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EFFECTS OF VENTURE CAPITAL INVESTMENTS ON OPEN SOURCE SOFTWARE FIRMS

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A chi ha reso tutto questo possible...

e a chi ha reso questi cinque anni indimenticabili…

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Abstract

The aim of this research paper is to investigate the effects of venture capital investments on open source software firms, and in particular how different conditions which may occur during venture capital funding can affect the performances of the funded open source companies. This has been done in order to fill the current theory gap in economic literature, since such theme has been poorly investigated and usually these two subjects are treated separately.

To fulfil this objective a critical review of current literature has been done, and the major contributions have been reported in order to fully understand the subject and, thus, to be able to formulate a series of research questions.

To analyse such queries a unique set of hand collected data has been created which measures the performances of OSS companies before and after the funding of VCs. This allowed to test the hypothesis of this paper on a set of reliable and updated data.

In particular the empirical analysis confirms the general positive effect that VC funding has on OSS companies, and suggests that certain conditions which may arise during this process may positively influence the performances of the financed OSS firms. In particular the statistical tests suggest that the presence of syndication, namely the fact that more than one VC decides to invest in the same OS firm, tends to favour positive performances of the financed firms. The presence of multiple funding rounds, instead, has a less clear impact on the performances of such firms, but the results tend to suggest a slightly positive impact on the performances of funded firms too, and most importantly state that such behaviour, which is typically used by VCs in order to increase the control over the process and to reduce the risk of investments, does not harm funded firms. On the other hand factors like experience of the VC, size of syndication, number of raised funds and being funded by a specific type of VC instead of another (i.e. Private VC) did not result as relevant in terms of influence on the performances of the financed OSS firms.

Abstract (italiano)

L'obiettivo di questo *paper* vuole essere quello di analizzare gli effetti degli investimenti di *venture capital* nei confronti di società atte a sviluppare software *open source*, ed in particolare quello di comprendere come alcune condizioni che possono variare durante tale processo di finanziamento possano influire sulle performance delle imprese finanziate. Ciò è stato fatto con l'intento di colmare l'attuale lacuna riscontrabile nella letteratura teorica, in quanto raramente viene trattato il tema del rapporto tra VC e imprese OS e tali soggetti sono tipicamente analizzati separatamente.

Per raggiungere tale obiettivo in primo luogo è stata eseguita una rassegna critica della letteratura teorica così da poter comprendere a pieno l'argomento in esame e, di conseguenza, essere in grado di formulare delle ipotesi di domande da verificare empiricamente.

Per effettuare l'analisi empirica è stato utilizzato un set di dati personalmente raccolto, in grado di misurare le performance delle imprese finanziate dai VC prima e dopo il finanziamento, così da poter ottenere dei riscontri attendibile e aggiornati.

La verifica empirica ha confermato l'impatto positivo del finanziamento dei VC sulle performance delle imprese OS finanziate, indicando come alcune condizioni di contorno che possono variare durante tale processo siano effettivamente in grado di influire sulle prestazioni delle imprese finanziate. In particolare i test statistici hanno indicato che la presenza di investimenti sindacati, ovvero il fatto che più VC decidano di investire nella stessa impresa, tende ad impattare positivamente sulle performance delle imprese OS finanziate. Il fatto di rilasciare tali finanziamenti in più tranche, invece, e quindi di dilazionare l'erogazione dei crediti, ha un impatto meno evidente sulle performance di tali imprese, ma i risultati della verifica empirica suggeriscono che vi possa essere anche in questo caso un impatto positivo sulle prestazioni dell'impresa OS. Soprattutto i risultati di tali test statistici mettono in luce il fatto che questa modalità di erogazione del credito, che viene tipicamente utilizzata dai VC per aumentare il controllo sul processo e per diminuire il rischio associato all'investimento, non abbia un impatto negativo sulle prestazioni delle imprese finanziate. Condizioni di contorno quali l'esperienza dei VC, le dimensioni degli investimenti sindacati, il numero di tranche di erogazione del credito o il fatto di venire finanziati da una particolare tipologia di VC (i.e.

VC Privati), invece, non sono risultati determinanti per quanto riguarda il possibile impatto sulle performance dell'impresa finanziata.

1. Introduction

"*There is a quite fine line between genius and sanctity, and this is probably even more the case when speaking about Open Source Software, where the fundamental premise is that the software doesn't cost anything to get started with it*" says professor Peter Fenton at Stanford University when speaking about Open Source Software (OSS). When OSS became popular in the late 90's, which was later labelled as the open software "gold rush" period (source: Peter Fenton, Stanford University, 2005), the whole economic world was trying to understand which was the best way to exploit this new way of developing software, while Open Source firms started being founded and investors started raising funds in favour of this new way of doing business.

However one aspect which may not seem clear to the most is why investors, and more specifically Venture Capitalists, should finance firms which develop free software, thus making no apparent profit from its sale.

This is a complex subject which has not yet been much investigated by scholars, and very few research papers have deepened in this specific topic, since most of the times the two arguments are treated separately.

Open Source Software, in fact, has been analysed by various authors which were able to explain the reasons of the rapid diffusion of this new phenomenon (Perr, Sullivan and Appleyard, 2010), the origins of the Open Source movement and where it derives from (Benussi, 2006), the reasons which encourage programmers and firms to adopt this new way of developing software (Lerner and Tirole, 2002), the different licensing possibilities (Mann, 2006 or The 451 Group, 2010), the main differences between proprietary and open source software (Bonaccorsi, Giannangeli and Rossi, 2006) and how to commercially exploit this kind of software (Perr, Sullivan and Appleyard, 2010).

There is also lots of anecdotal evidence which shows how Open Source is a spreading phenomenon which is gaining more and more *consensus* both by scholars and by business men since this new way of dealing with software is on one hand very interesting from an academic point of view, and on the other hand is an important potential source of revenue for firms.

Venture capitalists are also discussed in economic literature, where for example Gompers and Lerner (2001) give an accurate background of their history, Colombo and Piva (2008) explain the reasons that bring new technology-based firms to look for VC

backing and in which way VCs support such firms. The whole venture cycle has been clearly analysed by Gompers and Lerner (2001), while many papers have been written on the implications of VC funding for firms (Hellman and Puri, 2000 or Engel, 2002).
The relationship between OSS and Venture Capitalists is, however, a subject which has been poorly discussed in economic literature. Some empirical research has been made (The 451 Group, 2010), but theory shows an important gap regarding the relationship between the above mentioned topics.
The purpose of this paper is to fill this theory gap by investigating on the effects of venture capital funding on OSS firms. This will be achieved starting from a critical review of current economic literature (Chapter 2) where the main studies on OSS firms and VC will be analysed, correlating the two subjects when feasible even if, as already explained, current economic literature rarely studies their relationship and mainly treats such arguments separately. The main research question of this paper, which aims at investigating the impact of different conditions in VC financing on the performances of OSS firms, will then be introduced in Chapter 3, and the relative sub-questions will be exposed and described. Chapter 4, on the other hand, aims at giving a brief description of the hand collected data which allowed the research questions to be analysed, explaining how such data has been obtained and describing the importance of the different variables. The data analysis section is in Chapter 5, where the research questions are studied thanks to statistical tests and descriptive statistics of the hand collected data which measures the performances of OSS firms, and thanks to the comparison of such performances before and after the funding of a VC. Finally Chapter 6 contains the conclusions which have been driven from the data analysis section, while Chapter 7 describes possible interesting follow ups to this research paper.

2. Literature Review

2.1 OVERVIEW

The aim of this literature review is to deeply analyse and understand the two main topics that are dealt with in this paper, namely Open Source Software and Venture Capital. The intent of this section is to highlight the main academic research on the two subjects with a clear focus on relating them to each other. Scholars, in fact, typically treat these topics separately, and very poor analysis has been carried out in this particular direction, which is why this review will try to fill this gap and the following data analysis section will continue with this intent.

To best fulfil this objective the two topics have been developed following the same path. Both OSS and VC reviews, in fact, start with an overview of their history to understand the origins of the phenomenon, which is a fundamental aspect to understand in order to fully grasp the evolvement of such interesting aspects of modern economy. Both topics are then explained in their general aspects, and the most relevant literature contributions are reported. The aspects which are more interesting for the objectives of this paper are finally further investigated, following a personal path which reflects the intent of understanding the interaction between Open Source Software and Venture Capital.

In particular the chapter is divided as follows:

- Section 2.2 aims at describing OSS in all of its aspects, starting with a brief introduction of the topic which reports why the said phenomenon should be considered interesting and worthwhile studying. Then a summary of the historical steps which brought to the current scenario follows, with the intent of grasping the most important steps of the OSS evolution to better understand where it derives from. The literature review continues with an in depth analysis of the reasons which incite programmers to support this new way of developing software, explaining why a software developer should invest his time writing software code in absence of a monetary payoff and knowing that other people will benefit form his own work. Afterwards there is a section dedicated to organizational aspects and governance, which delves deeper into the conditions

which favour the success of OS projects. An exhaustive section which explains the different types of licenses comes next, with a subsequent focus on other ways to protect OSS, which mainly consist in taking posses of complementary assets. Next comes an important part which examines business models which allow firms to gain profit through OSS, and the logic used to describe this aspect is the same as the one used in the whole paper: a brief historical overview of the evolution of business models to understand their origins, followed by an in depth analysis of the most common business models which are currently being used by profit oriented firms. Finally the chapter ends with anecdotal evidence of the OS phenomenon, reporting the fields and the countries in which such software is mainly used, and finishes with an interesting forecast presented during the 2011 Open Source Business Conference which displays the prediction of OSS usage for the next five year.

- The purpose of section 2.3 is to give an in depth description of VCs, and the chosen path to do so is specular to the one used to describe OSS. The analysis, in fact, starts with a brief introduction to the subject and is followed by an overview of the history of VC, starting from 1946 and from the firm which is generally considered to be the first venture capitalist. The analysis continues with a review of the main difficulties NTBFs encounter, namely funding and knowledge gaps, and with the explanation of why VC can help such firms. An accurate review of the venture cycle comes next, where the main steps of venture funding are analysed, and the following section describes the implications of such funding. Next a brief paragraph covers the alternatives to VC, explaining how there are different possibilities for firms which seek funding, followed by an analysis of syndicated investments among VCs. Finally the last section runs parallel to the last section of OSS analysis, and reports anecdotal evidence of VC funding towards OSS projects, analysing one of the few research papers which connects these two subjects.

2.2 OPEN SOURCE

The open source (OS) movement has progressively acquired economic importance thanks to the increasing better quality of community developed software (Raymond, 2001), thus large incumbents such as IBM, Compaq, HP and Sun Microsystems started to release their source code. Along with big incumbents, many firms started entering this new sector, developing business models that could exploit this new phenomenon (Bonaccorsi, Giannangeli and Rossi, 2006).

Perr, Sullivan and Appleyard in their paper (2010) explain the reasons of the rapid diffusion of this new phenomenon, revealing how two main forces combine in order for OSS to create value for the market and the society in general: *market pull* and *technology push*.

OS software has been pulled into the market because of its ability to reduce development costs and improve product margin, along with typical low time-to-market and technical superiority.

On the other hand, "customer capture" is the main and most obvious reason for firms and organizations to push the adoption and free distribution of OSS. In this way firms can easily create a large user base, which can be exploited in the future to gain profit. Another way to exploit OS software is to use it to destabilize market equilibrium, and to change competitive positions which are usually difficult to modify. Lastly some organization and firms try to push for the adoption of OS software to achieve social and economic development purposes, with governments and institutions becoming more and more aware of this possibility and trying to push for the diffusion of such technology too.

The open source software development, in fact, has been studied with increasing interest both by scholars and by firms. Lerner and Tirole (2002) find three main reasons to explain the increasing and recent interest in this new way of developing software, which allows people from different places and organization to share and jointly develop new software.

The first one concerns the very fast diffusion of OS software since more and more people, firms and organizations have been replacing proprietary software with open source programs. Another factor that helped OS software become so interesting and worth studying has been the significant capital investments made which involved OS projects. Most of the major incumbents (HP, IBM, Sun) have started investing and

developing OS software, while firms which already had been working with free licences received important venture capital financing to upgrade their products.
The third reason is that the organizational structure behind the OS software development process has been seen as innovative and revolutionary.

2.2.1 HISTORY OF OPEN SOURCE SOFTWARE

As in most situations to fully understand a subject, and before starting an in depth analysis, it is fundamental to understand its history, where it derives from and in virtue of what principles it has been conceived. It is thus important to understand where OS comes from, the origins of the phenomenon and its evolution during these last years.
Six main steps can be recognized in the evolution of OS software (Benussi, 2006), each representing an important pace towards the current characteristics of open source.

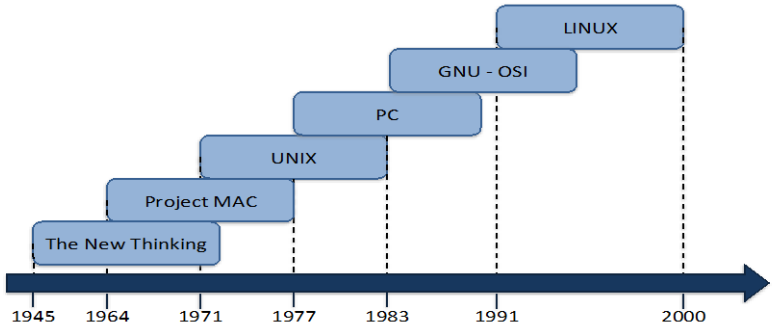


Figure 1: The six steps of OSS history

The first stage taken into consideration is the so-called “new thinking” period, which goes from 1945 to 1969. This period describes the birth of a new approach towards research which is the origin of the practice of sharing software programs (Bush, 1945). During the Second World War, in fact, scientists were forced to collaborate in order to create war-related innovation, with the terrifying results that history has shown us. However this forced collaboration opened up a totally new way of thinking at science and technology in general: the importance of technological progress and leadership was proven, along with the consciousness that to achieve the said result the only practicable road was the one of communicating, producing and managing large amount of data. One

of the major duties of ICT was, at that time, processing data, and the solution was to share energy and technological resources to go over those difficulties. This can be seen as a symbolic start of a new way of developing technology, a new way of thinking which will slowly lead to Open Source (Benussi, 2006). This new way of thinking started being accepted and being used by different universities, leading to a second revolutionary plan: connecting computers in a network in order to be more protected from external attacks (Baran, 1964).

The second step, "the big MAC", starts in 1963 and ends in 1975. This period is characterized by the establishment and development of one the most important projects of modern computing: The Project Mac at the MIT. The project was developed to solve a problem related to computers which were available in that period: big and complex machines capable of running only one program at a time. At MIT they understood that the way to solve the said problem was through *time-sharing* techniques, and by having a time-sharing system capable of working on many tasks at the same time, switching very fast between different duties. This new technique, and the general idea of creating communities for sharing capacity in order to be more efficient in processing data (Antonelli, 2005), is the key idea which also lays behind OS software development. Along with the MAC project another important step was made, that is the creation of an online storage system capable of storing data and programs for all programmers, creating a veritable information community (Fano and Corbató, 1966).

The third period, from 1971 to 1982, takes into consideration the development of the operating system the open source is based on: UNIX, the first operating system to be released with its source code. Analysing the way UNIX has been conceived is not the duty of this research paper, yet it's important to understand which features of the UNIX software have triggered the open source birth. The most important aspect of UNIX is the philosophy behind it, which is based on the idea that any amount of complexity can be created starting from simple components, and that it's the way these simple components interact with each other which leads to advanced functionalities. The described philosophy explicates a key feature of open source: modularity (Benussi, 2006).

The fourth period describes the birth of several technologies, and the most important was the PC (even if, as Langlois explains in 1992, the history and idea of the personal computer starts after WWII). This stage starts in 1977, when the Apple Computer was founded, and ends in 1991 with the publication of the World Wide Web project from the CERN Laboratories. The definition of a standard took place a few years later, with the

arrival of the Windows-IBM PC. It's important to analyse this historic period since Free Software movement came as a reaction to the fact that software was becoming more and more proprietary and monopolized, and that Microsoft was focusing more on how to sell software rather than on how to improve its quality.

The fifth step starts in 1983 with the official announcement of the GNU project and ends in 1998 with the foundation of the Open Source Initiative. The GNU project was created in reaction to the commercialization of UNIX, which led to the development of the former operating system, based on UNIX but new, reliable and totally free. The programmer who developed GNU also created the GNU General Public License, a necessary legal instrument to protect the new-born operating system and to avoid the possibility of seeing it become proprietary. In the same year the Free Software Foundation was funded, a "*non-profit foundation with a worldwide mission to promote computer user freedom and to defend the rights of all free software users*" (source: http://www.fsf.org/about/).

The Open Source Initiative (OSI) was funded in 1998, a "non-profit corporation with global scope formed to educate about and advocate for the benefits of open source and to build bridges among different constituencies in the open source community" (source: http://opensource.org). A terminological debate was issued between Open Source and Free Software, with the former winning the conflict, and providing a concrete definition of Open Source, the Open Source Definition, which became the starting point for the OS community and the open development model (Raymond, 2000). The distribution terms of open-source software must, in fact, comply with the following criteria:

- *Free Redistribution*: The license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources. The license shall not require a royalty or other fee for such sale;
- *Source Code*: The program must include source code, and must allow distribution in source code as well as compiled form;
- *Derived Works*: The license must allow modifications and derived works, and must allow them to be distributed under the same terms as the license of the original software;
- *Integrity of The Author's Source Code*: The license may restrict source-code from being distributed in modified form only if the license allows the distribution of

"patch files" with the source code for the purpose of modifying the program at build time. The license must explicitly permit distribution of software built from modified source code;

- *No Discrimination Against Persons or Groups*: The license must not discriminate against any person or group of persons;
- No Discrimination Against Fields of Endeavor: The license must not restrict anyone from making use of the program in a specific field of endeavor;
- *Distribution of License*: The rights attached to the program must apply to all to whom the program is redistributed without the need for execution of an additional license by those parties;
- *License Must Not Be Specific to a Product*: The rights attached to the program must not depend on the program's being part of a particular software distribution;
- *License Must Not Restrict Other Software*: The license must not place restrictions on other software that is distributed along with the licensed software;
- *License Must Be Technology-Neutral*: No provision of the license may be predicated on any individual technology or style of interface.

source*: http://opensource.org, Open Source Definition v. 1.9 (Annotaded)*

The OSI created the OSI Certified Mark, which is the only way to certify that a license matches the Open Source Definition and can be called Open Source.

Finally, the sixth and last step goes from 1991 to 2001 embracing the birth of Linux and finishing with the Web 2.0. The new idea behind Linux was to exploit the massive use of Web in order to connect programmers worldwide, since the GNU project was having difficulties in developing the operating system's kernel (central and fundamental part of an operating system, responsible for providing secure access to the hardware of various computer programs).

A few years after the launch of the project, the kernel for the GNU/Linux operating system had been developed (Benussi, 2006).

This brief historical overview allows one to understand how open source software is on one hand a new way of developing software, but on the other hand it also reveals that its roots and the ideas from which it has been developed are intrinsic factors of computer's

history (David, 1998), and its origins can be found in a new way of thinking which was developed many years before anybody could even think about OS.

2.2.2 PROGRAMMERS' MOTIVATIONS

It is now clear why open source software development has been taken so much into consideration during these last years. What is still not clear to the most, and actually might seem irrational, is why programmers and software experts should deliver for free to the community many hours of their own work, and obviously altruism cannot be the only answer.

It's important to understand why programmers and software experts should deliver for free to the community the code they have developed, and to grasp the motivations which lay behind this decision.

A programmer, in fact, will take part in an OS project (or any project in general), only if he will be able to gain a net benefit from it, defined as *immediate payoff* (current benefit minus current cost) plus *delayed payoff* (delayed benefit minus delayed cost) (Lerner and Tirole, 2002). When taking part in an OS project, programmers fall into various costs and benefits. The major cost is, of course, the opportunity cost of the time the programmer takes to develop the OS software, both in the case he works independently and if he is hired by a commercial firm or university. In the first situation, in fact, while developing OS software the programmer won't be able to get a paid job, and is thus renouncing to the related salary. If, on the other hand, the software expert is working for a firm, a university or a research lab, developing OS software independently will inevitably have him drift away from the goal ordered by his main job. This will be more expensive in terms of opportunity cost the more effort and pressure brought by the job.

The above mentioned opportunity cost may be compensated by two immediate benefits (Lerner and Tirole, 2002). The first one takes into consideration that, while developing OS software, the programmer may actually improve the goal of its current job (if he's currently working for a company, university or research lab). This will be the case if the OS software and the code developed for his employer refer to the same research area. The second benefit refers to a "soft" factor, which is the possibility that developing OS software for an interesting and fascinating project may be more exciting and stimulating than ordinary tasks.

There are also delayed rewards that may benefit programmers who work for OS projects. One is related to the future possibility of careers, since if programmers work well and distinguish themselves from other OS software developers, they might be noticed (and eventually hired) by firms that are looking for valuable employers. Another delayed reward derives from the ego gratification that the programmer can receive from the community if he proves to be worthy. These incentives are positively related to the visibility the developed software can get and to the impact of the effort and talent on the performance (Holmström, 1999).

From this brief theoretical background it is possible to draw another important conclusion, that is the description of which kind of profile would be more interested in contributing to OS projects. Sophisticated users, in fact, will be on average more interested in customizing and fixing bugs in OS projects, while there will be another category, programmers with strong signalling incentives, which will be more interested in exploiting OS project development as a port of entry. In particular four main classes of programmers can be identified: workers who are mainly motivated by education/intellectual reasons (29%), non workers who develop open source software as a hobby (27%), professional workers who need it for their own job (25%) and programmers who believe in the OS movement and want to help the community (19%) (Maurer and Scotchmer, 2006).

2.2.3 ORGANIZATION AND GOVERNANCE

Another interesting aspect is to analyse the organizational side of the development of OS software, and to understand under which initial conditions it is easier for the project to be successful. There are, in fact, two characteristics that favour the production of OS software: modularity and the existence of interesting challenges to accomplish (Lerner and Tirole, 2002). It's fundamental for an OS project to be successful to be able to split it into many separate independent modules, in order to allow all of the programmers willing to develop it to work on it separately. By doing so developers will be able to expand the code individually, and all the community will benefit from it. For such a thing to happen there has to be a project leader able to give a common vision, to attract the biggest number possible of developers and to coordinate the project, in order to make sure everyone goes in the same direction. This aspect is actually very tricky, since the

leader must on one hand develop enough code to prove that the project will be valuable, and on the other he must leave enough challenging tasks to the community to be able to attract many programmers (Valloppillil, 1998). The nature and the characteristics of the leader are also very important for an OS project to be successful, and the most common situation is that the person who developed the first code of the project becomes its leader.

The individualistic nature of OS projects mustn't lead into error by suggesting that there might not be any necessity of a project leader. Although the leader doesn't have any "formal authority", since he can't give orders to the community and every programmer can freely decide what to develop, he has "real authority" (Aghion and Tirole, 1997), meaning that through his initial vision and his continuous "recommendations" he can address the projects to different goals and objectives. In order for the process to be successful, though, the leader must be recognized as one by the community, and this will only happen if his objectives will be seen as congruent as possible to the ones of the other programmers, and not influenced by personal ego, commercial firms or politics. This is the best way to avoid process forking, and to have as many programmers as possible working to reach the same goal (Lerner and Tirole, 2002).

Another organizational aspect which deserves further deepening is to understand how liabilities of smallness and newness of start-ups and further market entry barriers, three major aspects of this new way of doing business, can influence the expansion of new OS ventures (Gruber and Henkel, 2006).

The burden of newness is typically manifested through lack of organization, firm-specific roles and contacts with external customers, suppliers and partners (Stinchcombe, 1965).

Moreover firms are typically not known by the market and lack experience and reputation (Romanelli, 1989), which makes it difficult for customers and suppliers to get to know the quality of the product/service offered. Developing OSS helps counterweighting this negative aspect if a firm takes part in OS community projects. By doing so it is possible both to let the market know about the firm's skills, since the produced software can be evaluated, and to create a visible track record of the various goals reached. This can be considered a marketing activity to all intents and purposes. Developing OS software can alleviate another liability related to the newness of a firm, that is the difficulties in establishing exchange relationships. Customers who approach a proprietary software vendor, in fact, incur in transactional costs when negotiating,

contracting and monitoring. These costs become, obviously, void when talking about firms offering OS software (Gruber and Henkel, 2006).

Smallness, on the other hand, means having to deal with financial gaps, inefficiencies and reduced market power (Carson, 1985). The limited size of a firm also impacts on the ability of a firm to attract and hire valuable employers, which is particularly relevant when speaking of OSS related firms, and more in general smallness doesn't favour firm survival (Birch, 1987). Also in this case commercializing OS software can help firms avoid some of these problems.

Selling software means that the product must first be developed, which requires adequate skills and resources, then continuously updated, mistakes must be removed and it might be necessary to personalize it for customers. Working with OSS, on the other hand, means having an always up to date software which only needs to be modified to fit customers' needs. Along with updated and valuable software, such firms can benefit from the support and help of the OS community.

Finally, talking about general market entry barriers, Porter (1980) explains how there are six main barriers: product differentiation of incumbent firms, capital requirements, cost advantages of incumbent firms, access to distribution channels, switching costs of customers, and government policy.

As mentioned in the previous paragraphs, using OSS helps compensating financial gaps related to the R&D efforts needed to develop new software, since firms have access to previously developed software codes. Developing OSS also helps against another barrier: switching costs of customers. When buying software, in fact, customers must, in most of the situations, customize it so that it can best fit their needs. This is often facilitated by having access to the source code of the software program, making it easier and cheaper to use both of the levers to adapt the product to the firm's needs: parameterization and modification of the code (Gruber and Henkel, 2006).

An interesting theory regarding the effect of OS software on industry organization can be developed starting from the fact that strong intellectual property rights tend to favour investments in specialized and highly innovative firms (Arora and Ceccagnoli, 2006). Since spillover effects are reduced, in fact, smaller firms are granted benefits in such environments. On the contrary weaker intellectual property rights tend to favour the establishment of bigger firms and industry consolidation. Thanks to the general strengthening of the intellectual property rights in the mid 90's, and to the fact that software development benefits from market fragmentation in terms of innovative

capacity since different and numerous solutions can be found to solve technological issues, the software market became more and more fragmented. It is thus interesting to understand how OS software development can influence the current state of things, and there are "good reasons to believe" (Mann, 2006) that OS software will support industry consolidation instead of fragmentation. When utilizing proprietary software, in fact, firms have the warranty (formal or informal) that the producer of the software will keep updating, developing and bug fixing the product, since there is a specific and fully identifiable company behind it and since reputation in software market is mainly build around such factors. On the other hand when talking about OS software nobody has to answer legally about any problem regarding the developed software, and the only incentive to keep evolving and supporting the development of an OS product is reputational. When a firm decides to adopt an OS software, it is rational to believe that reassurance will be needed in terms of development and maintenance of the product, and a large and publicly visible firm will be much more responsive to reputational incentives than smaller companies. Generally speaking, a system with property rights favours new entrants that can rely on patents and first-mover advantage to contrast incumbent firms, which have many ways to defend their technological knowledge, like market power, brand identification and leveraging value chains. Although small open source firms can benefit from the advantages described in the previous paragraphs, the open source business model, and not patents, is the real threat to fragmentation of the market and to the survival of small software firms (Mann, 2006).

2.2.4 OPEN SOURCE LICENSING

Licensing concerning proprietary software products is very straight and simple: the programmer who develops software licenses it, and the license runs directly to the end user. When speaking about OS software the topic becomes more complex, and involves two separate stages of licensing (Mann, 2006). The first stage, namely the development phase in which different programmers help writing the source code, where the copyright of the programmer usually rests with him or with one of the non profit organizations which acquire the copyright through designation. If the copyright isn't assigned, the programmer usually licenses the code under the license pertinent to the project. During the second phase, distribution, the code is released under an open

source license, and to be qualified in such a manner it must have the Open Source Initiative certification, which has been already explained in previous paragraphs.

There are, in fact, over eighty OS licenses available and recognized by the Open Source Initiative, covering a wide spectrum of possibilities and attitudes towards the diffusion of software, and there are three main differences between the available OS licenses (Rosen, 2004).

The first one considers the constraints regarding the possibility of including licensed code in future products, and has always been the major point of differentiation between the existing OS licenses. There is, in fact, a *continuum* of licenses which goes from "*reciprocal*" licenses, like the GPL, which states that the restrictions imposed by the license must apply to any "*modified work*" that contains GPL code unless "*identifiable sections*" of the new code "*can be reasonably considered independent and separate work themselves*", and provide the four freedoms (to use, to copy, to modify and to redistribute software) (Perr, Appleyard and Sullivan, 2010). This implies that programmers can use the code under GPL license to their own needs, provided that any code they further develop from the original one remains under the same OS license. This license is usually classified as "strong copyleft" (The 451 Group, 2010), referring to the method created by Free Software Foundation to grant that modified versions of OSS are also OS.

Another possibility is to use the LGPL (Lesser GPL), which "*allows other developers to incorporate OS libraries into their own application code licensed under other, often proprietary, terms*", and is classified as "weak copyleft" (The 451 Group, 2010).

On the other side of the *continuum* there are the Apache Public License (APL) and the Berkley Software Distribution (BSD), which define when developers of code derived from OSS may, or instead must, make the code available (Mann, 2006), and are thus classified as "non copyleft".

The figure below shows interesting empirical evidence of the usage of the above-described software licenses over time. From 1997 to 2009 the most commonly used licenses have been strong copyleft, with a peak of preference in 2006, while during these last years the usage of non copyleft licenses has been rising and overtook the rank of most used type of licenses in 2010.

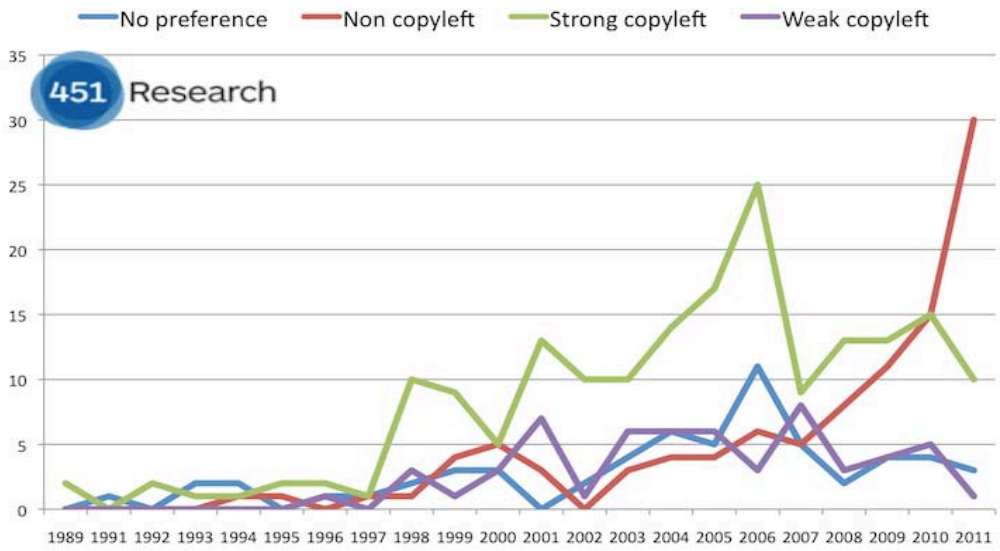


Figure 2: Software license usage over time 1
Source: © 2010 THE 451 GROUP, LLC, TIER1 RESEARCH, LLC

A more specific analysis on the type of licenses used is shown in figure three, and results are coherent with the diagram above: the use of GPL family licenses has fallen during these last years, and dropped from 70% of usage in 2008 to less than 50% in 2012. On the other hand the usage of non copyleft licenses has been rising, from roughly 15% in mid 2009 to 30% in 2012. It's important to highlight how the use of GPL family licenses has risen during these last years in real terms, for example the number of GPLv2 licensed projects has grown by 5,5% from 2009 to 2011, but the overall number of OS projects has grown by 16,6%, while for example MIT licensed projects grew 152% during the past four years (source: http://blogs.the451group.com/opensource/2011/06/06/the-trend-towards-permissive-licensing/).

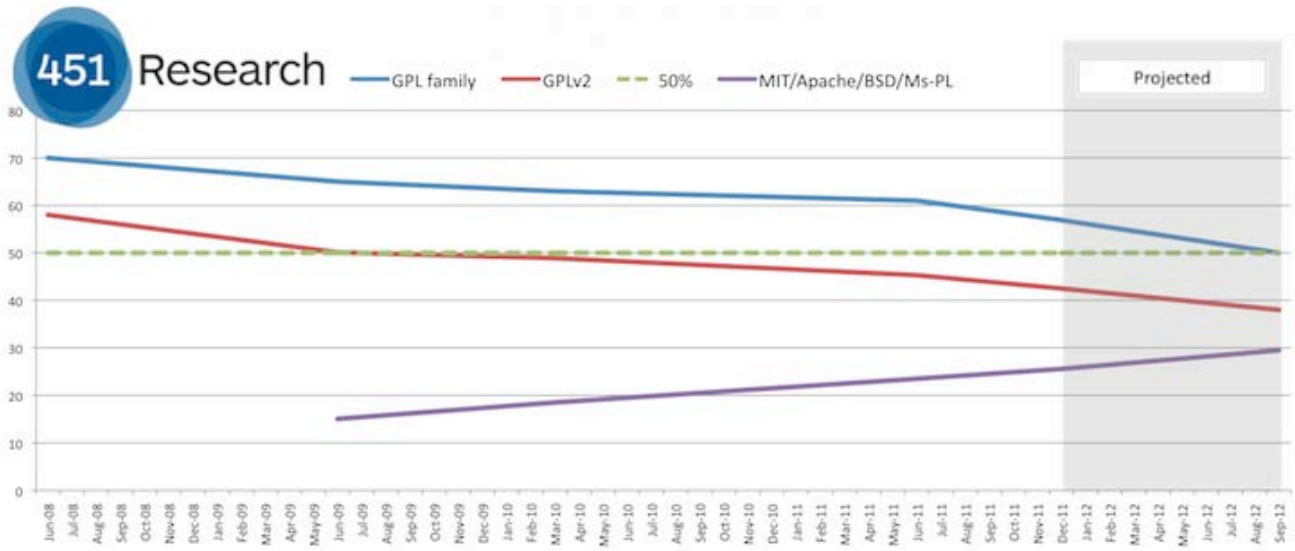


Figure 3: Software license usage over time 2
Source: www.blackducksoftware.com/oss/licenses#top20

The second big difference between OS licenses is the coverage of intellectual property rights held by programmers who help developing the code. The usual behaviour is to rely on the understanding that anyone who helps developing an open source code would grant an implied license which allowed to use the software (Rosen, 2004). Some recent licenses, though, go more into detail in this subject, differing in the way follow ups of software patents are treated.

The diagram below describes the different categories of copyright ownership usage over time: "vendor" refers to the situation where there is only one vendor owning the copyright, and it is the most common situation. "Distributed" means that the copyright of a software is distributed across various programmers, "withheld" is used to describe a situation where the copyright is hold by another vendor, and "Foundation", the less common of all the four possibilities, refers to the copyright being owned by a foundation (The 451 Group, 2010).

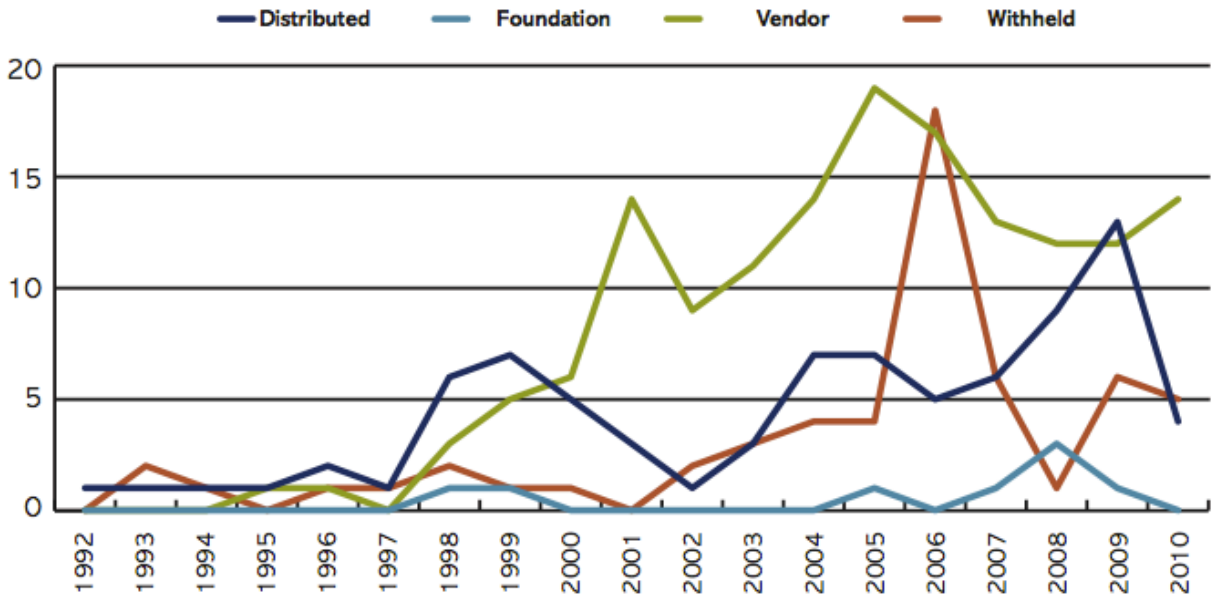


Figure 4: Copyright ownership usage over time
Source: © 2010 THE 451 GROUP, LLC, TIER1 RESEARCH, LLC

The third and final difference is on how different licenses handle indictments of patent infringement. Proprietary software patents usually protect users from such infringement claims, while for OS patents the most similar thing to a safeguard of noninfringement is "the warranty of provenance", where the programmer states that he "believes" that his work on the code is his own original creation and noninfringing (Mann, 2006).

2.2.5 PROTECTION OF OPEN SOURCE SOFTWARE

Given the weakness of legal intellectual property protection of OS software, profit oriented firms who want to commercialize in OS products need to protect their software in other ways, for example by taking control of complementary assets (Fosfuri, Giarratana and Luzzi, 2008). In order for this to be a concrete advantage, such asset must be difficult for competitors to replicate (Barney, 1991). An interesting example of complementary asset difficult for competitors to imitate is proprietary software previously developed by the firm. In particular there are two main types of intellectual property protection possibilities: trademarks and patents. Patens are defined as an "*intellectual proprietary right granted by sovereign states to an inventor to exclude others*

from making, using, offering for sale, or selling the invention throughout the state or importing the invention into the state for a limited time in exchange for public disclosure of the invention when the patent is granted" (source: http://www.uspto.gov/patents/index.jsp), while trademarks "*include any word, name, symbol, device, or any combination, used or intended to be used to identify and distinguish the goods/services of one seller or provider from those of others, and to indicate the source of the goods/services*" (source: http://www.uspto.gov/trademarks/index.jsp).

There are three reasons to explain why patents can be considered a complementary asset which supports OSS development.

The first reason is the possibility for patented software to be complementary to the OS software, for example when a server software is released under an OS license, but needs proprietary addons to be compatible with other popular formats. In such a case a firm could make profit by requiring a fee in order to install the above mentioned addon, while providing the basic version of the software for free (Teece, 1986).

The second reason is related to the possibility of controlling the development of an OSS project (Mann, 2006). If a firm owns an important software patent portfolio, they can claim their property right for a certain patent which could be fundamental for a project, thus interrupting the project development or addressing it to their own needs. By doing so firms greatly reduce the cost of the openness of the software code, but they might cause the community to avoid participating in the project.

The third and last reason is defensive, since when a firm releases a software product which bundles many other contributions, it may violate patents held by others. In such a situation, the wider the firm's patent portfolio, the stronger its bargaining power and the higher the possibility to solve eventual problems without appealing to juridical procedures (Ziedonis, 2004).

Taking into account all of the above mentioned reasons Fosfuri, Giarratana and Luzzi (2008) come to the conclusion that "*the larger a firm's preexisting stock of software patents, the more likely it is to build OSS into its commercial software products*".

On the other hand, strong trademarks usually reflect the willingness of a firm to invest in a brand in order to make customers more conscious of the reliability and quality of the products, stressing and enhancing switching costs. Offering an OS product with a different market target and positioning while exploiting the same brand might lead to a market cannibalization (Mitchell and Singh, 1992). This leads to the direct conclusion

that preexisting large software trademarks are negatively related to the development of OS products (Fosfuri, Giarratana and Luzzi, 2008).

Another aspect that needs to be taken into consideration when talking about commercialization of OSS products is hardware. Hardware producers will benefit from OS software since it is generally cheaper than proprietary one partially thanks to the possibility of combining different available modules instead of developing it from the beginning (Samuelson, 2006), and can take advantage of this situation by exploiting eventual complementarities. Firms with a large portfolio of hardware trademarks will, therefore, be well-disposed towards OS software initiatives, especially if software is only used to make their hardware operative, relieving them from the burden (and relative cost) of updating and upgrading it. The same line of reasoning cannot be applied to hardware patents, since firms with the high level of technological specialization needed for that sector are less encouraged to invest in software products because of the structural divergence between the required knowledge and skills (Fosfuri, Giarratana and Luzzi, 2008).

Now that complementarity between patens, trademarks and OS software has been cleared, the further step is to understand the impact of OS software on firm value, and the relative appropriation mechanisms used in order to create the said value. The key finding is that OS software's impact on firm value, unlike proprietary software, depends strongly on the intellectual property protection mechanism used (Aksoy, Fosfuri and Giarratana, 2011).

In particular empirical analysis reveal how "*firms' stocks of trademarks positively affect the relationship between OS software portfolio and firm value*". This means that the "promotion" effect of trademark stocks, meaning the fact that trademarks are used as a way to signal the quality of a firm, more than counterbalances the eventual "cannibalization" effect of a different market target suggested by Fosfuri, Giarratana and Luzzi in 2008.

This important result emphasizes the importance, for firms who decide to develop OS software, to adopt a coherent strategy and to use the most suitable appropriation mechanisms. Another important implication is for managers who decide to adapt a hybrid business model, a decision which must be taken with extreme care and that must be analysed in the long run, taking into consideration the above mentioned findings.

Another form of protection typically used by firms which decide to develop OSS and to contribute to OS community projects is to decide to avoid revealing all of their code, and

to “selectively reveal” their work (Henkel, 2006). Degree of revealing varies a lot between firms, and is not a random process, on the contrary it draws from rational and economic considerations. In order to fully understand this particular aspect of OSS development, it is necessary to clarify a fundamental point: derived OSS work does not always need to be made public. Let’s take into account GPL (General Public License), the most widely used free software license, as an example. The above mentioned software license only requires the sellers of derived work to make the source code available for customers. This means that if customers are not interested in publishing the code, the latter can be kept secret. Another way to keep the software code secret is by exploiting lead time (Sattler, 2003). This means revealing the code only when the software product is sold to the market or requested by customers, which on average happens more than a year after the code has been developed.

As these brief examples clarify, there are several ways to avoid software code from being published, even if written under an OS license, and firms tend to reveal generic code which can’t harm the competitive position of the company (Fauchart, 2003). The interesting aspect, then, becomes to understand under which circumstances firms decide to publish their code, and which are the determinants that favour this kind of behaviour. Henkel (2006), thanks to his study based on surveys on firms involved in OSS business, explains how revealing behaviour between firms is very heterogeneous, and can be in a large part explained by analysing firms’ peculiarities. In particular smaller firms tend, *ceteris paribus*, to reveal more software in order to be able to benefit more from external support. Also firms which can count on complementary assets tend to reveal more software, along with firms which are more experienced in developing OS software products.

This behaviour obviously reflects the need of a firm to get as much support as possible from the community in terms of code development, maintenance and improvement, which is the most significant driver of revealing.

2.2.6 OPEN SOURCE AND PROPRIETARY BUSINESS MODELS

Firms need to decide which business model to adopt, evaluating pros and cons of all possibilities. Proprietary software is usually packaged according to industrial standards in terms of documentation, maintenance, product updating, and product responsibility

clauses. These are highly appreciated by final customers, because they greatly reduce the perceived risk. On the other hand, OS software reduces the ratio between fixed costs and total costs (Bonaccorsi, Giannangeli and Rossi, 2006) but increases the perceived risk of final customers, since buying open standards from small new entrants.

Generally speaking, the main advantage of a proprietary business model, which allows coordination, funding and research directions to be decided and handled centrally, is to assure that all funds and resources behave as a whole, and head towards the planned development direction. This is a great plus, especially when unexpected events occur, which may force the firm to change their initial plans. On the other hand OS projects, even if they cannot be fully controlled and directed, thus resulting in a more decentralised and non coordinated process, have a much bigger potential, since programmers from all over the world and with many different formative backgrounds can help developing the code, often producing higher quality and more innovative products (Mann, 2006).

The two different environments alter incentives for programmers too, both in the short-term and in the long-term scenario (Lerner and Tirole, 2002). Commercial software development programs obviously affect the compensation dimension: programmers are rewarded with a salary since proprietary software's sale generates income. On the other hand OS projects may lower the cost for the programmer for two main reasons: the first one is the *alumni effect*, which takes into consideration the fact that many OS languages and codes are studied in schools and universities and used for learning purposes, making it already familiar for developers and programmers. The second reason refers to the *customization and bug-fixing benefits*, that is the fact that if taking part in an OS project helps developing and fixing bugs related to software useful for the firm or the programmer himself, this activity also brings a private benefit. Delayed rewards are better when developing OS software too, since *signalling incentives* are stronger. This occurs for three reasons: better performance measurement, meaning that in an OS project it's easier to see how much the single programmer contributed to the development of the code, and it's easier to understand how valuable the added quantity of script is, the fact that in an OS project the programmer has full responsibility on the output of the project, while inside a commercial firm the programmer usually has to submit to his employer's decisions. Again, it is much easier to measure the programmer's performance if involved in an OS project (Ortega, 2000). The last reason

is that labour market is more fluid, programmers have less constraints and can shift between different projects and subjects with more ease.

It's interesting to analyse how proprietary software firms react to this, and to understand to which extent they try to emulate this new phenomenon or to adapt it to their personal situation.

As already explained, there are certain OS benefits which cannot be exploited by proprietary software firms, for example the *alumni effect* (free programming training at universities and schools), the fact of allowing customers to modify and customize the software code or the visibility that an OS project can grant the programmers who work in it. One aspect which can, instead, be emulated from proprietary software firms, even if to a minor extent, is the *signalling incentive* (Lerner and Tirole, 2002). Commercial software firms are, in fact, becoming more and more aware of this fact, and are starting to publish the names of the programmers who develop software products, in order to give them visibility and reward them for their good work (Gibbons, 1997). Many firms, on the other hand, are reluctant to do so, worried that competitor firms may notice their most valuable employees and might try to convince them to work for them (Claymon, 1999). The result is that most project leaders get their name published, gaining fame and good reputation among other programmers, while second-line programmers still suffer from the problem that it is actually difficult to verify which person developed which part of the code. Another important step that proprietary software firms are trying to make is to focus on sharing the developed code inside the firm, and to make sure that best practices and achieved results are available to any programmer inside the company. This last aspect mustn't be taken for granted, since in many situations programming teams are largely autonomous, and tend to keep all of the relevant information among the group members. By avoiding this kind of behaviour firms will be able to reduce code duplication and to become more efficient (Lerner and Tirole, 2002).

Proprietary software firms, aware of the increasing importance of the OS phenomenon in the software market, are developing business strategies which aim at exploiting this situation to gain as much profit as possible from it. A common strategy between leading commercial software firms is, in fact, to foster OS projects in those sectors of the value chain in which they don't have core competences (Bar-Gill and Parchomovsky, 2003). By doing so firms will maintain the leadership in the sector in which they have their core competences, and at the same time they encourage the commoditization of those portions of the value chain in which they don't and in which, perhaps, their direct

competitors do. By following this strategy firms boost their image by helping the OS community, weaken their competitors in sectors of the value chain in which they currently don't have any core competence and, of course, gain potential benefits from the OS project they finance (Mann, 2006).

Another widespread plan of action used by commercial software firms is to exploit the complementarity between OS software and proprietary software in market segments which are currently being boosted by OS products. In particular they are adopting a so called "reactive strategy", which consists in constantly supporting OS products with proprietary products and services which integrate the OS offer. These kind of firms (e.g. Red Hat) usually try to encourage the OS project development by allocating some programmers to help in the source code development, both for a marketing reason and because the success of their own firm is strictly bounded to the one of the OS project (Lerner and Tirole, 2002).

A second strategy expects the commercial firm to take a "proactive role", which consists in releasing a proprietary code to create a governance structure for the resulting process. It is interesting to understand under which conditions it's profitable to adopt such a strategy. The first condition is, of course, the expectation of a boost in the complementary segment which the firm is looking forward to exploiting after releasing the software, along with the expectation that the profit gained from the complementary proprietary product or service will be greater than the profit earned if the initial software remained under a proprietary license. This implies that the above mentioned strategy can be useful in situations where the firm is too small or inadequate to compete in the primary sector, and decides to release the code of its software to try and gain revenue from complementary products and services (Taschek, 1999).

As proven with these first brief examples, many firms decided to adopt a "hybrid business model" (Bonaccorsi and Rossi, 2003), combining both OS and proprietary business models, but need to decide the "degree of openness" of their product portfolio, which is the ratio between proprietary and OS software they offer to the final consumer.

It's interesting to understand, among those firms which have already decided to adopt OS software, which are the determinants of the degree of openness of their business model.

The first determinant is, of course, related to the concept of switching costs, which can be generally defined as "*costs which arise when transactions, learning, or pecuniary costs are incurred by a user who changes suppliers"* (Klemperer, 2005). Talking about software

market, switching costs usually refer to the compatibility between hardware and software and between successive generations of software (Shy, 2001). The direct implication is that firms who have already developed software under proprietary license for many years might fall into incompatibility problems. This means that the more experience a firm has with proprietary software, the more difficulties it will find in switching to OS (Bonaccorsi et al., 2006). A similar reasoning can be done on the demand side, taking into account customers, who may find it a waste of time and resources to switch to OS, if this requires extra training or the conversion of files and archives, which leads to the same above mentioned conclusion: the negative correlation between length of experience with proprietary software and degree of openness of a firm's business model.

The second determinant considers the fact that, in order to use OS software, firms need to learn new organizational routines and change internal competencies, which is difficult (Pisano et al., 1997) and involves drawing on and making contributions to the code, accessing the community, assembling, selling and pricing products for which licenses are not proprietary and managing open code that is available on the internet. This implies that new adopting firms take some time to fully adapt their routines to this new business model, and that the shorter the period after the initial adoption of OS, the lower the degree of openness to OS (Bonaccorsi et al., 2006).

Finally, the third determinant considers network externalities. Direct network externalities, defined as *a direct effect of the number of purchasers on the quality of the product* (Katz and Shapiro, 1985), since the utility of a software program increases with the current and expected size of the user network, and indirect network externalities, which occur when two or more goods are strictly complementary, since the larger the diffusion of a given software package the stronger the incentives for companies and individual programmers to develop compatible applications. At present, OS software still suffers from prejudice both from skilled and unskilled workers, leading to the direct implication that proprietary software benefits from larger network externality effects and that this reduces the openness of firms toward OS (Bonaccorsi et al., 2006).

To better understand the relationship between the effort a firm puts into OSS development and the value gain from it, and thus to understand to which extent hybrid business models are valid for profit oriented firms, it's interesting to look at Carleton University and Nortel's "Maturity Curve":

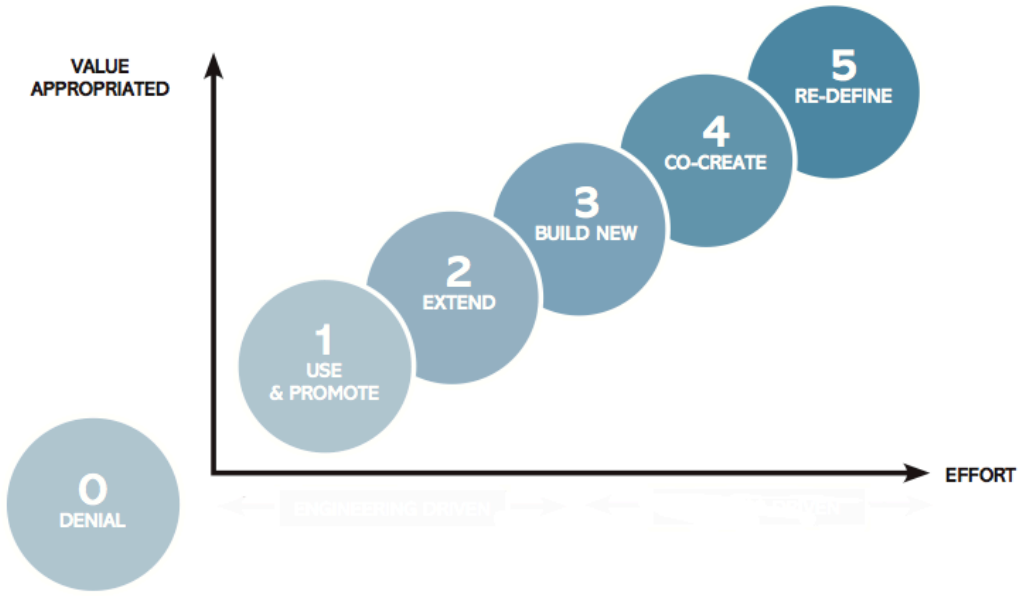


Figure 5: Open Source maturity curve
Source: Eclipse Foundation/Carleton University & Nortel

The diagram shows the relationship between the effort a firm decides to put in OSS development and the consequent value which can be generated from it, distinguishing five different stages. The first one considers the simple use and promotion of OS, while the second stage implies to extend existing OS projects thus developing new code, realizing that to grasp full value from OS it is necessary to contribute to the development of the code. In the third stage firms start to build new OS projects and to understand that collaboration can bring mutual advantages. In stages four and five industries understand the real value of OS, start developing multiple projects and extending open source itself (The 451 Group, 2010). The said research revealed that firms start gaining real value from OS projects when moving from extending current OS projects and building new ones into the last two stages of the maturity curve.

2.2.7 EVOLUTION OF OPEN SOURCE BUSINESS MODELS

A first brief outline of possible business strategies has been given, but a more detailed and accurate classification of the different business models which allow firms to generate revenue from OSS is required. Before doing so it is necessary to briefly delve deeper into the history of the different stages which led to the current business models.

Four main stages have been identified by the "451 Research Group" (2010):

- Stage 1 – Software developed by communities of individuals
- Stage 2– Vendors begin to engage with existing open source communities
- Stage 3 – Vendor-dominated open source development and distribution projects
- Stage 4 – Corporate-dominated open source development communities

During the first stage OS software was being developed by individuals, communicating through internet, which were mainly interested in code development rather than on gaining revenue from OS software.

In the second stage the first vendors started to understand that OS software was a potential source of profit, and began building business plans around it while also helping the communities in developing the code.

Enthusiastic about the success of the first vendors, others started entering the new OS market, with the goal of disrupting existing software markets, trying to take control over the OS projects.

The last stage brings us to the current situation, where many incumbents have entered the OS field, with the result that, as it will be better explained in the following section, many OS projects are now controlled by these big firms, in exchange of concrete support for the OS code development.

The following figure gives an idea of the trends of the above mentioned OS strategies:

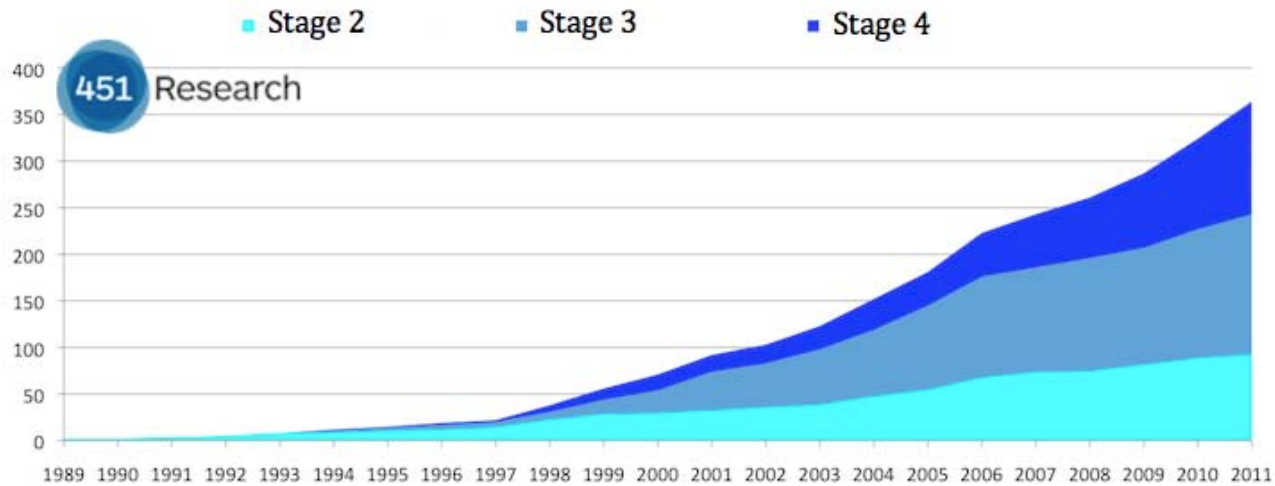


Figure 6: Open Source strategy trends
Source: © 2010 THE 451 GROUP, LLC, TIER1 RESEARCH, LLC

As shown in the above diagram the second stage lasts approximately until 1999, when many other vendors start entering the OS market and dominate until approximately 2005. From there onwards incumbents started entering the market and initiating collaborative development projects with the OS communities.

2.2.8 CLASSIFICATION OF OPEN SOURCE BUSINESS MODELS

It's interesting to understand which business models allow OSS to gain revenue even if their product is distributed for free, and to analyse under which circumstances the different strategies are typically used. Let's start with a clear definition of business model, defined by Perr, Sullivan and Appleyard (2010) as "*not merely the method(s) by which companies derive their revenue, but also the accompanying set of business processes and organizational arrangements required to realise the revenue model*".

The first step is to evaluate the main factors which are consistent with value capture. Three main factors have been identified as determinants of the adoption of a certain business model concerning OSS: software license selection, which is related to intellectual property (IP) ownership strategies, community management and the characteristics of the market and products in which the firm competes (Perr, Sullivan and Appleyard, 2010).

Starting with the first factor, the choice of the software license is fundamental to understand which business models can be adapted (Lerner and Tirole, 2005), since it directly influences IP rights, and the importance of this aspect has been deeply analysed in previous paragraphs.

A different but related subject is the IP ownership, especially copyright assignment. Companies able to keep, or at least to share, the copyright of the OS software they develop will, in fact, be able to dual license their software and distribute a commercial version along with the OS one, or decide to develop addons or complementary extensions of the software and to protect them with proprietary licenses (Perr, Sullivan and Appleyard, 2010).

Another important decision for a firm that wants to invest in OS software is the strategy to adopt towards the community. There are many different ways of approaching a community, and there are different types of communities as well, formed by hobbyists, professional programmers and industries. It's important for firms to have some kind of

control over the community, and to be able to influence it to their own needs in terms of direction of software development. This shouldn't lead to the idea that firms act like parasites toward the communities, since they often contribute both by developing software code and by investing liquidity in such communities (Foley, 2001).

The last factor obviously concerns the market segment and the product category in which the firm operates, where a clear distinction is usually made between applications suitable for horizontal market sectors or for vertical markets where more specific skills are required. Market value is, in fact, enhanced when choices of licensing, IP management and community management are coherent with the characteristics of the market in which the firm operates (Perr, Sullivan and Appleyard, 2010).

Now that the determinants of the choice of a specific business model have been cleared, it's interesting to study the main business models adopted by firms which are currently operating in the OS software market. In practice there are very few firms who decide to purely adopt one of the seven business models, and the typical situation results in industries trying to use a mixture of the models that will be now described in order to capture the most value from business opportunities.

Model	Revenue description	Licensing and IP issues	Community profile	Target markets	Examples
Professional services/ consulting	Professional services, training, consulting or customsation of OSS	• Typically GPL • Lack of IP ownership	Broad and not controlled by a single vendor	Often horizontal	• Pree-2002 RedHat • IBM
Support	Customer support contracts	• Typically GPL • Lack of IP ownership	Broad and not controlled by a single vendor	Often horizontal	• JBoss • Compiere
Subscription	Annual service agreements bundling OSS, support and software updates	• Typically GPL • Lack of IP ownership	Broad and not controlled by a single vendor	Often horizontal	• RedHat • SpikeSource
Dual license	Free "public" licence and paid "commercial" license	• GPL for "public" • Commercial licence • Vendor owns IP	Narrow and largely controlled by single vendor	Often vertical	• MySQL • Sleepycat
Hybrid/ proprietary extensions	Proprietary versions or product extensions	• GPL for base version • Commercial for exended version • Vendor owns IP	Narrow and generally controlled by single vendor	Often vertical	• SugarCRM • Zend • Sendmail • Scalix
Device	Hardware devices incorporating OSS	• Typically GPL • Lack of IP ownership	Broad or narrow and not controlled by a single vendor	Horizontal and vertical	• Mazu Networks
Community source/Consortia	Consortia jointly developing OSS to be used by all	• Typically GPL • Lack of IP ownership	Broad or narrow	Often vertical	• Kuali and Sakai projects

Figure 7 : Open Source business models
Source: Perr, Appleyard, Sullivan, 2010

Figure 7 gives a brief explanation of the seven business models identified, along with some examples of some of the most known firms which adopt a particular model.

The first described business model is "Professional services and consulting". Software vendors try to gain revenue by selling services, training, customisation or consulting on the OS software which is available for free since typically released under the GPL license. Customers are interested in the technical superiority of the solution and in the low development cost, even if the software might be still immature or not perfectly suitable for them. The software firm will then be able to exploit this situation by offering the above mentioned services in exchange of a fee. The community plays a fundamental role both for the software development aspect and for the customer capture aspect. The market focus tends to be horizontal in order for the services to be able to scale across industries. One of the most important adopters of such a business model is IBM, which started investing and offering services regarding Linux in December 2000 (Evans, 2000).

The second model, "Support", gains revenue from the customer support offered to the end users, and can be provided in various forms: by e-mail, phone, help desks or live. Again the license used is typically GPL, and the business model relies on a broad and vast community for code development and to assure technical superiority.

"Subscription" model refers to the fact of bundling to the OSS annual agreements concerning support and product updates. This model is based on a decentralised development model which is guaranteed by a broad community, and thus the license is usually the GPL. The subscription model is targeted to horizontal markets for the same reason as the two above described models. Red Hat moved from the "services" to the "subscription" business model in 2003, and by 2005 it accounted for 77% of its revenue (Red Hat Inc., 2005b).

The "Dual License" is, on the other hand, substantially different from these first three models. Vendors typically use two different licenses for the developed software: one is a free public or community license, typically the GPL, and gives access to a free copy of the software, while the second one is a commercial proprietary license, which grants the customer the possibility to redistribute the software and to obtain eventual support or additional tools. Customers must decide if receiving the support of the firm is worth the price, or else they can use the software on their own (Olson, 2005). The community is usually smaller than the ones previously described, and a large part of the project is typically controlled by the firm. The market target is, thus, vertical.

The “Hybrid/Proprietary extensions” include a revenue gain which derives from selling either proprietary extensions to an OS software or proprietary versions of the said software with increased functionalities. This model is usually compared to the “razor and razor blades” model, where the razor refers to the OS software, and the razor blades obviously refer to the proprietary extensions which are sold after a large user base has been captured exploiting the OS product. This kind of model is highly dependent on both the level of control of the IP and the community. Licenses are, in fact, typically GPL for the basic OS product, and proprietary for the “professional” product which is being sold. As a consequence communities are typically narrow, and the market target is vertical.

The “Device” model refers to firms selling hardware devices that feature incorporated OS software, which represent a great cost reduction for them. The license used it typically GPL, and communities can be both wide or small, and the firm has no interest in controlling it. Also the market target can vary from horizontal to vertical, with no particular restriction.

Finally the last model, “Community source/consortia”, refers to consortia of firms or end-user organizations who develop OS software for everybody, and in many situations public organizations join the development effort in order to reach the social goal of giving access to technologically advanced software at a low cost. Communities can be both broad or narrow, the license used it typically the GPL and the target is usually vertical or enterprise (Perr, Sullivan and Appleyard, 2010).

A different and more horizontal view of the possible revenue generating sources and their relative percentage of usage are displayed in the following diagram, driven from an empirical research made in 2010 by the 451 Group:

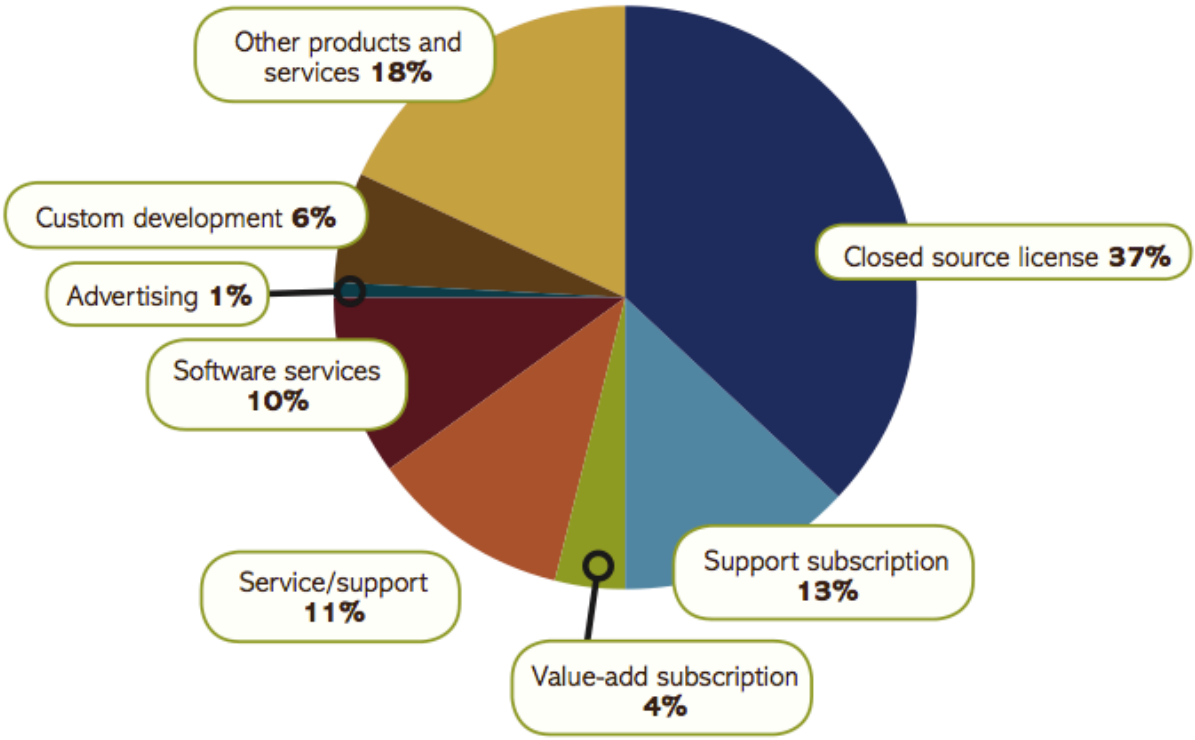


Figure 8: Open Source revenue generator – vendor usage
Source: © 2010 THE 451 GROUP, LLC, TIER1 RESEARCH, LLC

The bigger source of revenue for OSS vendors comes from "Closed source license", which refers either to a version of the full project, a larger software package, hardware appliance based on the project or to extensions of the open source core. "Other products and services" follow, and include complementary products which are used as a revenue source, while the OS software doesn't create any revenue. "Support subscription" means that the revenue is generated via an annual service and support agreement, while "Service/Support" refer to ad-hoc support calls, training and service contracts, and represent the 11% of the revenues. "Software services" refer to customers who can access and use the software via hosted or cloud services and counts for the 10% of total value. The least influent revenue generation methods are "Value-add subscription", which is an annual agreement of support and service with additional functionalities offered as a service, "Custom development" where customers pay for an ad-hoc and specific software development and "Advertising" where the software is completely free, and revenue is made by exploiting associated advertising (The 451 Group, 2010).

Now that it is clear how making revenue from OSS is not only feasible, but also an increasing phenomenon within the software market, it's interesting to understand how these business models, and the OSS movement in general, meet the three Tecee's

building blocks (Teece, 1986). The author in his paper explains how returns on innovation mainly depend on complementary assets, appropriability regime and the dominant design paradigm. In particular he comes to the conclusion that strong appropriability and complementary assets increase the chances of converting technological success into commercial one, clearly contrasting the characteristics of the OS software development model.

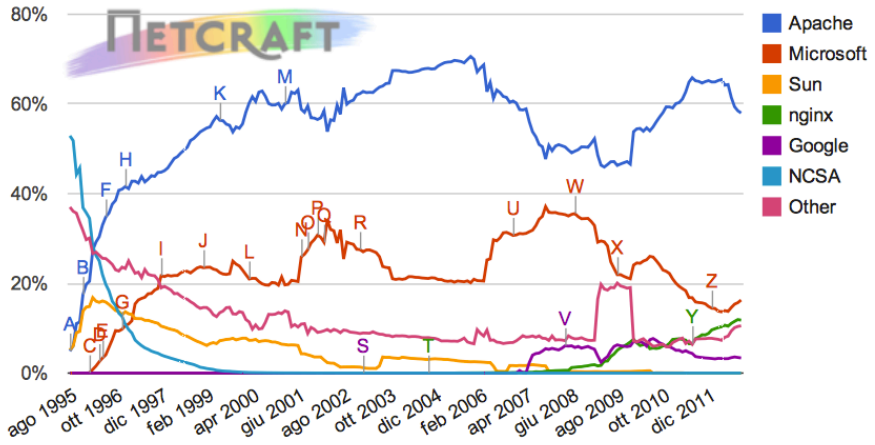
Bonaccorsi, Piscitello, Merito and Rossi (2006) in their work note how the above mentioned model developed by Teece should be updated; OS can be, in fact, a perfectly sustainable business model even without any appropriability as proven in the description of the business models viable for OSS, and this has been possible thanks to new legal inventions, namely the OS licenses and in particular copyleft licenses, which make cooperation sustainable even in large groups and which apply "*to everyone whom the software is redistributed"* (Gomulkiewicz, 1999). ICT has, on the other hand, greatly increased the accessibility to complementary assets. Distribution, for example, has been granted by internet (Choi and Winston, 2000), especially in the software market, while receiving feedback and help from the community can be seen as a cheap and easily achievable after sales assistance. The most important aspect is that these assets are collectively distributed and don't represent a comparative advantage for anybody since available for the whole community. Lastly, speaking about dominant designs which need to be found in order for a market sector to "shake-out" some industries and then consolidate, traditional theories don't take into consideration the possibility that dominant designs can be created also by a community of users and producers and not only by a powerful large community (von Hippel, 1988), with the fundamental premise which is that "network effects make the notion of dominant design strictly relate to the notion of standard" Bonaccorsi,

Piscitello, Merito and Rossi (2006).

2.2.9 ANECDOTAL EVIDENCE

Now that the OSS phenomenon has been described in its general characteristics, it's interesting to analyse its anecdotal evidence and to view some data on its diffusion and usage.

The first figure shows the result of a survey made in 2012 by Netcraft, thanks to the responses of over 600.000.000 sites, evaluating market shares for top web servers. The figure shows the rapid diffusion of Apache, a well-known open source web server, which from 1996 has become the most used web server. As of 2012, Apache currently serves the 54,98% of active websites and the 58,49% of top servers across all domains (source: http://news.netcraft.com/archives/2012/09/10/september-2012-web-server-survey.html), clearly positioning itself as the market leader at the expense of Microsoft, which has the second biggest market share, with almost one quarter of Apache's customers. Apache is supported by the Apache Software Foundation, which "*provides support for the Apache community of open-source software projects, which provide software products for the public good*" (source: http://www.apache.org).



Developer	September 2012	Percent	October 2012	Percent	Change
Apache	362,714,083	58.49%	359,875,516	58.00%	-0.49
Microsoft	97,368,803	15.70%	101,005,285	16.28%	0.58
nginx	73,976,009	11.93%	73,243,944	11.80%	-0.12
Google	21,576,233	3.48%	20,947,340	3.38%	-0.10

Figure 9: Market shares for top servers across all domains
Source: http://news.netcraft.com/archives/2012/10/02/october-2012-web-server-survey.html#more-6650

In the figure below the diffusion of OSS in the world is reported, and it's interesting to see how Europe is the current leader of this particular ranking. OSS solutions, in fact, have bigger market shares in Europe both regarding servers and desktop applications, and most of the OS programmers live in Europe too. In particular France and Germany are the countries in which OSS is more widespread, both at the time of the survey and in the forthcoming future, since they respectively have the 15% and 13% of firms which

are currently piloting or planning on piloting a OS project in the next year. In the United States, on the other hand, most of the firms still need to grasp the importance of this new way of developing software on the contrary of what one may think, since only the 17% of firms were adopting OSS at the time of the survey.

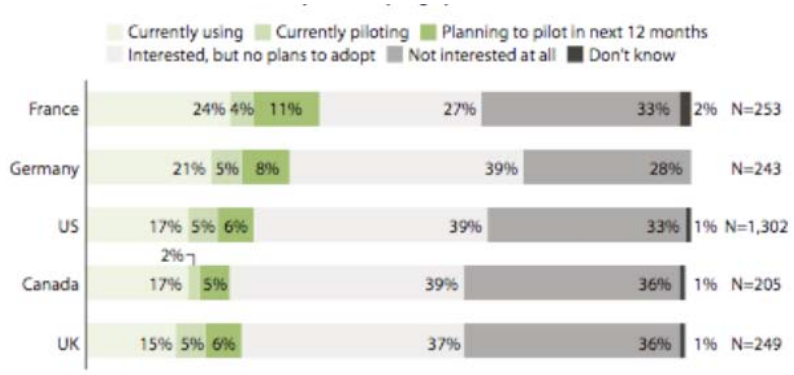


Figure 10: Adoption statistics of OSS in 2007
Source: http://www.openlogic.com/wazi/bid/188004/A-Primer-on-Europe-for-US-Based-Open-Source-Communities-and-Vendors

RedHat in 2009 made a similar survey in order to understand where OSS was being primarily developed, and came to comparable conclusions which have been displayed in the interesting world map reported below. Europe leads in terms of diffusion of OSS development, and in particular France, Germany and UK appear to be the three European countries where OSS is being mostly developed. The United States follow, coherently with the results of the above mentioned survey, and then come other countries such as Brazil, China, Japan and South Africa, revealing once more how OSS is a phenomenon which is increasingly spreading worldwide, being taken into considerations both by "developed countries" (i.e. US, Europe and Japan) and by emerging countries (i.e. China and Brazil), which are grasping the importance and the profitability of this new way of dealing with software.

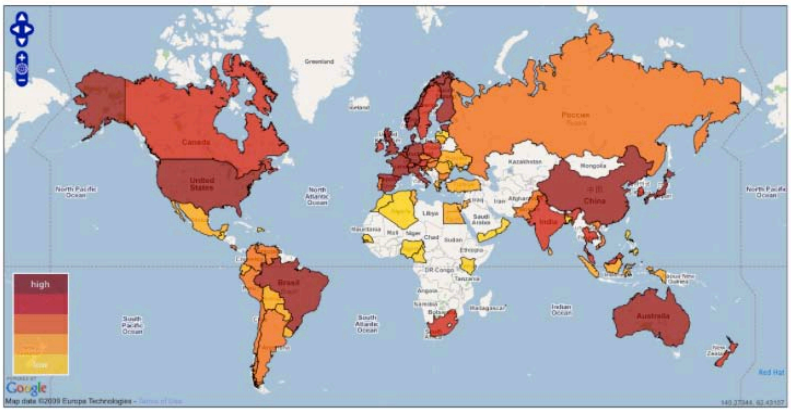


Figure 11: Statistics on OSS development worldwide
Source: http://www.openlogic.com/wazi/bid/188004/A-Primer-on-Europe-for-US-Based-Open-Source-Communities-and-Vendors

Another interesting aspect to analyse is the purpose for which OSS is currently mostly being used, thus inspecting which are the most common OS applications, which is exactly what figures twelve and thirteen explain. In particular the first one gives an idea of how strong the interest for OS products is in many business related categories, and clearly shows how OSS is mainly used for Database and Data integration applications, both with the 18% of usage. Another interesting aspect which can be noticed is how the attention on OSS keeps growing: there are, in fact, an increasing number of firms which are prototyping, evaluating or considering the idea of adopting OSS, and only a minority of these industries don't have any future plan regarding OSS. Again, this last point supports a concept which has been already stressed in the above paragraphs: OSS is a spreading phenomenon which is worth analysing and studying in order to fully grasp its business potentialities.

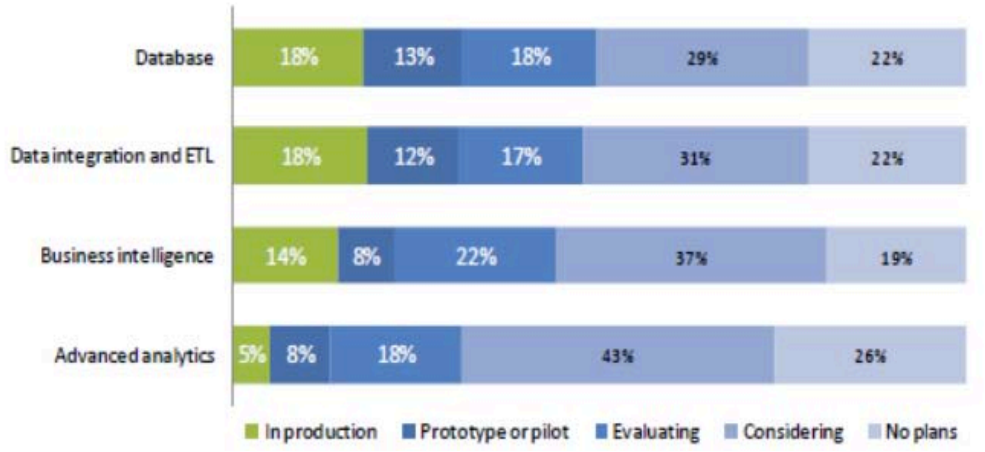


Figure 12: Interest and use of OSS by software type
Source: http://www.dashboardinsight.com/articles/new-concepts-in-business-intelligence/open-source-solutions.aspx?page=4

On the other hand, the figure below explains which are the main purposes of adopting OSS, and which functions firms expect OSS to accomplish within the above mentioned business related categories. As depicted OS applications are mainly used in new projects for all of the four categories which have been considered in the survey, while firms still have difficulties in using such software to add new functionalities to existing systems or, more generally speaking, to replace some of the software which is currently being used. This findings confirm the importance of OSS in a long-term view, underlining how this new way of developing software is a growing trend which will find more and more place in profit-oriented firms, and how firms are starting to look at it as a feasible and interesting option for forthcoming future operations.

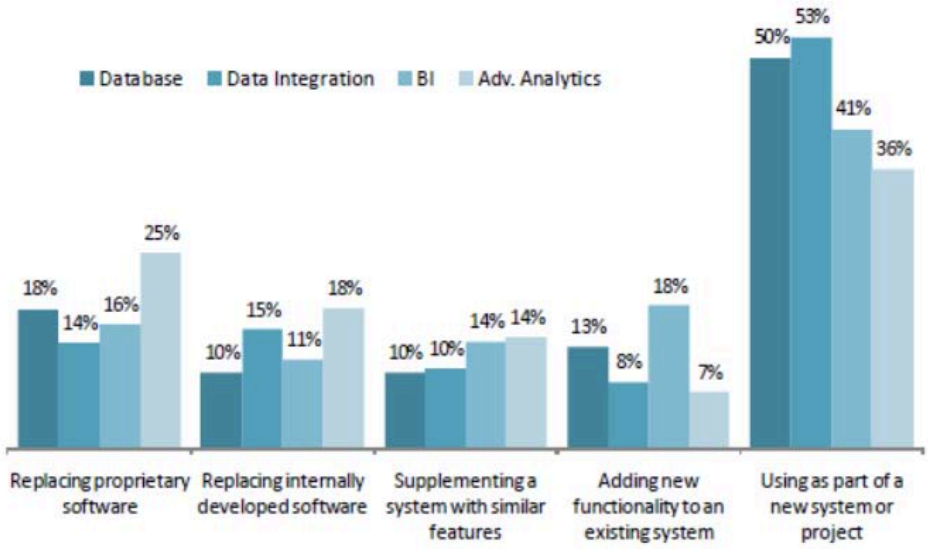


Figure 13: Current scenario of deployment by software category
Source: http://www.dashboardinsight.com/articles/new-concepts-in-business-intelligence/open-source-solutions.aspx?page=4

This final figure shows a very interesting forecast of OSS adoption which has been presented during the 2011 "Future of Open Source Survey", held in San Francisco for the Open Source Business Conference. OSS is expected to rapidly grow in terms of diffusion and adoption, more than doubling its customers within the next five years. In particular this forecast predicts that by 2017 more than 50% of the software used will be open source, and that its expansion will be driven by adoption of databases, operating systems and especially by the mobile sector, which has seen 3.800 new projects arise in 2010 (source: 2011 Future of Open Source Survey). For this scenario to become truthful firms and customers in general will have to develop the technical skills needed to deal with OSS and will need to get to know the subject better, through information and publications.

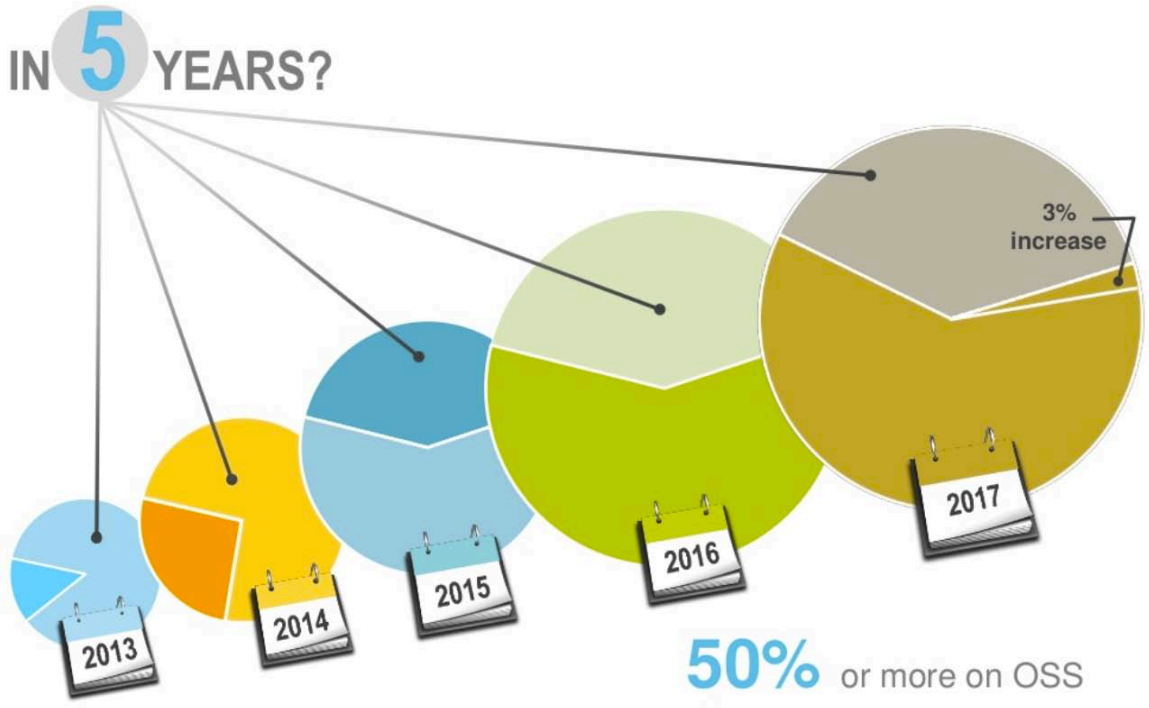


Figure 14: Forecast of OSS adoption
Source: http://www.slideshare.net/AcquiaInc/future-of-open-source-2011-survey-open-source-business-conference

2.3 VENTURE CAPITAL

Venture Capital (VC) has assumed a major role in financial markets, becoming a fundamental intermediary able to provide funds especially to young and small firms characterized by high levels of risk, which would otherwise have difficulties in finding capital, typically by acquiring equity or equity-linked stakes.
Before delving deeper into the VC subject it is necessary, coherently with the approach held towards OSS in previous paragraphs, to give a clear definition of VC and a brief background of its history, in order to fully understand the topic and to have all of the elements necessary for an in-depth analysis.

2.3.1 HISTORY OF VENTURE CAPITAL

Gompers and Lerner (2001) define VCs as "independent, professionally managed, dedicated pools of capital that focus on equity or equity-linked investments in privately held, high growth companies".
Venture Capital is a very young industry, and the first example of such a new way of doing business can be found in 1946 with the American Research and Development (ARD), a firm established by MIT President along with local businessmen. The said firm started by investing their capital in particularly risky projects based on the technological innovations derived from World War 2. Because of this new approach, the firm alternated successful and non successful investments, and the business model adopted was still raw. It was, in fact, organized as a publicly traded closed-end fund, which is an investment company that raises capital through an initial public offering (IPO), and then shares are traded "from investor to investor on an exchange like an individual stock". Because of the high risk associated with such shares, most of them were traded to individuals (Liles, 1977). This type of business model immediately showed some problems: funds were being sold to investors who were looking for immediate pay-off instead of a long-term gain, which lead to a general dissatisfaction towards VC. The first VC formed by a partnership arose in 1958, which on one hand had less constraints in terms of regulations but on the other hand could count on less investors for gaining capital. Another side effect of being a partnership was that they usually had finite

lifetimes, which meant that returns on investments had to be made within a defined amount of time.

In the 60's and 70's most VC firms were closed-end funds or Small Business Investment Companies (SBICs), privately owned business companies, but they still weren't common among profit oriented firms. The situation started changing in the late 70's and 80's, where VC's starting gaining popularity and funds were being risen both by individuals and by institutional investors. From then onwards VC's have always alternated good times and bad times, on one hand supporting very successful technologic firms (Apple, Cisco, Microsoft) and on the other hand seeing the returns on investments decrease thanks to the entrance on the market of inexperienced and new venture capitalists (Gompers and Lerner, 2001). The VC market gained definitive importance in the 90's, busted especially by pension funds and corporate investments which started raising funds.

2.3.2 KNOWLEDGE AND FUNDING GAPS

In order to fully understand the role of VC's in firm financing it's important to grasp the general difficulties that all new technology-based firms (NTBFs), and thus OSS start ups, have to face.

Economic literature generally recognises four main resources to firms: financial, physical, human and organizational. For high-tech start ups the financial aspect is extremely important, since it allows to acquire tangible and intangible assets needed for business development (Colombo and Piva, 2008). Such firms generally suffer from a so-called "funding gap", which refers to the difficulties of firms in finding external sources of capital needed for their business, thus obliging them to rely primarily on personal capital of founders which is often insufficient. The ability of such firms in raising funds is strictly related to the founders (Heirman and Clarysse, 2004) and in particular to their economic wealth, their reputation and ability to raise further funds through their network of acquaintances (Cressy, 2002). The general difficulties of these firms in getting access to debt financing are caused by four main factors:

- *Adverse selection*: interested investors have difficulties in distinguishing valuable firms from unprofitable ones, due to the high uncertainty and information asymmetries;

- *Moral hazard*: entrepreneurs may be subject to unprofitable behaviour and invest in extremely leveraged and risky projects, conscious that the maximum they can loose is the equity capital;
- *No collateral*: the intangible assets most of these firms have cannot be used as a guarantee for debt rising;
- *High risk,* which is an intrinsic factor for these firms.

Another major problem which typically affects start ups is the "knowledge gap" (Lockett, Siegel, Wright and Ensley, 2005), which refers to the lack of competences and skills among the employees and founders of firms. These competences are strictly related to the ones of the founders, especially in the first years after the foundation, and typically lack in either the economical, technical, scientific or commercial aspect (Heirman and Clarysse, 2004).

One of the possible closing strategy to partially solve both funding and knowledge gaps, and the most commonly used by NTBFs, is to look for the support of IVCs and CVCs (Berger and Udell, 1998), where the formers are "independent investors interested in selecting the most promising start-ups to support their growth so as to achieve sizeable capital gains" and the latters have strategic aims in addition to financial ones (Colombo and Piva, 2008). The support that a VC can give to solve the above mentioned problems will be clarified through a detailed explanation on how VCs work.

2.3.3 THE VENTURE CYCLE

To fully understand the VC market, it's important to analyse the "Venture Cycle" (Gompers and Lerner, 2001), which consists in:

1. Raising a venture fund;
2. Investing, monitoring, adding value to firms;
3. VC firm exiting;
4. Raising additional fund.

The first step of the venture cycle is about fundraising. As explained during the brief historical review, interest in VC has always been subject to much variation and it's interesting to understand what are the main determinants of the said phenomenon. Poterba (1987) has investigated the impact of changes in the capital gains tax rate on

VC, and Gompers and Lerner (1998) continued to delve deeper into the subject, realising how the said tax rate was effecting the amount of VC supplied even if most of the suppliers were "tax-exempt investors". This is caused by the resulting change in the demand for VC by corporate employees in their trial of becoming entrepreneurs. Another determinant of VC commitment is the health of the public market (Black and Gilson, 1998): the authors explain how the two markets have always had parallel trends, and it is necessary to have a healthy and prosperous market in order for firms to be able to trade and allocate shares.

The second step involves venture investing. Scholars have thoroughly debated on the problems involving investments in small and young firms, where uncertainty and informational asymmetries are generally high and managers can be subject to opportunistic behaviour (Jensen and Meckling, 1976). Such difficulties arise especially when talking about technologic firms, which are characterized by intangible assets and which heavily rely on R&D. VCs can reduce the informative gap by deeply analysing a firm before investing, and above all by constant monitoring once the capital has been delivered (Gompers and Lerner, 2001). There are different techniques adopted by VCs to reduce the information gap and uncertainty when financing a start-up. One is to deliver capital in discrete stages subsequently to the achievement of milestones, which allows the VC to constantly keep the development of the project under control, to avoid risking too much capital all at once and to reduce potential loss from non-profitable decisions (Sahlman, 1990). A second typical attitude of venture capitalists is to have other VC firms (with similar or better experience) join the funding; this allows on one hand a more precise and reliable analysis of the goodness of the investment, and on the other hand VC firms are able to increase the diversification of their portfolio and reduce the relative investment risk (Lerner, 1994). A third possibility for VC firms to increase its control on funded companies is to take place on the board of directors, in order to be able to supply all the advice and support needed (Lerner, 1995). The last mechanism used by VC firms to ensure total commitment of the funded firm's management is to align their interests to the ones of the firm by having part of their compensation be in the form of equity. Another element which influences the result of a VC funding towards a firm is the amount of capital given to the latter (Gompers and Lerner, 2001), statement which has been empirically tested by the authors with the finding that "a doubling of inflows into venture funds leads to between a 7 and 21 percent increase in valuation levels".

The third stage of the Venture Cycle refers to VC firms exiting their investment, turning shares in private companies into capital gain. The most common situation which allows a venture capitalist to do so is through an IPO, where shares are sold to the general public.

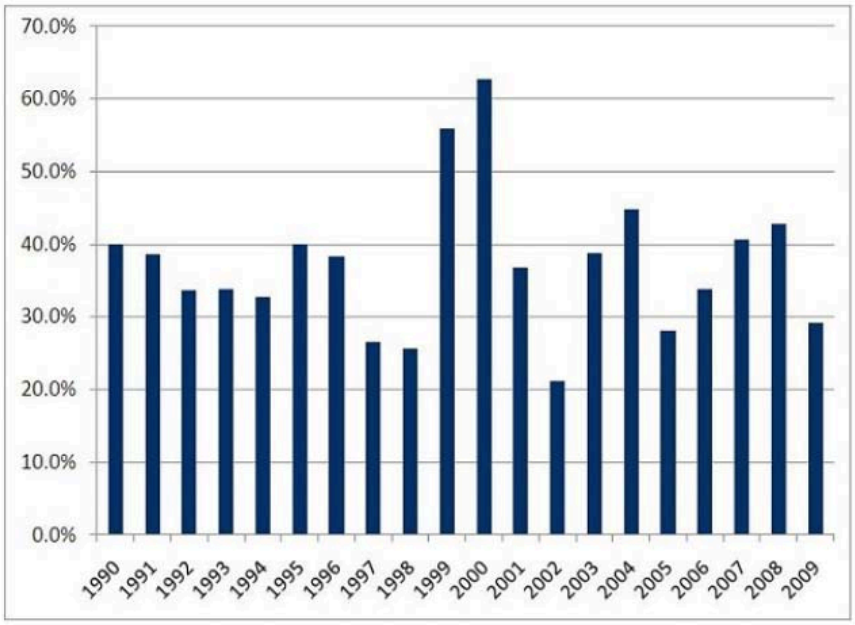


Figure 15: VC-backed IPOs, as a % of all IPOs
Source: Ritter, 2010

The diagram displays the number of VC backed IPO's as a percentage of total IPO's from 1990 to 2009, and it is clear that this is a very common way for venture capitalists to exit from their investment. Delving deeper into this subject, Barry, Muscarella, Peavy and Vetsuypens (1990) analysed the typical behaviour of VC firms after an IPO. The said companies usually avoid selling all of their shares after the initial IPO, and keep them averagely for another year. The authors suggest that "investors need less of a discount to purchase these shares", since they have been monitored by the VC which acts as a warrantee, thus resulting in a less of a positive return on their first trading days. Brav and Gompers (2000), on the other hand, suggest that this attitude reflects the willingness to reassure the market about the health of the company, and to avoid the sale of the firm to be seen as an exit strategy for inside problems.

Another interesting aspect of this third stage is that VC firms usually decide to bring their funded companies public at market peaks, and instead proceed with further private funding if valuations are lower (Lerner, 1994). This implies that more experienced VC firms, which have more flexibility as to when making the company go

public, usually prove to have better timing abilities. This is also caused by the fact that new VC firms have other constraints to fulfil, for example building a good reputation among the market to gain further funding. Gompers, (1996) describes this phenomenon and finds that IPOs backed by younger VC firms usually take place two years earlier than the ones backed by more established venture capitalists.

2.3.4 IMPLICATIONS OF VENTURE CAPITAL FUNDING

Now that the general mechanics of VC have been analysed, it's interesting to understand under which conditions VCs decide to finance a firm, what are the implications for the said firm after receiving backup from venture capitalists and in particular what are the effects on the firm's development path.

The main advantages of receiving VC support come as a direct consequence of the venture cycle just described. Corporate governance and professionalization of the company, in fact, are provided by the presence of the VC inside the company, which brings its experience and knowledge to support firm's business. Certification to outside stakeholders, on the other hand, is a direct consequence of the interest that the VC shows for the firm: the market, in fact, uses VCs as a "warrantee" of the validity and future profitability of the firm. Finally strategic advice and mentoring are provided by the constant interaction with the VC, which doesn't simply act as a financer, but fully supports the firm during all of its activities (Hellman and Puri, 2000). Such services provided by the VC are, in fact, positively related to the performance of the firm (Sapienza, 1992). An aspect which hasn't already been analysed, on the other hand, is the cost related to VC which refers to the loss of control for the entrepreneur, the time the entrepreneur needs to commit to the venture capitalist and the general consideration that VC is an expensive source of capital (Hellman and Puri, 2000).

The same authors, thanks to their analysis done on a set of hand-collected data from Silicon Valley high-tech start-ups, discover other interesting aspects regarding the influence of VC funding on firms. In particular they divide firms in two categories: innovators, defined as companies "either creating a new market, introducing a radical innovation in an existing market, or developing a technology that will lead to products that satisfy either of the above criteria" and imitators, defined as firms which "typically still have a certain amount of inventiveness, but seek their competitive advantages not

through innovation itself, but rather through differentiation, typically in terms of product features or marketing". The results of their research suggest that innovator firms have more chances to be financed by VCs than imitators, which is coherent with the findings of Kortum and Lerner (1998), and that innovators typically get access to VC funding earlier in their life compared to imitators. Another interesting point is that being backed up by a VC directly and positively influences the time to market of firms, and that this relationship is particularly strong for innovator firms, which draw a major part of their competitive advantage from this factor. This second finding connects to and better explains the first one: innovator firms, for whom time to market is particularly important, are more likely to gain access to VC which directly influences the capability of the financed firm to bring a product to the market in short time (Hellman and Puri, 2000).

On the other hand VC is associated with greater amounts of external financing for imitators, which is the main reason for them for seeking VC help. This means that VC has a double role and that its main utility is seen differently depending on the type of firm: funding support from an imitator's point of view while innovators look at VC mainly as a way to improve their time to market (Hellman and Puri, 2000).

Engel (2002) analyses the impact of VC on firm growth, basing his study on an empirical investigation of German firms, and draws two important conclusions which confirm the findings of the above mentioned authors: firms which are backed by VCs generally perform better than non-backed ones as a consequence of the involvement of the VC, thanks to the funding, the services and the monitoring of activities provided by the VC, and the fact that being backed up by a VC has a higher impact on early stage firm's growth compared to being supported by other type of external firms, both in terms of rapidness and of extent of growth. VCs are, in fact, more profit oriented and thus will try to make the firm grow rapidly in order to generate revenue. On the contrary other types of external firms may be interested in other aspects, such as gaining competitive advantage by exploiting a new technology or gaining market shares.

VC funding is particularly important for companies with a high level of uncertainty, and the fact that a VC decides to support a firm is a strong signal to the market, and is typically looked at as a mark of attractiveness (Engel, 2002).

2.3.5 VENTURE CAPITAL SYNDICATION

Venture Capitalists commonly use syndicated investments when financing a firm. Such practice consists in two or more VCs taking an equity stake in an investment for a future joint payoff. One of the reasons for VC firms to share investments with their competitors is to be able to share resources like experience, skills, contacts and capital in order to maximize the chances of succeeding in raising funds. Syndicating an investment also brings advantages in terms of risk reduction and product diversification. This means that such a practice creates value for funded firms by increasing their probability of survival and by improving their chances of successful business development (Lerner, 1994). Syndication has also a potential cost, that is the fact of disseminating information among competitors (Chiplin, Brian and Wright, 1997). VCs, in fact, through such practices gain information and knowledge on new industries since they spend time and resources investigating on the target firm in order to understand the potential profitability of the investment. Toldra (2012) carried out an interesting research on the relationship between syndicated investments and firm entry. The author states how, on one hand, syndication can facilitate firm entry because of the above described information-spreading phenomenon, which facilitates other investors in gaining enough information and experience to give funds to other similar deals and hence accommodate the entry of rivals. On the other hand VCs may use syndication strategically by coordinating with other VCs and sharing with them a large enough equity stake in order to share the monopoly profits and create a collusive mechanism which limits the financing of competitor firms and deters competition. The study explains how syndication facilitates the entry of rival firms when the number of VC investors is large, and that it is negatively related to the entry of new firms in the market when such number is small since collusive mechanisms are more easily accomplished.

2.3.6 ALTERNATIVES TO VENTURE CAPITAL

Venture Capitalists are not the only possibility when speaking about financing firms and there are, in fact, many other subjects able to play that role.

Vermuelen (2004) analyses five different financing methods available for firms, describing pros and cons of all the possibilities, which are summarized in the figure below:

	Operations	Partners	Self	Debt	Friends	VC
Size of investment	Varies	Varies	Small (~$100K)	Varies	Small (~$100K)	$2-20M
Cost of capital	Free	Free to 10%	Free to 5%	5-10%	8-12% + option	25-60%

Figure 16: Alternatives to VC
Source: Vermuelen (2004)

The first alternative refers to retrieving funds from existing operations, for example by reducing cash needs or by gaining more cash from customers. It's obviously a very good option when available, since it's free.

The second option refers to finding business partners interested in financing the firm, and it can be done through various methods: by licensing part of the solution thus permitting others to benefit from the business, by involving some particularly interested customers or suppliers in the R&D phase and in the resulting financing, by utilizing research grants typically given by governments (Lerner, 1996) or by paying possible investors with stock-options.

Another possibility is to fund the business with own money; this solution can be interesting, if feasible, since there would be no creditors to answer to and the return on investment would probably be higher in case of successful business (Fluck, Holtz-Eakin and Rosen, 1998)

Debt financing is always a possibility but with the current economic situation, and considering that most high-tech firms have intangible assets, the interests on the eventual loans would be considerably high, also considering that banks tend to be more conservative investors (Hellman, 1997b).

The last possibility considers friends, meaning parents, friends or also prosperous people one is introduced to, which are typically called angel investors, and defined as "*independently wealthy individuals who diversify part of their wealth by investing in young companies*" (Hellman and Puri, 2000).

2.3.7 ANECDOTAL EVIDENCE

Coherently with the approach held with the OSS analysis, this paragraph will bring some anecdotal evidence of VC funding, with a particular focus on funds directed to OSS firms. There are very few papers which analyse the relationship between VC and OSS, and even less which bring anecdotal evidence of this phenomenon. The 451 Group (2010) made an interesting analysis on this topic, and the figure below displays the cumulative investments in OS vendors from 1999 to 2009. As shown in the figure, OSS is a growing and in continuous expansion phenomenon, and so is the funding it is recieving. From year 2000, in fact, investments involving OSS market have been increasingly rising, and so has the OS market as a whole, with more and more firms realising the profitability of this new way of dealing with software and thus trying to exploit it at their best in order to gain as much profit as possible from it.

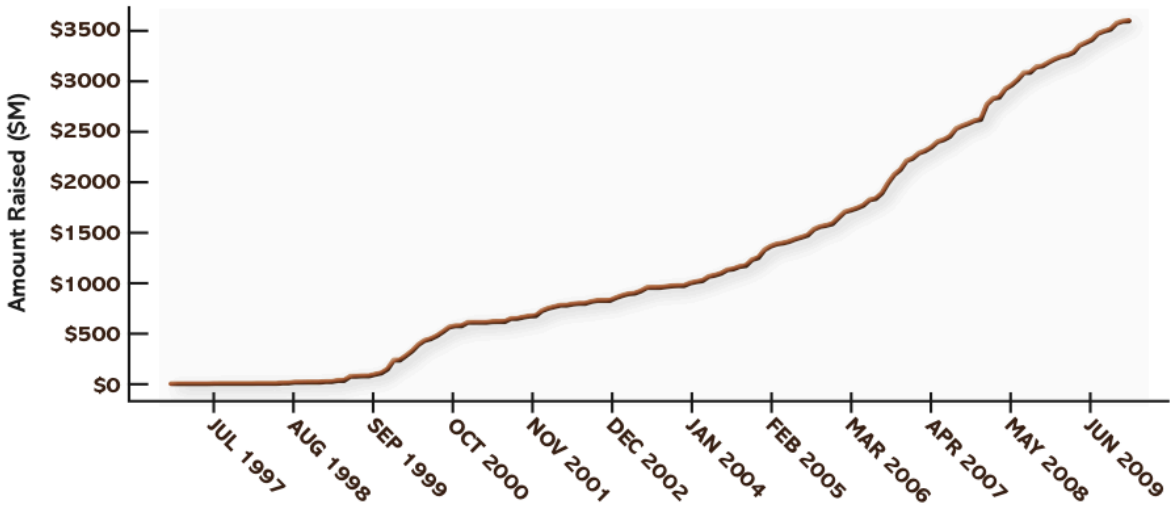


Figure 17: Cumuative investments in OS vendors
Source: the 451 Group 2010

Figure 18, on the other hand, shows the funds raised by VCs in OSS-related vendors from 1997 to 2011 (expressed in $M), and the growing trend is easily noticeable. The peak in 2000 can be explained with the boom of the "dotcoms" in that year, and the drop in 2007 has been mainly caused by the economic crisis subsequent to the fall of Lehman Brothers. Such a pronounced increase of VC funding towards OSS vendors during the past ten years reflects the increasing importance of OSS in the software market, and the relevance of VC funding for the development of this new way of doing business can be

easily noticed by comparing these two figures; in 2008, for example, VCs contributed to approximately 1/5 of the total investments made in OSS.

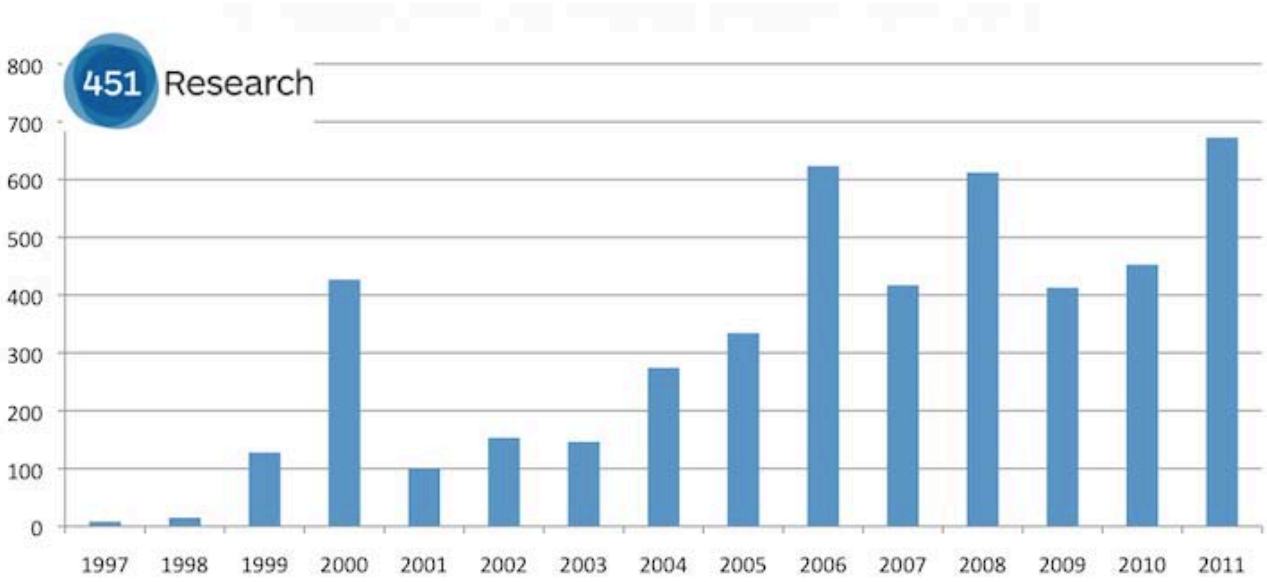


Figure 18: VC funding for OSS-related vendors 1997-2011
Source: http://blogs.the451group.com/opensource/2011/12/16/vc-funding-for-oss-hits-new-high-or-does-it/

It's also very interesting to notice how investments in OS firms have been primarily made by three venture companies: Benchmark Capital, Intel Capital and Index Ventures. Figure 19, in fact, shows the ten largest VC-backed OS exits from 1997 to 2009, providing information on the name of the acquirer company, the purchase price, the funding and the relative investors. It's noticeable how at least one of the three above mentioned venture companies appears in 60% of the "investors" lists, thus dealing with the 62,4% of the money involved in the purchasing of the financed firms. This suggests that the VC funding for OS software is a very concentrated market sector, with three main venture capitalists standing out as market leaders, and the figure below gives evidence to this fact.

TARGET	ACQUIRER	PURCHASE PRICE ($M)	DISCLOSED FUNDING ($M)	INVESTORS
MYSQL	Sun	1,000	39	Scope Capital Holtron Ventures Benchmark Capital Index Ventures Intel Capital Red Hat SAP Ventures
CYGNUS	Red Hat	674	6.25	August Capital Greylock Partners
XENSOURCE	Citrix	500	44.5	Kleiner Perkins Caufield & Byers, Sevin Rosen Funds Accel Partners New Enterprise Associates, Radar Partners
SPRINGSOURCE	VMware	420	73	Accel Partners Benchmark Capital
JBOSS	Red Hat	350	10	Intel Capital Accel Partners Matrix Partners Bain Capital Ventures
ZIMBRA	Yahoo	350	31.5	Redpoint Ventures Benchmark Capital Inventures Group Accel Partners Presidio STX Duff Ackerman & Goodrich
POSTPATH	Cisco	215	30	WorldView Technology Partners, JAFCO Matrix Partners
SUSE	Novell	210	32.7	Intel Capital Apax Partners Capital Research Compaq SGI e-millennium 1 Ad Astra
TROLLTECH	Nokia	153	15.8	Canopy Group Borland Teknoinvest Northzone Venture Index Ventures
QUMRANET	Red Hat	107	Undisclosed	Sequoia Capital Norwest Venture Partners

Figure 19: The 10 largets VC-backed OS exits from 1997 to 2009
Source: the 451 group

3. Research Questions

The general positive effect of Venture Capital funding on NTBFs has been discussed and proven among scholars, and some of the main contributions have already been reported in the literature review of this paper.

Such firms, in fact, generally suffer from funding and knowledge gaps (Colombo and Piva, 2008), and getting access to any form of financing is extremely challenging because of factors such as adverse selection, moral hazard, the absence of collateral and the general high investment risk which is typically associated to such investments.

Venture capitalists help such firms by partially filling both of the above mentioned gaps (Berger and Udell, 1998) by providing, for example, certification to outside stakeholders which helps such firms building a good reputation in the market (Engel, 2002). Strategic advice and mentoring are also provided thanks to the continuous interaction and monitoring of the VC, and the presence of experienced personal coming from the VC inside the firm helps with the strategic governance and the professionalization of the company (Hellman and Puri, 2000). VCs also have a positive impact on the firm's growth rate, both in terms of rapidness and of extent of growth (Engel, 2002).

All of these factors are generally considered to favour the positive performance of such firms, and thus VC funding has proven to be positively related to their performance (Sapienza 1992, Engel 2002).

To the extent that the above mentioned literature is correct, and thus starting from the cornerstone statement that the impact of VC funding on OSS firms is in general positive, this paper aims at understanding how different conditions which may occur when a VC decides to finance an OSS firm can influence the performance of such companies, since very few papers deeply analyse the relationship between these two topics.

Such reasoning translates into the following main research question:

What is the impact of different conditions in VC financing on the performances of OSS firms ?

This is a general question, which indicates the path chosen for this research paper, but needs to be further addressed into more specific queries. Therefore, thanks to the unique set of hand collected data, this paper will try and expand the main research

question and investigate the topic more specifically. The collected data allows to analyse the different characteristics both of VCs and of OSS firms before, after and at the time of funding, and their subsequent performances.
This can be translated into the following sub-questions:

3.1 RESEARCH QUESTION 1

What is the impact of the experience of the VC on the performances of funded OSS firms ?

The objective of this research question is to understand if, and eventually to which extent, the experience of the VC at the first round of funding can influence the performance of an OSS firm. Such characteristic will be taken into consideration through the combined effect of two variables: the age and the total amount of investments made by the VCs.
This first research question will be addressed in different ways in order to better fulfil the aim of this research paper. In the first version OS companies will be considered funded by "experienced" VCs if the VCs are averagely older than the average age of VCs and have averagely totally invested more than the average total investment made by VCs. In the second version OS companies will be considered funded by "experienced" VCs if the VCs are averagely older than the median of the age of VCs and have averagely totally invested more than the median of the total investment made by VCs.
This has been done to check all possible aspects of the relationship between the experience of VCs and the effects it has on funded OS firms.

3.2 RESEARCH QUESTION 2

What is the impact of syndication on the performances of funded OSS firms ?

Syndication refers to the number of firms which invest in a company. A typical behaviour of venture capitalists, in fact, is to have other VC firms participate in the investment, thus allowing on one hand a more accurate analysis of the goodness of the investment to be done, and on the other hand allowing to increase the diversification of their portfolio thus reducing the relative investment risk (Lerner, 1994). The aim of this

research question is to understand if such a typical behaviour among VCs can affect the performances of the funded OS firm.
To better investigate the research question, syndication has been considered in two different ways: in terms of presence, meaning the fact that the OS companies have (or haven't) been financed by more than one VC during their first round of funding, and in terms of size, meaning the number of different VCs which financed the OS companies. Both of these aspects have been analysed to fully understand their impact on the performances of funded companies.

3.3 RESEARCH QUESTION 3

What is the impact of the different types of VCs on the performances of funded OSS firms ?

The aim of this research question is to investigate if being funded by different types of venture capitalists during the first funding round can influence the performances of OSS firms. In particular the hand collected data allows to distinguish between Private Venture Capitalists (PVCs), Corporate Venture Capitalists (CVCs), Bank affiliated Venture Capitalists (BVCs), Individuals, which are also known as "angel investors", and Others, which are mainly governments and universities. A more detailed description of these subjects will be given in the following paragraphs.
Since the majority of OS companies are funded by PVCs at their first round of funding, it's interesting to understand if this fact has an impact on the performances of the funded OS company.

3.4 RESEARCH QUESTION 4

What is the impact of the number of raised funds on the performances of funded OSS firms ?

The objective is to understand if there is an effect on the performance of the financed firm if the funds are raised all in one tranche rather than being given to the firm in different stages during the first round of funding. This aspect becomes extremely relevant since economic literature (Sahlman, 1990) states that firms tend to deliver capital in discrete stages in order to keep projects more under control and to reduce the

risk of the investment. It could be, thus, very interesting to understand if this behaviour influences the chances of success of the OSS firm, and if such was the case VCs should consider this important aspect.
This research question will be studied both in terms of presence of multiple rounds of funding, meaning the fact that an OS company does (or doesn't) get funded in more rounds rather than in a single one, and in terms of number of funding rounds, meaning the number of funding rounds that OS companies get, to fully understand its impact on the performances of the funded OS companies.

The results of these sub-questions, which are directly linked to the main research question of this paper, will be useful both for scholars, since it is an expansion of current economic literature that aims at investigating a research field which has been very poorly analysed until now, and for the two subjects of the investigation, namely VCs and OSS companies looking for funds. In particular the former will be interested in knowing what behaviours to adopt in order to facilitate the growth of the OS companies in which they decide to invest, and the latter will be interested in knowing what characteristics to look for in VCs when searching for funds in order to improve their own performances.

4. Data Description

4.1 SOURCES OF DATA

To obtain the data needed for the analysis different databases have been used, and the following section aims at giving a brief explanation of the origins of such data.
This paper focuses on analysing the impact of different conditions in VC financing on the performances of funded OSS firms; to do so previously collected data on the characteristics of VCs and of OSS firms have been used, and this data collection has then been expanded with hand collected information about the products developed by such firms. For the purpose of this paper the number of developed OS products will be used as a proxy of the performance of the analysed firms.
The sources of the data used for the analysis are:

VentureXpert

The data used in this paper which refers to VC has been obtained through VentureXpert, a database on venture capital provided by Venture Economics, a Thomson Financial company. The database provides information on firms, funds, partners involved in VC funding and on VC backed IPOs from 1961 to date, and contains information on more than 7.000 funds.

PROMT and ASAP

The PROMT (Predicast Overview of Markets and Technology) database is a multiple-industry database that gives wide, international information on products, markets, firms and technologies. PROMT consists in abstracts and full-text information from the most renowned trade and business journals, newspapers (both national and international), business publications, industry newsletters, research studies, investment analysts' reports, corporate news releases and corporate annual reports. The information provided covers major international events and activities of both public and private companies in the entire world.

Such data has been integrated with the one stored in the ASAP database, which contains the same type of information, even if it covers a wider temporal frame and allows for more advanced queries to be done.
These two databases have been used both to understand which firms work in the OSS market sector, and to obtain information on the developed products of such firms, differentiating them between OS and proprietary products.

LexisNexis® Academic

The LexisNexis® Academic is a database that provides students and faculty members in both colleges and universities access to more than 10.000 credible legal, business and news sources. In particular the interesting information for this paper consists in full text of articles of more than 2.500 newspapers, 1.000 newsletters, magazines and journals, wire services, transcripts from major television and radio networks and premium blogs or video blogs. It also provides company profiles for both public and private companies. This database has been used to obtain important information about the products developed by OSS firms, which together with the data from the PROMT and ASAP databases has allowed a complete and useful product portfolio of OSS firms to be edited.

4.2 THE DATA SET

A clear distinction needs to be done between the data which had already been obtained from previous research work, and data which I have personally collected to complete and expand the dataset in order to create a product portfolio of OSS firms which was essential to investigate the main research question of this paper.

Both of these datasets will be described, and an in depth analysis of the methodology used to create the above mentioned product portfolio will be done.

Starting from the first dataset, it's important to clearly describe the information which had already been previously obtained, since it gave important contributions to the final outcome of this research work.

In particular the data consists in:

ID	Identification code assigned to the OS firms.
COMPANY NAME	Name of the OS company.
COMPANY STATE/REGION	State/Region of the headquarter of the OS company.
COMPANY CITY	City of the headquarter of the OS company.
COMPANY ZIP CODE	Zip code of the headquarter of the OS company.
COMPANY INDUSTRY CLASS	Industry class of the OS company (eg. IT).
COMPANY SHORT BUSINESS DESCRIPTION	A brief description of the company's business activity.
COMPANY WEB SITE	Web site of the OS company.
COMPANY STATUS	Distinguishes between companies which are still active, the ones that went public, the ones that got acquired, the ones that declared bankruptcy and the ones that are defunct.
COMPANY IPO DATE	Date of company's IPO in case it went public.

COMPANY FOUNDATION YEAR	Foundation year of the company. When official data is missing, significant events such as start of business activity are used.
AGE AT FINANCING	The age of the OS company when first invested by a VC firm.
NO. OF PRIVATE VCs	Number of Private VCs which funded the OS company during the first round of funding. Private VCs are defined as independent funds which invest in ventures.
NO. OF CORPORATE VCs	Number of Corporate VCs which funded the OS company during the first round of funding. Corporate VCs are defined as corporations that invest in ventures seeking both strategic and financial gains.
NO. OF BANK VCs	Number of Bank affiliated VCs which funded the OS company during the first round of funding. Bank affiliated VCs are defined as funds which come from commercial or investment banks.
NO. OF INDIVIDUALS	Number of wealthy individuals (formerly known as "angel investors") which diversify their investment portfolio by investing in ventures during the first round of funding.
NO. OF OTHERS	This residual category of funds considers the number of investments during the first round of funding made by other subjects such as governments or universities.
SYNDICATION	Syndication size at first round of

	funding.
FIRST INVESTMENT DATE	The date when the OS firm received the first investment.
LAST INVESTMENT DATE	The date when the OS firm received the last investment.
TOTAL INVESTED	Total amount of invested money into a company.
NO. OF ROUNDS	Number of investment rounds made into a company during the first round of funding.
NUM. FIRMS	Total number of firms which invested in the OSS company.
VC NAME	Names of firms which invested in the company.
VC TYPE	Distinguishes between the different types of funding firms (Private VCs, Corporate VCs, Bank affiliated VCs, Individuals and others).
VC FOUNDATION YEAR	Foundation year of the firm. When official data is missing, significant events such as start of business activity are used.
VC TOTAL INVESTMENT	Total amount of money invested by the firm.
VC AVERAGE AGE	Average age of firms which invested in the OS company during the first round of funding.
VC TOTAL AVERAGE INVESTMENT	Total average investment of firms which invested in the OS company during the first round of funding.

The above mentioned information has been the starting point for the data integration needed for this paper. Information about VCs, their investments and the OS firms which had received such funds had already been found, and the missing data was the one related to the output of the firms before and after such investments. A complete product portfolio was, in fact, needed in order to answer the research questions which are the reasons behind the development of this paper.
In order to do so, the starting point has been accessing the PROMT and ASAP databases and thinking about an adequate research query, and the result was the following:

> *Your search ((Keyword="Product/Service Evaluation" OR "Product Announcement" OR "Software Review") AND (SIC Code=7372)) returned the following results in Business Index ASAP, PROMT, and Newsletters.*
> *Results limited to (Date=01/01/1999-12/31/2010; Fulltext).*

The query investigated all *fulltext* articles taken from the mentioned databases which referred to "*Product/Service Evaluation" OR "Product Announcement" OR "Software Review"* AND "*7372 SIC Code*" (which refers to *Computer Software*).
The total result was 1421 files of articles, which were divided into separate folders depending on the year of the article thus facilitating the management of such a big data source.
Once that a clear distinction between proprietary and open source firms which were cited in the articles had been made thanks to the above mentioned list of OS firms, it was possible to proceed with the creation of the product portfolio.
Both for proprietary and for OS firms the articles have been searched, evaluating the relevance of the article and manually extracting the information needed, which for each firm was:

COMPANY CODE	Unique ID code assigned to each company.
COMPANY NAME	Name of the company which developed the product.
OTHER NAME	Sometimes companies are "formerly

	known" with another name, and this is the information inserted in this field.
YEAR	Products were catalogued depending on their announcement year.
DOCUMENT NUMBER	The number of the document where the information was extracted from was reported, in order to be able to quickly find the original source of the data if necessary.
PROPRIETARY	If the product was licensed as proprietary this dummy variable assumed value 1, 0 otherwise.
OSS	If the product was licensed as open source this dummy variable assumed value 1, 0 otherwise.
FREE	If the product was free this dummy variable assumed value 1, 0 otherwise.
PRODUCT NAME	Complete name of the developed product.
PRODUCT TYPE	Product typology (e.g. Integration software, web content manager, browser ecc.).
RELEASE DATE	Expected product release date. When such date wasn't explicated by the firm, N.D. (Not Defined) was reported.
PUBLICATION NAME	Name of the publisher of the article where the information was extracted from.
PUBLICATION YEAR	Year of the publication of the article where the information was extracted from.
PUBLICATION MONTH	Month of the publication of the article where the information was extracted

	from.
PUBLICATION DAY	Day of the publication of the article where the information was extracted from.
MAIN PLATFORM	Eventual main platform suitable for running the software. N.D. (Not Defined) was reported when no particular platform was requested.
DESCRIPTION	Brief description of the main features of the product.
WITH COLLABORATION	If the product had been developed with the collaboration of another firm this dummy variable assumed value 1, 0 otherwise.
COLLABORATOR	If the "WITH COLLABORATOR" dummy assumed value 1 the name of the collaborator (or collaborators) was explicated, the field was left blank otherwise.
SENTENCE REFERRING TO PROPRIETARY OR OS	A brief sentence which clearly referred to the product as proprietary or OS was reported.
TOT. OS PRODUCTS	Total number of OS products developed by the firm.
OS PROD. BEFORE	Number of OS products developed before the first round of funding.
OS PROD. AFTER	Number of OS products developed after the first round of funding.

The downloaded articles didn't always contain all of the required information. When this was the case the missing information has been recovered through web search, which included other articles, firm's websites and any other useful and appropriate

source of information. In case such information couldn't be found through other sources either, N.D. (Not Defined) has been reported in the relative field.

After this first datasheet was completed, it was clear that the number of cited products wasn't enough in order to make a reliable and truthful database. In particular 189 proprietary products were identified, but only 10 OS products. The identified remedy has been to "clean" the name of the firms used in the search query, since in many articles such companies were referred to with abbreviations or without legal form indications. In particular the operations done in order to clean the data have been:

1. Punctuation cleaning: punctuation characters such as ",", "." and "-" have been removed from firms' names;
2. Legal form cleaning: legal forms indications such as "Inc." or "Ltd" have been removed from the search field;
3. Legal form indications such as "Company" and "Corporation" have been removed when not necessary to clearly distinguish one firm from another;
4. Companies are at times referred to with abbreviations or with just one part of their proper name, and when possible this has been taken into consideration.

The result was that firms which were initially searched as, for example, "Virtual Iron Software, Inc.", were cleaned and searched as "Virtual Iron".

This research gave better results than the first one, but it still wasn't good enough for the purpose of this paper, since only 23 OS products were found.

At this point it was clear that another information source was needed, thus the decision to access another database to download more data was taken.

The chosen database has been LexisNexis® Academic, which has already been described in previous paragraphs.

Both "cleaned" and full names of the OSS firms have been used as search terms for the query correlating them with the "OR" logical command, in order to find the most results possible and to enlarge the database.

Using the same example as in the previous paragraph, the firm "Virtual Iron Software Inc." has thus been searched as: *"Virtual Iron Software Inc."OR"Virtual Iron Software"OR"Virtual Iron".* The query has been done specifying the following research fields for *All available dates*, since they were the most relevant to the subject of this

research paper: "*Computing & Information Technology", "Computing Products", "Media & Telecommunications"* and "*Company Activities & Management"*.

All of the files have been analysed to be able to extract the information referring to OS products, and the results have been added to the datasheet which had been already partially filled with the data from PROMPT and ASAP databases. Some of the products found with this new database had already been found in the first part of the research, and in such cases the old references have been kept.

The result of this long research process, and thus the new data which will be used for the forthcoming data analysis section, is that 127 OSS firms have been identified and 423 OS products have been recorded.

5. Data Analysis

The research questions which have been driven from the literature review and aim at filling the above mentioned literature gap will be analysed in the following paragraph thanks to the collected data.

Before starting with the research questions, it is important to give a brief statistical description of the most important variables which have been introduced in the previous sections, describing the number of observations (Obs), their mean (Mean), their standard deviation (Std. Dev.) and their minimum (Min) and maximum (Max) value.

Variable	Obs	Mean	Std. Dev.	Min	Max
Tot. OS products	127	3.251969	4.396912	0	24
OS prod. before	127	.1181102	.6250609	0	6
OS prod. after	127	3.133858	4.368651	0	24
Syndication	127	2.370079	1.64656	1	11
Age at financing	127	25.35433	24.98016	0	120
Total invested	127	30043.26	26368.29	191	147199.9
No. of rounds	127	4.527559	2.858645	1	17
VC average age	127	16.63851	10.70196	0	54
VC average inv.	127	9295248	15397554.9	7400	79646513.4

Table 1: Descriptive statistics of the most relevant variables of the sample

On a total of 127 observed OS firms, the average number of OS products released is 3,3, with a minimum value of 0 and a maximum value of 24 released products. The relevant impact that the first round of funding has on a firm can be grasped by looking at the difference between the statistics which refer to the number of OS products developed by firms before the first round of funding, which on average is equal to 0,1, with a value range which goes from 0 to 6, and the number of OS products released after the first round of funding, which on average is equal to 3,1, with a minimum value of 0 and a maximum of 24. The average syndication size at first round of funding, which refers to the number of firms investing in the OS company, displays a value of 2,3, with a value range which goes from 1 to a maximum of 11 firms. The average total amount of money invested in an OS company is 30.000.000$, with peaks that go up to 147.200.000$ dollars, highlighting how these type of firms appear to be very interesting for VCs and investors in general. The average number of funding rounds is 4,5, with a value range

which goes from 1 up to 17, giving empirical evidence to Sahlman (1990) who states that investors tend to raise funds in discrete stages. The collected data on VCs shows how their average age is of 16,6 years, with a maximum value of 54, while the average amount of money invested is 9.295.248.000$, with peaks which go up to 79.646.513.000$, highlighting the enormous economical power of these economical subjects.

Now that the most relevant variables of the collected data have been described, and before moving on to the research questions which have already been introduced, it's interesting to empirically test the statement which forms the cornerstone of such research questions, namely the fact that VCs have a positive impact on the development of NTBFs, and in particular on OS based firms (Berger and Udell 1998, Engel 2002, Hellman and Puri 2000, Sapienza 1992).

A statistical test which is suitable for this purpose is the "paired t-test", which tests the null hypothesis that the difference between two responses measured on the same statistical unit has a mean value of zero, which in this case means testing for differences between the number of OS products released by firms before and after the first funding round. In order to apply this test the difference between the pairs must be normally distributed, thus the first step has been to test such normality in the distribution with a Q-Q plot.

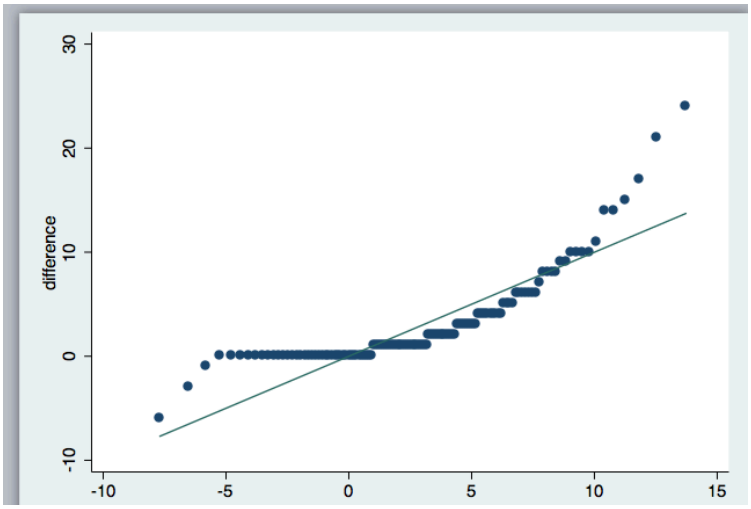


Figure 20: Q-Q plot of difference between pairs of the sample

As highlighted in the figure above the data is severely non-normal, and even if the t-test isn't very sensitive to deviations from normality, it has been decided to adopt a more suitable test to avoid unreliable responses from the test.

The decision has been to adopt a non-parametric test of hypothesis, since these kind of tests don't have any constraint regarding the probability distribution of the data set. In particular the "Wilcoxon signet-ranked test" has been used, which is considered to be an alternative to the above described t-test when the population cannot be assumed to be normally distributed, and it tests for differences of median ranks of repeated measurements on a single sample.
In particular such test has given the following results:

sign	obs	sum ranks	expected
positive	3	239.5	3693.5
negative	86	7147.5	3693.5
zero	38	741	741
all	127	8128	8128

unadjusted variance	172720.00
adjustment for ties	-466.88
adjustment for zeros	-4754.75
adjusted variance	167498.38

Ho: NOOSPRODCUTSBEFOREFUND = NOOSPRODCUTSAFTERFUND
z = -8.440
Prob > |z| = 0.0000

Table 2: Wilcoxon signed-rank test

The null hypothesis (H_0) that the number of OS products before the first round of funding is the same as the number of OS products after the first round of funding can be rejected since the p-value is below the threshold value of 0,1. This means that there is evidence that VC funding has a positive impact on the number of OS products developed by firms, coherently with the examined economic literature.

Now that this first cornerstone statement has been tested and has given the expected result, it is possible to start analysing the research question which is the main aim of this paper:

What is the impact of different conditions in VC financing on the performances of OSS firms ?

5.1 RESEARCH QUESTION 1

What is the impact of the experience of the VC on the performances of funded OSS firms ?

As already explained in the data description paragraph, the total number of OS products developed by a firm will be used as a proxy of its performance. On the other hand, two variables will be used as a proxy of the experience of the VC at the first round of funding: "VC average age" and "VC total average investment". In this way it is possible to divide the OS companies into two separate groups:

A-1.) DETERMINANT: Mean of "Age"

GROUP 1: *Companies which have been funded during their first round by VCs which were averagely older than the average age of VCs (16,63 years), which means:*

"*VC average age" > 16,63*

GROUP 0: *Companies which have been funded during their first round by VCs which were averagely younger or equal to the average age of VCs (16,63 years), which means:*

"*VC average age" ≤ 16,63*

An appropriate statistical test to verify the first research question is the "two independent samples t-test", which tests for the null hypothesis of equality of means of the two samples. Again, the test requires the data to be normally distributed in order to be used, which is the reason why a Q-Q plot has been done to verify the normality of the distribution of the data sample.

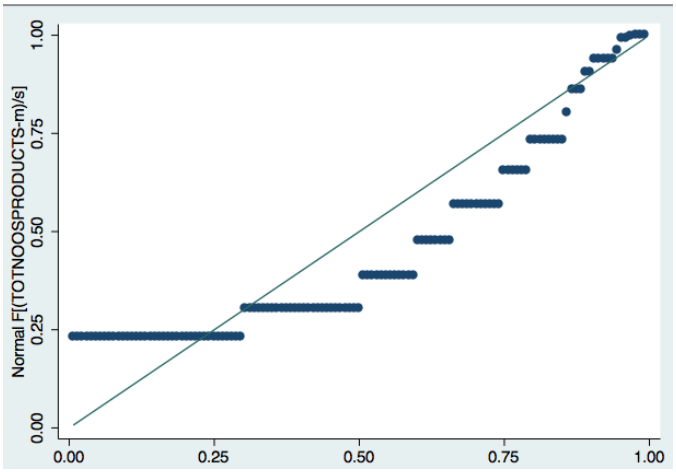


Figure 21: Q-Q plot of "Total number of OS products" variable

The sample has proven to be severely non-normal, and it has been decided to adopt another test to avoid unreliable and biased results.

The choice has been to adopt another non-parametric test of hypothesis which doesn't require the sample to be normally distributed, but only requires the variable to be ordinal and the observations to be independent (hypothesis which are fulfilled by the data set): the "Wilcoxon-Mann-Whitney test", which tests for the null hypothesis of equality of values between two samples through the comparison of their medians. In particular the said test gave the following results:

GROUP	obs	rank sum	expected
0	68	4293.5	4352
1	59	3834.5	3776
combined	127	8128	8128

unadjusted variance	42794.67
adjustment for ties	-1604.47
adjusted variance	41190.19

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)

z = -0.288

Prob > |z| = 0.7732

Table 3: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Mean of "Age"

Such a high p-value doesn't allow to reject the null hypothesis of equality of the samples, which means that the two groups do not differ in a statistically relevant way. To further check the result the "Kolmogorov-Smirnov test" (K-S test) has been used, which is another non-parametric test of hypothesis which tests for equality of probability

distributions. The null hypothesis of the test is that the two samples are drawn from the same probability distribution.

Smaller group	D	P-value	Corrected
0:	**0.1157**	**0.430**	
1:	**-0.0658**	**0.761**	
Combined K-S:	**0.1157**	**0.792**	**0.733**

Table 4: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Mean of "Age"

Since the corrected p-value is higher than the threshold value of 0,1 the hypothesis of equality of distributions cannot be rejected. The two tests gave the same type of result, namely the fact that the two groups can't be considered statistically different, thus implying that being funded by "experienced VCs" in terms of age won't impact on the performances of the funded firm.

A-2.) DETERMINANT: Mean of "Total investment"

It is also interesting to understand if the total amount of investments raised by VCs, used as a different proxy of their experience, influences the performances of funded OS firms. This new determinant allows to separate the firms into two new groups:

GROUP 1: *Companies which have been funded during their first round by VCs which had averagely totally invested more than the total average investment done by VCs (9.295.248.000$), which means:*

"VC total average investment" > 9.295.248.000$

GROUP 0: *Companies which have been funded during their first round by VCs which had averagely totally invested less or equal to the total average investment done by VCs (9.295.248.000$), which means:*

"VC total average investment" ≤ 9.295.248.000

Following the same path of the first research question, the "Wilcoxon-Mann-Whitney test" has been used to test for equality of medians of the two groups:

GROUP	obs	rank sum	expected
0	94	5907	6016
1	33	2221	2112
combined	127	8128	8128

unadjusted variance	33088.00
adjustment for ties	-1240.55
adjusted variance	31847.45

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)

z = -0.611

Prob > |z| = 0.5413

Table 5: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Mean of "Total investment

The resulting p-value doesn't allow to reject the null hypothesis of equality of medians, thus implying that there is no statistical evidence that the two groups differ. Again the "Kolmogorov-Smirnov test" (K-S test) has been used to further check such result:

Smaller group	D	P-value	Corrected
0:	0.1177	0.508	
1:	-0.0561	0.858	
Combined K-S:	0.1177	0.888	0.840

Table 6: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Mean of "Total investment"

The two tests gave the same type of result, namely the fact that the two groups can't be considered statistically different, thus implying that being funded by "experienced" VCs in terms of total investments made won't impact on the performances of the funded firm.

More generally speaking the results of these first tests state that there is no statistical evidence which relates experience of the VC, which has been considered both in terms of age and of total investments, and the performance of the funded OS firm.

B-1.) DETERMINANT: Median of "Age"

Mean and median differ a lot in the variables "VC average age" and "VC total average investment", where the former has a mean of 16,6 years compared to a median of only 15,8 years, and the latter has a mean of 9.295.248.000$ compared to a median of 2.357.337.000$, thus it can be interesting to understand if the above depicted tests of hypothesis change their result when grouping the "total number of OS products" variable considering the median instead of the mean. This new grouping determinant would make the two groups become:

GROUP 1: *Companies which have been funded during their first round by VCs which were averagely older than the median of the age of VCs (15,8 years), which means:*

"*VC average age" > 15,8*

GROUP 0: *Companies which have been funded during their first round by VCs which were averagely younger or equal to the median of the age of VCs (15,8 years), which means:*

"*VC average age" ≤ 15,8*

With this new grouping methodology the "Wilcoxon-Mann-Whitney test" becomes:

GROUP	obs	rank sum	expected
0	64	3993	4096
1	63	4135	4032
combined	127	8128	8128

unadjusted variance	43008.00
adjustment for ties	-1612.47
adjusted variance	41395.53

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)

z = -0.506

Prob > |z| = 0.6127

Table 7: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Median of "Age"

The p-value is still higher than the threshold value of 0,1, and again the null hypothesis cannot be rejected.
The "Kolmogorov-Smirnov test" with the new groups on the other hand becomes:

Smaller group	D	P-value	Corrected
0:	0.1213	0.393	
1:	-0.0409	0.899	
Combined K-S:	0.1213	0.739	0.673

Table 8: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Median of "Age"

Again the corrected p-value doesn't allow to reject the null hypothesis, confirming the fact that the two samples have the same distribution and that being funded by older VCs, and thus more experienced, does not influence the performance of the funded firm.

B-2.) DETERMINANT: Median of "Total investment"

The last grouping methodology uses the median of "Total investments" made by VCs as the determinant in order to understand if such characteristic influences the performance of the funded firms.

GROUP 1: *Companies which have been funded during their first round by VCs which had averagely totally invested more than the median of the total investment done by VCs (2.357.337.000$), which means:*

"VC total average investment" > 2.357.337.000$

GROUP 0: *Companies which have been funded during their first round by VCs which had averagely totally invested less or equal to the median of the total investment done by VCs (2.357.337.000$), which means:*

"VC total average investment" ≤ 2.357.337.000$

Coherently with the other research questions, the "Wilcoxon-Mann-Whitney test" has been used to test for equality of the medians of the above mentioned groups:

GROUP	obs	rank sum	expected
0	64	4143	4096
1	63	3985	4032
combined	127	8128	8128

unadjusted variance	43008.00
adjustment for ties	-1612.47
adjusted variance	41395.53

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)

z =	0.231
Prob > |z| =	0.8173

Table 9: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Median of "Total investment"

The resulting p-value is even higher than the one of the first test, confirming the fact that the two groups do not differ in a statistically relevant way.
The "Kolmogorov-Smirnov test" has been used to further check the result:

Smaller group	D	P-value	Corrected
0:	0.0809	0.660	
1:	-0.1039	0.504	
Combined K-S:	0.1039	0.883	0.841

Table 10: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Median of "Total investment"

Again the corrected p-value is even higher than the one resulting from the first test, confirming the equality of distribution of the two samples.

All of the tests and all of the different grouping methodologies rejected the hypothesis of the first research question, which stated that experience of the VC (measured with a proxy through the "VC average age" and "VC total average investment" variables) would influence the total number of OS products developed by the company.

5.2 RESEARCH QUESTION 2

What is the impact of syndication on the performances of funded OSS firms ?

Syndication can be measured both in terms of presence and in terms of size, and both of these aspects will be analysed in this research question. This will be done by grouping the OS firms and their relative total number of OS products in two separate ways to test for differences in the distributions.

A.) DETERMINANT: Presence of syndication

In the first grouping methodology the presence of syndication during the first funding round will be the determinant, which leads to the following two groups:

GROUP 1: *Companies which have been funded by only one VC, which means:*

"Syndication" = 1

GROUP 0: *Companies which have been funded by more than one VC, which means:*

"Syndication" > 1

Like in the first research question, the "Wilcoxon-Mann-Whitney test" has been used to test for equality of medians of the two groups, and the result has been the following:

GROUP	obs	rank sum	expected
0	85	5825.5	5440
1	42	2302.5	2688
combined	127	8128	8128

unadjusted variance	38080.00
adjustment for ties	-1427.71
adjusted variance	36652.29

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)

z =	2.014
Prob > |z| =	0.0441

Table 11: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Presence of syndication

The resulting p-value is smaller than the threshold value of 0,1 meaning that there is statistical evidence that the two groups differ in terms of medians and the null hypothesis can be rejected. In particular "GROUP 0", namely the group including OS companies which have been funded by more than one VC, shows a higher rank sum and thus a general higher number of developed OS products.
To further check this result the "Kolmogorov-Smirnov test" has been done to check for equality of distributions of the two groups, and the result is the following:

Smaller group	D	P-value	Corrected
0:	0.0000	1.000	
1:	-0.2569	0.024	
Combined K-S:	0.2569	0.049	0.031

Table 12: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Presence of syndication

This test gave a result which is coherent with the first one, confirming the fact that the two distributions are not equally distributed since the corrected p-value is below the threshold value of 0,1, and confirming that the presence of syndication favours the development of OS products.

B.) DETERMINANT: Mean of "Syndication"

Now that the effect of the presence of syndication on the total number of OS products developed by a firm has been tested, it is interesting to understand the impact that the size of syndication during the first funding round has on the same variable.
To do so the methodology used has been the same as the one used for the first research question, but since mean and median of syndication size do not differ much (respectively 2,3 and 2) only one grouping methodology has been tested, and in particular the two groups become:

GROUP 1: *Companies which have been funded by a number of VCs bigger than the average syndication size, which means:*

"Syndication" > 2,3

GROUP 0: *Companies which have been funded by a number of VCs smaller or equal to the average syndication size, which means:*

"Syndication" ≤ 2,3

The result of the "Wilcoxon-Mann-Whitney test" is the following:

GROUP	obs	rank sum	expected
0	87	5334	5568
1	40	2794	2560
combined	127	8128	8128

unadjusted variance	37120.00
adjustment for ties	-1391.72
adjusted variance	35728.28

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)
z = -1.238
Prob > |z| = 0.2157

Table 13: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Mean of syndication

The p-value doesn't allow to reject the null hypothesis, thus implying that the two samples do not differ.

Again, to further check the result, the "Kolmogorov-Smirnov" test has been used:

Smaller group	D	P-value	Corrected
0:	0.1626	0.235	
1:	-0.0284	0.957	
Combined K-S:	0.1626	0.463	0.382

Table 14: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Mean of syndication

Even in this case the corrected p-value is above the threshold value of 0,1 implying that the null hypothesis of equality of distribution functions must be accepted.

This means that the presence of syndication favours the development of OS products in financed companies, but the size of syndication doesn't have the same relevance.

5.3 RESEARCH QUESTION 3

What is the impact of the different types of VCs on the performances of funded OSS firms ?

The figure below shows the number of different types of VCs which funded the 127 OSS companies at their first round of funding. "Private VCs" are the most common type of VCs among the analysed ones, representing the 75% of the data set. It is, thus, interesting to understand if the presence of this type of VC during the first round of funding is associated to a general better performance of the financed firms.

Number of obs = **127**

	Total
NOOFPRIVATEVCs	**228**
NOOFCORPORATEVCs	**24**
NOOFBANKVCs	**21**
NOOFINDIVIDUAL	**19**
NOOFOTHERS	**9**

Table 15: Descriptive statistics of different types of VCs

As already done with the previous research questions, in order to test this hypothesis the funded companies have been divided into two groups, respectively:

DETERMINANT: Majority of funds raised by "Private VCs"

GROUP 1: *Companies which have been majorly funded by "Private VCs" during their first round of funding, which means:*

"No. of private VCs" > "No. of corporate VCs" +"No. of bank VCs" + "No. of individuals" + "No. of others"

GROUP 0: *Companies which have not been majorly funded by "Private VCs" during their first round of funding, which means:*

"No. of private VCs" ≤ "No. of corporate VCs" +"No. of bank VCs" + "No. of individuals" + "No. of others"

To test this research question a "Wilcoxon-Mann-Whitney test" has been done, and its results are the following:

GROUP	obs	rank sum	expected
0	30	1769.5	1920
1	97	6358.5	6208
combined	127	8128	8128

unadjusted variance	31040.00
adjustment for ties	-1163.76
adjusted variance	29876.24

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)
z = -0.871
Prob > |z| = 0.3839

Table 16: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Majority of funds raised by PVCs

Since the p-value is above the threshold value of 0,1 the null hypothesis cannot be rejected, implying that the two groups have the same medians. Like in previous research questions, to further investigate the result, the "Kolmogorov-Smirnov" test has been done, which gave the following result:

Smaller group	D	P-value	Corrected
0:	0.1330	0.445	
1:	-0.0739	0.779	
Combined K-S:	0.1330	0.812	0.746

Table 17: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Majority of funds raised by PVCs

Coherently with the result of the "Wilcoxon-Mann-Whitney test", even in this situation the corrected p-value is above the 0,1 threshold, which doesn't allow to reject the null hypothesis, confirming the equality of the two distributions.
This means that the presence of a "Corporate VC" during the first round of funding does not have a statistically relevant impact on the performances of the funded firm.

5.4 RESEARCH QUESTION 4

What is the impact of the number of raised funds on the performances of funded OSS firms ?

The last research question aims at investigating whether funding an OSS company in more rounds rather than in one during the first funding round has an effect on its performances. Multiple rounds of funding can be measured both in terms of presence and in terms of size, so both grouping methodologies have been tested to study which one was the most relevant for the purposes of this research paper. In particular the first grouping determinant is the presence of multiple funding rounds during the first round of funding, which makes the two groups become:

A.) DETERMINANT: Presence of multiple funding rounds

GROUP 1: *Companies which have been funded in a single round, which means: "No. of rounds" = 1*

GROUP 0: *Companies which have been funded in more rounds, which means: "No. of rounds" > 1*

The first test used to verify this research question has been the "Wilcoxon-Mann-Whitney test", and the result is the following:

GROUP	obs	rank sum	expected
0	112	7404.5	7168
1	15	723.5	960
combined	127	8128	8128

unadjusted variance 17920.00
adjustment for ties -671.86

adjusted variance 17248.14

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)
z = 1.801
Prob > |z| = 0.0717

Table 18: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Presence of multiple funding rounds

The resulting p-value is lower than the threshold value of 0,1 which means that the null hypothesis of equality of medians can be rejected, implying that the two groups are statistically different. To further check this result the "Kolmogorov-Smirnov" test has been done:

Smaller group	D	P-value	Corrected
0:	0.0000	1.000	
1:	-0.2655	0.155	
Combined K-S:	0.2655	0.309	0.217

Table 19: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Presence of multiple funding rounds

This second test gave an unexpected result since the corrected p-value of 0,217 implies that the two groups have the same probability distribution, whereas the "Wilcoxon-Mann-Whitney test" highlighted that the two groups differ. The two tests are thus in contrast in terms of results, even if the generally recognised higher reliability of the rank-sum test tends to suggest that raising funds in more rounds has a slightly positive impact on the performances of the funded firm.

B.) DETERMINANT: Size of funding rounds

Since mean and median of "No. of rounds" are very similar, respectively 4,527 and 4, there was no need to test for both of the grouping methodologies like for the first research question. The result is that the two groups are the following:

GROUP 1: *Companies which have been funded by more than the average number of funding rounds, which means:*

"No. of rounds" > 4,527

GROUP 0: *Companies which have been funded by less or equal to the average number of funding rounds, which means:*

"No. of rounds" ≤ 4,527

The “Wilcoxon-Mann-Whitney test” used to test the research question with this new grouping determinant is the one depicted in the figure beneath:

GROUP	obs	rank sum	expected
0	73	4358.5	4672
1	54	3769.5	3456
combined	127	8128	8128

unadjusted variance 42048.00
adjustment for ties -1576.48

adjusted variance 40471.52

Ho: TOTNOO~S(GROUP==0) = TOTNOO~S(GROUP==1)
z = -1.558
Prob > |z| = 0.1192

Table 20: Two-sample Wilcoxon-Mann-Whitney test
Determinant: Size of funding rounds

The p-value is slightly above the threshold value of 0,1 which means that there is not enough evidence to reject the null hypothesis, even if the result is less clear than the ones of the previous tests. This suggests that a “Kolmogorov-Smirnov” test is needed:

Smaller group	D	P-value	Corrected
0:	0.1357	0.319	
1:	0.0000	1.000	
Combined K-S:	0.1357	0.617	0.541

Table 21: Two-sample Kolmogorov-Smirnov test for equality of distribution functions
Determinant: Size of funding rounds

The corrected p-value of 0,541 gives, on the other hand, a clear indication of the equality of distribution of the two samples.
The results of the tests suggest that there is no statistical evidence of the impact of the size of multiple funding rounds during the first round of funding on the performance of funded OS firms.

6. Conclusions

The following paragraph aims at drawing conclusions from the results of the research questions, in order to understand the implications and findings which derive from the data analysis which has just been presented.

The first important statement which has been tested is the fact that VC funding has an overall positive impact on the performances of funded OSS companies. This can be grasped by the first general descriptive statistics by looking at the depicted values of the variables “OS products before” and “OS products after”, which greatly differ both in terms of mean (respectively 0,1 and 3,1) and in terms of maximum value (respectively 6 and 24). This, of course, cannot be considered a reliable statistic test, but it is useful to give a first general idea of the situation. To obtain a truthful result it is necessary to look at the outcome of the “Wilcoxon signed-rank test”, which tests for the null hypothesis of equality of the two above mentioned variables. The results clearly state that the null hypothesis must be rejected, confirming the impression which had already been drawn from the first general descriptive statistics: the overall positive impact of VC funding on OSS firms. This first result was largely expected, since various research papers had already analysed this positive correlation between the presence of a VC and the performances of the funded OSS firm (Berger and Udell 1998, Engel 2002, Hellman and Puri 2000, Sapienza 1992), yet it was important to empirically test the truthfulness of such statement in the light of the hand collected data, in order to be able to start analysing the research questions from a solid and reliable statement, which is the main intent of this paper.

6.1 RESEARCH QUESTION 1

What is the impact of the experience of the VC on the performances of funded OSS firms ?

The doubt of the possible effect of the experience of the VC at the first round of funding on the performances of the funded OSS firms arose by looking at the general descriptive statistics, and by noticing the wide range of values of the two variables which have been used as proxies of the experience of the VCs, namely "VC average age" and "VC total average investment". The former, in fact, has a minimum value of 0 and a maximum value of 54, while the latter has a minimum of 7.400.000$ and a maximum of 79.646.513.000$. Such wide value ranges, and thus such a wide spectrum of experience levels among VCs, could have meant the existence of correlations between the experience of the VC and the performance of the funded OSS firm, but this was not the case. The initial grouping methodology took into consideration the mean of the "VC average age" and "VC total average investment" variables as determinants, but both the "Wilcoxon-Mann-Whitney test" and the "Kolmogorov-Smirnov test" did not give the expected result, and clearly stated that the null hypothesis of equality of the two groups had to be accepted. Because of the significant difference between the mean and median of the above mentioned variables, the same tests have been repeated using the median as the grouping determinant instead of the mean hoping to find a different result, but again this was not the case. The tests with the new grouping methodologies gave even more clear results regarding the equality of the two groups of variables.

The results, in fact, clearly state that the experience of the VC does not affect the performances of the funded OSS firm. A possible explanation of such outcome can be the fact that VCs are generally well structured realities, which base their investment choices on best practises and frameworks which have been largely tested, along with the fact that investments are usually syndicated among other VCs (Lerner, 1994), thus reducing the effects and the impacts of experience of the funding firm on the funded company.

6.2 RESEARCH QUESTION 2

What is the impact of syndication on the performances of funded OSS firms ?

Syndication is a widespread phenomenon among VCs as proven by the descriptive statistics, which show how the mean of syndication is 2,3. This implies that, on average, firms are well disposed to syndication and prefer to share their investment with at least another firm. The reason of such a behaviour is the increase of expertise and support, which is particularly important when speaking of a field characterized by so high uncertainty, along with the possibility to share investment risk and to obtain more information about the company in order to better decide if to make the investment or not (Gompers & Lerner 1999, Lerner 1994).

The results of the first tests, which used the presence of syndication during the first funding round as the determinant for the grouping methodology, suggest that the null hypothesis of equality of the two groups must be rejected since both the p-values, respectively 0,0441 for the "Wilcoxon-Mann-Whitney test" and 0,031 for the "Kolmogorov-Smirnov test", are below the threshold value of 0,1. This implies that syndicated investments tend to have a positive impact on the performances of the funded OSS firms.

This result makes allowance for the above described widespread behaviour among VC firms, proving the positive effect both for VCs and for OSS firm, which makes syndication a "win-win" behaviour.

The second tests were aimed at understanding if the size of syndication could be as important as the presence itself in terms of impact on the performances of financed firms. To do so the chosen determinant of the grouping methodology has been the mean of syndication size. The results of these tests, however, did not allow to reject the null hypothesis of equality of samples, implying that the size of syndication does not have any statistically relevant impact on the performances of the funded OSS firms.

In general this second research question highlighted how syndication is a common behaviour among VCs, which on average share their investment with at least another VC firm. This behaviour is positive both for VCs and for funded OSS firms since it favours the performances of the latter, while the size of such syndication does not matter in terms of impact on the performances of the funded OSS firm.

6.3 RESEARCH QUESTION 3

What is the impact of the different types of VCs on the performances of funded OSS firms ?

The hand collected data allows to distinguish between five different types of VCs which can finance an OSS company during the first round of funding, in particular Private VCs, Corporate VCs, Bank affiliated VCs, Individuals (angel investors) and Others (mainly governments and universities).

The descriptive statistics of the data analysis section clearly show how Private VCs are the most common type of VC which decide to participate in the first funding round of OSS companies, since they took part at 75% of the analysed first funding rounds. Since such a clear preponderance was depicted by the descriptive statistics, it has been natural to verify if being mainly funded by PVCs could affect the performances of the funded OSS firm.

The results of both the "Wilcoxon-Mann-Whitney" and the "Kolmogorov-Smirnov" tests, however, clearly state that the two groups, which have been divided depending on whether a firm had been (or hadn't been) mainly funded by PVCs during the first round of funding, do not differ in a statistically relevant way.

This result implies that the fact that the vast majority of investors which decide to fund OSS firms at their first round of funding are Private VCs does not affect the performances of the funded firms. Such results suggest that being funded by a PVC instead of, for example, a CVC does not affect the overall performances of the firm, even if the funding strategies of these two economical subjects are different, since the latter aims at both strategic and financial gains, while the former is usually only interested in the financial aspect. This result might be explained by the limited size of the dataset and by the fact that the statistical tests of hypothesis which have been used for the data analysis of this paper might not be sophisticated enough to grasp an eventual effect of this factor, which nevertheless has proven to be not so strong as one may think.

6.4 RESEARCH QUESTION 4

What is the impact of the number of raised funds on the performances of funded OSS firms ?

A typical behaviour of VCs is to avoid delivering funds all in one round to try and increase the control over the financed project and to consequently reduce the risk associated to the investment (Sahlman, 1990). This attitude can be easily noticed by looking at the descriptive statistics which show how, on average, an OSS company receives more than 4 rounds of funding, and sometimes the number of rounds can increase up to 17. This fully supports the above mentioned economic literature, and gives empirical evidence to the fact that very few firms deliver all of their funds in one tranche.

The "Wilcoxon-Mann-Whitney test" and the "Kolmogorov-Smirnov test" have been used to test the effects of this behaviour on the performances of the OSS firms, and the first step has been to check for a relationship between the presence of multiple funding rounds during the first round of funding (which has been used as the determinant for the two groups) and the performances of such companies. The "Wilcoxon-Mann-Whitney test" gave a p-value result of 0,07 which is below the threshold value of 0,1, implying that OSS companies which had been funded with multiple funding rounds had demonstrated overall better performances than the ones which had been funded in only one round. The "Kolmogorov-Smirnov test", on the other hand, gave an unexpected p-value of 0,217, not allowing to reject the null hypothesis of equality of distributions. The two tests, thus, gave contrasting results. The higher reliability of the "Wilcoxon-Mann-Whitney test", though, might suggest that this typical behaviour of VCs to deliver funds in multiple rounds could have a slightly positive impact on the performances of the funded firms, even if the result of the second test suggests that further and more in-depth statistical analysis should be done in order to fully check this result.

The above mentioned non-parametric tests of hypothesis have been used also to test the impact of the size of funding rounds on the performances of funded OSS firms, and in particular the average number of funding rounds has been used as the determinant for the grouping methodology. In this case the "Wilcoxon-Mann-Whitney test" gave a p-value result of 0,1192 which is slightly above the threshold value of 0,1, while the

“Kolmogorov-Smirnov test” gave a p-value of 0,541, clearly accepting the null hypothesis of the test.

The general interpretation of the results of this fourth research question, thus, can be that the presence of multiple funding rounds during the first round of funding might have a slightly positive effect on the performances of the funded OSS firm, while the number of raised funds doesn’t seem to be as relevant. But the important finding is that this behaviour which VCs use to increase their control over the companies they decided to finance and to diminish the risk of their investment did not show to have a negative impact on the performances of the funded firms, and thus can be used by VCs without the fear of damaging the OSS companies which are being funded.

7. Follow up

The aim of this research paper is to provide a first analysis of the relationship between the investments made by VCs and the performances of the funded OSS firms, since economic literature has not delved deep into this particular subject, limiting its contributions to affirming the general positive impact of the investments made by VCs on the funded OSS companies.

It was, thus, necessary to start a specific study on this subject, and to investigate how different conditions which may occur during the VC funding could affect the performances of such OSS companies, which is the reason why this paper has been conceived.

The study which has been presented is mainly based on providing an accurate description of data features, with the aim of analysing the hand collected data through descriptive statistics, graphs and simple statistical tests.

This implies that there are many paths available for future investigations and that this research paper is meant to be the groundwork for more in-depth analysis, which could for example aim at studying the preliminary findings which have been presented in previous paragraphs with more sophisticated statistical tools in order to fully grasp the correlation between the different conditions which may occur during VC funding and the effects of such conditions on performances of funded OSS firms. Another interesting follow up to this paper could be investigating how other conditions could affect the interaction between VCs and the funded OSS firms, for example by analysing the effects of the competitive environment, thus trying to understand how the presence (or absence of presence) of incumbents could interfere with the funding process, or for example by studying how the presence of different patents and trademarks could influence the performances of OSS firms which have been funded by VCs. One last and more general follow up could be to investigate if, and eventually how, the OS business model could be adapted to other business sectors such as, for example, automobile components development or pharmaceutical development, and how the funds raised by VCs could favour this new way of doing business.

As proven in this brief conclusive paragraph the relationship between VC financing and OSS development is a wide and still unexplored subject, and this research paper could be considered a starting point for the many possible future developments, confident that

such a current theme which is so quickly expanding in both the business and literature environment will be studied with increasing interest in the forthcoming future.

Bibliography

Aghion, P. and Tirole, J., 1997, "Formal and Real Authority in Organizations", Journal of political Economy, 105, pp. 1^29.

Aksoy, D., Fosfuri, A., Giarratana, M., 2011, "The Impact of Open Source Software on Firm Value", Copenhagen Business School, Druid Society.

Antonelli, C., 2005, "Models of knowledge and systems of governance", Journal of Institutional Economics 1(1), pp. 51-73.

Arora, A. and Ceccagnoli, M., 2006, "Patent Protection, Complementary Assets, and Firms' Incentives for Technology Licensing", 52 MGMT. SCI. 293.

Baran, P., 1964, "On distributed communications", RAND Corporation Research Documents, vol. I-XI.

Barney, J. B., 1991, "Firms resources and sustained competitive advantage", J. Management 17, 99–120.

Barry, C.B., Muscarella C.J., Peavy J.W. III and Vetsuypens M.R., 1990, "The Role of Venture Capital in the Creation of Public Companies: Evidence from the Going Public Process", Journal of Financial Economics, 27, pp. 447-471.

Benussi, L., 2006, "The History of the Free/Libre/Open Source Software: Stories from the Open Source Evolution", Politecnico di Milano, DIG.

Berger, A.N. and Udell, G.F., "The economics of small business finance: The roles of private equity and debt markets in the financial growth cycle", J. Banking Finan., vol. 22, pp. 613–673.

Birch, D., 1987, "Job Creation in America", The Free Press.

Black, B. and Gilson, R., 1998, "Venture Capital and the Structure of Capital Markets: Banks versus Stock Markets", Journal of Financial Economics, 47, pp. 243-277.

Bonaccorsi, A., Giannangeli, S. and Rossi, C., 2006, "Entry Strategies Under Competing Standards: Hybrid Business Models in the Open Source Software Industry", Management Science 52(7), pp. 1085–1098, © 2006 INFORMS.

Bonaccorsi, A., Piscitello, L., Merito, M. and Rossi, C., 2006, "Profiting from "Open Innovation". Teece's Building Blocks Meet the Open Source Production Paradigm", Politecnico di Milano, DIG.

Bonaccorsi, A., Rossi, C., 2003, "Why open source can succeed", Res. Policy 32(7) 1243–1258.

Brav, A., Gompers, P.A., 2000, "Insider Trading Subsequent to Initial Public Offerings: Evidence from Expirations of Lock-up Provisions", Harvard University.

Bush, V., 1945, "Science – The Endless Frontier", United States Government Printing Office.

Carson, D.J., 1985, “The evolution of marketing in small firms”, European Journal of Marketing, Vol. 19, pp.7–16.

Chiplin, Brian and Wright, 1997, "The syndication of venture capital deals: buy-outs and buy-ins", Entrepreneurship: Theory and Practice, 21 (4), 9-28.

Choi, S. and Winston, A., 2000, “Benefits and requirements for interoperability in electronic marketplace”, Technology in Society, 22.

Claymon, D., 1999, “Apple in Tiff with Programmers over Signature Work”, San Jose Mercury News.

Colombo, M. G. and Piva, E., 2008, “Strengths and Weaknesses of Academic Startups: A Conceptual Model”, IEEE transactions on engineering management, VOL. 55, NO. 1.

Cressy, R., 2002, “Introduction: Funding gaps”, Economic. Journal, vol. 112, pp. F1–F16.

David, P.A., 1998, “Common agency contracting and the emergence of “Open Science” institutions”, American Economic Review, 88, 2, pp. 15-21.

Engel, D., 2002, “The Impact of Venture Capital on Firm Growth: An Empirical Investigation”, Center for European Economic Research (ZEW), No. 02-02.

Evans, J., 2000, “IBM to invest almost $1 billion in Linux development”, Infoworld .

Fano, R.M. and Corbató, F.J., 1966, “Time-sharing on computers”, Scientific American 215, 3, pp. 128-140.

Fauchart, E., 2003, “On knowledge sharing patterns among rival firms: The case of knowledge on safety”, Working Paper, http://userinnovation.mit.edu/papers/safety3.pdf.

Fluck, Z., Holtz-Eakin, D. and Rosen, H., 1998, "Where Does the Money Come From? The Finanicing of Small Entrepreneurial Enterprises", working paper, New York University Salomon Center.

Foley, M.J., 2001, “Stallman strikes back at Microsoft”, ZD Net Asia.

Fosfuri, A., Giarratana, M.S., Luzzi, A., 2008, “The penguin has entered the building: the commercialization of open source software products”, Organization Science 19(2), pp. 292–305, © 2008 INFORMS.

Gibbons, R., 1997, “Incentives and Careers in Organizations”, Advances in Economic Theory and Econometrics, vol. 2 (Cambridge University Press).

Gompers, P., 1996, “Grandstanding in the Venture Capital Industry”, Journal of Financial Economics, 42, pp. 135-156.

Gompers, P., Lerner, J., 1998, “What Drives Venture Fundraising ?”, Brookings Papers on Economic Activity – Microeconomics, pp.149-192.

Gompers, P., Lerner, J., 1999, “The Venture Capital Cycle”, Cambridge: The MIT Press.

Gompers, P., Lerner, J., 2001, “The Venture Capital Revolution”, The Journal of Economic Prospectives, Vol. 15, No. 2, pp. 145-168.

Gomulkiewicz, R.W., 1999, "How copyleft uses license rights to succeed in the Open Source software revolution and the implications for article 2B", Huston Law Review 36.

Gruber, M. and Henkel, J., 2006, "New ventures based on open innovation – an empirical analysis of start-up firms in embedded Linux", Int. J. Technology Management, Vol. 33, No. 4.

Heirman and Clarysse, B., "How and why do research-based start-ups differ at founding? A resource-based configurational perspective", J. Tech. Transfer, vol. 29, pp. 247–268.

Hellman, T. and Puri, M., 2000, "The interaction between Product Market and Financing Strategy: The Role of Venture Capital", The Review of Financial Studies, Vol. 13, No. 4, pp. 959-984.

Hellmann, T., 1997b, "Venture Capital: A Challenge for Commercial Banks", Journal of Private Equity, 1, 49-55.

Henkel, J., 2006, "Selective Revealing n Open Innovation Processes: The Case of Embedded Linux", CEPR .

Holmström, B., 1999, "Managerial Incentive Problems: A Dynamic Perspective", Review of Economic Studies, 66, pp. 169-182.

Jensen, M.C. and Meckling, W.H., 1976, "Theory of the Firm: Managerial Behaviour, Agency Costs and Ownership Structure", Journal of Financial Economics 3, pp. 305-360.

Katz, M., Shapiro, C., 1985, "Network externalities, competition and compatibility", American Economic Review 75(3)424–440.

Klemperer, P., 2005, "Network Effects and Switching Costs: two short essays for the new Palgrave", © Paul Klemperer, 2004, 2005.

Kortum, S., and Lerner, J., 1998, "Does Venture Capital Spur Innovation?" mimeo, Harvard Business School.

Langlois, R.N., 1992, "External economies and economic progress: the case of the microcomputer industry", The Business History Review, 66, 1, High-Technology Industries, pp. 1-50 .

Lerner, J. and Tirole, J., 2002, "Some simple economics of open source", The Journal of Industrial Economics, Volume L, No.2, 0022-1821.

Lerner, J. and Tirole, J., 2005, "The scope of open source licensing", The Journal of Law, Economics & Organization, vol.2, no. 1, pp. 20-56.

Lerner, J., 1994, "Venture Capitalists and the Decision to go Public", Journal of Financial Economics, 35, pp. 293-316.

Lerner, J., 1995, "Venture Capitalists and the Oversight of Private Firms", Journal of Finance, 50, pp. 301-318.

Lerner, J., 1996, "The Government as Venture Capitalists: the Long-Run Impact of the SBIR Program", Working Paper 5753, NBER.

Liles, P., 1977, “Sustaining the Venture Capital Firm”, Cambridge: Management Analysis Center.

Lockett, A., Siegel, D., Wright, M. and Ensley, M.D., 2005, “The creation of spin-off firms at public research institutions: Managerial and policy implications”, Res. Pol., vol. 34, pp. 981–993.

Mann, R.J., 2006, “Commercializing Open Source Software: Do Property Rights Still Matter ?”, Harvard Journal of Law & Technology, Volume 20, Number 1.

Maurer, S.M. and Scotchmer S., 2006, "Open Source Software: The New Intellectual Property Paradigm", NBER Working Papers 12148, National Bureau of Economic Research, Inc.

Mitchell, W., Singh K., 1992, “Incumbents’ use of preentry alliances before expansion into new technical subfields of an industry”, J. Econom. Behav. Organ., 18(3), 347–372.

Olson, M., 2005, “Open Source Business Models”, SCCT presentation at University of California

Oren, B.G. and Parchomovsky, G., 2003, “The Value of Giving Away Secrets”, 89 VA. L. REV. 1857, 1973–74.

Ortega, J., 2000, “Power in the Firm and Managerial Career Concerns”, Unpublished working paper, Universidad Carlos III de Madrid.

Perr, J., Appleyard, M.M., Sullivan, P., 2010, “Open for business: emerging business models in open source software”, Int. J. Technology Management, Vol. 52, Nos. ¾.

Pisano, G., Teece, D., Shuen, A., 1997, “Dynamic capabilities and strategic management”, Strategic Management J., 18(7), pp.509–533.

Porter, M.E., 1980, “Competitive Strategy”, The Free Press.

Poterba, J., 1987, “How Burdensome are Capital Gain Taxes? Evidence from the United States”, Journal of Public Economics, 33, pp. 157-172.

Raymon, E.S., 2000, “The cathedral and the bazaar”, O’Reilly.

Raymond, E.S., 2001, “The Cathedral and the Bazaar. Musings on Linux and Open Source by an Accidental Revolutionary”, O’Reilly & Associates.

Red Hat Inc., 2005b, “Red Hat reports fiscal fourth quarter and year end results”, available at http://investors.redhat.com.

Romanelli, E., 1989, “Environments and strategies of organization start-up: effects on early survival”, Administrative Science Quarterly, vol. 34, pp. 369-387.

Rosen, L., 2004, “Open Source Licensing: Software Freedom and Intellectual Property Law”, Prentice Hall.

Sahlman, W.A., 1990, “The Structure and Governance of Venture Capital Organizations”, Journal of Financial Economics, 27, pp. 473-524.

Samuelson, P., 2006, “IBM’s pragmatic embrace of open source”, Comm., ACM, 49(10).

Sapienza, H. J., 1992, "When Do Venture Capitalists Add Value", Journal of Business Venturing 7, 9-27.

Sattler, H., 2003, "Appropriability of product innovations: An empirical analysis for Germany", International Journal of Technology Management, 26(5-6), 502–516.

Shy, O., 2001, "The Economics of the Network Industries", Cambridge University Press.

Stinchcombe, A.L., 1965, "Social Structure and Organizations", Handbook of Organizations, Rand McNally, pp.153-193.

Taschek, J., 1999, "Vendor Seeks Salvation By Giving Away Technology", http://www.zdnet.com/pcweek/stories/news/0,4153,404867,00.html.

Teece, D.J., 1986, "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy", Research Policy 15, pp. 285-305.

The 451 Group, 2010, "Commercial adoption of open source", LLC, Tier1 research.

Toldra, A., 2012, "Venture Capital Syndication and Firm Entry: Theory and Evidence", Universidad Carlos III de Madrid.

Valloppillil, V., 1998, "Open Source Software: A (New?) Development Methodology", Unpublished working paper, Microsoft Corporation.

Vermeulen, B., 2004, "Alternatives to Venture Capital Funding", Corp2.

von Hippel, E., 1988, "The sources of innovation", Oxford University Press.

Ziedonis, R. H., 2004, "Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms", Management Sci., 50(6), 804–820.