INNOVATORS HINDER THE TECHNOLOGY ADOPTION BY EARLY ADOPTERS: THE CASE OF SPACE INDUSTRY

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Abstract

The objective of this paper is to study how first adopters may hinder the adoption of innovations by the bulk of adopters. We show that first adopters achieve this objective by prolonging the length of the emergence stage of the technology life cycle. The procurement strategy of innovators may induce many technological variations that maintain a high level of uncertainty in the industry. As the bulk of adopters avoid uncertainty they do not adopt the innovations. We explain this procurement strategy by the features of first adopters and the competition existing between them.

While first adopters hinder the adoption, we do not consider that they have a negative influence on the technology life cycle. Indeed, innovators stimulate the emergence stage. We apply our research to the space industry.

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1 Introduction

There is debate within the life cycle literature regarding the influence of adopters on the dynamic of adoption. Most of the scholars analyzing the life cycle of the industry and the technology ignore the influence of adopters. By adopting a technology push perspective, these scholars tend to focus on the influence of producers (Di Stephano et al, 2012). The underestimation of the influence of adopters has been recognized as a limitation (Klepper, 1996; Anderson and Tushman, 1990). Studies analyzing the product life cycle generally consider that adopters may influence the adoption dynamic (Chiesa and Frattini, 2011; Rogers, 2003; Arthur and Lane, 1993; Di Maggio and Powell, 1983). These studies usually show that first adopters are able to speed up the diffusion of innovations. Some scholars consider that first adopters may also have negative influence on the adoption however they recognize the lack of studies on this topic (Frattini et al 2014, Rogers, 2003). This paper aims at contributing to this issue by analyzing how first adopters may slow down the adoption by the bulk of adopters.

The life cycle literature is aheterogeneous body based on various approaches.On the one hand it analyses three different life cycles: product, industry and technology. On the other hand this literature is growing thanks to contributions from different disciplines (economics, business strategy, marketing, sociology, etc.). In order to handle our research question, we consider that it is useful to combine some concepts coming from these various approaches (Taylor and Taylor, 2012).

In each cycle scholars tend to recognize the existence of three different stages. The stage one starts with a discontinuous innovation and is characterized by a high rate of major product innovation (Anderson and Tushman, 1990; Teece, 1986; Abernathy and Utterback, 1978). This implies a strong diversity among products because performance criteria are unclear (Taylor and Taylor, 2012; Christensen and Bower, 1996, Suarez and Utterback, 1995). During this stage one products are primitive and experimental which implies that they are complex to use (Rogers, 2003; Scranton, 2007; Suarez and Utterback, 1995). It is recognized by the life cycle literature that the technological context existing in the stage one induces a high level of uncertainty. This implies that most of the potential adopters are reluctant to purchase the product.During the stage one the sales are very low and increase slowly (Hauser et al, 2006; Rogers, 2003; Mahajan et al, 1990).

The stage three displays alow rate of major product innovation (Anderson and Tushman, 1990; Teece, 1986; Abernathy and Utterback, 1978). This implies that performance criteria are stable, clear and limited to a reduced number of attributes (Taylor and Taylor 2012). During this stage three the sales are stabilized at a high level (Hauser et al, 2006; Rogers, 2003; Mahajan et al, 1990).

In the life cycle literature, the reduction of the level of uncertainty explains the evolution from stage one to stage three (Taylor and Taylor 2012; Murman and Frenken, 2006; Tang, 2006; Rogers, 2003; Cainarca et al, 1992; Anderson and Tushman 1990). This reduction mainly occurs in the stage two that is regarded as a transitional stage(Abernathy and Utterback, 1978). It implies in particular that the sales rapidly increase in this stage (Hauser et al, 2006; Rogers, 2003; Mahajan et al, 1990).

During these three stages five types of adopter are going to purchase the product: innovators, early adopters, early majority, late majority and laggards (Rogers, 2003). Innovators adopt the product before the bulk of adopters because they are not hampered by the high level of uncertainty existing in the stage one. They cope with thishigh uncertainty due to several features. They display a high level of expertise, they expect to obtain a high benefit from the adoption (Rogers, 2003; von Hippel, 1986) and they have significant resources. Early adopters, early majority, late majority and laggards display a decreasing expertise regarding the discontinuous innovation that generated the life cycle. For them the complexity of the products is an obstacle to adoption (Rogers, 2003). This leads the bulk of adopters to prefer standardized products and to make the purchase rather in the stages two and three of the life cycle.

In this paper we focus on the influence of innovators on the length of the stage one of the technology life cycle. We argue that innovators may hinder the adoption of innovations by the bulk when they are able to influence the technology life cycle.

To validate this proposition we decided to focus on the space industry. We selected this industry because it is a market pull industry where customers have a high bargaining power (Ruttan 2006; Krige et al 2000; Logsdon et al 1998; McDougall 1985). More precisely the

space industry has been created by its customers and in particular by military and institutional customers. We also selected this industry because it displays very strong innovation dynamic where most of the spacecraft are innovations.
This paper adopts an descriptive methodology (Zikmund, 2002; Mahajan et al, 1990) based on a historical case study focusing on a large period that goes from 1957 to 2011. In order to observe and interpret the life cycles in the space industry, we use quantitative and qualitative data. This data allows us to plot variables such as the rate of major product innovation, the sales and the type of adopters.

We observe that technology life cycle of the space industry is different from the typical shape. In particular the average rate of major product innovation remains high. The shape of the product life cycle is also significantly different from the typical cycle. We do not observe the traditional three stages. Regarding the adopters, we see that the large majority of adopters are innovators in the space industry. These observations lead us to argue that the space industry is in a prolonged emergence stage since 1957.
This situation is explained by the influence of innovators in the technology life cycle. The procurement strategy of innovators inducesthe emergence and the survival of many technological variations that maintain a high level of uncertainty. This context hampers the adoption of spacecraft by the bulk of adopters which hinders the increase of sales.
We propose several arguments to explain the existence of the procurement strategy implemented by innovators. Firstly, innovators ask for numerous major product innovations because of their own features. Secondly, the competition existing between innovators to adopt new technologies leads to technology duplication. Thirdly, innovators prefer primitive and experimental products which favor the survival of many technological variations.

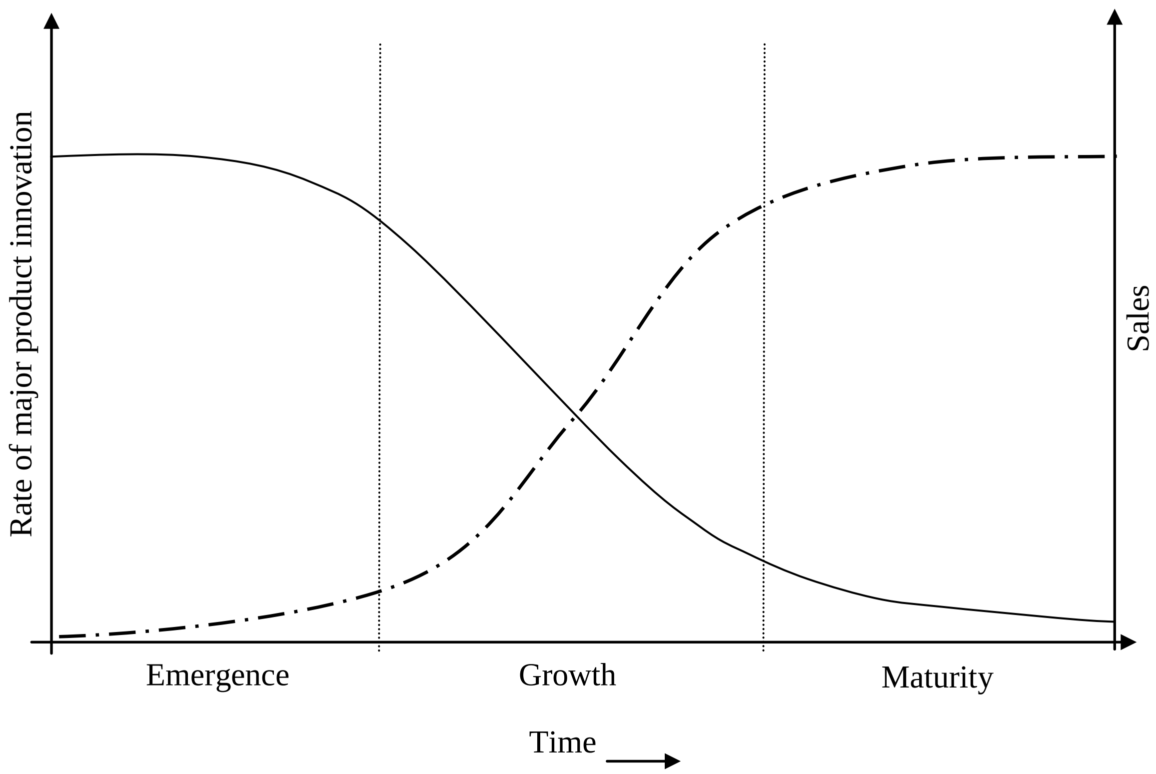
The next section introduces the literature of this paper. The section 2 presents the research design. The section 5 displays our results. In the last section we discuss our results and we draw conclusions.

2 Literature review

2.1 The life cycle literature

The theoretical framework of the paper is the life cycle literature which is not a homogeneous body. Three main life cycles can be identified, the product life cycle (1), the industry life cycle (2) and the technology life cycle (3)(Taylor and Taylor, 2012). Scholars from very different disciplines adopted the life cycle theory. There are for instance works on economics, business strategy, marketing, sociology,geography and history that adopted a life cycle approach (Frattini et al, 2014, Young, 2009, Baptista 1999; Mahajan et al, 1990). In each discipline, scholars made significant contributions that can be very useful for the life cycle literature. While several concepts provided by scholars appear as similar and complementary, one cannot easily combine them. Put differently, the diversity and the confusion existing in life cycle literaturehamperthe buildingof a more homogeneous literature (Taylor and Taylor, 2012). In this paper we decided to contribute to this convergence process.

We recognize a coevolution between the product, the technology and the industry life cycles. However, as product and industry life cycles refer both to a technology class; we consider that the evolution through these cycles is strongly influenced by the technology life cycle (see for instance Taylor and Taylor, 2012; Klepper, 1996; Cainarca et al 1992). In each cycle scholars tend to recognize the existence of three different stages[1] (see figure 1).



[1]Some scholars analyzing the product life cycle indent a fourth stage called decline.

Figure 1: Typical technology and product life cycle

The stage one that we call *emergence* is also referred to as introduction, era of ferment, fluid and embryonic. This stage starts with a discontinuous innovation and is characterized by a high rate of major product innovation(Anderson and Tushman, 1990; Teece, 1986; Abernathy and Utterback, 1978). Thisimplies a strong creative destruction process where many variations of the initial discontinuous innovation appear and disappear. There is competition between all the technological variations to become the dominant design (Anderson and Tushman 1990). The emergence stage ends when one or a limited number of dominant designs are selected. Before this tuning point, there is a strong diversity among products because performance criteria are unclear (Taylor and Taylor, 2012; Christensen and Bower, 1996, Suarez and Utterback, 1995). In particular, performance criteria change rapidly and display several dimensionspartly incompatible. The high diversity among products implies on the one hand that products are made in small batches and on the other hand that is possible for skilled adopters to find a highly customized product (Dodgson et al 2008; Suarez and Utterback, 1995). During emergence stage, products are primitive and experimental which implies that they are complex to use and they display a low level of reliability (Rogers, 2003; Scranton, 2007; Suarez and Utterback, 1995).

It is recognized by the life cycle literature that the technological context existing in the stage one induces a high level of uncertainty that hinders the adoption.Potential adopters do not understand the purpose of the products. They also consider that that adoption implies significant costs such as learning costs, switching costs and reliability costs (Dos Santos Paulino, 2014; Hargadon and Douglas, 2001). During this stage most of the potential adopters adopt a wait a see behavior (Rosenberg, 1976). Put differently, the demand is very low and it increases slowly (Hauser et al, 2006; Rogers, 2003; Mahajan et al, 1990).

The stage three of the life cycle has several names. It is sometimes called era of cumulative change and specific, we decided to name it *maturity*. During this stage the rate ofmajor product innovation is very low and we no longer observe variations of the discontinuous innovation that originated the cycle (Anderson and Tushman, 1990; Teece, 1986; Abernathy and Utterback, 1978). As the creative destruction process is very weak, performance criteria are stable, clear and limited to a reduced number of attributes where the price is of paramount importance (Taylor and Taylor 2012). The products available are standardized, simple to use and reliable. Put differently, the products are specific to a well-known purpose and large batches are proposed.This implies that is difficult for adopters to find highly customized products. Because of this technological context, the level of uncertainty is low in the maturity stage. This implies that the demand understands the purpose of the product and does not display a wait and see behavior (Rosenberg, 1976). Put differently the sales are stabilized at a high level (Hauser et al, 2006; Rogers, 2003; Mahajan et al, 1990).

In the life cycle literature, the reduction of the level of uncertainty explains the evolution from stage one to stage three (Taylor and Taylor 2012; Murman and Frenken, 2006; Tang, 2006; Rogers, 2003; Cainarca et al, 1992; Anderson and Tushman 1990). The reduction of uncertainty mainly occurs in the stage two that is regarded as transitional and we call it *growth*(Abernathy and Utterback, 1978). It implies that the demand increases rapidly in this stage (Hauser et al, 2006; Rogers, 2003; Mahajan et al, 1990).

2.2 The nature of adopters

In this paper we argue that first adopters may influence the adoption of potential adopters. The diversity existing in the life cycle literature implies that not all the scholars consider the same categories of adopters (Frattini et al, 2009; Young, 2009; von Hipple, 1986; Mahajan et al, 1990). We use Rogers's approach (2003) that retains five types of adopters: innovators, early adopters, early majority, late majority and laggards (figure 2).

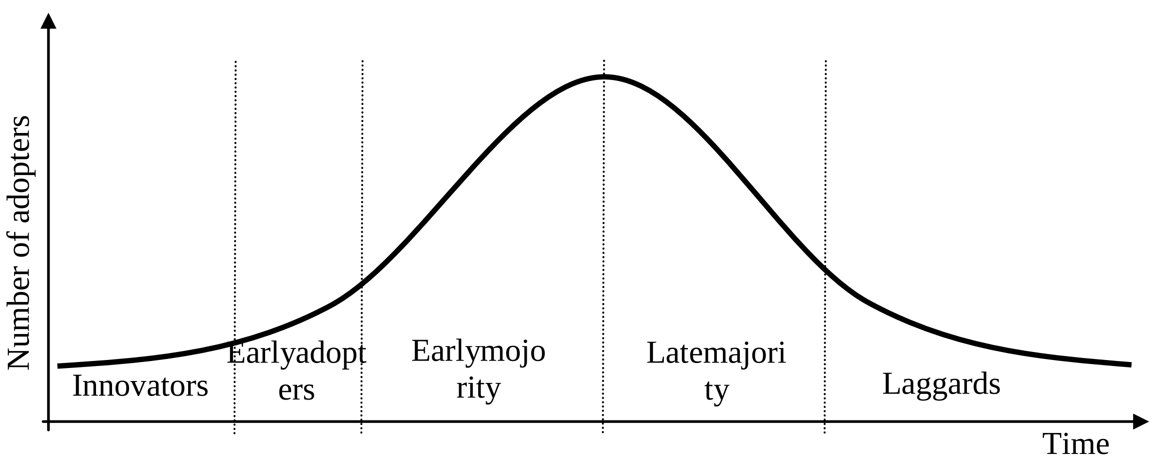


Figure 2: Type of adopters

This classification is first based on the level of innovativeness of adopters, namely the time at which adopters adopt the innovation in the life cycle. As proposed by scholars in product life cycle literature, we assume on the one hand that adopters are organizations rather than individuals, and on the other hand that the adoption is embedded in a social system (Le Nagard-Assayag and Manceau, 2011; Frattini et al 2009; Rogers, 2003; Kumar and Krishnan, 2002; Baptista, 1999). Put differently, the first organization in the country B that adopts an innovation already adopted by early adopters in the country A should be regarded as an innovator if the two countries are different social systems.

Because identifying innovators only thanks to innovativeness can by misguiding, we may take advantage of other features of adopters. Innovators, sometimes also called lead users (von Hippel, 1968), represent 2.5% of the population. They adopt the product first in the social system because they are not hampered by the high level of uncertainty existing in the emergence stage. They cope with the uncertainty for several reasons. They first display a high level of expertise regarding the discontinuous innovation that triggered the technological life cycle. Put differently, they foresee some of the possible purposes of the discontinuous innovation. This implies that their current needs display some similarities with the future needs of the bulk of adopters. However, scholars mention that the level of similarity can vary between product classes (von Hippel, 1986). In some cases, very limited information about the needs of innovators would be useful to know about the needs of the remaining adopters. The high expertise of innovators alsoinduces that the difference between innovators and producers may be very thin (von Hippel). Scholars also mention that innovators prefer primitive and experimental products which are complex to use rather than standardized products dedicated to a very specific purpose (Rogers 2003). Indeed, expert users can get more benefit from complex and highly customized products. The second main feature of innovators is that they expect to obtain a high benefit from the adoption (Rogers, 2003; von Hippel, 1986). This implies that there are often complementary and competition relationships between innovators (Frattini et al 2014; Rogers, 2003; von Hippel, 1986). Innovators display significant resources and are low price sensitive. Some studies detail this point by adding that innovators tend to be largerorganizations than subsequent adopters (Rogers, 2003). These features allow them to be highly product failure tolerant. A last relevant feature of innovators is that they cannot be regarded as a homogenous group because they adopt the product before the emergence of the dominant design. During the emergence stage, performance criteria change rapidly and display several dimensions partly incompatible. In other words,there are several subgroups of innovators with partly incompatible needs.

The remaining adopters represent 97.5% of the population and are more hampered by the uncertainty. They tend to adopt the product rather during the stages two and three in the following order: early adopters, early majority and late majority and laggards. These adopters display a decreasing expertise regarding the discontinuous innovation that generated the life cycle. Because of that, the complexity of the products is an obstacle to adoption for them (Rogers, 2003). Their lower level of expertise also leads them to prefer standardized products.Put differently, these adopters are willing to adopt the product when the emphasis of the life cycle changes from technology development per se to its commercialization (Taylor and Taylor, 2012; von Hippel, 1986). These four types of adopter expect a lower and decreasing benefit from the adoption compared innovators. While early adopters recognize a certain benefit to adopt, late majority is skeptical about innovations and laggards are suspicious (Rogers, 2003). This situation is partly explained by the decreasing resources that display the four types of adopters. Put differently, they are not really failure tolerant, especially the last types of adopters.We recognize that form product and industry life cycle perspectives, the four categories of adopters are different. However from a technology life cycle perspective, these four types of adopters are tend to be a homogeneous group. Indeed, they adopt products with compatible performance criteria dedicated to a specific purpose.

2.3 Influence of adopters in the life cycles

The majority of studies in the industry and technology life cycle literature adopt a technology push perspective where producers are able to shape the life cycle (Di Stephano et al, 2012). By giving a major role to the supply side, in particular in mass production industries, many studiesunderestimate the influence of adopters (Klepper 1996; Anderson and Tushman, 1990). In capital goods industries, such as complex products and systems (Hobday, 1998), the influence of adopters is recognized. According to scholars,governmental customers may have a strong influence in the technology life cycle (Cowan and Foray, 1996; Suarez and Utterback, 1995; Anderson and Tushman, 1990). Because of their significant bargaining power, military customers are able to reduce the technological uncertainty by favoring a particular technological variation. Military customers are also able to increase this uncertainty when they are for instance interested in exploring many technological variations before to make a choice. Put differently, governmental customers are able to increase and reduce the length of the stage one of the life cycle. While these scholars recognize the influence of adopters on the life cycle, they also put forward the need for more work in this area.

Among product life cycle literature, the influence of adopters is a more popular topic of analysis, even in mass production industries. While there is a debate among scholars to know if early adopters may influence the adoption of potential adopters (Frattini et al 2011). Severalscholars argue that first adopters are able to influence the adoption dynamic (Chiesa and Frattini, 2011; Rogers, 2003; Arthur and Lane, 1993; Di Maggio and Powell, 1983). Among these scholars,Frattini et al (2014) put forward that early adopters are able to reduce the level of uncertainty of potential adopters thanks to the dissemination of their positive experience regarding the use of the innovation. In a competitive context between adopters, these scholars also show that the adoption by early adopters will also foster imitation strategies among the bulk of adopters. While the majority of studies analyze how the first adopters may have a positive influence on the adoption, some scholars consider that first adopters may also have a negative influence on the adoption (Frattini et al 2014, Rogers, 2003). For instance, when the competition between adopters is strong, Frattini et al (2014) mention that first adopters may be reluctant to share their knowledge about the innovation. This choice may hinder the reduction of the level of uncertainty and slow down the adoption dynamic. However, theses scholars recognize the lack of studies analyzing the negative influence of first adopters and encourage research in this area.

Finally, several scholars of the life cycle literature recognize the need to detail how adopters may increase the length of the stage one of the life cycle (Frattini et al 2014, Rogers, 2003; Klepper 1996; Anderson and Tushman, 1990). This papers aims at contributing to this less explored topic.

3 Research design

This contribution adopts an descriptive methodology (Zikmund, 2002; Mahajan et al, 1990) based on a historical case study focusing on the evolution of the spacecraft industry from 1957 to 2011. We adopted this methodolgy because it allows us to draw life cycles. In particular, we are able to plot between 1957 and 2011 the main variables of the lifecycle litterautre presented above, namely: the rate of major product innovation, the sales and the type of adopters.

3.1 Data sources

In this paper we use both quantitative and qualitative data. We built an original quantitative database by merging several quantitative open databases available on the Internet (e.g., NASA NSSDC Master Catalog, Claude Lafleur, Gunter Krebs and Jonathan McDowell databases). These databases are often provided by the active community of space amateurs and they are regularly used to conduct research applied the space industry (Zelnio, 2007). In order to merge these databases it has been also necessary to examine qualitative open databases (Encyclopedia Astronautica, Global Security, Federation of American Scientists, Space Corner and Nuclear Threat Initiative). By using these data sources, we built an original quantitative database on which conducting an in-depth analysis of the 7099 spacecraft launched between 1957 and 2011 in the world. By spacecraft we mean the space segment products (e.g. satellites, space probes, space stations and other spacecraft) and we exclude launchers. This sample aims at being comprehensive since only 0.5% of spacecraft launched have been ignored. Our database includes spacecraft launch dates, the type of adopter and the nature of the spacecraft.

In addition, we complemented our original qualitative database by examining academic publications analyzing the influence of customers in the evolution of space industry (e.g., (Gaubert and Lebeau, 2009; Hertzfeld, 2007; Zelnio, 2007; d'Armagnac, 2004; Chaumeron et al.,1999; Cohen and Noll, 1986; McDougall, 1985, 1982).

3.2 A brief history of space industry: customers and applications

It is acknowledged by scholars (McDougall 1985, Logsdon et al 1998, Krige et al 2000a, 2000b, Ruttan, 2006) that the space industry is a market pull industry. This industry has been created by its customers and in particular military and institutional ones.

The space industry isdominated by three types of customers: military, institutional and commercial. A customer's type refers to its organizational and legal identity as a "consumer" of spacecraft. Ministries of Defense and military organizations entered in the market in 1957 and ordered 4078 spacecraft (57.4% of spacecraft)between 1957 and 2011. Institutional organizations (e.g., space agencies, universities, radio amateur organizations) ordered 1523 spacecraft (21.5% of spacecraft) and entered in the market in 1959. Commercial firms (e.g., telecommunication satellites operators) ordered a total of 857 spacecraft (12.1% of spacecraft) and entered in the market in 1962. The remaining and significant 9% of launches (641 spacecraft) had been jointly ordered by different types of customers. We call them mixed customers and they entered in the sector in 1957. In particular, military and institutional organizations often joined together to co-finance spacecraft. In addition, a number of launches occurring within socialist countries (e.g., China and the USSR) did not allow us to precisely identify customers' identity. Indeed, military, institutional and even sometimes commercial organizations are often integrated in these countries. Finally, some of public-private partnerships involving institutional organizations and commercial firms also involved joint orderings of space technology (21 spacecraft).

Regarding the technology side it is generally assumed that the space industry appears in October 4th 1957 with the launch of Sputnik 1 by the OKB-1 supervised by Korolev (USSR). This satellite paved the way for the development of what we shall call the Research & Development (R&D) space application. R&D spacecraft aim at developing technical knowledge related to space technology by testing technological solutions, both architectural and component knowledge, in space environment(7.4% of launches). The same year, the Leica dog on board of Sputnik 2 initiated the science application. Science spacecraft are used to conduct fundamental research for instance in astronomy, biology, microgravity and space exploration(16.5% launches). The other applications, including remote sensing, navigation, piloted and telecommunication spacecraft appeared between 1959 and 1960 and represent 76.1% of launches.

3.3 Measuring innovations and adopters types

Most of the spacecraft are product innovations because they are produced in very small batches for a single customer. In this paper, we assume that major product innovations can be measured by computing the number of R&D and science spacecraft launched.

We identify the nature of adopters by analyzing the innovativeness andthe level of uncertainty acceptance of each type of customer. We use several indicators to measure the innovativeness. We identified the date of entry of the first customer type and we computed the average date of entry of all customers of each type. We also integrated the influence of the social system to refine this measurement. In this paper the social system refers to the country of the customers.

For instance, USAcustomers are not part of the same social system as Chinacustomers. This implies that the first Chinese customer should be regarded as an innovator while it entered in the industry 13 years after the first Americancustomer. We assess the level of uncertainty acceptance thanks to the rate of major innovations purchased by each customer type. This rate is measured by the rate of R&D and science spacecraft purchased by customers. We assume that the more customers purchase major product innovations the higher their level of uncertainty acceptance.
The table below displays our measurements and puts forward the adopter type for each customer type.

Customer type	**Innovativeness**			**Level of uncertainty acceptance**		**Adopter type**
	Date of entry of the first customer	Average date of entry		Rate of major product innovations purchased		
Military	1957	1996	High	9.0%	High	Innovator
Institutional	1959	1999	High	11.2%	High	Innovator
Mixed	1957	1994	High	3.2%	Intermediate	Innovator
Commercial	1962	2001	Intermediate	0.5%	Low	Early adopter

Table 1: Customers and adopters types

We identify two main types of adopters in the space industry. We regard military, institutional and mixed customers as innovators while commercial customers are regarded as early adopters.

4 Results

4.1 Observations

The technology life cycle in the space sector has been created by the launch of Sputnik 1 which is a discontinuous innovation. The average rate of major product innovation is 24%. According to us this is a high rate that implies a high rate of uncertainty for potential adopters. When we look at the evolution of thisrate in the figure below we observe two main cycles. The first cycle starts in 1957 and ends in 1993, the second cycle goes until 2001. Between 1957 and 1982 there is a high and decreasing rate of major product innovation. During this stage the average rate of major product innovation is 36%. Between 1982 and 1993 the rate of major product innovation is lower at 10% and more stable. In thisfirst cycle we seem observing an emergence stage, a maturity stage and in between a transitional stage. However, this cycle displays a high average rate major product innovation, in particular in the maturity stage. Regarding the second cycle, we do not observe the traditional three stages. We rather notice an increase of the major product innovation with a maximum in 2006. This leads us to argue that second cycle can be regarded as a long emergence stage.

When we look now at the evolution of salesit is more difficult to observe different cycles as well as typical stages. The product life cycle seems to start with a growth stage followed by a chaotic maturity stage. It is difficult to date the end of this stage and the start of a new stage that will trigger a new product life cycle. Finally, the analysis of sales leads us to argue that there is no a typical product life cycle in the space industry.

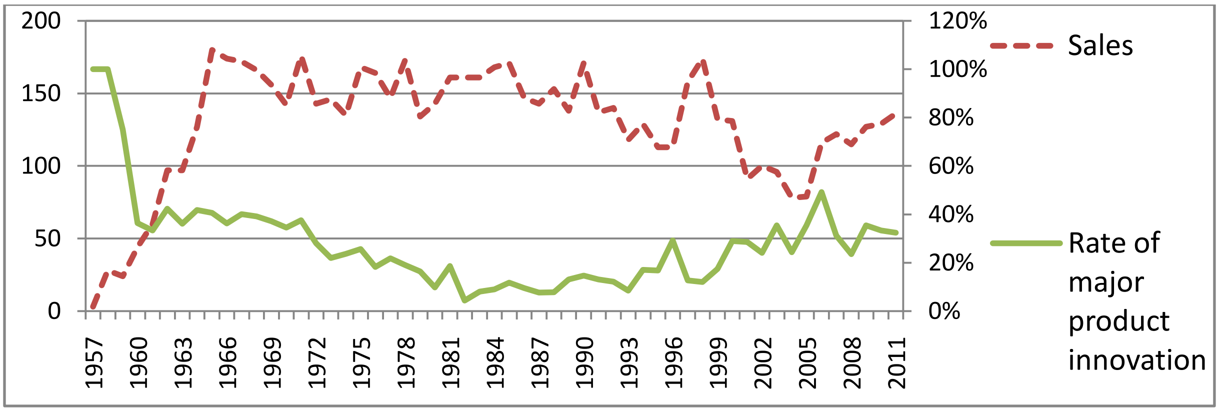


Figure 3: Technology and product life cycle in the space industry

The analysis of the purchases made by the adoptertypes provides interesting insights. We observe in the figure below that most of the adopters of spacecraft are innovators since they represent 88% of purchases between 1957 and 2011. According to us the adoption by the potential adopters is hampered by the high level of uncertainty existing in the space industry. Potential adopters do not understand precisely the purpose of spacecraft and anticipate high costs related to adoption. Our data shows that in the space industry there are no adopters of the following types: early majority, late majority and laggards.

We observe that early adopters entered in the market in 1962 and became really visible in the 1980s. At that time the rate of major product innovation was the lowest. In the 1990s, when the new technological life started, early adopters kept increasing their purchases until they accounted to 60% of the sales in 1998. However their purchases after collapsed and they only represent 24% of sales in 2011.

When we look at the nature of adopters, the evolution of sales and the rate of major product innovation, we have evidences to argue that the space industry is in a sort of prolonged emergence stage.

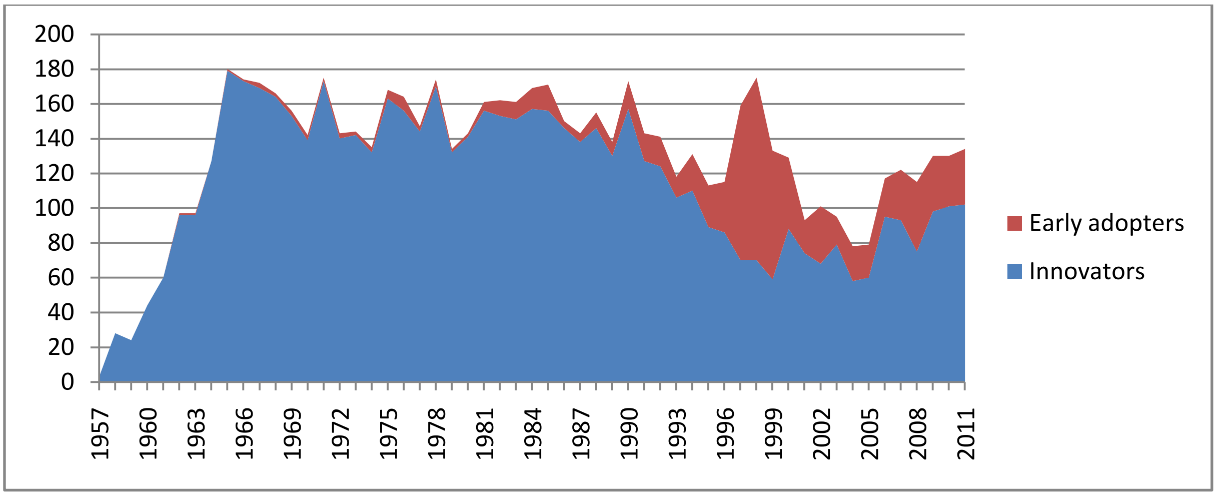


Figure 4: Purchases made by innovators and early adopters between

4.2 Analysis

We consider that the space industry is in a prolonged emergence stage because of the procurement strategy of innovators. We argue that innovators are able to influence the technology life of the industry which has a strong consequence on the adoption of early adopters and following adopters.

4.2.1 Innovators ask for many major product innovations

We observed that space industry displays a high rate of major product innovations. In the table below we see that 98% of major product innovations of the space industry have been purchased by innovators. Innovators influence the technology life cycle of the space industry by asking for most of the major product innovations.

	Innovators	Military	Institutional	Mixed
Rate of major product innovations purchased	98%	38%	47%	13%

Table 2: Rate of major product innovations purchased by innovators

Put differently, the high rate of major product innovations result from the procurement strategy of innovators.This procurement strategy allows innovators to prolong the emergence stage. According to us, thisinfluence may be explained on the one hand by the features of innovators and on the other hand by the nature of space technologies.

4.2.1.1 The features of innovators favor a high rate of innovation

Innovators expect that innovations will allow them to increase their strategic advantage. This leads space innovators to give a significant importance to technological objectives. Put differently, innovators ask for many primitive and experimental products. We observe that in the above table where space agencies and ministries of defense respectively funded 47% and 38% of major product innovations of the space industry.

Another relevant feature to understand why innovators favor the emergence of many major product innovations is their heterogeneity. The differences between innovators induce the emergence of many technical variations at the industry level. Evidently, ministries of defense do not have the same needs as space agencies. National security is not a primary concern for space agencies. Thereare also s different needs within each category of innovators. The very different budget of innovators partly explains this situation. There is for instance a significant difference between NASA budget (US space agency) and the budget of secondary space agencies such as CNES, JAXA, ISRO (respectively French, Japan and Indian space agencies).

This implies that NASA asks for a larger range of spacecraft compared to secondary space agencies. Another argument is the different objectives forming the needs of innovators. For instance, NASA essentially pursued technologic objectives when it funded the TIROS program that was the first civil remote sensing program used for environmental objectives. When ESSA (Environmental Science Services Administration) becamein charge and funded the same TIROS program, technologic objectives became secondary compared environmental ones (McQuaid, 2006; Ruttan, 2006).

4.2.1.2 The nature of technologies favor duplication

According to us, the procurement strategy of innovators induces a strong duplication of space technologies (Zervos and Siegel, 2008; Hertzfeld, 2007; Pisano, 2006; Cowan and Foray, 1995; Cohen and Noll, 1986). The starting point of this argument is that space technologies are dual technologies (they can serve both military and commercial purposes)that may provide a strategic advantage for first adopters. For instance the efficiency of nuclear weapons of ministries of defense can be significantly enhanced by a space infrastructure providing surveillance, meteorology, geodesy, targeting, and telecommunication services (McDougall, 1985). In the commercial area, telecommunication satellites reduce the global cost of the telecommunication infrastructure since it is useless to deploy an extensive terrestrial telecommunication network. The first adopter of telecommunication satellites would be then in amonopolistic situation. This strategic advantage implies a competition between first adopters to adopt strategic space technologies. The Space Race between USSR and USA is an illustration of this competition. This strategic advantage also may leadinnovators to aim at limiting the diffusion of space technologies toward the bulk of adopters and in particular the innovators and early adopters in foreign countries.

This strategy displays several dimensions observed through the existence of various barriers to entry for potential adopters.In the 1970s the Symphony program is an interesting illustration. NASA first refused to launch the first European-built telecommunication satellite because this satellite would be a significant step in the creation a European telecommunication satellite operator that will compete with US firms. NASA after changed its mind and launched in 1974 the Symphony spacecraft under the condition it was an experimental satellite (Hertzfeld, 2007; Chaumeron et al. 1999).

The strategy of the US DoD (Department of Defense) with the GPS navigation system is also noteworthy. As the DoD funded, designed and operatesthe GPS system, he decided to keep its governance (Hertzfeld, 2007). It means that DoD may at any moment crypt the signal at local level as he did it for military operations in Iraq, Afghanistan and Yugoslavia. This choice of DoD hampers the adoption of GPS system by other innovators such as foreign space agencies and ministries of defense.

Innovators are large organizations with strong bargaining power in market as well in non-market areas such as politics and regulation (Hertzfeld, 2007). They sometimes use this non-market bargaining power to create barriers to entry for potential adopters. Export control regulation is a good illustration since it exists in all space countries (e.g. International Traffic in Arms Regulations in USA). This regulation is supported by military innovators and limits the diffusion of space technologies because they often provide a strategic advantage in military operations (Zelnio, 2007).

Another way to hinder the diffusion of strategic space technologies is to limit the collaboration with foreign innovators and in particular with foreign space agencies. This strategy has been for instance adopted in US space activities and expressed by US presidents Eisenhowerand Johnson (Hertzfeld, 2007).

As evoked by several scholars in life cycle literature as well by those analyzing the space industry, the barriers to entry induce a duplication of existing technologies. Innovators excluded from the market have strong incentives to adopt technologies providing a strategic advantage. This leads them to create a domestic space industry where domestic producers will duplicate technologies already available for first innovators. We may mention the case of the rival navigation systems GLONASS and Galileo which are respectively funded by theRussian Ministry of defense and the European Union.

We may notice that this strategy is even stronger among foreign adopters who value technologic leadership and military independence (McDougall, 1985).Technologic leadership allowsestablishing a monopoly over specific markets. Military independence is a priority for ministries of defense of superpowers as well as regional powers (e.g. USA, USSR, France, China and Iran).

At the industry level, the strategy of excluded innovators induces an increase of the number of technological variations. Put differently, the barriers to entry contribute to explain why the high rate of major product innovations is explained at 98% by the purchases of innovators.

4.2.2 Innovators favor the survival of many technological variations

By asking for many technological variations, innovators are able to prolong the emergence stage of the technology life cycle. Innovators also prolonged this stage because they are able to favor the survival of many technological variations.

Another time the features of innovators are of importance to understand this argument. Innovators favor the survival of many technological variations first because they are a heterogeneous group and because they prefer primitive and experimental products. Innovators need spacecraft with performance criteria very different and sometimes partly incompatible. A standardization of spacecraft would lead to the emergence of one or several dominant designs and would prevent innovators to find spacecraft that fit to their specific needs.

The level of similarity between the innovators needs and the needs of the bulk of adopters is also relevant to understand why innovators may favor the survival of many technological variations. While innovators tend to have similar needs compared to the future needs of potential adopters, scholars recognize that the level of similarity may vary between products classes (von Hippel, 1986). We argue that in the space industry the level of similarity is low because spacecraft are dual technologies. As mentioned by Cowan and Foray (1995), the standardization of technologies reduces their dual potential. Standardization implies that it progressively appears two very different groups of technologies with on the one hand military and institutional technologies and on the other hand commercial technologies. As this process implies that commercial technologies fit less and less with the needs of military and institutional customers, progressively the range of choice for these customers will decrease. Any adopter would try to prevent his marginalization in a niche market with a limited variety of products. Innovators with a high bargaining power such as ministries of defense and space agencies will be more successful at this attempt. A relevant strategy to favor the survival of many technological variations isto hamper the competition and the selection of variations. Some barriers to entry that favor technological duplication contribute to achieve this objective. For instance, export control regulation and the limitation of collaboration between innovators leads to the emergence of space technologies with different and sometimes incompatible performance criteria. Once these space technologies are available they tend to become the dominant design in their local markets. Indeed, local ministries of defense and local space agencies cannot usually afford the expensive competition between technological variations. Put differently, because of their significant bargaining power, local innovators impose a particular technological variation as a local standard (Cowan and Foray, 1996;

Suarez and Utterback, 1995; Anderson and Tushman, 1990). The Alphabus program jointly funded by CNES and ESA (European Space Agency) in the first decade of 2000 is a good illustration. When both space agencies funded the new platform generation for telecommunication satellites,they asked the two main European satellite manufacturers (Astrium and Alcatel Space) to work together on one single platformthat would become the French-European standard (d'Armagnac, 2004).

Every local innovator naturally favors the survival of its local standard because it tends to better suit its requirements. European innovators tend to favor the standard they funded, and the other local innovators such as US, Russian and Chinese innovators do the same thing. Put differently, the local standards are not really in competition with the other local standards designs. This lack of selection induces the survival of many technological variations. We notice that the competition between technological variations is even weaker when local innovators aim at impose globally their standard and when they aim military independence. In this case, we may assume that technologies displaying low performance criteria will survive long time (e.g. US space shuttle).

Local innovators have several procurement rules to prevent competition between technological variations. A simple one is that the producer has to have the same nationality as the innovator. This rule is popular among military innovators. As space agencies display more complementary relations between them, it exists more sophisticated procurement rules such as the "georeturn" at ESA[2] (Gaubert and Lebeau, 2009).

4.2.3 Influence of innovators on early adopters

Innovators are able to prolong the emergence stage of the technology life cycle on the one hand by asking for many technological variations, and on the other hand by favoring the survival of many technological variations.

This situation induces a high level of uncertainty for the bulk of adopters and in particular for early adopters. Because of their features, especially their lower expertise, early adopters (namely satellite operators) are strongly impacted by this high level of uncertainty. It is difficult for them to understand the purpose of spacecraft. Too many variations are available which creates confusion regarding the relevance of spacecraft. When early adopters

[2]The georeturn "consists inproportioning the amount of industrial contracts to the level of participation of the contributing member states" of ESA (Gaubert and Lebeau, 2009).

understand the purpose of the spacecraft, they often implement wait and see strategies to avoid adoption costs such as learning costs, switching costs and lack of reliability costs. According to us, this rational explains why in the space industry the purchases made by early adopter are lower than those made by innovators. In a detailed way, 93% of spacecraft purchased by early adopters are telecommunication satellites. It means that the influence of innovators is stronger for remote sensing, piloted and navigation spacecraft.

5 Discussion and conclusions

As we decided to use concepts from technology, product and industry life cycles, this work contributes to build a more homogeneous life cycle literature. More precisely, this paper contributes to the debate on the influence of first adopters on the adoption of the bulk of adopters (Frattini et al 2011). We show that first adopters have an influence on the dynamics of adoption (Chiesa and Frattini, 2011; Rogers, 2003; Arthur and Lane, 1993; Di Maggio and Powell, 1983). In particular, we put forward that first adopters hinder the adoption of the bulk of adopters. By exploring this influence we contribute to increase the knowledge in a less explored topic. Indeed, several scholars put forward the lack of studies analyzing how first adopters may hinder the dynamics of adoption (Frattini et al 2014, Rogers, 2003; Klepper 1996; Anderson and Tushman, 1990).

In this paper we show that first adopters may slow down the adoption by the bulk of adopters because first adopters are able to influence the length of the technological life cycle which has an influence on the product life cycle. Innovators hamper the adoption of early adopters because they are able to favor on the one hand the emergence of many technological variations, and on the other hand the survival of many technological variations. This induces a high level of uncertainty in the industry that hinders the adoption.

While we show that first adopters hinder the adoption of the bulk of adopters, we consider that it is an over simplification to argue that first adopters have a negative influence on the three life cycles. When we argue that innovators prolong the emergence stage we mean they hinder the start of the growth stage ant they reinforce the emergence stage. We cannot say that the many major product innovations asked by innovators is negative for the industry development since these orders contribute to the global sales of the industry.In the same way, the duplication of space technologies asked by innovators favor the start of an emergence stage in many foreign markets.

As mentioned by the literature, innovators also display several complementary relations between themselves (Frattini et al 2014; Rogers, 2003; von Hippel, 1986). These relations also contribute to reinforce the emergence stage. In the space industry, we observe a lot of collaborations between foreign space agencies. There are in particular numerous international collaborations in low strategic technologies such asin science spacecraft (e.g. International Space Station, Mars 96).While the Symphony program did not occurred as European wanted, this program is an example of collaboration between innovators in secondary technologies. Indeed, NASA accepted to launch the Symphony satellites once Europeans accepted that they would be experimental.As our results also apply to military customers, this paper contributes to the literature dealing with the influence of military procurement on development of the industry (Cowan and Foray, 1995). We show that military customers have a two edge sword influence on the life cycles.

By building on the seminal work of Abernathy and Utterback (1978), we show that aprolonged high rate of major product innovations hinders the growth of the industry. This situation is a source of waste of resources since too many major product innovations emerge in the space industry (Scranton, 2007: Cohen and Noll, 1986). For instance, the technology duplication is well a known manifestation is this waste. In this paper, we computed that the average rate of major product innovations is 24% between 1957 and 2011. According to us, the space industry needs a lower rate to enter in the growth stage.The space industry needs a reduction of the rate of major product innovations to leave the infancy stage and to ensure its commercial survival. This can be achieved if innovators remove strict domestic preference procurement strategies, avoid excessively appropriating strategic technologies (e.g. relax ITAR) and fund less major product innovations. These recommendations are proposed by many scholarswho value the commercial development of the space industry (Hertzfeld, 2007; Zelnio, 2007). However these recommendations may be contradictory with the dual nature of space activities. The commercial diffusion of space technologies providing a significant advantage in the battlefield is a real concern for national security. A solution could be to implement the above recommendations with a fine-tuning of what is a dual technology. This would increase sales by allowing early adopters to enter in remote sensing, piloted and navigation applications. Regarding the communication application, it would allow the diffusion toward early majority, late majority and laggards.

This work displays several limitations. We consider that it would be possible to extract more indicators from our quantitative database. We think for instance about indicators about innovativeness and the match between the nationally of customer and supply for each spacecraft. It would be also interesting to focus in some periods of the space industry to detail more precisely how first adopters hinder the adoption of the bulk of adopters. Another limitation is that we assumed endogenous the technology life cycle.One may also consider that exogenous influences shape this life cycle. For instance, space technologies may have specific features that induce more major product innovations than other technologies. McDougall (1982) adopts this perspective by arguing that Sputnik 1 is a saltation technology. This exogenous approach calls for a better analysis of the technology that created the life cycle. These limitations are opportunities for future research.

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