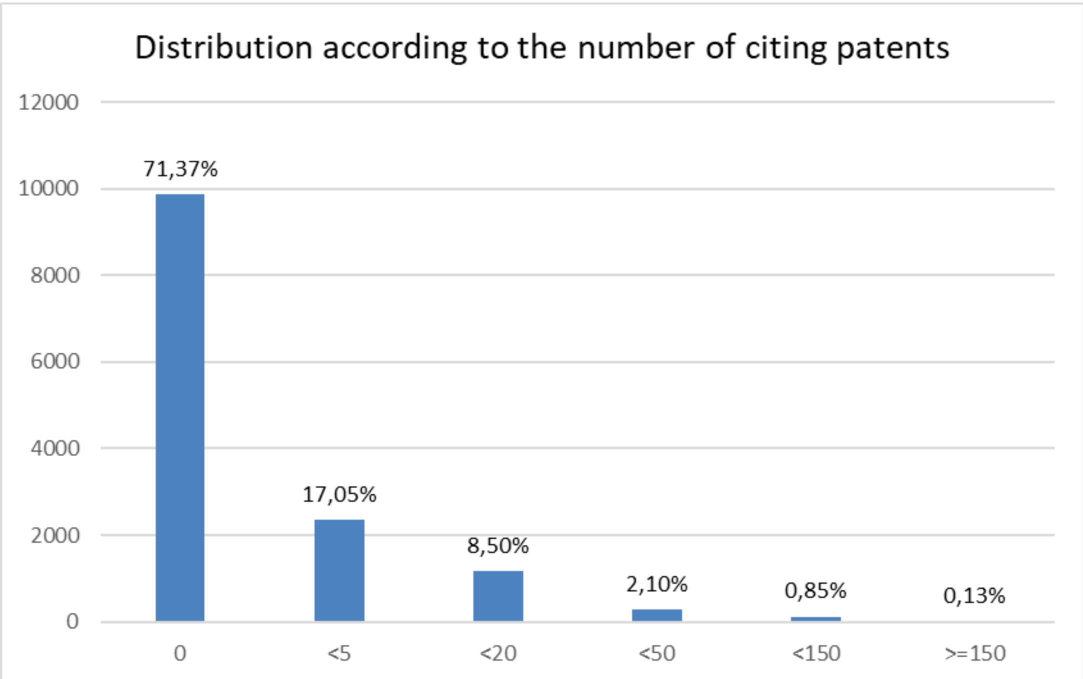

Figure 17. Distribution according to the number of citing patents.

After showing some descriptive statistics, other two indicators have been computed: *cit_space* and *cit_no_space*. The first one takes a value different from null if, among the citing patents, at least one is classified as *"space"* according to the criteria presented in 3.6.1. The other one, instead, is different from null if, among the citing patents, at least one is classified as "no space" according to the criteria listed in 3.6.1.
These results are summed up in Table 11 below.

	% of total patents
cit_space	10,20%
cit_no_space	25,96%

Table 11. Percentage of *cit_space* and *cit_no_space* indicators.

From the digits in Table 11, it appears clearly that the number of patents with at least one citation in a *"no space"* patent is way larger than the number of patents with at least one *"space"* citation. These are simple indicators that confirm what already has emerged in the previous paragraphs: the aerospace technologies of the firms included in the analysis are diffused more in other industrial sectors than in the aerospace one. This is a very important result that, however, as already said, can be affected by the selection criteria of the companies: big corporations were excluded, and firms included maybe operate at the edges between the aerospace and other industrial sectors.
Besides the criteria adopted, it's clear that the perimeter of the industrial sector outside of the pure aerospace is way larger than the aerospace sector alone: this aspect inevitably increases the probability of being cited by "no space" patents.

Applying the indicators described above, it is possible to categorize the root patents in four different classes that are meaningful for the analysis:

- *No citing*. This class includes all those patents that are not cited by anyone.
- *Only space*. This class includes all those patents that are cited only by citing patents that are classified as *"space"*, according to the criteria listed in 3.6.1.
- *Only no space*. This class includes all those patents that are cited only by citing patents which do not belong to the *"space"* sector.
- *Both*. This class includes all those patents that are cited by at least one citing patent belonging to the *"space"* and at least one citing patent classified as *"no space"*.

Table 12 shows the percentage of each class. These figures are important since they provide a quick sign about the possibility of a patent applied by aerospace companies to be cited and the probability of generating a knowledge flow inside or outside the aerospace sector. Looking at them allows to understand if the results of Table 11 have been confirmed or not.

CLASS TYPE	% of total patents
No citing	71,37%
Only space	2,67%
Only no_space	18,43%
Both	7,53%

Table 12. The percentage of each class is presented.

Looking at Table 12, it appears clearly that most of the root patents (71,37%) are not cited by others. There can be many reasons behind this figure: probably the most affecting one regards the companies that have been selected for the analysis. Since they are mostly small and medium enterprises or start-ups, it is likely that their inventions or new technologies are not so spread among the other players of the sector or among other industries. Probably, if the companies' sample would have included more large firms or well-known space agencies, this percentage would have been significantly lower.

The table above is particularly meaningful since it answers to one of the founding questions of the thesis: trying to understand the direction of the spillovers generated by the aerospace sector (always keeping in mind that the analysis does not cover the whole aerospace sector). It is clear from the figures of Table 12 that the technologies generated by the aerospace sector spread easier in different industrial sectors than remaining in the aerospace one. This is surely an important outcome of the analysis that confirms also the results presented in Table 11. The patents cited only by citing patents not classified as *"space"* (18,43%) are almost seven times the number of patents cited just by other *"space"* patents (2,67%).
The reasons behind these values are several: on one hand, it is likely that the aerospace technologies are important also for other industrial sectors, like telecommunications or wireless data exchanging, as confirmed also by the analysis of the IPC codes. But on the other hand, this outcome confirms that the companies identified by the *dealroom.co* platform operates at the edge between aerospace sector and other industries.
The last class shown in Table 12 includes those patents that have been cited by at least one *"space"* patent and at the same time at least one out of the aerospace domain patent. The fact that this percentage is significantly higher than the one related only to *"space"* citation reinforces the fact that aerospace spillovers spread more across other industries than remain within the sector.

3.7 Linear regression analysis

This last paragraph focuses on the explanation of the linear regression analysis that was done to understand if some variables related to the root patents can affect the probability of being cited by aerospace patents or not.
The paragraph is divided into two main sections: the first deals with the description of the variables that will be used, whereas the second one explains the models applied and the related results got. It is important to remark that the patents involved in the models are the ones that are classified at least under one IPC code: as already pointed out in 3.4, 4,18% of the patents gathered are not classified under any IPC code. This can be because of many reasons, like some missing data in the database applied or many design patents (applied particularly in the US) that do not have any industrial classification. The reason these patents have been excluded is that the aim of the models is to show the direction of the diffusion of a specific invention, then it's impossible that a new technology is not classified under any industrial domain. The patents involved in the linear regression analysis are 13162.

The models that will be presented show the probability of being cited by a space patent or not, firstly taking into consideration the whole patents sample (13162 observations) and secondly considering only the patents that are effectively cited by others (3878 observations).

3.7.1 Description of the variables

The independent variables included in the models are the following:

- *#_IPC*. This variable counts the number of different IPC codes under which the patent is classified. The larger the number, the wider the technological domain to which the innovation belongs.
- *ApplicationYear*. This variable contains the year in which the assignee/applicant has applied the patent.
- *dummy_US.* This dummy variable is equal to one if the patent has been applied under the US regulation, zero otherwise.
- *dummy_CN.* This dummy variable is equal to one if the patent has been applied under the Chinese regulation, zero otherwise.
- *dummy_EP.* This dummy variable is equal to one if the patent has been applied under the European regulation, zero otherwise.
- *dummy_WO.* This dummy is equal to one if the patent is a PCT patent, zero otherwise.
- *dummy_GB.* This dummy is equal to one if the patent has been applied under the British regulation, zero otherwise.
- *dummy_space.* This dummy is equal to one if the patent is classified under at least one technological domain identified as *"space"*, according to the criteria listed in 3.6.

- *dim_portfolio.* This variable shows the wideness of the portfolio of the company, which is the assignee of the patent.
- *founding year.* This variable contains the foundation year of the company which owns the patent, according to the data reported in *dealroom.co*.

Some variables presented above can be considered as control variables: for example, *ApplicationYear* or the geographical dummies are simply created to check the robustness of the model. Then, when the model will be presented, they will be listed in the lower part of the tables. Specifically, the geographical dummies have been entered to detect effects related to the patenting process of the different institutions.
The dependent variables that should be estimated through the linear regression are *cit_space* e *cit_no_space*, whose definitions have already been reported in 3.6.
Table 13 below reports the statistics related to the variables involved in the models.

Variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
#_IPC	13162	3,315302	2,465313	1	21
ApplicationYear	13162	2011,918	7,934967	1925	2022
dummy_US	13162	0,227473	0,4192164	0	1
dummy_CN	13162	0,086461	0,2810543	0	1
dummy_EP	13162	0,203844	0,4028699	0	1
dummy_WO	13162	0,1070506	0,3091893	0	1
dummy_GB	13162	0,0509041	0,2198103	0	1
dummy_space	13162	0,1236134	0,3291525	0	1
dim_portfolio	13162	288,0198	218,7736	1	633
foundingyear	13162	1991,351	24,39937	1899	2019

Table 13. Variables general statistics.

The most interesting aspects to notice in Table 13 above are the fact that, as already explained, the patents without an IPC classification have been excluded and that the differences between the portfolios are quite important. As already explained in 3.3, the companies' sample includes players very different from one another, from small start-ups to well-established medium companies. This partially also explains the reason why the minimum of the founding year is very remote: also established companies, maybe founded far in the past with well-defined aerospace activities, have been included in the sample.
From the statistics above, it's also confirmed that the regulation in which the larger quota of the patents has been applied are the US: in fact, the mean of *dummy_US* (0,2275) is the largest among the countries' dummies, followed by the Europe's one. These data were already shown in Table 5, in 3.3.

To identify properly variables to enter the model, it's custom to compute the correlation values for finding some relationships that could affect the robustness of the model. Correlation values of the models' variables are reported in Table 14.

	#_IPC	ApplicationYear	dummy_US	dummy_CN	dummy_EP	dummy_WO	dummy_GB	dummy_space	dim_portfolio	foundingyear
#_IPC	1,0000									
ApplicationYear	-0,0846	1,0000								
dummy_US	0,1320	0,1462	1,0000							
dummy_CN	-0,0550	0,1260	-0,1669	1,0000						
dummy_EP	-0,0056	-0,0119	-0,2746	-0,1557	1,0000					
dummy_WO	-0,0396	0,0538	-0,1879	-0,1065	-0,1752	1,0000				
dummy_GB	0,0228	-0,0946	-0,1257	-0,0712	-0,1172	-0,0802	1,0000			
dummy_space	0,0505	-0,0783	-0,0199	-0,0613	-0,0101	-0,0195	0,0212	1,0000		
dim_portfolio	0,1355	-0,2573	0,0347	-0,0515	0,0470	-0,0820	0,0227	0,1965	1,0000	
foundingyear	0,0840	0,2247	0,0748	0,0708	0,0160	0,0204	0,0530	-0,3108	-0,4221	1,0000

Table 14. Correlation matrix.

From the values in Table 14, it's possible to identify a correlation between some variables applied in the models. In this analysis, the rule of thumb is 33%, which means that if the correlation value is larger in absolute value than this threshold, the variables should be considered as correlated. According to this rule of thumb, *dim_portoflio* and *foundingyear* appear to be negatively correlated (-0,4221). Then, to check for the effects of this correlation, the models 3 and 4 have been also analyzed.

3.7.2 Model 1: cit_space of whole sample

First model to be described is the *logit* one on the likelihood of a patent to be cited by at least one patent classified as *"space"*, tested on the whole sample of patents with at least one IPC code classification.

Table 15 on the following page reports the coefficient of the variables testing the *logit* model. Table 15 contains different coefficients got through subsequent iterations of the *logit* model. The stars next to the coefficients represent the statistical significance: from one to three they mean respectively a significance of 10%, 5% and 1%. The coefficients which do not have any stars cannot be considered statistically significant.

Along with the coefficients, also the values of standard error are reported between round brackets.

The same approach has been adopted also for the models that will be presented in the following paragraphs.

As already explained, even if the geographical dummies are just control variables, they can provide a hint of some effects. It's important to point out that they should be intended as a linear combination of an underlined dummy representing the rest of the world. Thus, the correct interpretation of the *dummy_US* coefficient, for example, is that the likelihood of

being cited by at least one *"space"* patent is more related to *dummy_US* than to the underlined dummy referred to the other institutions in the world.
As expected, there is a positive relationship with *dummy_space*: it is more likely that patents included in the aerospace industrial domain are cited by other *"space"* patents.
It is less clear the role of the number of IPC. From Table 15, it seems that the fact of being classified under several industrial domains negatively affects the likelihood of being cited by *"space"* patents. Thus, more focused innovations are more likely to be cited by *"space"* patents.
The dimensional effects are positive, but tiny: this means that the portfolio size does not affect so much the likelihood of being cited by *"space"* patents.
Finally, it is important to look at the statistical significance of *foundingyear*: this variable is not significant for the model depicted, meaning that it's unable to explain the variability of the dependent variable.

Variables	**(1)**	**(2)**	**(3)**	**(4)**
dummy_space	1,022 *** (0,078)	1,049 *** (0,078)	0,983 *** (0,080)	0,982 *** (0,083)
#_IPC		-0,040 *** (0,012)	-0,047 *** (0,012)	-0,047 *** (0,012)
dim_portfolio			0,0006 *** (0,0001)	0,0006 *** (0,0002)
foundingyear				-0,00007 (0,001)
ApplicationYear	-0,060 *** (0,004)	-0,060 *** (0,004)	-0,057 *** (0,004)	-0,057 *** (0,004)
dummy_US	2,784 *** (0,112)	2,822 *** (0,112)	2,808 *** (0,112)	2,809 *** (0,113)
dummy_CN	1,778 *** (0,148)	1,782 *** (0,149)	1,782 *** (0,149)	1,783 *** (0,149)
dummy_EP	1,100 *** (0,126)	1,117 *** (0,127)	1,097 *** (0,127)	1,097 *** (0,127)
dummy_WO	2,511 *** (0,122)	2,514 *** (0,122)	2,531 *** (0,122)	2,532*** (0,122)
dummy_GB	1,306 *** (0,164)	1,344 *** (0,165)	1,320 *** (0,165)	1,321 *** (0,166)

Table 15. Results of the logit model for *cit_space* are reported.

3.7.3 Model 2: cit_no_space of whole sample

The second model shown estimates the likelihood of a patent of being cited by at least one citing patent identifies as *"no space".* This model is tested on the whole sample of patents with at least one IPC code classification.
Table 16 reports the results got through the logit model.

Variables	**(1)**	**(2)**	**(3)**	**(4)**
dummy_space	-0,623 *** (0,076)	-0,591 *** (0,076)	-0,593*** (0,077)	-0,556 *** (0,079)
#_IPC		-0,052 *** (0,009)	-0,052*** (0,009)	-0,056 *** (0,009)
dim_portfolio			0,00001 (0,0001)	0,00001 (0,0001)
foundingyear				0,003 ** (0,001)
ApplicationYear	-0,928 *** (0,003)	-0,095 *** (0,003)	-0,095*** (0,004)	-0,096 *** (0,004)
dummy_US	3,336 *** (0,079)	3,395 *** (0,080)	3,394 *** (0,080)	3,380*** (0,080)
dummy_CN	2,181 *** (0,096)	2,185 *** (0,096)	2,184 *** (0,096)	2,169 *** (0,097)
dummy_EP	1,325 *** (0,080)	1,340 *** (0,081)	1,339 *** (0,081)	1,326 *** (0,081)
dummy_WO	2,571 *** (0,087)	2,576 *** (0,087)	2,576 *** (0,087)	2,567 *** (0,087)
dummy_GB	1,154 *** (0,117)	1,184 *** (0,117)	1,183 *** (0,117)	1,155 *** (0,118)

Table 16. Results of the logit model for *cit_no_space* are reported.

Observing the coefficients reported in Table 16, it is possible to identify some similarities and differences with the ones reported in Table 15 in 3.7.2. The role of the countries is similar, even stronger with out-of-space citations: specifically, applying a patent in the US is positively related with the likelihood of being cited by at least one patent out-of-space.
As expected, the coefficient of *dummy_space* is negative: if a patent is strictly belonging to the space sector (at least one IPC code among the ones identified in 3.6) it's less likely to be cited by out-of-space patents.
Instead, interpreting the sign of the coefficient of *#_IPC* is not so trivial. The contribution is negative, meaning that the likelihood of being cited by at least one *"no space"* citing patent is greater for more focused invention (lower number of IPC codes). The sign of this coefficient is the same as in Table 15, then it is possible to conclude that being a more focused invention increases the possibility of being cited, regardless of whether it is a *"space"* citing patents or not. This is because of several reasons: the nature of the selected companies, which are not

always purely space, the variable *dummy_space* in the model and, finally, how the dependent variables have been created. They do not count the number of citations, neither the number of industrial domains in which an invention is cited, but just the direction of the citation, distinguishing between *"space"* and out-of-space.
Moreover, it is possible to notice how the effect of portfolio size disappears completely, since the variable cannot be considered statistically significant, and that there is a positive influence related to the latest companies: patents applied by the recently founded companies are more likely to spread out of the aerospace sector.

3.7.4 Model 3: cit_space of cited patents

The third model shows the results of the *logit* one, searching for the likelihood of being cited by at least one *"space"* patent. The difference with Model 1 is that this model is tested on the sample of patents which have at least one citation (always considering the number of IPC codes larger than zero).
The aim of conducting this analysis is to understand if restricting the sample of patents changes the contribution of the variables of the model. As shown in 3.6, most of the root patents do not have citation, then excluding them changes a lot the sample of analysis. In fact, the model is made up of 3878 observations. Table 17 below shows some general statistics related to the restricted sample of cited patents.

Variables	Obs	Mean	Std. Dev.	Min	Max
#_IPC	3878	3,333935	2,513341	1	18
ApplicationYear	3878	2010,38	8,079814	1925	2021
dummy_US	3878	0,4499742	0,4975553	0	1
dummy_CN	3878	0,0910263	0,2876836	0	1
dummy_EP	3878	0,146983	0,3541346	0	1
dummy_WO	3878	0,1650335	0,3712587	0	1
dummy_GB	3878	0,042032	0,200688	0	1
dummy_space	3878	0,112687	0,3162505	0	1
dim_portfolio	3878	303,0768	219,1218	1	633
foundingyear	3878	1991,974	22,29882	1899	2019

Table 17. Variables general statistics, sample restricted to cited patents.

Through the comparison between Table 17 and Table 13, it is possible to identify some differences between the two samples. The number of IPC per patent it is not deeply affected

and remains almost the same, while the data that changes most is the mean of the portfolio dimensions.
Considering the restricted sample, the average portfolio size increases consistently (+ 5,23%) confirming that patents cited tend to be applied averagely by larger firms. Other differences can be found looking at the geographical dummies: specifically, the mean for *dummy_US* increases a lot (+97,81%), proving that the quota of patents applied in the US is larger when considering this restricted sample.

After having presented some general statistics on the restricted sample, results of the application of *logit* model are presented in Table 18.

Variables	**(1)**	**(2)**	**(3)**	**(4)**
dummy_space	1,760 *** (0,114)	1,761 *** (0,114)	1,707 *** (0,115)	1,662 *** (0,118)
#_IPC		-0,003 (0,014)	-0,012 (0,014)	-0,007 (0,014)
dim_portfolio			0,0007 *** (0,0002)	0,0006 *** (0,0002)
foundingyear				-0,003 * (0,002)
ApplicationYear	-0,016 *** (0,004)	-0,016 *** (0,004)	-0,013 *** (0,004)	-0,011 ** (0,005)
dummy_US	0,514 *** (0,128)	0,516 *** (0,128)	0,501 *** (0,128)	0,530 *** (0,130)
dummy_CN	0,042 (0,170)	0,042 (0,170)	0,042 (0,171)	0,067 (0171)
dummy_EP	0,03 (0,150)	0,039 (0,150)	0,017 (0,150)	0,043 (0,151)
dummy_WO	0,629 *** (0,143)	0,629 *** (0,143)	0,647 *** (0,143)	0,671 *** (0,144)
dummy_GB	0,550 *** (0,202)	0,551 *** (0,202)	0,546 *** (0,202)	0,592 *** (0,204)

Table 18. Results for *cit_space* on the sample of cited patents.

Analyzing the coefficients shown in Table 18, it's clear that with this smaller sample the influence of the geographical dummies is lower compared to Model 1. Conversely, the contribution of *dummy_space* is larger: belonging strictly to the *"space"* domain increases a lot the possibility of being cited by at least one space citing patent.
Moreover, there is a small and negative effect related to *foundingyear,* while in Model 1 it was not statistically significant.
Finally, from Table 18, it is possible to see that many variables are not statistically significant: *#_IPC* is unable to explain the variability of the dependent variable. This is an important takeaway if compared with the results got in the analysis of the whole sample, presented in

3.7.2: when restricting the sample, the number of IPC codes is not statistically significant anymore, while when analyzing the whole sample, it is negatively related with the likelihood of being cited by at least one aerospace patent. To conclude, this means that the negative contribution of the number of IPC codes is because of the large quota of patents without citation. When considering only the patents that are effectively cited by others, the number of IPC codes does not have any relationship with the likelihood of citation within the boundaries of aerospace industry.

3.7.5 Model 4: cit_no_space of cited patents

The last model shown estimates the likelihood of being cited by at least one out-of-space patent and it is tested on the sample of root patents which have at least one citation.
Table 19 reports the results of the *logit* model.

Variables	**(1)**	**(2)**	**(3)**	**(4)**
dummy_space	-1,945 *** (0,132)	-1,971 *** (0,133)	-1,953 *** (0,134)	-1,88 *** (0,138)
#_IPC		0,072 ** (0,029)	0,074 ** (0,029)	0,061 ** (0,029)
dim_portfolio			-0,0003 (0,0003)	-0,00007 (0,0003)
foundingyear				0,005 ** (0,002)
ApplicationYear	-0,083 *** (0,010)	-0,081 *** (0,011)	-0,083 *** (0,011)	-0,086 *** (0,011)
dummy_US	1,407 *** (0,186)	1,337 *** (0,188)	1,350 *** (0,188)	1,313 *** (0,190)
dummy_CN	0,801 *** (0,242)	0,780 *** (0,243)	0,784 *** (0,243)	0,741 *** (0,243)
dummy_EP	0,442 *** (0,205)	0,435 ** (0,206)	0,441 ** (0,206)	0,403 * (0,207)
dummy_WO	0,434 *** (0,196)	0,423 ** (0,197)	0,419 ** (0,197)	0,393 ** (0,198)
dummy_GB	-0,07 (0,275)	-0,092 (0,276)	-0,093 (0,276)	-0,169 (0,279)

Table 19. Results for *cit_no_space* on the sample of cited patents.

As already observed for *cit_space*, restricting the sample just to the cited patents, decreases the relevance of the geographical dummies. As expected, the coefficient of *dummy_space* is large and negative: in fact, belonging strictly to the space domain, decreases the likelihood of being cited by out-of-space patents.

It is interesting to look at the contribution of #_IPC. When considering the whole sample, it was small and negative, while in Table 19 it's positive. This means that, when considering just the patents which have effectively at least one citation, to be classified among several IPC codes is positively related to the probability of being cited out of the space domain.

This confirms that the negative contribution of #_IPC shown in Table 16 is mainly due to the large quota of patents which do not have any citation.

From the figures in Table 19, it emerges that the portfolio's dimensions of the assignee are not a statistically significant variable for estimating *cit_no_space*, while the coefficient of *foundingyear* is positive and small, meaning that the age of the firms is positively related to the possibility of being cited by an out-of-space patent.

CONCLUSIONS

This last chapter sums up the main outcomes of the thesis that have been presented, identifying if the aerospace spillovers remain within the edges of the industry or spread within the civil sectors. Through the application of different linear regression models, it was possible to understand which are the variables that can affect the diffusion of these spillovers.

The thesis, as already done by other research (Caviggioli et al., 2022), uses the citation pattern among patents to understand how innovations coming from a specific sector could spread. When using patent citations to identify knowledge flows, it is important to remember the possible biased outcomes that can originate from various specificities of the patent application process: for example, some prior arts or sources can be unknown to the assignee of the patent, and they are added just by the patent office or by the examiners. (Caviggioli et al., 2022).

The process of data gathering has been done through the platform *dealroom.co*, for identifying the companies belonging to the aerospace industry, and through the software *Derwent Innovation*, for exporting all the information related to the patents applied by those firms. As already explained, the study described in the thesis includes among the selected companies, mostly start-ups or small and medium firms: this choice has been made for distinguishing clearly between the patents belonging to aerospace operations and the ones not. Otherwise, including also large firms or multinationals, which operate in many industries, would have been made exceedingly difficult to trace back the diffusion path with an acceptable certainty. Government space agencies have also been left out from the analysis: this was done since space agencies tend not to patent some of their inventions. This way of operating can be because of several reasons: they may want to hide the matter of their research or their operations to the public and the innovations in most cases can be so complex that reverse engineering them is very difficult and long. Thus, on many occasions, they do not have the willingness or the need to patent their innovations.
Anyway, it is important to remark that the thesis does not consider the whole and complete space sector, and then the outcomes should be considered related to the sample of companies and patents presented in the previous chapter. Extending these considerations to the entire industry it is not the aim of this study.

The analysis of data highlighted how the largest part of the patents gathered are not cited by others (71,37%). This is a meaningful aspect of the sample analyzed and it is due to different reasons: firm-level features are probably the clearest. Through the creation of the index *SPACE_tech* it was possible to define a method and a several criteria through which classify a citing patent as *"space"* or not. Once this classification was made, it was possible to create many statistics on the root patents and some interesting results was obtained: the percentage of patents which are cited by at least one patent not classified as space (25,96%) is more than twice the percentage of patents which at least one citation by *"space"* patent (10,20%). This

is a very important result that shows how the root patents are more likely to be cited outside of the aerospace industry that being cited by other patents within the sector. These data also provide other important information related to the nature of the selected firm: the companies included in the research are not simply operating in the space sector, but many of them operate at the crossroads with other industries or can be located downstream with respect to the space industry, using just aerospace data as input.
Another reason behind the values above that cannot be neglected is that the size of the industrial domain outside of the aerospace one is surely larger than the aerospace domain industry alone.

Through the application of the *SPACE_tech* index, it was also possible to classify the root patents according to the characteristics of their citations. Four classes have been created. Comparing the percentage of patents which have only *"space"* citation (2,67%) with the one which are cited only by out of aerospace patents (18,43%) confirms what stated above. Aerospace spillovers spread more easily towards other industries. This an important statement that highlights how the aerospace technologies and innovations are important for many other industries, as highlighted also by the IPC codes analyses in the previous chapter, and how the operations of the selected firms should be considered at the edges between aerospace and other sectors.

Through the creation of some econometric models, it was possible to gather other interesting results. To reinforce the outputs got, two different samples have been compared: first, the whole patents' sample, excluding only the ones without an IPC classification, and secondly just the patents which are effectively cited by others. The dependent variables that were estimated are: probability of being cited by at least one *"space"* patent and likelihood of being cited by at least one patent classified out of the aerospace domain.

When considering the likelihood of being cited by at least one *"space"* patent, there is not a constant relationship with the number of IPC codes: in the first sample is negatively related, meaning that the more focused is the innovation the larger the probability, while in the second sample it is not statistically significant. Instead, being strictly a space patent, according to the criteria listed in the previous paragraphs, as expected, is positively related to the probability of being cited by other space patents: the coefficient of this variable is larger when considering only the cited patents. The relationship with other variables, like the portfolio dimensions and the founding year of the company is less noteworthy: probability is slightly and positively related to the portfolio size, meaning that the companies' dimensions limitedly affect it, while founding year is negatively related when considering the whole sample and not statistically significant when restricting the regression to the cited patents.

Going to the likelihood of citation by an out of aerospace patent, it is, as expected, negatively related to the fact of being strictly an aerospace patent in both samples. It's more interesting instead to interpret the contribution of the number of IPC classification: when considering the whole model, the relationship is negative, thus the more focused an invention the higher the probability of being cited outside of the aerospace domain. Instead, when the regression

is restricted to the sample of cited patents, the sign changes and the relationship is positive: the larger the field of application of an invention, the higher the probability of being cited outside of the space industry. This comparison shows that the large quota of patents which do not have any citations affects the contribution of this variable.
Talking about the other variables, it's difficult to identify a consistent relationship with the portfolio dimensions since it is not statistically significant, while the foundation year is in both cases positively related with the possibility of being cited by at least one out-of-space patent.

In conclusion, it is clear from the *logit* models that the likelihood of citation depends more on patents' characteristics that on companies' features. The contribution of being strictly an aerospace patent and the wideness of the IPC classification affect deeper the probability of being cited compared to the portfolio dimensions or the foundation year of the assignees.

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