Openess and innovation: comparing Free/Open Source and proprietary solution

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Abstract

The innovation processes in the software sector is currently widely debated. Challenging questions arise about what products/services have to be considered innovative, and whether a specific artefact is innovative or not. In this framework, The widespread success of the Free/Open Source Software (FOSS) puts forward new research issues, dealing with whether and how the free circulation of ideas championed by the FOSS movement and its collective management on intellectual property rights (IPRs) on computer programs foster or humble innovation. The aim of this paper is to contribute to the existing literature by addressing the following research question: are programs based on FOSS solutions more innovative than proprietary ones, and, if so, why?

This exploratory study, basing on a sample of 134 software solutions produced by Italian Small and Medium Enterprises (SMEs) and using a frequently used methodology in technology management to evaluate innovativeness of products and services, provides first insights of what emerges if, setting aside the traditional innovation indicators, we endeavour to build alternative metrics, specifically developed to target the complexity of the innovation processes in the software markets.

JEL code: L17, L86

1. Introduction

The issue of innovation processes taking place in the software industry - and, more generally, in all the sectors of the so called *New Economy* (Information and Communication Technologies-ICT-, business and professional services enabled by the Internet, an so on, Carlsson, 2004) - is widely debated by economic scholars (see for instance Bloch, 2007). Challenging questions arise about what products/services have to be considered innovative, and whether a specific artefact is innovative or not. Which is the boundary line between an innovative software solution and a program that is not at all innovative? Does the process of adapting solutions to different platforms to satisfy heterogeneous customers' can be considered *innovation*? Which aspects should be taken into account in order to highlight the most important elements of innovation processes in the software sector?

In this framework, the increasing diffusion and adoption (Weeheler, 2007) by individual users and companies of the Free/Open Source Software (FOSS) put forward new research issues, dealing with whether and how programs developed according to the FOSS production mode turn out to be more innovative than those produced according to the traditional proprietary model. Whilst several practitioners[i] and researchers (Ghosh, 2006; Osterloh and Rota, 2006; Raymond, 2001) agree that FOSS model leads to faster incorporation of innovative ideas than the proprietary regime, others (Tuomi, 2005; Dulaney, 2007) refer to it as a simple imitation exercise. For instance, is it possible to state that a suite as Open Office[ii] is something innovative? Or is it simple imitation of the analogous Microsoft product? The theme turns out to be fairly intriguing for economic scholars as FOSS represents in itself a disruptive innovation process, currently affecting industrial dynamics within the software sector (Dalle et al., 2007), and it can be regarded as a crucial example of the Open Innovation framework (West and Gallagher, 2006).

The paper aims at contributing to the literature by addressing the following research question: are programs based on FOSS solutions[iii] more innovative than proprietary ones? And, if so, which innovation dimensions are typical of the FOSS production model? We think that this issue is likely to be of great interest for economic and management scholars doing research on FOSS. Indeed, while plenty of descriptive evidence has been provided on business models of firms themselves involved in the FOSS movement (Iansiti, 2006: Krishnamurthy, 2005; West, 2007), the effort devoted to explore economic and innovation performances of companies doing business out of FOSS is still scant. Assessing whether and how FOSS production mode may lead to innovative solutions may represent a first step towards this new and challenging research direction.

In order to answer the research question the paper focuses on a sample of 134 software solutions developed by Italian SMEs. We are aware that focusing on the Italian case made our results far from being generalizable, however, given the exploratory nature of our study and the lack of quantitative analysis on FOSS innovativeness, we are reasonably confident that the empirical evidence we provide may contribute to the literature on the topic. Specifically, using a methodology based on structured experts' assessments to address the problem of evaluating innovation in the software field, the paper provides some first insights of what emerges if we set aside the traditional innovation indicators (namely, patents and trademarks) and endower to build alternative metrics, developed to capture the complexity of the innovation processes in the software sector.

The article is organised as follows. Section 2 reviews the literature on innovation processes in the software sector, focusing in particular on the relationship between FOSS and innovation, section 3 describes data and methodology, while results are presented in section 4. Section 5 concludes and sketches some future directions of the research .

2. Literature review. Innovation in the software sector: which role for FOSS?

The concept of *innovation is old as mankind as* (Fagerberg, 2004) and is one of the mostly studied by scholars in social science (see for instance Flichy and Carey-Libbrecht, 2007; Mahajan and Petterson, 1985; Rogers, 1995), in general, and in economics, in particular (Dosi, 2000; Fagerberg et al., 2004; Freeman, 1982, Nelson and Winter, 1977; Scotchmer, 2004; von Hippel, 1988). However, while its obvious importance for the growth and development of social and economic systems has been widely acknowledged and explored both under theoretical and empirical viewpoints, new and challenging research directions on the topic come into the limelight prompted by the continuous evolution of science, technologies, and human organisations.

The notion has been analysed in several seminal studies, which have highlighted its multiform peculiar aspects, such as the distinction between *invention* and *innovation* (Schumpeter, 1934), the former referring to the first occurrence of an idea for a new product or process, while the latter to its first commercialization; the changes in the characteristics of innovation processes, depending on the different phases of technology development and on a firm's environment and competitive strategies (with initial emphasis on product performance, then emphasis on product variety, and later emphasis on product standardization and costs: Utterback and Abernathy, 1975: 642); the non-linearity of innovation processes (Kline and Rosenberg, 1986); and their fundament role in economic growth (Grossman and Helpman, 1991).

However, scholars seem far from having disentangled all the aspects of a so pervasive, complex, and multiform phenomenon and there is still plenty of room for challenging and insightful researches on the topic. Specifically, it has been acknowledged that the term *innovation*[iv] and *innovativeness* are prone to different interpretations and meanings, depending also on the peculiar industrial sector taken into account (Garcia and Calantone, 2002; Pavitt, 1984).

Let's think, for instance, to the attempts of classifying innovation according to *types*. Schumpeter (1934) distinguished between five different classes: new products, new methods of production, new sources of supply, exploitation of new markets, and new ways to organize business. Whilst several authors have focused on the distinction between incremental and radical innovation (Freeman and Soete, 1997; Koberg et al., 2003) or product vs. process innovation (Edquist et al., 2001), others have identified three (Kleinschmidt and Cooper, 1991) or even more possible levels (Kleinknecht, 1993).

Consequently, it is no surprising that a *comprehensive indicator*, capable to account for every type of innovation in every sector, does not exist. A short list of the most used metrics of firms' innovation effort include: (i) data on Research and Development (R&D) activities both at firm and sectoral level (e.g. R&D expenditure, R&D employees, OECD, 2002); (ii) patents (Cohen and Lemley, 2001; Granstrand, 2004); (iii) bibliometrical data (also called Literature-Based Innovation Output, LIBIO, indicators), as publications in scientific and technical journals (Miyazaki and Klincewicz, 2007).

Moreover, specific surveys and databases have been developed by research groups and public bodies aiming at collecting primary data from firms on their innovative activity. For instance, the Community Innovation Survey (CIS)[v] were developed, for the first time, by the Member States of the European Union in 1992. Data collection is done by the statistical offices or competent research institutes in the Member States, and results of the surveys are treated at national level, using a common methodology, and further processed by Eurostat to increase cross country comparability. Several studies on innovations processes in the ICT sectors (e.g. Gago and Rubalcaba, 2007; Van Leeuwen and Van der Wiel, 2003) are based on data collected by CIS, even if several limitations have been highlighted. Arundel (1997) has stressed the need of paying attention not only to the economic elements of innovation processes, but also to human capital-related aspects; Tether (2001) has pointed out the difficulty to conflate a wide range of activities into a single definition of innovation, obscuring the differences in behaviour of different types of innovators.

Anyway, all previous indicators suffer from several shortcomings (see Kleinknecht et al., 2002, for a comprehensive survey and comparison of the different methods for measuring innovation), which turn out to be fairly severe when attempting to measure innovation in the sectors of the so called *New Economy* (Haskel, 2007). These industries are characterised by elements that make traditional instruments for measuring innovation (as patents or trademarks) almost useless. Indeed, the transiction from a commodity-driven to a knowledge-driven economy forces to consider a whole new set of variables related to how knowledge is created, managed, and circulated among different actors. For instance, special attention should be devoted to the role of knowledge-intensive business services, which are of particular importance for innovation processes (Hipp and Grupp, 2005). For ICT sectors, the very definition of innovation (Preissl, 1998) needs to be renovated, considering aspects related not only to the product itself but also to the services offered with it, treating more deeply all interdependences and knowledge flows (Bloch, 2007). Jordan and Segelod (2006, p. 129) have highlighted that software innovatinevess *can be related to several aspect of the product, such as its features…the impression of its newness, the novelty of architectural structure*.

Specifically, as far as the software field, it has been noted (Blind et al., 2004) that patents are often unable to follow the rapid evolution of the software market (Jaffe, 1999; Nalley, 2000) and to account for the complexity of complementary activities (Kash and Kingston, 2001); other problems deal with the fact that software companies often use alternative instruments of protection (as, for instance, patents on hardware in embedded solutions). The idea stemming from various works is that some modifications to the patent system would be needed (Cohen and Lemley, 2001) to address innovation in the software field[vi].

As a consequence, new indicators are needed to assess innovation in ICT fields (Maruyama et al., 2007). In the case of software, such indicators should take into account not only general aspects, as the drivers of the internal innovation process or the comparisons with other solutions available on the market, but also specific elements, as the use of certain programming languages and platforms, the organisation of the software modules, the writing of new code or the reuse of existing libraries, and so on.

In this framework, the rapid pace of diffusion of FOSS is another source of complexity in analysing innovation taking place in the software sector, as FOSS undoubtedly represents an innovation in processes, business models, and products.

It has been widely acknowledge (Bonaccorsi and Rossi, 2003; von Hippel, 2005; von Hippel and von Krogh, 2003) that FOSS is a disruptive *process innovation* affecting the way in which software is developed and distributed. The centralised and hierarchical production mode traditionally adopted by large software factories (*the cathedral mode*, Raymond, 2001) is now challenged by the de-centralised and bottom up organisation of FOSS projects, where developers from all around the world contribute code and knowledge interacting through the Internet network (*the bazaar mode*, Raymond, 2001). The FOSS success is deeply affecting industrial dynamics within the software sector (Fusfuri et al., 2008, Fitzgerald, 2006). Large enterprises dominating the market are getting more and more involved in the movement. It is no more a matter of simple code releasing to the community (as Netscape did in 1998 with its Navigator), nowadays, complex and multiform collaborations with FOSS communities are maintained by commercial companies like IBM, Sun Microsystem, and even Microsoft. Moreover, the phenomenon does not only deal with large incumbents: an increasing number of SMEs are entering the market by offering FOSS-based solutions to their customers (*Open Source firms*, Bonaccorsi et al., 2006a). In other words, scholars have highlighted as FOSS represents also an *innovation in business models,* based on the rejection of the proprietary control over the source code (Henkel, 2006), the building of communities of users (Franke and von Hippel, 2003; Wang and Chen, 2005), the creative use of licensing (Manenti and Comino, 2007, Lerner, 2005), and the offering of services on successful FOSS programs, like Linux or Apache (Venkatraman et al., 2004).

While many researches have studied FOSS as a process or business model innovation, up to now, few efforts have been devoted to analysing FOSS as a *product innovation*. This represents a very challenging issue as complexity in defining and measuring innovation in the software sector is coupled with the peculiarities of the FOSS phenomenon. For instance, the very distinction between innovation and invention, based mainly on commercialisation, calls for a re-definition in the FOSS world, as barriers between companies and users tend to vanish.

Under a theoretical viewpoint, it has been claimed that the free circulation of ideas, which characterises the FOSS production and organisation model, is likely to favour knowledge creation and accumulation (Murray and O'Mahony, 2007), thus promoting innovation. At the same time, being innovation in the software field largely sequential and cumulative (Bessen and Maskin, 2000), several scholars have pointed out at the risk of enforcing restrictive intellectual property regimes on pieces of code (Kleeman, 1996; Grosche, 2006). The FOSS design of IPRs fosters, instead of forbidding the access to source code (McGowan, 2003), but avoids the *tragedy of digital commons* (Greco and Floridi, 2004) by preventing code hijacking to detriment of the developers' community. Hence, it may be a valid alternative for managing knowledge and preserving the incentives of innovators. Indeed, it has been widely acknowledged that FOSS developers are driven mainly by intrinsic motivations (Hertel et al., 2003), fairly similar to those of scientists doing scientific research (Dalle and David, 2003). FOSS IPRs vouch for the continuous visibility of the source code, which reveals each programmer's ability to their peers, thus providing incentives for the development of valuable code and bright algorithmic solutions.

However, empirical evidence on innovativeness of FOSS products is scant and controversial. For instance, Tuomi (2005) explains that, in his view, there is nothing innovative in a system like Linux, because it simply re-implements functions already present in Windows systems. Klincewicz (2005) has attempted to provide an original classification of innovations in FOSS, based on four classes: radical innovation, technological modifications, platform modifications (passing a solution from one platform to another, a common practise among FOSS developers), and market innovations providing new uses for existing technologies. The author has analysed 500 projects hosted on SourceForge[vii], the largest FOSS repository on the Web, assessing that 436 of them are not innovative, and only 5 can be defined as radical innovations as complex and reliable as proprietary ones. On the contrary, practitioners from the software field often acknowledge the high quality and reliability of many FOSS products (The Economist, 2006). The debate is far from a conclusion, this paper aims at contributing to it by providing empirical evidence on product innovation in FOSS by comparing, under this viewpoint, proprietary and FOSS solutions.

Data and Methodology

The firms whose products are examined in this study come from a large scale survey taken, in 2004, on more than 900 software companies (NACE code[viii] 72.2) from Finland, Germany, Italy, Portugal, and Spain (see Bonaccorsi et al., 2006b, for further details on this survey).

Specifically, we focused on the 323 Italian respondents to this survey in order to inquire about the innovativeness of the software solutions that they produce. The rationales behind the decision to restrict the analysis to the Italian case are twofold. On the one side, it depends on database characteristics. Indeed, corporate names or company VAT numbers, which allowed us to link the survey database to other private and public data sources containing information of our interest, are not available for all the five countries. On the other side, the choice of focusing on Italian respondents reflects our purpose of conducting an assessment of product innovation through experts' evaluations. We had the possibility of engaging Italian experts boasting an in depth knowledge of the Italian software market, hence we focused on Italian firms providing information on their products in Italian. Choosing Italian as the original language of the analysis, we exploited expert knowledge at their best, avoiding language-related problems.

Structural characteristics of the 323 Italian firms are reported in table 1.

Table 1: Structural characteristics of the 323 Italian firms.

Variable	*Unit of Measurement*	*No. of obs.*	*Min.*	*Max.*	*Mean*	*St. Dev.*
Age (at the moment of the survey)	Unit	323	0	33	10.8	6.3
Size	Unit	318	1	230	9.3	18.3
Number of founders	Unit	316	1	9	2.6	1.5
Graduate staff	%	300	0	100	36	0.4
Software developers	%	293	0	50	30	0.2

They are mainly SMEs that have entered the market only recently. More than 90% of them have a total staff of less than 20 employees, and, in about 16% of cases, they are one-man businesses. About 59% have been founded by one or two promoting partners; 66 firms out of 323 (20.4%) were founded since 2000. The entry process seems to continue: about 6% have entered the market after 2002. 167 companies provide to their customers FOSS-based software, often mixing it with proprietary offerings (*hybrid firms*, Bonaccorsi et al, 2006a). As far as skills, the average percentage of staff with a University degree is fairly high (about 36%), as it is the one of software developers (almost 30%).

Evidence on firms' main customers is reported in table 2. Respondents serve mainly business customers (81%), particularly SMEs (64%), while very few refer to University (3%) or end users (3%).

Table 2: Italian firms' customers.

Customers' typology	*No.*	*%*
Small and medium enterprises	207	64
Large firms	54	17
University and research centres	9	3
Public sector	38	12
End users	10	3
Other customers	5	2
TOTAL	323	100

These figures highlight as the peculiarity of the Italian software market and its difference from the United States market. First, it is a matter of sale volumes: the US software sector is passed from 269.4 billion dollars in 2004 to 302.8 billion dollars in 2006, during the same time period, the Italian software industry passed from 13,280 million euros in 2004 to 13,481 million euros in 2006[ix]. Second, also firms' structural characteristics are different between the two countries. Italian software companies are prominently very small: more than 94% of them have less than 10 employees, and around 98% have less than 20 employees[x]. On the other hand, US firms have an average number of employees equal to 125, while the 90th percentile is reached with 150 employees[xi]. Moreover, while Italian firms target mainly business costumers to whom they provide personalised solutions, in the US there is a well developed market of software targeted to end users.

In order to address whether there is a real need for the development of alternatives to traditional indicators to assess innovation in the software industry, we have collected data on three main innovation metrics for the Italian firms in our sample: (i) trademarks, using the database of the European Office for Trademarks and Design[xii]; (ii) patents, referring to the Delphion database[xiii]; (iii) scientific and technical publications hosted on Scopus[xiv]. We found that traditional instruments for protecting and communicating innovations are used in very few cases (only 9 firms out of 323: less than 3%). As far as trademarks, only 5 companies out of 323 registered distinctive elements at the European Office for Trademarks and Designs. Specifically, these five firms registered, globally, 35 trademarks: 26 figurative elements (logos), and 9 names (the name of the company itself, not of its products). At the same time, we observed that only 3 firms hold a patent (for a total of 15 patents) and only 3 were involved in scientific and technical publications. Moreover, two out of the three firms that published in scientific and technical journals are divisions of multinational companies and belong also to the group of five firms with a trademark.

These findings corroborate the idea that traditional metrics are not suitable to capture innovative processes in a software sector formed mainly by SMEs, thus justifying the turning to alternative methodologies for assessing innovation.

Along these lines, we develop a methodology based on evaluations of software solutions by a group of experts, using information collected through companies' Web sites. Namely, we visited the Web sites of the 323 Italian respondents to look for information useful to asses innovativeness of their products. The Internet surfing allowed us to collect comprehensive data on 134 solutions developed by a sub-sample of 70 companies. It is important to underline that, according to this methodology, the unit of analysis is no more the firm as a patent or trademark holder, but its software solutions whose innovativeness we are aiming at addressing.

These programs target mainly business customers: in fact, only 8% (11 software solutions) are intended for home users. Looking at the product category, managerial systems are the most widespread ones (e.g. ERP systems) - constituting the 45% of the sample - other relevant groups are Web oriented applications (9%) and software for security (e.g. anti-virus systems; 3%), followed by a plethora of heterogeneous applications. Moreover, as far as intellectual property rights, most solutions (107 out of 134) are released under a proprietary license, while the remaining ones (27) are distributed under Open Source licenses.

Three Italian practitioners expert of the Italian software markets were involved (Expert A, B, and C) and each of them was asked to evaluate the level of innovativeness of the 134 software solutions. Expert A is a 27-year old, graduated in Telecommunication Engineering in 2005 at Sant'Anna School of Advanced Studies in Pisa[xv], a top ranking public university in the field of applied science, enrolling students on the basis of an extremely selective national competition. After a one year stage at the research laboratories of the Italian Telephone Company[xvi], he is currently employed in a large company providing solutions for electronic trading, position and risk management, and pricing. He has been serving for years as developer in FOSS projects, participating in forums and contributing code. Expert B graduated in Computer Science in 2001, she is 34 years old. After graduation, she worked as IT programmer and consultant in several Italian ICT companies and public bodies and gained a four years experience in the Laboratory of Economics and Management of Sant'Anna School of Advanced Studies[xvii] as responsible of construction and management of scientific databases[xviii]. In 2003, she was appointed as a CEO in a small Italian company providing ICT services for scientific research activities (mainly data collection and advanced analysis). In 2006, she earned a master in Internet Technologies at the Italian National Research Council. She is currently working as a system administration for a large public institution in the healthcare sector. The third expert (C) is 29 years old and graduated in Computer Science at the University of Pisa, he obtained a master degree in Information

Technologies providing also a framework on economics and managerial aspects of ICT. He is currently Research Assistant at the Italian Institute of Informatics and Telematics of the National Concil of Research[xix] and he is PhD student in Computer Science at the University of Siena[xx], focusing his research activities on information retrieval and bioinformatics. He has published his researches on proceedings of international conferences and referred journals[xxi].

In brief, given the experts' background, business experience, and personal interests, we are reasonably confident that they have enough knowledge of the software market to perform the task we assigned to them. Each expert, after an in depth colloquium during which we explained him/her the main aims of our project, received a table to be filled and a guide for its compilation. For each solution, the table contained the name of the product, its brief description together with the one of its producing firm, the link to its Web page (an example is in table 3). Using this information, evaluators were asked to assign a mark ranging from 1 (*not at all innovative*) to 5 (*very innovative*) to each product, referring to three main dimensions: the firm, its reference market, and the global world.

Table 3: Example of a record of experts' table.

Innovation dimension	*Field*	*Content*
	Product index	081
	Firm index	051
	Name of the product (with link to its Web page)	XXX
	Product typology	Software for e-commerce
	Brief description of product	Web oriented application for the business to business commerce, targeted to the fashion sector; possibility of acquisition of orders and real time checks; interoperability among different databases (postgreSQL, ms-SQL, IBM DB2, Oracle) and operative systems (it runs on both Windows and Linux); multi-language; modular structure; possibility of documents tracking; based on the managerial system as400 or stealth v.3; it uses a php 4 technology; possibility of SSL cryptography
	Brief description of firm	YYY: development of Web oriented applications, in particular targeted to the fashion sector; development of software for e-learning and content management
I	Indicator 1: product new to the firm	2
	Eventual notes on Indicator 1	-----
II	Indicator 2: product new to the market in what it does	2
	Eventual notes on Indicator 2	-----
II	Indicator 3: product new to the market under technological viewpoint	4
	Eventual notes on Indicator 3	-----
III	Indicator 4: modules new to the world	2
	Eventual notes on Indicator 4	-----
III	Indicator 5: platform new to the world	3
	Eventual notes on Indicator 5	-----

In defining these dimensions we strictly referred to the classification of product innovation activities[xxii] used by the Community Innovation Survey we cited in literature review section. Given the widespread diffusion of the CIS survey, which is produced in 27 Member States of the European Union and designed to perform inter-temporal comparisons and to obtain data for academic or policy uses[xxiii], we can conclude that this taxonomy, extensively illustrated in the OSLO Manual (OECD, 2005), is now the standard for collection of primary data on firms' innovation activities. Moreover, following the literature on software innovativeness, in general, and the work of Jordan and Segelod (2004, 2006), in particular, the three dimensions were articulated in five indicators, taking into account both technical and architectural features and product capacity to satisfy users' needs.

The first dimension is related to the level of innovation within the firm: the idea is to compare each software solution with other programs developed by the same company, in order to highlight peculiarities and differences (*Indicator 1: is the product new to the firm?*).

The second dimension refers to the market in which the firm operates. Namely, we ask the experts whether a product is innovative compared with other similar solutions available on the market. This dimension was addressed by two indicators: the first referring to innovation in *what* a software solution does (*Indicator 2: is the software innovative in the sense that it better satisfies needs or requests from users than other solutions available on the market?*), the second referring to *how* a software succeeds in accomplishing a given task. In this latter case, the aim is to explore technical and architectural aspects, trying to evaluate the peculiarities in the implementation of a given solution (*Indicator 3: is the product new to the market under a technological viewpoint?*).

The third dimension has the widest perspective. Indeed, we asked the experts to evaluate the level of innovativeness of the products referring not only to the specific market in which firms' compete, but to the general state of the art of technology and knowledge in the software sector (*is the product new to the world?*). Two indicators account for this dimension, specifically we asked the experts to report about innovation in: (i) the modules composing the software (*Indicator 4: is the software innovative as it contains peculiar and original modules, which can be hardly found in other solutions, also in different market segments?*); (ii) what we synthetically labelled as *platform*, meaning those aspects not related to software modules and their organization, but to the other technological characteristics, such as programming languages, implemented algorithms, use of libraries, databases or other applications, and so on (*Indicator 5: how the software platform is new with respect to those of other software solutions, also in different market segments?*). Indeed, each of these elements is, in some sense, related to innovation. For instance, as far as programming languages, it appears clear that new, object oriented languages –such as Java, Phyton or Php - allow for faster and easier development and boost reuse, thus fostering the implementation of original and advanced features (Fichman and Kemerer, 1993).

In this framework, it would also be useful to relate our indicators to other traditional classifications of innovation activities, such as *radical vs. incremental innovations*, in order to link our analysis to the wide literature on product innovativeness. For instance, innovations related to technical aspects of the software (indicator 3), as the implementation of bright algorithmic solutions or the adoption of new architectures, can be regarded as a sign of a more radical innovation process. A software with an implementation which can be considered new referring to the general level of knowledge, can be more reasonably labelled as a *radical innovation* with respect to a solution having original modules as the only element of novelty (in this case is more correct to refer to *incremental innovation*).

We are aware that our methodology suffers from several shortcomings, stemming from the fact that experts' evaluations are based on information contained in firms' Web sites and are subjective in their nature. We acknowledge that these problems represent, in some sense, unsolvable difficulties, however, several strategies for reducing their impact on evaluation outcome were adopted. First of all, we carefully reviewed each Web site, focusing on sites having dedicated sections (i.e. a specific page) for the products to be evaluated. Among these latter, we discarded those that, in our opinion, did not provide sufficient details to allow experts to perform their assessment. We did follow up briefings with the three experts after the evaluation process: in general, none of them claimed to have experienced severe problems of information shortage in evaluating product innovativeness. A slight difficulty in finding information was claimed as far as innovation in modules (indicator 4) is concerned, we acknowledge this in our data analysis. It is worth noting that our dataset have no missing data.

Subjectivity of the evaluations can hardly be overcome, however, multiple opinions help to mitigate it. Moreover, metrics of accordance of judgements were computed, showing that experts' assessments were consistent. In particular, as our study is characterised by multiple ratings per subject (each one of the five indicators), measures of interrater agreement (Fleiss, 1981) were computed[xxiv]. Table 4 summarises the Cohen's kappa values.

Table 4: Cohen's Kappa values.

DIM	*Indicator*	*p.: proportion of positive evaluation (score equal or lager than 3)*	*q.: proportion of negative evaluation (score smaller than 3)*	*Cohen's kappa*
I	*Indicator 1: product new to the firm*	0.56	0.44	0.75
II	*Indicator 2: product new to the market in what it does*	0.61	0.39	0.86
	Indicator 3: product new to the market under technological viewpoint	0.52	0.48	0.91
III	*Indicator 4: modules new to the world*	0.69	0.31	0.71
	Indicator 5: platform new to the world	0.48	0.52	0.78

The Cohen's kappa measure of agreement is scaled to be 0 when the amount of agreement is what would be expected by chance and 1 when there is perfect agreement. In our case, the measure is higher than 0.70 for all the indicators, showing, according to the classification proposed by Landis and Koch (1977), a *substantial agreement*.

Finally, we are aware of the complexity of the task we assigned to the three experts. Indeed, each of them is asked to report on 134 products from 70 SMEs, across five indicators. Hence, the reliability of our data relies on the assumption that each expert can perform the assigned task, being able to elaborate the available information and having sufficient knowledge about the markets served by the 70 SMEs. The experts' background, their in depth knowledge of the market, the fact they received a monetary compensation for their job, and devoted to it on average three-four working days, make us confident that they performed their task conscientiously, avoiding to simply assign the numbers by chance. This is supported also by the fact that, in our dataset, the *central tendency bias*, which may affect evaluations made on 1-5 Likert scales (see for instance Dawes, 2008), is fairly weak. Specifically, the percentage of scores equal to 3 assigned by the three experts, across the five indicators, is higher than 30% only in three cases out of fifteen (three evaluators per five indicators)[xxv]. At the same time, no *acquiescence bias* (Greenleaf, 1992) seems to emerge, as, for all the indicators, score 5 is chosen in less than 15% of the cases.

Summing up, we can conclude that, despite its shortcoming, the proposed methodology represents a valid alternative to the failing collection of traditional innovation indicators. Moreover, it is worth noting that other qualitative methodologies, such as surveys taken on firms' partners and employees or case studies, would have run the risk to be useless because of the need of information both deep (e.g. about technical aspects) and wide (e.g. having a large sample of solutions).

We reflected about the possible ways to aggregate evaluations we collected from the three practitioners involved (e.g. using median, mode, etc.), and finally we chose to compute, for each indicator, the sum of the three evaluations: in this way, we obtained synthetic scores ranging between three (all three experts assigned one) and fifteen (all assigned five). This solution has the advantage of preserving variability even if mitigating the effect of outlier evaluations.

4. Empirical results

4.1. Innovativeness of software solutions: a general assessment

Descriptive statistics of the (sum of the) scores assigned to the 134 software solutions by the three experts are reported in table 5[xxvi].

Table 5: Descriptive statistics of innovation indicators.

Dim.	*Indicator*	*Min.*	*Max.*	*Mode*	*Mean*[xxvii]	*Std. Dev.*	*Median*	*75th perc*	*90th perc*	*99th perc*
I	*1: product new to the firm*	4	14	7	8.4	2.11	8	10	11	14
II	*2: product new to the market in what it does*	3	14	8	8.8	2.46	9	10.7	12.7	13.7
	3: product new to the market under technological viewpoint	3	14	8	8.0	2.78	8	10	12	13.7
III	*4: modules new to the world*	5	13	8	8.4	2.04	8	10	11	13
	5: platform new to the world	3	14	8	7.8	2.46	8	9	11	13.7

Whilst results obtained with traditional innovation indicators are fairly useless for assessing the innovativeness of these products, using experts' evaluations we succeed in painting a more complex picture and in disentangling innovation into its main dimensions. Specifically, our data allow to inquire about the *innovativeness of the solutions* produced by Italian SMEs and about *what typologies of innovations are implemented*. Table 6 reports the distributions of the sum of the scores assigned by the three experts. It emerges that a remarkable portion of the solutions in our sample are considered fairly innovative both at the firms, market, and global level. As far as indicator 1, more than 30% of the solutions received a mark equal or larger than 10 (at least two experts assigning high scores as 4 or 5), while only 20% of the solutions received a mark equal or lower than 7 (at least two experts assigning low scores as 1 or 2). More than 35% of the solutions are considered *new to the market* in the respect of *what* the software does (indicator 2), while around 28% are considered *new to the market* under a technological viewpoint (indicator 3). In general, indicator 2 received higher scores than indicator 3, supporting the idea that innovation activities are more targeted to *what* a software solution does, than to *how* it does it. Interestingly, around 25% of the solutions are considered *new to the world*, also in this case, innovation seems to be more focused on the organization of modules than on technical aspects.

Table 6: Innovation indicators: percentage of low and high scores.

Dim.	*Indicator*	*% of low score (≤ 7)*	*% of Intermediate score (8 or 9).*	*% of high scores (≤ 10)*	*Total*
I	*1: product new to the firm*	40.3	27.6	32.1	100
II	*2: product new to the market in what it does*	31.3	31.4	37.3	100
	3: product new to the market under technological viewpoint	47.8	22.4	28.4	100
III	*4: modules new to the world*	32.8	40.3	26.9	100
	5: platform new to the world	47.0	29.1	23.9	100

4.2. Innovativeness of software solutions: comparison between FOSS and proprietary software

After the analysis of the whole sample, we performed comparisons between proprietary and FOSS solutions in order to address our main research question: *are software based on FOSS more innovative than proprietary ones?*

As mentioned in section 3, the sample of 134 software solutions was formed by 109 proprietary and 27 FOSS programs. The latter group is much smaller than the former, and its numerousness makes it impossible to reach generalizable conclusions. However, to the best of our knowledge, we are not aware of studies performing an in depth analysis of innovativeness of FOSS as compared to proprietary software. Thus, acknowledging the exploratory nature of our work, this can be regarded as an acceptable sample. The scanty presence of FOSS solutions within the firms' offering portfolios is mainly due to the fact that commercial companies' involvement in FOSS is a relatively new phenomenon, especially as far as the Italian market is concerned. The median year of adoption of FOSS by the 70 Italian SMEs producing the 134 software solutions in the sample is 2001. Moreover, several barriers to adoption persist such as the competences and experience accumulated by firms in the proprietary software fields (Bonaccorsi et al., 2006a), the resistance of their customers against FOSS programs, often perceived as incompatible with the installed base of proprietary solutions (Bonaccorsi et al., 2003), or the so called *GPL fear* (Rosenberg, 2002).

Table 7 reports descriptive statistics of the five indicators for the sub-sample of proprietary and FOSS solutions.

Table 7: Descriptive statistics of innovation indicators. Proprietary vs. FOSS solutions

		Proprietary solutions							*FOSS solutions*							*Mann Whitney P value*	*Nonparametric equality of medians test P value*
Dim.	*Ind.*	*Min.*	*Max.*	*Median*	*Mean*	*Std. Dev.*	*75th perc.*	*90th perc*	*Min.*	*Max.*	*Median*	*Mean*	*Std. Dev.*	*75th perc*	*90th perc*		
I	*1*	*4*	*14*	*8*	*8.1*	*2.03*	*10*	*11*	*6*	*14*	*10*	*9.4*	*2.15*	*11*	*12*	*0.007*	*0.027*
II	*2*	*3*	*14*	*8*	*8.5*	*2.30*	*10*	*11*	*5*	*14*	*11*	*10.1*	*2.66*	*12.5*	*13*	*0.004*	*0.002*
	3	*3*	*14*	*7*	*7.6*	*2.55*	*9*	*11*	*3*	*14*	*11*	*9.6*	*3.14*	*12*	*13*	*0.003*	*0.001*
III	*4*	*5*	*13*	*8*	*8.4*	*2.03*	*10*	*11*	*5*	*13*	*9*	*8.6*	*2.12*	*10*	*11*	*0.428*	*0.061*
	5	*3*	*14*	*7*	*7.3*	*2.21*	*9*	*10*	*4*	*14*	*10*	*9.6*	*2.58*	*11*	*12.4*	*0.000*	*0.000*

Note. Indicator 1: product new to the firm; indicator 2: product new to the market in what it does; indicator 3: product new to the market under technological viewpoint; 4: modules new to the world; 5: platform new to the world.

Figures support the idea that FOSS solutions are more innovative than proprietary ones: indeed, in all the three dimensions, experts' evaluations are higher for FOSS than for proprietary software.

Specifically, indicator 1 has higher median and mean evaluation for FOSS software and statistical tests show that these differences are significant. This is corroborated by data distribution. For instance, focusing on the score range 5-7, the proportion for FOSS (26%, with only one evaluation equal to 6 and none to 5) is much lower than the one for proprietary programs (44%), while the opposite emerges for values equal or higher than 10 (51% vs. 27%). One could object that this difference is due to the time schedule: FOSS solutions were introduced only recently in the firms' offering portfolio and this could lead the expert to consider them new. However, the experts were called to assess product innovation, in the sense that they were asked to evaluate whether the product is new to the firms with respect to what it does and what kind of needs it satisfy. FOSS was not examined in its role of business model or organisation innovation, so that the simple introduction of the FOSS production mode is not considered as *new to the firm*. Moreover, it is worth noting that 36% of the 70 firms adopt FOSS from its very start.

As far as the second dimension, FOSS solutions seem to be more innovative too. For both indicators 2 and 3, statistical tests confirm a higher level of innovativeness. As far as indicator 2, above 30% of the solutions received a score equal or higher than 12, while the same happens for less than 10% of the proprietary solutions. Indicator 3 displays similar patterns of evaluations. Percentiles confirm these tendencies: while values for 75th and 90th percentiles, in the case of FOSS software, are always between 12 and 13, they decrease to 9-11 for proprietary ones.

Leaving the distinction between the two sub-samples aside, and focusing on differences between indicators 2 and 3 within the same group, we notice that, in both cases, evaluations for the indicator 3 are lower than those of indicator 2, confirming the considerations made for the entire sample.

Comparing the two groups with respect to the third dimension, no significant difference emerges between the two sub-samples for indicator 4. Anyway this result should be carefully evaluated. A possible explanation deals with the quality of the evaluations made by the three experts. During the follow up briefings, experts claim that, in general, information about modules seemed to be less accurate. We controlled for central tendency bias: it emerges only for evaluations of Expert A (79.8% of scores equal to 3), while distributions of the scores for Expert B and C are comparable with those of the other indicators. Anyway, differences remain not significant also eliminating Expert A's scores. On the contrary, FOSS solutions appear to be more innovative as far as indicator 5 is concerned. Specifically, statistical tests confirm the existence of significant differences between the two groups of solutions: above 18% of the FOSS solutions receive a score equal or higher than 12, while the same happens only for 2% of proprietary solutions. Focusing on the *new to the world dimension*, it is also of interest to consider the differences between indicators 4 and 5 within each group. Indeed, proprietary solutions show higher evaluations for modules than for other technological aspects, while FOSS programs follow an opposite pattern. Specifically, in case of FOSS solutions, indicator 5 shows higher values for median (9 for indicator 4 vs. 10 for indicator 5), 75th percentile (10 vs. 11), and 90th percentile (11 vs. 12.4), moreover 18.5% of the solutions receive scores equal or higher than 12 vs. 7.4% for indicator 4, the percentages are respectively 1.9% vs. 9.3% in case of proprietary solutions. While, for indicator 4, evaluations over 10 constitute the 15% (only 4 software solutions out of 27), they reach the 48% for indicator 5 (13 out of 27).

5. Conclusions

The economic literature has widely acknowledged as innovation in ICT sectors, in general, and in software industry, in particular, can hardly be defined and measured. Moreover, the success of the FOSS movement has brought into the limelight new actors, technologies, and modes of knowledge creation and sharing which undoubtedly deserve in depth investigations by economic and managerial scholars. This paper adds to the current research on software innovativeness by making (to the best of our knowledge, for the first time) a comparison between proprietary and FOSS solutions offered by Italian SMEs, across three main dimensions and five innovation indicators. After having argued that traditional measures are useless to assess innovation activities of these firms, we propose a methodology, frequently used in technology management literature, based on evaluation of product innovativeness by a panel of three experts.

Given the focus on the Italian software market, we are aware of the very limited generalization potential of our findings, however three main findings are worth summarising.

First, we have found that solutions produced by Italian SMEs are judged, in general, fairly innovative, not only within the firms, but also within the market in which they operate, and, even, at the level of the entire software sector.

Second, it has also been possible to delineate some general characteristics and patterns of the innovation processes. In particular, innovations related to technical aspects (for both the referring market and the global level of technology) are less prominent than those associated other aspects (specifically: innovations in what a program does, considering the market in which firm operates; innovations in modules, focusing on the global software sector). This is likely to depend on the characteristics of the Italian software market, dominated by SMEs, having low R&D spending and limited market breath. The offering portfolio of these companies is characterized mainly by adaptations, customizations, transfer of programs into different platforms or of technologies into different market segments rather than by mass products target to end users and laying at the frontier of the technology. In particular, given the low sale volumes, Italian SMEs are unable to amortize the high fixed costs shaping the production of standardized software applications. Hence, they specialize in the provision of personalized solutions, mainly for business customers, commercialising not only the software but also a plethora of software-related services.

Third, and most importantly, our analysis has highlighted some intriguing differences between innovativeness of FOSS and proprietary software. Specifically, FOSS solutions seem to be more innovative: they receive higher scores for all the examined indicators and differences are confirmed by statistical tests. Diversities emerge, not only *within* each indicators, but also in the relationships *between* indicators. It seems that proprietary and FOSS software not only show different levels of innovativeness, but they seem also to be shaped by different innovation processes. Specifically, focusing on the *new to the world dimension*, FOSS solutions show higher values for technical aspects than for modules as, on the contrary, it happens for proprietary software and for the entire sample of solutions. This is a fairly insightful result as it points to the advanced technical features of FOSS solutions, thus confirming the efficacy of the FOSS model of knowledge creation, sharing, and accumulation.

Summing up, even if, as we widely acknowledged in the paper, the characteristics of the sample made our results hardly generalizable, we can reasonably conclude that our work contributes to advance of knowledge on software innovativeness by shedding some light on intriguing questions posed by the very existence of the FOSS paradigm. Our figures support the idea that the open way of sharing and managing code and information, typical of the FOSS production mode, fosters innovation process, so that the FOSS may represent a valid alternative for SMEs whishing to operate with leading-edge technologies, without bearing the high costs of developing and appropriating proprietary code.

Finally, there are many relevant aspects of software innovativeness that we were unable to analyse in this paper and that are potential avenues for future research. Specifically, it would be of great interest to apply the proposed analytical framework to the global software market, focusing, in particular, to the most popular proprietary and FOSS solutions, in specific market segments. Moreover, cross-country comparisons should be performed, by comparing solutions produced by Italian SMEs with those of SMEs located in both European countries and in the United States. Such an exercise would allow to inquire about how innovative performances depend on the characteristics of the software market. Moreover, more information would be needed on the degree of firms' participation in the FOSS communities in order to investigate the impact of firm's presence on the software development process (*does firms' presence enhance software innovativeness?*) and define better the interaction between the commercial world and the FOSS developers and users. Finally, the proposed methodology is susceptible of improvements, for instance, by (i) increasing the number of experts, thus reducing the impact of subjective evaluations; (ii) enlarging the sample of examined solutions and having more balanced sub-samples of FOSS and proprietary software, and (iii) grouping the examined solutions on the basis of their referring market (for instance operating systems, Internet applications, management software, and so on) and having different groups of experts judging each market segment, thus reducing the complexity of the assigned task and enhancing the trustworthiness of the results.

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[i] See for instance the IBM Open Source Portal (http://www-03.ibm.com/linux/opensource) and the blog of its Vice President for Standards and Open Source, Bob Sutor (http://www.sutor.com/newsite/blog-open/?cat=4).
[ii] http://www.openoffice.org.
[iii] We label as *FOSS solutions* software released under an Open Source license (http://www.opensource.org/licenses) or products/services having FOSS programs as their main input.
[iv] A fairly comprehensive definition of innovation is provided by OECD (1992) according to which innovation is an iterative process coming from the perception of a new market or opportunity for an invention based on technology, taking to development, production and commercialization, in the idea of a commercial success. Another definition is in Drucker (1985).
[v] For more information about CIS: http://cordis.europa.eu/innovation-smes/src/cis.htm. Other interesting databases have been assembled by the Science Policy Research Unit of Sussex University (SPRU, http://www.sussex.ac.uk/spru), and by US Small Business Administration (http://www.sba.gov).
[vi] As a note, it is important to highlight that, at the moment, software patents are not allowed in Europe, differently to what happens in the United States.
[vii] http://www.sourceforge.net
[viii] The NACE code system (Nomenclature Generale des Activites Economiques dans I`Union Europeenne) is the European standard for industry classifications. It assigns a unique digit code to each industry sector, for example, DA.15.83 – Manufacture of Sugar. It is the equivalent of Standard Industrial Classification (SIC) of the United States.
[ix] Assinform report: http://www.rapportoassinform.it/
[x] Data from EUROSTAT 2003: http://epp.eurostat.ec.europa.eu
[xi] Data from Bureau van Dijk Icarus: http://www.bvdep.com/en/ICARUS.html
[xii] http://oami.eu.int.
[xiii] http://www.delphion.com.
[xiv] http://www.scopus.com/scopus/home.url
[xv] http://www.sssup.it
[xvi] http://www.telecomitalia.com.
[xvii] http://www.lem.sssup.it.
[xviii] In particular, databases of bibliometric data.
[xix] http://www.iit.cnr.it
[xx] http://www.dii.unisi.it/
[xxi] http://www.iit.cnr.it/staff/filippo.geraci/research.php
[xxii] According to the OSLO Manual (2005) a **product innovation** *is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.*
[xxiii] See CIS: Access to microdata,
http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1913,47567825,1913_57936852&_dad=portal&_schema=PORTAL.

[xxiv] Cohen Kappa has been computed using the following formula: $\hat{k}_j = 1 - \frac{\sum_{i=1}^{n} \frac{x_i(m - x_i)}{m}}{n(m-1)p_j q_j}$

Where: $p_j = \frac{\sum_{i=1}^{n} x_i}{nm}$; $q_j = 1 - p_j$, $n = 134$, number of software solutions evaluated by the experts, $m = 3$ (number of experts), x_i : number of positive evaluations (score equal or larger than 3) received by each software, it varies from 0 (nobody assigned a positive score) to 3 (everybody assigned a positive score).
[xxv] Expert B assigned 3 to indicator 2 for 48 solutions out of 134 (35.8%), expert C assigned 3 to indicator 5 for 56 solutions (41.8%), while expert A assigned 3 to indicator 4 for 107 solutions (79.8%). Such a high percentage is recorded only for expert A, for expert B and C the percentage is 24.6% and 15.7%, respectively.
[xxvi] We used the standard statistical descriptive for ordinal variables.
[xxvii] We are aware that it is not entirely correct to compute means of ordinal variables. However, it allows us to provide an insightful and synthetic representation of the data.