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Some Policy Issues on Open Source and Proprietary Software

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Abstract

Software industry is a fast growing sector of the economy which is undergoing significant changes both for the presence of the open source mode of production and for the challenges of globalization and convergence with other industries. This paper analyses the role of open source software (OSS) on competition and innovation in the software industry and debates the economic rationales for promoting the adoption of OSS by national and local governments.

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Introduction

In September 2007, the House of Representatives of the United States passed a bill on patent legislation (*Reform Act of 2007 – H.R.1908*). To become a law, the bill has to be approved by the Senate House and signed by the President. Anyhow, it is on its way. On December 2007, the new version of the European Patent Convention has become effective. It is a treaty, ratified by the 34 members of the European Patent Organisation. It provides a unified legal framework for granting and litigation of the European patents by the European Patent Office (EPO) for all the states members of the organisation. The treaty may be considered a further step toward harmonisation which in Europe is still backward[1].

These recent events, strongly advocated by institutional representatives, mostly from the commercial software industry, are the outcome of a renewed vibrant debate on the protection of Intellectual Property Rights (IPRs) which involves governments and private institutions, together with academic economists, software developers and final users. The debate has been fuelled not only by the growth of the "information economy" (Hall, 2007) but also by the changes that the software industry is undergoing due to the presence of two distinct modes of production and distribution of the software products: proprietary and open source software .

Since software industry plays a relevant role in the development of the economy, many governments look quite involved in favouring the growth of their industries. But while some government policies promote open source software (OSS), through procurement suggestions or subsidies to research, others tend to strengthen the patent system with the aim of improving the protection of IPRs. These policies may look somewhat contradictory.

The paper is organized as follows: Section 1 introduces few stylized facts on OSS; Section 2, relying on a growing body of theoretical and empirical studies, analyses the consequences on competition and innovation of OSS in the software industry and Section 3, disputes the rationales of government policies supporting OSS and concludes with few policy recommendations.

[1] The UE Directive on the patent system for Computer-Implemented Innovations (CIIs) has been reject by the European Parliament on July 2005.

1. Stylized facts

Software products, as all the information goods, are the outcome of the human ingenuity. They are complementary goods, easily replicable, almost at zero cost, with large network externalities. This is true specially for those products called software platforms[2] that are software programs whose functionality can be increased through interfaces (Applications Programming Interfaces) that permit to hook other software programs (Etro, 2007) and that put together a large number of people (customers, sellers and developers). When the number of users increases, also the value of these products increases to them. The software products are non-rival and non-excludable, two characteristics that they share with public goods. These market failures have been traditionally treated giving protection to intellectual property rights mainly through copyrights or patents system (Scotchmer 2004). Software product's characteristics are common to both proprietary and open source software that differ, instead, for their mode of production and diffusion.

Proprietary Software (PS) is realized by hired programmers working along hierarchical procedures defined by private firms. PS is protected by patent and distributed through commercial channels under the payment of a licence fee.

Free[3] or Open Source Software[4] (OSS) is, on the contrary, the result of the joint work of a great number of contributors, usually unpaid, scattered throughout the Web which share their results, i.e. the source code of the computer program, that are therefore, publicly accessible. It can be copied, modified and even redistributed, under some kind of restriction to avoid the appropriation and sale by commercial firms. The OS licensing options more commonly used are GPL (GNU[5] General Public Licence) or

[2] See Evans *et al.*(2006) for a detailed account on software platforms and multi sided markets.
[3] In this paper, free software or open source software will be used as a synonymous since the distinction lies mainly on philosophical ground. Free Software was the original term, while Open Source Software was coined later, in 1998. Members of the two communities may contribute to the same project but consider themselves to belong to different movements.
[4] A program is defined open source if it satisfies the criteria stated in the Open Source Definition which is a document prepared by the OSI (Open Source Initiative) foundation.
[5] GNU is the acronym for GNU's Not Unix. It is an operating system which looks like Unix but it is a free software. GNU/Linux is a combination of the two operating systems.

copyleft licence[6] and BSD (Berkeley Software Distribution) or non-copyleft licence. The GPL requires the full accessibility to the source code which may be modified but has to be redistributed under the same licensing condition. This explains why the licence is considered the most restrictive one. BSD, instead, is less restrictive and allows anyone to modify and sell derived products which include the source code released under that licence without disclosing the source code of the derived products.

The diffusion of desktop computers and their connections through network applications via Internet has created, in the early 90s[7], the right environment for the growth and diffusion of OSS. Apache, Linux, Mozilla are just few of the best known OSS.

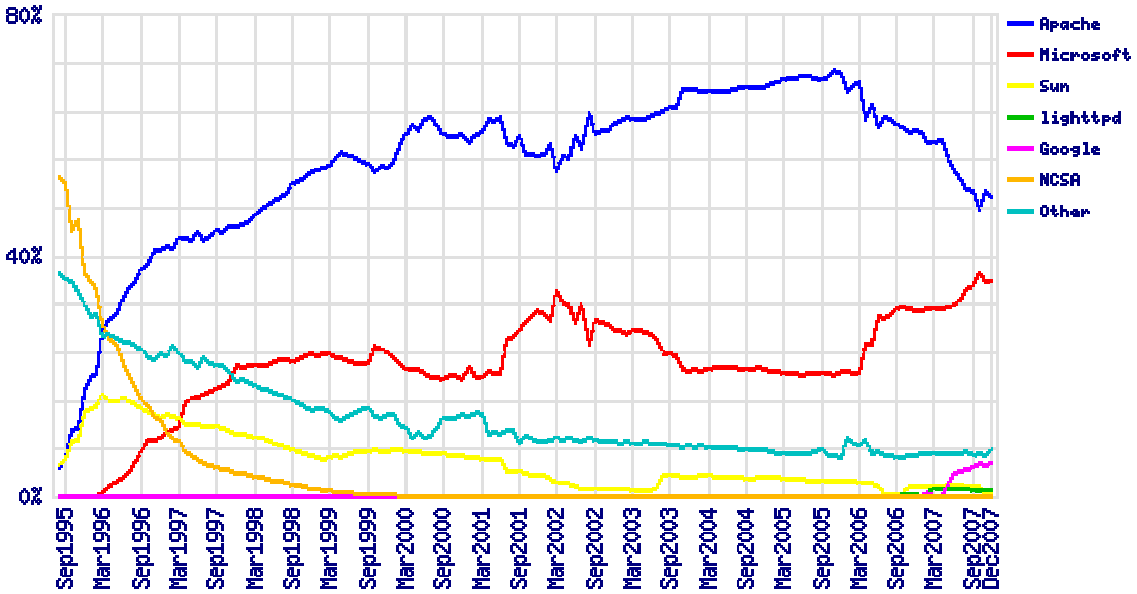
Two features of the software market are now raising the interest of scholars and politicians: the growth of OSS and the increasing attention of commercial firm for OSS products.

1.2 The growth of OSS in the software industry

In the market for web servers we can see, looking at the monthly web server survey by Netcraft[8], that the position reached by the Apache is really impressive (Fig.1). Starting in 1995, Apache has quickly gained market share, together with Microsoft-IIs[9] which appeared later in 1996, at the expense of the already existing software programs: NCSA[10] and Netscape (now included in Sun). In October 2005, Apache reached the 70% of the market. Since then it has progressively lost market share and now it has a 50% of the whole market and a 10% advantage over Microsoft-IIs. This is the smallest gap between the two. The increasing number of sites, which testify the growth of the market, is recently due to the growth of blog providers. Google is now the third operator of the market with a 5% share.

[6] The term was chosen by Raymond to contrast the concept of copyright.
[7] See Graham and Mowery (2003) for a short account of the history of software industry in U.S.
[8] The survey monitors the web servers that actually develop web sites and started in August 1995.
[9] Microsoft-Internet Information Server is the web server of Microsoft.
[10] Apache has been derived from a public domain released by NCSA (National Center for Supercomputing Applications) a research center of the University of Illinois (Varian, Shapiro 2005).

Figure 1. Market shares in the Market Web Server



Source: www.netcraft.com, December 2007.

In the market for server and desktop, Linux[11] is the best known OSS operating system. Information on the diffusion of Linux are very difficult to obtain since it can be easily downloaded with a click. Various sources try to give approximate estimates and suggests that the market share for server should be around 20-23% (Economides, Katsamakas 2006; Lerner, Tirole 2005) while the number of desktop users is in the range of 29 millions[12] or the 3-4% of this market segment. Even taking into account the copies of Linux distributed through commercial firms, like RedHat or Suse which assemble parts of the program and give it for free asking only the price for the complementary services offered, the data on the number of users are largely underestimated. On the contrary, data on proprietary software may be over estimated because very often people buy personal computer with preinstalled a PS and afterwards they install Linux.

[11] Linux is not just a program but a collection of modules that can be assembled to form the "kernel". The modules can be modified and customized according to user needs by software vendors (Varian, Shapiro 2003).

[12] The estimate, dated December 2007, is a guess of the author of the site (http://counter.li.org), where the users can register themselves on a voluntary basis, and it takes into account the fact that many users don't care to get registered or don't even know the existence of the site.

Linux is increasingly used by internet companies such as Amazon and Google and used as operating system in embedded software in mobile phones such a Motorola SCPL, Samsung Qtopia, the newest Google Android and other devices and web gadgets.

Linux's share is due to increase also because it is adopted, or it has been suggested for adoption, by many European and Asian governments. Even the Department of Defence and the National Security Agency of the US government have adopted Linux.

1.2 The role of commercial firms in the growth of OSS

Another relevant feature of the software market is that firms are starting to work with, and not only to compete with, the Open Source Community. There is a number of ways in which they can do it. Commercial firms can provide complementary services to the OS products in order to make their use more friendly. They can subsidize open source projects or release some of their proprietary code or even contribute some of their patents into a "patent commons".

This is the case of IBM which has decided to participate to more than 120 OS projects[13], financing the development of Linux with more than $1 billion, and has contributed 500 patents to the Open Invention Network (OIN)[14] a company established in 2005 with the mission to create an environment to promote, improve and protect Linux. The OIN is financed by firms such as IBM, Novell, Philips, Red Hat, Sony and Google and has adopted an intellectual property model where the patents contributed are available, at no licence fee, to any person or firm or institution which agrees not to use its own patents against Linux. It is a kind of legal protection which favours investments by firms which embed Linux in their product or offer some complementary product.

Commercial firms decide to become part of an OS project if they expect to increase their profitability, when they work on complementary segments of the market or if they disclose some of their proprietary source code[15], or to decrease their costs of production,

[13] Among these: Eclipse, Apache Derby, Apache Geronimo, Globus, Apache Tuscany and Apache Harmony.

[14] http://www.openinventionnetwork.com.

[15] IBM has released parts of its Cloudscape program; Sun Microsystems has released its StarOffice program; Hewlett-Packard has released its Spectrum Object Model-Linker to allow a better connection of Linux to its RISC computer architecture (Lerner, Tirole 2005).

when they use open source code. When the commercial firms release some of their source code they are very often trying to involve the OS community in the improvement or development of some of their products. An example is given by Mozilla, a portion of browser source code released by Netscape in 1998. The final result of these decisions may be quite interesting, also from the users' point of view, although they may bring about different problems concerning the governance of the new mixed project and its legal protection[16]. The problem of the commitment of a commercial firm to the open source project has been solved sometimes choosing to release the source code through intermediaries: Collab.net acted for HP, while the Apache Software Foundation did it for IBM.

When the commercial firms use open source code some kind of legal problems may arise. But in this case what really matters is the degree of restrictiveness of the OSS licenses. An example is given by Microsoft which has incorporated source code from an open source product (BSD operating system) in its Windows 2000 and XP. This licence requires only to acknowledge publicly the use of a BSD's code, that Microsoft did, but does not require to disclose the source of the derived work which has embedded the open source code itself (Krishnamurthy, 2005). Apart from this anecdotal evidence, there is a growing empirical literature which tries to shed light on the preference of the commercial firms for different OS licensing schemes (Koski, 2005; Bonaccorsi, Rossi 2004).

Morover, commercial firms buy open source companies. Sun Microsystems has recently bought MySql, the most famous open source database[17], to integrate it on its server and operating system Solaris. Microsoft has announced that it might buy open

[16] The Mozilla case is a vivid example. After an initial attempt to disclose the Mozilla source code, which did not succeed in attracting the OS developers attention because the program lacked of modularity, Netscape restructured the program and released the new version of the source code. Once obtained the improvements from the OS developers, Netscape tried to bring the program back to a proprietary type of licence but the OS community complained about this decision. Eventually, Netscape chose to maintain the source code open under a new type of licence, the "Mozilla Public Licence" which protects the openness of the source even more than the GPL (Mockus *et al*. 2005; Lerner Tirole, 2005).

[17] MySql has distributed more than 100 million copies and its users are Facebook, Google, Alcatel-Lucent, Nokia and China Mobile.

source companies revealing a first public acknowledgement of the creativity of the open source model which other commercial firms have already shown[18].

These are just few recent examples of how the OS products are changing the strategies of commercial firms and their business models. A growing empirical literature is now trying to assess the role of OSS in the software market looking not only at the size and the dynamics of the phenomenon but also investigating into the drivers of individual and firm motivations to choose the open source mode of production.

2. OSS on innovation and competition

The stylized facts introduced pose now the question of why should OSS products be realized and innovated in a market where firms are driven by the profit incentive.

2.1 OSS and the incentives to innovate

The economic analysis of the innovation process starts from the study of the incentives and suggests two main views on the source of innovation and creativity which bring to different policy suggestions. For the "incentives school", as Farrell and Shapiro (2004) call it, innovation is driven by returns. What matters for the innovators is the appropriation of the largest portion of benefit from their innovations. This way of reasoning is deeply rooted into the economic theory which argue in favour of the intellectual property rights protection. The introduction of a patent system has become the most common adopted policy to protect intellectual property, granting a temporary monopoly to the patent holder, in order to recover the costs sustained for the innovation and make enough profit to invest in further R&D activities. The loss in social welfare due to the monopoly prices is compensated by the gain brought to the community by the innovation.

The "openness school", on the contrary, points out that there are other incentives apart from achieving profit. This view is grounded in the "open science" paradigm where scientists disclose and share the results of their researches and the commercial firm work with or finance scientific foundations (Dasgupta, David 2004). A behaviour which was very common in the early stages of development of the software projects,

[18] In 1998, Microsoft had already expressed a private opinion on the effectiveness of OSS in some internal and supposedly secret documents which were disclosed subsequently and became known as the Halloween Documents.

until the beginning of 1980s, when AT&T started to enforce its intellectual property rights on Unix, which was originally developed in its Bell Laboratories (Lerner, Tirole 2005).

For the OSS contributors the incentives rely mainly within the mode of production of their programs. The most widely cited piece of economic analysis (Lerner and Tirole 2002), on the motivations of OSS contributors try to give an answer to the startling question of why people, apart some kind of altruistic motivation, should devote their time in working at projects without pay. With a simple scheme of cost benefit analysis, the authors compare the opportunity cost of the contributor‘s time with the sum of her immediate benefit, due to fixing a bug or customizing an OS program, and her delayed benefit in terms of future career and peer recognition. These two incentives goes under the heading of “signalling incentive”, since the developers receive public credits for their contributions, and are considered the most relevant drivers in contributors’ motivation. But the findings of a growing empirical literature[19], reveal a more complex and rich motivational framework than that asserted by Lerner and Tirole.

The empirical studies suggest that individual motivations might be both intrinsic, i.e. the contribution has a value per se, and extrinsic, i.e. the contribution will bring external benefits. Contributors are usually driven by a combination of intrinsic and extrinsic motivations and for many of them the intrinsic motivations (to enjoy their personal creativity, to expand and share their knowledge, to feel the sense of community identification[20]) prevail over the extrinsic ones concerning future career and monetary rewards (Lakhani, Wolf 2005). This brings us back to the role of altruism and reciprocity and suggests that further investigations on individual motivations are required .

[19]The data are collected trough questionnaires administered by sample to OSS contributors or looking at the entire community or at the characteristics of the projects. The survey gives also insights into the personal characteristics of contributors. On average, the contributor is usually a male, with an average age of 30 years, highly educated, living in North America or Western Europe (Lakani, Wolf 2005; Hars, Ou 2002; Ghosh et al. 2002).

[20] To be recognised an *hacker* is a sign of honour within the OS community which use this term to mean someone able to solve programming problems, to have fun and to share code with others. The meaning is quite different from that commonly used to identify someone who tries to obtain valuable information in a unlawful way and that should, instead, be called *cracker* (Raymond, 1996).

The empirical findings on the motivations of commercial firm, which have started to work with the OS community and support OS projects, suggest instead that firms are more likely to be driven by economic incentives (Wichmann 2002; Bonaccorsi, Rossi 2004; Iansiti, Richards 2006) although the trust they enjoy within the OS community might be considered somewhat equivalent to an intrinsic motivation to work with the community.

In addition to investigate into the motivations of contributors, to join and to stay within the OS community, the empirical surveys give also significant insights into the organisational patterns of OS projects as well. The development of OSS is relevant to understand if and how it can empower the innovation process in the software market and if its organisational procedure could be adopted by the commercial firms as well.

Although the number of developers and projects is very large and steadily increasing[21], the participation of each developer is usually limited to a small numbers of projects and only about 30% of the projects are developed by more than 5 contributors (Krishnamurthy 2002; Ghosh *el al*., 2002). Within each of these, so called, large projects one of the contributors is recognised as the leader of the project by the others. Usually she is the programmer who has started the project and has been clever enough to leave some relevant problems still unsolved for gaining further contributors to the project. Her leadership lies entirely on the trust she is able to obtain from the contributors of her project who share her objectives, follow her suggestions and work on a pure voluntary basis, mostly just for few hours a week. A good leadership is essential for the success of the project and to reduce the risk of forking, i.e. the splitting of the project or its development into a variety of applications which may waste resources of the community (Lerner Tirole, 2002). So the entire OSS development process looks much less loose than it is conventionally thought.

Two more features of the OSS innovation process look relevant. One is the fact that, since the source code is open and thousands of people are running OSS on their PC, the probability to get feedback from them is quite high. This is the so called “user driven

[21] As recorded at January 2008, the number of projects and users registered on SourceForge.net is 167.880 and 1.778.800 respectively with an increase of 400% if compared with the data on projects (39.000) referred in Lerner and Tirole (2002). SourceForge.net is one of the largest Open Source Repositories togheter with Savannah, Freshmeat and the GNU repository.

innovation process" (Von Hippel, 2005) or demand side learning effect (Casadeus-Masanell, Ghemawat 2003) and it represents another engine in the innovation process which is not shared with the PS whose users can, at most, send a note but cannot work on the source code even if they have the skill to do so. The other is connected to the fact that, lacking of economic incentives, the contributors may sometimes decide to follow more expensive research paths that could not have been followed in a profit driven context and which may instead turn out very fruitful.

When the knowledge process is cumulative, as often it happens for the software products, the disclosure of the results achieved turns out to be an efficient procedure because it permits to intervene from the very early stages of the development of the product and this explains why the number of OSS versions released is much higher than those of proprietary software (Bitzer Schroder, 2005; Krishnamurthy, 2005).

Released often[22] and under the scrutiny of a large number of interested experts, the OSS is considered by users and competitors a product of high quality, reliability and security for its adaptability to individual and organizations' needs.

The OSS production mode based on voluntary networks, supported by an improving communications technology, and the accessibility of the source code is therefore a unique and not repeatable by commercial firms. Only few features of the OSS organisational procedure could be adopted. One is related to the organisation of the working time of their programmers. Leaving them free to work for few hours a day or week on some their own project or to work within OSS projects during their working hours, the commercial firms might try to increase the productivity of their own employees. The other feature refers to the fact that the commercial firms may try to improve the communications with its own users to take advantage of its own demand side effects (Casadeus-Masanell , Ghemawat 2003).

Motivations and internal organisation of the OSS production mode are therefore relevant to understand if this process is efficient and how it contributes to the innovation of the software market. Another important aspect to investigate is whether the increased degree of competition on the software market, due to the emergence of the OSS products, can influence the innovation process as well.

[22] "Release early, release often" is a leading principle within the OSS community (Raymond 2001).

2.2 OSS and competition

The stylized facts considered previously suggest that OSS products improve competition and extend the software market. The OSS have added further segments to the software market through the customization of software to satisfy more sophisticated users [23] and it may represent a serious alternative to the proprietary products, when they compete on the same segments of the market. This happens, on the market of operating systems, with Linux, or on the market of web servers, with Apache. While on the market of desktop operating systems, which is a typical mass market of pre-packaged software products, the presence of OSS products is significantly lower.

In the segment of web server, Apache has been the first mover and this might explain its dominance for more than ten years. But the gap between Apache and Microsoft is almost closed now and the structure of this segment of the market is evolving toward duopoly. The increase in Microsoft share is mainly due to the growth of blog providers[24] such as MySpace, Windows Live Spaces which use its Internet Information Services (II-S). The decrease in Apache share is due also to the switch of sites at Blogger to Google's GFE which is emerging as a third competitor. The relative positions of the Apache and Microsoft are changing also within the different domains (*.com, .org, .edu*). It is interesting to notice that Microsoft has almost reached Apache in the *.com* domain (Netcraft, 2007[25]), while Apache keeps its dominant position in the *.edu* and *.org* domains. This might suggests that commercial firms still prefer proprietary software while institutions and non profit firms choose open source products.

On the segment of desktop operating system, instead, OSS cannot displace the incumbent firm which has a much larger installed base and enjoys strong network

[23] According to Bessen (2003) the inability of commercial software developers to offer a customized product can be considered as a case of incomplete contract, because of asymmetric information and transaction costs, which brings about a market failure which OSS may correct.

[24]Blog is a kind of personal diary or individual web page which anyone can put on Internet withe idea of sharing his or her own experience with others.

[25]The Survey is related to servers which host over 5000 sites. In the *.com* domain, the share of Apache is around 43%, behind its average on server segment of the market, while Microsoft is 38%, that is over its own average (August 2007). In the *.edu* domain the values are, instead, 54% for Apache and 31% for Microsoft (June, 2007) and in *.org* are 47% for Apache and 35% for Microsoft.

effects. Nevertheless OSS can increase competition, pushing the incumbent to lower its prices or to adopt different pricing strategies. Microsoft has been the first to move into the market of desktop operating system in1975. In 1985, Microsoft released the first version of Windows in 1995, and later on Windows 98, which included Internet Explorer, its own web browser[26], for free. Microsoft specialized in software but created strong vertical integration with the hardware side of the market. Microsoft signed exclusionary agreements with personal computer producers, with the aim to have its operating system preinstalled on their products in exchange of information on how the operating system could affect their computer architecture, and with Intel, the largest producer of microprocessors, in order to get the computing power needed to support its software platform (Evans *et al*. 2006).

In addition to its bundling strategy, Microsoft has also followed an aggressive pricing policy setting the price of Windows lower than its near-monopolist position could have allowed[27] and has adopted a policy of price discrimination toward some kind of users[28].

Therefore, with aggressive commercial and pricing strategies and large investments, in each new version of its operating system software and applications, Microsoft has been able to keep its dominant position with a market share of 90% compared to the 5% of Apple, the most known hardware-software vertical integrated company, and the 3-4% of Linux.

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[26] Netscape Communications and IBM were the first to introduce their own internet browsers in 1994, followed by Microsoft and Apple. In 1995, Netscape Navigator reached 80% of the market for this application.

[27] Hall and Hall (2000) have tried to quantify the effects of Microsoft's behaviour. Since any computer producer can develop an operating system instead of buying Windows, Microsoft priced Windows in order to make self-supply unprofitable to computer maker. Assuming that the costs to develop a new operating system would be around $9 billion, to set the price of Windows at $60 instead at the monopoly price of $813 allowed Microsoft to keep its dominant position in the desktop operating system.

[28] Microsoft has recently started to sell the last version of Windows Office (2007), which include in addition to the usual applications: Word, Excel, PowerPoint and Outlook, few others such as Access, Publisher, OneNote and Groove, at 10% of its price to students of high school and college in the U.S. and Europe, with the declared intention to fight piracy. That offer, named "The Ultimate Steal", might be interpreted, instead, as an attempt to induce students to chose a software product at a very low price and distract them from the temptation to download Linux in order to contrast the attitude of some government to introduce Linux in schools. Th is price discrimination policy looks more like a competition for the younger share of the market when users are at still sensible to some kind of "informational imprinting", in the attempt to reduce what Lerner and Tirole (2002) call the "alumni effect", instead of a fight against piracy.

But something is changing. From one side, Microsoft, alleged by antitrust authorities for adopting anticompetitive actions[29], has agreed to adopt less exclusionary arrangements with computer firms to give them and consumers the choice on alternative middleware, such as Windows Media Player[30] and Internet Explorer. Microsoft has also accepted to enhance the interoperability of its products with others. On the other side, some personal computer producers, such as Dell, are starting to sell their product with preinstalled Linux, while IBM and HP are actively contributing to Linux development. Intel, too, is working to improve the compatibility of its microprocessors with Linux in order to support Linux platform (Lintel) and become more independent from the Windows platform (Wintel). The OSS community is always very active and there are various attempts to improve the usability of OSS products which should attract the less sophisticated users.

To conclude, we notice that, although the desktop operating system has attracted wide attention, by scholars and institutions, what is ongoing in the server operating systems, as the recent attempt to acquire Yahoo by Microsoft, will be relevant for the future of the whole market.

2.2.1 Theoretical and empirical findings

Many analytical studies have tried to compare costs and benefits of commercial and OS software in general terms or comparing directly Linux to Windows as the best products available, although non entirely representative, of the two sets (Varian, Shapiro 2003). What is taken into account in these cost/benefits analysis is the total cost of ownership

[29] That binding strategy, gave rise in 1998 to a famous and much debated antitrust case *U.S. v/ Microsoft.* According to allegations, Microsoft adopted anti-competitive actions in the attempt to maintain unlawfully its monopoly. Netscape browser, in fact, could be run on different operating system and, in conjunction with Java- a new programming language, created by Sun Microsystems in the same period, that allows programs to be run on any operating systems -, could attract many application developers and become a platform in competition with Microsoft.

[30] Microsoft adopted again, in the following years, its binding strategy combining Windows with Media Player. This gave rise, together with the allegation of lack of interoperability information necessary to allow competition in the work group server operating system market, to another antitrust case by the European Commission for abuse of dominant position. The Commission's decision, taken in 2004, was confirmed by the European Court of Justice in September 2007. Microsoft has been required to pay a fine of € 497 millions, to release a version of Windows without Media Player and to supply interoperability information, licensing communications protocols between Windows users and non-Windows servers. This last requirement is much debated since the level of interoperability required by the Commission, will require, according to Microsoft, to disclose the full functionality of Windows and give information on the working of Windows server to Microsoft's competitors.

(TCO) and the software quality. TCO is obtained adding the initial price of software to the costs of maintenance, user training and upgrading, spanning over the entire life of the product. Software quality is a multi dimensions variable whose components are usability, compatibility, stability or reliability, and security. Although these variables are difficult to compare, mainly in the case of quality, according to evidence, purchase price and usability are the drivers in desktop operating system while compatibility and security are considered more relevant in the server and web server operating system segments of the market.

Few theoretical studies, instead, have tried to formalize the effects of direct competition of OSS in software markets. These contributions use duopoly competition type models or the theory of market leaders to explain the behaviour of the firms and to give insights into the evolution of the market. The duopoly competition models stylize different market features and the underlying assumptions. Bitzer and Schroder (2005) proposes a duopoly model where competition is on technology, instead on price or quantity, and show that the evolution of market structure toward a duopoly has a positive impact on innovation. Mustonen (2003) addresses the constraints that proprietary software monopolist faces, both on the programmer labour market and on the product market, in the presence of OSS. If the implementation costs of the OSS are sufficiently low, some customers will choose OSS and the monopolist has to take this into account in her pricing policy. Casadeus-Masanell and Ghemawat (2003) analyze competition between Linux and Windows in a dynamic setting. The OSS is characterized by a much stronger demand-side effect and Windows by a larger initial installed base. If Microsoft's first-mover advantage persists in time and it uses its market power to price Windows strategically, Linux will never obtain the market leadership unless the cost differences between the two increases significantly or strategic buyers, such as Governments and large corporations commit themselves to the development of Linux. Somewhat different is the contribution made by Economides and Katsamakas (2006) which compare Linux and Windows operating systems as platforms. Therefore pricing decisions for the products sold to end users can be used strategically to influence the complementary applications markets. An OS platform, such as Linux, allows compatible proprietary applications from commercial firms which may have

strong incentives to promote the OS platform to increase their profits. Under certain assumptions, the model suggests that the firm can make more profit, providing applications to the OS platform, than being proprietary both of the platform and its applications. Etro (2007) applies his theory of market leaders to explain some stylized facts of software market. His analytical tool gives a strong theoretical ground to the explanations proposed by Schmalensee (2000) and Economides (2001). They suggest that, although market share implies that Microsoft is a near-monopolist in the market for desktop operating system, the competitive pressure that Microsoft has to face, also from OSS products, has refrained it from pricing Windows at a monopoly price and to set a much lower price.

In general, these contributions state that there is no evidence of a negative impact of OSS product both on innovation and competition. On the contrary, the competition between OSS and commercial products refrain the incumbent firm from exerting fully its market power, pricing lower and investing in innovation.

How can OSS contribute to the evolution of market structure becomes therefore relevant to evaluate the social welfare consequences and the policy decisions taken by governments (Casadeus-Masanell, Ghemawat 2003; Johnson, 2002).

3. Government policies

Governments may decide to support the growth of their national software industries adopting different policies which may affect proprietary or OS software or both.

Before starting to evaluate the relevance of different policies on the software market, it is worthwhile to remember that government defence-related spending in R&D and procurement had sustained the early development of software industry in countries such as U.S. and U.K[31]. In the post war period, governments spending contributed to the development of computer technology, including the first attempts to separate software from hardware, and the training of researchers in computer science, a new academic discipline that joined basic research to the development of hardware. In the following years, the private computer industry, already active on innovations, attracted high

[31] See Mowery and Langlois (1996) for a detailed account on the role of government expenditures on evolution of U.S. software since the post war period.

trained people from universities and built on the results of researches mainly funded by the government. Therefore the role of governments, financing the relatively open research environment of universities, has been relevant in the dissemination of information and the diffusion of innovations. At the same time, government supported the growing industry as one of the largest buyers of software, at least until 1980s.

More recently, governments have started to support OSS, mainly acting as a purchaser, for a variety of reasons. For instance, because OSS is considered less costly or more secure and reliable than the proprietary software or because it may level the playing field improving competition in the software market.

Governments can then support national software industries adopting policies that may affect directly these industries and their evolution. At the same time, policy interventions may take the form of a legal protection, as the adoption of patent systems, that are justified by the presence of some kind of market failure which prevent producers to capture the full value of their products

3.1 Patent system

The introduction of a patent system has become one of the most common way to protect intellectual property granting a temporary monopoly to the patent holder, in order to make profit and to recover the costs sustained for the innovation, and requiring the disclosure of information on the innovation. The loss in social welfare due to the monopoly prices is compensated by the gain brought by innovations.

The big challenge to the innovation process of the OSS comes from the legal system of protection given to proprietary software.

Without entering into the debate over the role of the patent system to protect IPRs to incentive the innovation process, few considerations on the analytical contributions may support the discussion over the opportunity of granting and redefining the length and the breadth of patent legal protection for software products that is relevant for policy issues.

Theoretical contributions on this subject suggest contrasting views when innovations are cumulative and sequential as for software products. The analysis deeply rooted into the incentives school asserts that patent system gives the right incentive to innovate, when the incumbent monopolists are leaders in the patent race, and suggest that

innovators are not overcompensated (Etro 2007, Denicolò 2007). Moreover since innovations are cumulative, the patent system can also be shaped to share the profits among sequential innovators (Scotchmer 2004). On the contrary, other contributions (Bessen Hunt, 2004; Boldrin Levine, 2007; Bessen, Maskin, 2006) underline that, because innovations are sequential, the patent protection may refrain other competitors to work on further developments. In this case the conclusion is that without a strong protection by the patent system the industry might have been more innovative.

The empirical literature, too, is unable to give unambiguous results[32]. Boldrin and Levine (2007) going through more than twenty empirical studies have found week or no evidence that a tight patent system will increase innovations with the possible exception of pharmaceutical and biotechnology industries. On the contrary they found evidence, for software patents, that to strengthen the legal protection has increased the number of patents and their scope and their strategic use but has decreased the investment in R&D[33] This does not proof that patents favour innovations but don't exclude the contrary.

Both theoretical and empirical researches are unable to offer a clear cut answer to the role of patents on software growth process but the patent system is already well rooted into the legal system. As Fritz Machlup said, recalling a quote due to Edith Penrose:

"*If we did not have a patent system, it would be irresponsible to recommend instituting one. But since we have had a patent system for a long time it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it*"

So, most probably, patent system is here to stay, but the leading USA experience points out the need of some deep changes in the patent law.

3.1.1 The U.S.lesson

The debate surrounding the legal protection of software market, which is taking place now in U.S.[34], can contribute to understand the on-going discussion on the role of governments and suggest few answers to some significant policy questions that other

[32] The empirical studies on patents and innovations are often criticized because of the definition of patents adopted, or the data and methods of analysis used

[33] See also Bessen and Hunt (2004) and Mann (2006). See Sakakibara and Branstetter (2001) for an analysis of the effects of Japanese patent law reforms.

[34] See, for example, (Graham and Mowery 2003; Bessen and Hunt, 2004; Hall 2007).

countries are facing too. In a global economic environment, despite some changes in the location of new software products[35], the U.S. software industry will, undoubtedly, continue to have a dominant role[36] (Arora 2007). Moreover U.S. patent system is considered the most protective of all and U.S. have been very active in promoting a process of harmonization of patent systems across countries and in supporting international agreements, such as the Trade Related Aspects of Intellectual Property Rights (TRIPS) of the World Trade Organisation. The TRIPS agreement has introduced the protection of IPRs into multilateral trade agreements and has defined the guidelines to national laws.

Many relevant features characterize the U.S. model which is considered, in every respect, a "first mover". In fact, the U.S. has been the country where the software and its market has been created and the movement of software programmers, which gave rise to the open source community, appeared first. In the U.S., the protection of software related IPRs was first introduced and has become progressively more stringent. In the 1970s, computer programs were protected under the copyright law[37] but in 1981, the Supreme Court introduced a principle that allowed the patentability of computer programs[38]. In the following years many courts allowed software inventions to be patentable and many patents were granted. While the legal protection of software trough copyright law decreased continuously, the courts and the Courts of Appeal Federal Circuit (CAFC) rulings[39] strongly increased the protection through patents, although the U.S. congress has never legislated to grant patents to software. The rapid growth of software patent applications, due also to the diffusion of business methods[40]on the internet, has overburdened the patent office and, given the lack of specialised expertise on that subject, has increased the period of application examination and reduced the

[35] Ireland, India and Israel are the countries with the most active national software industries.
[36] According to OECD annual report (2004), 8 over 10 of the top software firms are in U.S.
[37] In that period, computer programs, as they were named, were assimilated to mathematical algorithms and, as such, not patentable. In the 1980 they were included in the U.S. Copyright law.
[38] In the *Diamond v. Diehr* case, the Supreme Court required the Patent and Trademark Office (USPTO) to grant patent to an invention largely based on a computer program.
[39] In 1994, *In re Alappat*, the CAFC stated that a mathematical algorithm loaded in a computer device has to be treated as a new physical device and therefore patentable thus eliminating the distinction between software and other inventions.
[40] The business method patents are patent on methods of selling products over the internet. One of the best known is the one-click patent granted to Amazon which used it to sue Barnes & Noble.

quality level of patents[41]. An increasing number of patents, due also to IPRs fragmentation [42], tend to create a "patent thicket"[43], that is a set of patents that protect overlapping IPRs and requires multiple licenses from patentees. Both fragmentation and patent thickets increase uncertainty in the market, for fear of infringements and litigation costs[44].

Therefore, the patent system has changed the industry organisation inducing large companies to increase strategically their patents portfolio to prevent entrance, to stifle innovations and to favour patent partnership and cross licensing agreements in order to protect themselves from litigation. So the licensing of software is indeed become an activity in itself, not only for firms with large portfolios but also for the so called "patent trolls" which act as intermediaries developing, acquiring and licensing patented technologies without producing any software.

Progressively, the issue on low quality patent and high litigation costs has overshadowed the issue on the relevance of patents to innovation. A number of legal and economic scholars and governmental institutions, such as the Federal Trade Commission (2003) and the National Academy of Science (2004) and the USPTO (2003), have started to recommend changes to the patent system. Suggestions[45] were mainly intended to simply the administrative procedure, to improve the patents quality, to reduce market uncertainty and to improve harmonization with the European and Japanese patent examination systems.

The bill on patent legislation, approved recently by the House of Representatives, tries a few steps in that direction. Switching from first-to-invent to first-to-file is the most relevant change related to the priority given to patent application and bring U.S. patent system more in line with every other country's patent system. Other changes

[41] Patent law require that an invention has to be new, useful and non-obvious. The quality is related to the degree of novelty. For instance an invention may be already in use but not yet patented (Hall, 2003).
[42] According to Mark Webbink, vice president of Red Hat, an example of this strategy is given by Microsoft that has 14 patents on positioning and movement of a cursor. In particular, one invention refer to add and delete white space on a document that is protected by two different patents: one to add and the other to delete the white space.
[43] See on this point Shapiro (2001) and Evans and Layne-Farrar (2004).
[44] The cost of litigation has been estimated in $ 1.5-2 millions per side, per claim (Webbink, 2005).
[45] The remedies suggested to tighten the evaluation standards of the requirement of non-obviousness, to give special attention to the scope of the patentable invention, to give publication to all patent application after 18 months and to provide more resources and experts to improve the patent examination procedure.

limit the amount of damages imposed on patent infringers, refer to the conditions of patentability and introduce of post-grant review procedures which should improve the quality of patents.

The bill is still at the centre of the debate. Before passing in the House, it has been in the works, in different forms, for more then five years and it might not be approved in the present version by the Senate or even signed by the President. Contenders of the bill point out that the changes introduced to the patent system will not make the granting procedures significantly more efficient and that the bill does not take into account that industries have different innovation paces.

Therefore, even if analytical contributions suggests that patents are controversial in software industry we observe that, in the real world, commercial firms continue to increase their patent portfolios, public and private institutions suggest to strenghten the patents legal protection and politicians debate over how to improve the patent system.

The relevant question, for the purpose of this paper, is whether the patent system and its changes may build barriers to threaten the OSS innovation process and its growth in the software market (Lessing, 2003). Given the cumulative character of software innovations and the increasing number of patents, a real problem is connected with the risk of intellectual property rights infringements and the changes introduced by the new bill [46] will not improve the present situation. Although a large commercial firm, such as Microsoft, claims that OSS infringes more than 230 of its patents but don't proceed to enforce its patents, others, such as patent trolls, have started to file suit against OSS vendors[47]. These legal issues might became more relevant for the development and, even more, for the diffusion of OSS because of the concern expressed by potential licensees about patents infringements when using OSS. However a number of non-profit entities born around the Community, such as Linux Foundation, the Software Freedom Law Center and the gpl-violations.org[48], are starting to provide legal advices and services to defend producers and vendors of OSS and, at the same time, to protect

[46] For instance, the Software Freedom Law Canter has expressed its concern on a provision of the bill that eliminate the request of the re-examination of patents by members of the public to the U.S. Patent Office.
[47] IP Innovation and Technology licensing Corporations, patent trolls filed a suit against Rad Hat and Novell.
[48] The gpl-violations.org is an organization founded by Herald Welte with the purpose to prosecute infringements of GPL and did it for all the enforcement actions in Germany.

Linux and other open source products against the infringements of their licences by commercial firms.

2.2 Procurement and subsidies

Governments may promote OSS products choosing or suggesting the choice of open source instead of proprietary software in all public administrations, schools and universities. Governments can also decide to fund software R&D. In this Section, we shall try seek the economic rationales that may justify the government decisions to support OSS products.

The increasing usage of OSS by governments is proved by a long list of anecdotal evidence and some systematic empirical evidence, obtained through surveys. Examples are given by European countries, U.S. and many other countries around the world. In Europe, some governments have decided to promote, software projects that disclose the source code, such as France, Germany[49] and Italy[50], or to consider OSS alongside proprietary software in procurement, as in U.K. In U.S., the NASA has adopted Open Source solutions to program its Mars projects. In 2007, the government of South Africa has decided, to migrate to OSS and the Russian government has decided to migrate all schools to GNU/Linux by 2009.

The European Union sponsored a very extensive survey on the usage of free (libre) and open source software (named FLOSS) by firms and public institutions in 13 European countries. The FLOSSPOLS final report (Ghosh *et al*., 2005), on the local governments, shows that about 49% of the participants in the survey use, on average, open source products and that the use of the Linux, as operating system, is much larger than its use on desk-top. Although the results suggest a growing attention by governments towards FLOSS, there exist some significant differences between European countries. Spain, Austria, Italy, Germany, Sweden and Belgium, are over the average countries' share of FLOSS users, while France is close to the average and the

[49] The German government passed, in 2001, a resolution "Germany's Economy in the Information Society" to promote OSS.

[50] Directive by the Minister of Innovation and Technologies, December 2003 (G.U. 7 February 2004, n. 31). See also the survey od the Minister of Innovation and Technologies (2003) on the usage of the OSS in Italian Public Administration.

U.K. is fairly behind. The survey came out with the conclusion that, although FLOSS has not become a standard, the positive attitudes towards open source suggest that the usage of FLOSS is due to increase but not to replace proprietary software.

In Italy, the national agency for ITC in Public Administration, in its 2006 annual report (CNIPA 2006), refers that 72% of national and local administrations use OSS on their servers, compared with 54% in 2003, but 9% only use it on desk-top. These results are in line with those presented by the European FLOSS survey. It is interesting to notice that the relevant motivations for choosing OSS are lesser costs (56%) and fast acquisition (29%).

Cost saving advantages, a motivations given by the Italian Public Administrations, is one of the economic rationale behind the choice of OSS products that cannot, therefore, be compared to a government intervention on the software market.

Besides to reduce the total cost of ownership (TCO), which should improve their static productive efficiency, governments may consider other motivations as well. To lessen of the risk of vendor's lock-in and to have open access to the source code allows public administrations to adapt the software to their needs, reducing the dependence on single providers and improving the level of security and protection of sensible information belonging to governments and citizens.

In addition, to support the usage of OSS products in public administrations, governments can and do promote their adoption in school and universities. Here, the motivations are not only the reduction of costs, as before, but also the construction of an open and stimulating environment which help to enhance the skills of future manpower that have to cope with fast changing requirements.

Although the government decisions to adopt OSS are driven by economic rationales, as we have just seen, critical voices against the adoption of OSS suggest that the increase in the OSS market share, due to the adoption by government agencies, may reduce social welfare when competition is between two or more compatible products. The argument is that, since commercial firms can't compete for that share of the market, they may increase the price of their software and, because of the reduced size of the market, their incentive to innovate will be reduced as well (Schmidt Schnitzer, 2003; Evans Reddy, 2002). This view can be contrasted with the findings in Section 2 that

suggest that the OSS products, when their market share has reached a critical mass, play a relevant role in the software market with regards both to competition and innovation. If so, the role of government, as a buyer, will help to increase the OSS market share and to level the playing field.

Another government intervention in software market is the funding of software projects. Here again U.S. have a prominent position because government's spending in R&D software are substantial[51] and much in line with the tradition of supporting basic research[52] through government research centres and universities. Since basic research are considered as a public good with large positive externalities that cannot be internalized, government funding represents the solution to this market failure and allows to reach the social optimal level of research. Although the strong economic motivation to fund basic research is uncontroversial, free-market supporters contend that the results of public funded research could be disseminated under the restrictive GPL licence and suggest the BSD licence or the dissemination to public domain. So the dissent is on the policy of funding research to support software that will be released under GPL licence (Evans Reddy, 2002; Lessing, 2003) and not on the subsidies to research.

To conclude, we underline that public policies in support of OSS may induce two further effects that enhance the productive efficiency of the whole economy, in dynamic terms. When governments promote OSS in public administrations and in education, they improve the training of highly educated manpower and provides an open computing environment that favours the development of its national software industry (Varian, Shapiro 2003). When governments fund software research and allows to protect the results of these research by the GPL licence, the new knowledge and the new inventions will be freely available to anyone increasing the collective knowledge and avoiding appropriation by commercial firms,.

Although, sometimes the rationales seem to be based on ideology, as some anecdotal evidence may suggests, there are strong economic rationales for promoting the adoption

[51] The most famous is the "Beowulf Linux Cluster", a software for Linux developed by NASA.

[52] Some countries have, instead, invested in the development of local versions of Linux. China has financed Red Flag Linux, and India is doing the same with a Hindi GNU/Linux called Indix.

of OSS by national and local governments. As we have seen those economic rationales aim to improve efficiency, both static and dynamic, and to correct the market failure, due to the nature of public good of the software products.

Conclusions

Software industry is a fast growing sector of the economy which is undergoing significant changes both for the presence of the open source mode of production and for the challenges of globalization and convergence with other industries, such as mobile phones.

As we have seen in Section 1, new strategies and new business models are emerging as a consequence of OSS presence. OSS is changing the industry organisation, because commercial firms are adopting new business models,. OSS is also shaping the market through the emergence of new subjects such as the OIN and the Foundations. OSS has induced the profit seeking firms to rethink both their mode to produce intellectual products and how to protect them. Patents commons and creative commons experiments testify the need of a deep change in the patent system and suggest that the idea of "one size fit for all" cannot work any more.

In Section 2, we have considered different government policies. We have discussed the role of IPRs legal protection for software products and found strong economic rationales for supporting the adoption of OSS products by governments. As a consequence, we suggest that governments should choose a combination of different policies instead of adopting the so-called "government neutrality" that requires only to protect market competition, given the existing patent system. But the adoption of this combinations of policies, requires to fulfil some assumptions on the existence of market failures and on the role of IPRs legal protection. In brief:

- If there is a market failure in the private production of knowledge, then legal protection can offer some remedies;
- If research have large spillover effects and don't attract private investment then government's spending remedies the market failure;

- If software products have given legal protection, this can be done both by copyright[53] and patent system;
- If a patent system is considered an appropriate solution for software products, it has to be shaped to take into account that the software industry has:
    - a technological pace faster then other industries, therefore a 6-8 years period would an adequate length;
    - a cumulative and sequential innovation process that requires to reduce the breadth;
    - strong network effects that requires to improve interoperability and possibly the disclosure of some of the source code.

This means that, in order to balance public and private interests, the patent system has to change, but not in the direction of increasing the legal protection as it has been suggested recently by some scholars and institutions[54].

The problem of balancing public with private interests gets even more complicated when we consider globalization. This is indeed a subject on its own. Here, we just want to underline that the globalization is not only a challenge to the development of the software industry, because the developing countries tend to promote OSS products, but also to the system of IPRs legal protection. The definition of an international IP regime with minimum standards requirements will probably avoid to consider the IP protection as a new kind of trade restriction.

To conclude on the role of OSS products we can say, with Varian and Shapiro (2003), that OSS is here to stay. OSS will go on fuelling the debate among scholars because it challenges some relevant pieces of economic theory such as the theory of economic incentives, of labour organization and that of the private provision of a public good.

[53] Copyright protection for software are recommended by scholars (Webbink 2005) and Institutions (Deutsche Bank Research 2004).
[54] See the Gower Review on Intellectual Property (2006).

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