OPEN SOURCE AND THE SOFTWARE INDUSTRY

HOW FIRMS DO BUSINESS OUT OF AN OPEN INNOVATION PARADIGM

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VERY PRELIMINARY VERSION

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Abstract

Open Source Software (OSS) represents an *"open innovation"* paradigm based on knowledge produced and shared by developers and users. The paper inquires how OSS challenges the three Teece's building blocks. New findings from a large survey of European software companies, show that within the OSS paradigm: (i) OSS can be a sustainable business model even in the absence of any *appropriability*; (ii) *complementary assets* are distributed collectively and made widely available without the need for dedicated contractual arrangements; (iii) a de facto *dominant design* may stem from a community of users/producers even independently of the presence of powerful large companies.

Keywords

Open Source, software industry, appropriability, complementary assets, dominant design

1. Introduction

When imitation is easy, profits from innovation may flow to imitators or firms that control complementary assets, rather than to innovators.

In fact, integrating complementary assets via proprietary rights may be exceedingly expensive for innovators. On the other hand, negotiating with owners of complementary assets may be subject to high transaction costs, so that in the end the innovators may discover that the net return is very low. In the analysis of Teece (1986) returns from innovation depend on the nature of complementary assets, the appropriability regime, and the stage in the evolutionary development of technological knowledge. In particular, under conditions of weak appropriability and large complementary assets the probability to profit from innovation is low.

In the period after Teece's seminal paper one of the phenomena that have raised the attention of scholars is the emergence and stabilization of a new production paradigm within the software industry which, apparently, operates *without* appropriability, i.e. the Open Source Software (OSS). Such an *"open innovation"* paradigm represents a disruptive process innovation based on open knowledge cumulatively produced and shared by developers and users.

Appropriability regimes are formed by a mix between IPRs and secrecy. IPRs may have several legal definitions, but in all cases are designed and used in order to prevent unauthorized use by competitors (notion of *excludability*). Industrial secrecy is a way to protect internal knowledge.

In the case of OSS, on the contrary, we witness a systematic use of IPRs, in the form of licensing, to obtain the widest possible use of information, deliberately *preventing* exclusion and secrecy. In OSS the code is available to everybody and can be used without restriction, with the only limitation that any piece of software including open code must be released according to the same rules, permitting circulation. All OSS circulates over the Internet with attached licensing schemes, and the download of OSS equates legally to approving the licensing conditions.

Recently, however, it has been noted that a large number of firms are profiting from OSS, both large IT companies allocating part of their intellectual property to the community and benefiting from interaction with it, and newly created or transformed small software houses adopting a business model centred on the provision of Open Source based products and services (Bonaccorsi and Rossi, 2003; Dahlander and Magnusson, 2005; Bonaccorsi et al., 2006). But, how is it possible to profit in the absence of any appropriability, i.e. under an *"open innovation"* paradigm?

In this contest, the paper aims at inquiring how the OSS meets the three Teece's basic building blocks. Specifically, we provide evidence that

(i) Open Source can be a sustainable business model for the software industry also in the absence of any *appropriability* meaning that firms successfully stay on the market despite an IPRs regime that favours, instead of forbidding, the access to relevant information (Lerner and Tirole, 2002b);

(ii) Within the OSS paradigm, *complementary assets* are distributed collectively, without a concentrated ownership structure. It is the community that owns these assets in a *democratic* way (von Hippel, 2005), and make them available without the need for dedicated contractual arrangements, apart from standard (and hence cheap to write and reinforce) licensing schemes;

(iii) In the OSS paradigm the strength of the network externalities shape the emergence of a de facto *dominant design* stemming from a community of users/producers even independently of the presence of powerful large companies

The empirical research is based on a large dataset on 769 European software companies, based on a field survey in five countries (Germany, Spain, Italy, Finland and Portugal) carried out during 2005, and designed in order to verify differences between firms working with OSS and with proprietary software.

The paper is organised as follows. In the next section we sketch the state of the art on firms' involvement in the Open Source field and disentangle how the *"open innovation"* paradigm calls for an updating of the Teece's model. Section 3 illustrates data and methodology while section 4 presents and discusses the empirical results. Section 5 summarises the main conclusions of the paper.

2. How the "open innovation" paradigm calls for updating the Teece's model

Open Source software is now booming. More and more users are running open programs on their systems; the Open Source Web server Apache is leading the market, its market share is around 70% while the Linux operating system is seriously threatening the MS Windows supremacy. Furthermore, an increasing number of developers is contributing code to the projects of the OSS community (on February 16th 2006 the largest Internet repository of Open Source projects, SourceForge[1], counted 112,895 registered projects and 1,247,105 registered users).

Scholars agree (Dahlander and Magnusson, 2005; Bärwolff, 2006) that, due to its proven track of technical quality (Raymond, 2001), cooperatively developed software has progressively acquired economic importance. Born in the Seventies as a reaction to the increasing monopoly power of large software companies, the Open Source movement is now deeply affecting the industrial dynamics in the software industry (Demil and Lecocq, 2003). Large incumbent firms like IBM, Hewlett Packard, Compaq, and Sun Microsystems have

[1] http://www.sourceforge.net.

begun to release their code to the community (Wichmann, 2002; Hawkins, 2004) so than even traditional commercial actors, such as Microsoft, are questioning their IPRS-based business models (Seemayer and Matusow, 2005). Moreover, particularly after the drawing up of the Open Source Definition in 1998, many new software firms have entered the industry, engaging with open source and trying to profit not from traditional license fees but from other software-related services (*OSS firms*, see for instance Hecker, 1999).

Such an intriguing way of doing business out of information goods without relying on IPRs, has gained a great interest by economic scholars, but, up to now, the research efforts have focused mainly on the incentives of individual developers to take part in the movement or on the engagement in Open Source activities by large software houses. The entrance on the market of firms adopting OSS-based business models has almost been neglected in so far.

The initial interest of the literature on OSS has been to explain, using economic theory, the motivations underlying the activity of programmers, that allocate their time to Open Source projects without a direct monetary reward (Lerner and Tirole, 2002a; Ghosh et al., 2002). While individual motivations may have several plausible explanations (see for instance Lerner and Tirole, 2001; Bitzer et al., 2004), the survival and growth of OSS companies turns out to be a more challenging issue. What the theory must be able to explain, in fact, is how to avoid that providing valuable software to competitors (due to the absence of appropriability) may destroy the bases for profitability.

These new phenomena call for updating Teece's framework and putting it into a dynamic perspective. In the following we will review the three Teece's bulding blocks and highlight as the new software production mode based on the information commons (von Hippel, 2005) supplied by the OSS community challenges and enriches each of them.

2.1. Appropriability regimes

In the classical Teece's model, innovators are recommended to strengthen the appropriability conditions of innovation, in order to prevent or delay imitation and improve the bargaining position with respect to external actors. A strong prediction from this framework is that, in the absence of appropriability, the flow of innovation in a given industry will come to an end. Imitators will benefit from no appropriability, but innovators will receive no incentives to invest. Innovation without appropriability is not sustainable in the long run (Granstrand, 1999; Towse and Holzhauer, 2002)

But how can OSS companies make profits without appropriability? What prevents them from creating imitators and destroying the bases for competitiveness?

The Open Source movement has taken the opposite direction, using in an original way copyright protection (McGowan, 2001) in order to maximize the circulation of innovations. The alternative IPRs management of OSS has been made possible by brilliant legal inventions. First of all, Open Source licenses in general and copyleft licenses in particular have made it possible to profit from the absence of appropriability. Everyone is allowed to download the code from the Internet and adapt it to fit her customers needs, but no one is allowed to close the code turning it into proprietary. Such a regime boost imitation behaviours but forbid to take private advantages from the code written by others. Copyleft licenses, in particular, force the ones who customise a copylefted software to release the modifications under the same copyleft license. Second, Open Source licenses are *shrink-wrap*, the rights attached to the software simply apply *to everyone to whom the software is redistributed* (Gomulkiewicz, 1999) without the need *for execution of an additional license* by those parties (Pearson, 2000). This makes the circulation of Open Source software easier.

Basically, these innovations have made it possible to sustain cooperation even in large groups, contrary to the common held belief, drawn from the traditional theory of private provision of collective goods (PPCG), that only in small groups detection of free-riders is possible (Hardin, 1982). If the provision of collective goods is reasonably expected, then an Open innovation model might prove to be more efficient than a model based on private appropriation of benefits.

2.2. Complementary assets

Teece's theory of complementary assets is a theory of imperfect markets. In competitive markets, there is no reason for owners of assets to earn profits in excess to the marginal contribution to the stream of profits from innovation.

There are several reasons for these types of imperfection. The first refers to classical indivisibilities, or more generally *increasing returns.* If creating a large distribution network is subject to indivisibility and there is almost saturation of capacity, then it is better to give away part of the profits from innovation to the owner of the network, rather than creating a new one from scratch. Another source is *contractual*, as classically described in the theories of contractual incompleteness and transaction costs. Under conditions of uncertainty, asymmetric information and imperfect knowledge, it is difficult to negotiate in such a way that each owner gets approximately his proportion to the marginal contribution to overall profits from innovation. Innovators easily become locked-in with owners of complementary assets and the latter can exploit their contractual advantage.

A more subtle issue is given by the *time dimension*: sometimes the innovator cannot allocate her (scarce) management time to secure complementary assets, because the opportunity costs of delaying the introduction to the market are extremely high. One solution is to appoint one of the available alternative providers of complementary assets - rarely a move that delivers maximum profits.

Over the last twenty years, technological advances in ICT have *drastically reduced the cost of accessing complementary assets* for software firms.

A classical example, mentioned by Teece, is *distribution* and *logistics*. Accessing a large network of retail outlets, or serving a large number of industrial customers, providing the adequate level of customer service, is clearly a major issue for innovators. The emergence of the Internet as a potential distribution channels has dramatically changed this picture (Choi and Winston, 2000). New entrants in the software industry can distribute programmes at low cost and provide distance assistance (manual writing, FAQs, on-line and off-line help). They can concentrate their business on face-to-face service interaction, rather than on product delivery. The Internet distribution structure is a general purpose complementary asset and firms have (almost) no transaction costs in accessing it.

Another critical issue is complementary *product technologies*, i.e. procurement of components and manufacturing. Innovators concentrating in a component cannot reap the benefits from innovation if they have to integrate it into a wider system, controlled by other players. At the same time it is possible that the task of integrating large technical systems requires huge investments in absorptive capacity or system integration knowledge (Brusoni et al., 2001). Here the main technological innovation has been in software engineering, with the introduction of object-oriented programming and of the notions of re-usability, libraries and standard interfaces. These process technologies have greatly increased the degree of modularisation, or decomposability of software products (Simon, 1967; Sanchez, 2000; Langlois, 2002). Designing new applications does no longer require to conceive the whole product architecture. It is possible to focus on the innovative effort while procuring the other software modules on the market, with a reasonable expectation that the interfaces will work smoothly.

This has substantially changed the cost structure of the software industry. While in a traditional software production mode, the cost structure is heavily geared towards front up and fixed costs (Shapiro and Varian, 1999), leading to high levels of break even, the above mentioned innovations allow companies to make costs largely variable, or at least to reduce the level of the break even point. This is even more important for OSS companies that do not have to sustain the fixed cost of licensing proprietary software.

Another important source of *feedback* for innovators is the after-sales service. Receiving comments from users is a major source of learning in many industries, particularly in durable goods, but one which is clearly accessible only to large firms. The emergence of professional communities linked by common practical interests and able to communicate frequently and cheaply has changed the role of this asset. Large communities of software users and groups of Open Source programmers provide a rich feedback on software bugs and limitations, greatly improving the value of the final product. Debugging services are offered for free by the community and this lowers considerably the cost of innovation. The costs a firm has to bear in order to receive feedbacks and contributions from the community consist mainly of the maintenance of a good reputation with the community.

Finally, the *pressure of time* does not necessarily lead innovators to accept alliances with incumbents and to sacrifice profits. Communication in the Internet is rapid and cheap. This has several implications for product innovation. Testing the potential value of an innovation is made rapidly and reliably, by opening a proposal in one of the largest repositories (e.g. Source Forge). Indeed, Lanzara and Morner (2003) show that programmers post a large number of proposals daily, but most of them disappear after a few days, if no other programmers declare an interest and join the proponent team. Also, the time to market of a potential innovation can be reduced by decomposing the overall architecture into smaller sub-tasks that are allocated in parallel to individuals or small teams on a worldwide basis. In this way, time-based competition can be managed also by small companies.

Because of these innovations, innovators that use OSS can more reliably, cheaply and rapidly reach the market. Within the OSS paradigm, complementary assets are distributed collectively, without a concentrated ownership structure. It is the community that owns these assets in a *democratic* way (von Hippel, 2005), and make them available without the need for contractual arrangements, apart from standard (and hence cheap to write and reinforce) licensing schemes. Firms must gain the confidence of the community by providing evidence that they fully respect the rules defined by OS licensing schemes and the non-written rules of the OS movement (Osterloh et al, 2003). After investment into these reputational costs, firms may get access to all complementary assets without having to negotiate on a repeated basis. The OS licensing framework is a fundamental legal innovation that has greatly reduced transaction costs. Our data provide detailed evidence on these issues.

2.3. Dominant design

The notion of *dominant design* stems from the research examining patterns in technological changes and industrial innovation conducted during the Seventies by Abernathy and Utterback (1978). Starting from their seminal work, many authors have investigated the effects of the establishment of a dominant design on industry dynamics (Smit and Pistorious, 1998), survival rate of the firms (Suarez and Utterback, 1995), performances (Henderson and Clark, 1990), and product standardisation (see for instance Jordan, 2001 for a survey of this literature). The emergence of dominant design has been used in Teece's model as a prediction for industry shake-out and consolidation, and hence the rise of price competition and the increasing difficulty for innovators to reap benefits without coming to an agreement with incumbents (and hence accepting lower profits).

Notwithstanding wide research effort, a clear-cut definition of dominant design is still missing[2], being unclear the unit of analysis and the causal factors leading to its emergence (Tushman and Murmann, 1998). Smit and Pistorious (1998) have observed that the concept may be studied both at the industry level, where several designs are competing for dominance,

[2] A valuable definition is from Lee at al. (1995): *a dominant design is the distinctive way of providing a generic service or function that has achieved and maintained the highest level of market acceptance and for a significant amount of time.*

and at the product level, where the dominant set of features and functionalities are determined over the time.

Analysing *dominant design* in software industry is even more challenging. First, as software programs are complex assembled products formed by various subsystems, dominant design is mainly a matter of the product level. Second, its emergence is not only the result of supply and technological considerations but also of the direct and indirect network externalities (Katz and Shapiro, 1985) at play on the demand side (Gandal, 1994; Shy, 2001). Network effects make the notion of dominant design strictly related to the notion of standard (Varian and Shapiro, 1999) as a leading role is played by factors like the number of users, compatibility concerns, and expectations of potential adopters on the future size of the network (Cottrell, 1997).

The traditional theory of dominant design does not take into account these network effects and the possibility that a de facto standard can be created not only by a powerful large company, but also by a community of users or producers (von Hippel, 1988). Nevertheless in the software industry, network externalities have proven to be crucial in shaping the emergence of two opposite conditions: extreme concentration in the segments of packaged software and current programmes (e.g. office automation, management systems, databases) and extreme fragmentation in segments in which customer needs are highly variable and customization is necessary (Torrisi, 1999).

3. Data and methodology

3.1. The sample

The ways in which the OSS business model challenges the traditional view about profiting from innovation are investigated using a large dataset on software companies (NACE code 72, computer and related activities), based on a field survey in five European countries

(Finland, Germany, Italy, Portugal, and Spain). A structured questionnaire was addressed to partners and system administrators of a sample of software companies selected through a random sampling procedure stratified according to size and regions (NUTS2 level). Respondents' orientation towards OSS was not known in advance. The questionnaire has benefited from a long preparatory phase; it was discussed in depth with practitioners (pilot testing) and pre-tested on 40 Spanish firms and 60 Italian firms. It was administered by phone, e-mail and through a dedicated Web site. The total number of respondents was 918; due to missing data the total number of usable answers was 769, with an average response rate around 17%. Data refer to 2004. To the best of our knowledge, there are no published surveys investigating software firms attitudes towards OSS at an international level.

Table 1 reports country and size characteristics of the respondents.

<insert table 1 about here>

The size distributions of the respondents, as measured by the number of employees, differ across countries (p-value=0.000) and reflect that of firms in the software sector at the national level (see table A 1 in the appendix). German and Spanish firms are, in general, larger than the others. Only 28% of them hire less than 10 employees versus 62.22%, 90.95% and 63.27% for Finland, Italy and Portugal respectively. At the same time, there are more German and Spanish firms hiring more than 500 employees (7.53% and 2.50% respectively versus 1.48% for Finland and 0 for the others). Italian firms are by far the smallest on average.

Table 2 shows some descriptive statistics on firms' structural characteristics. Cross-country differences emerges with respect to year of foundation (p value = 0.000), share of graduate personnel (p value = 0.000) and main customers served by the firms (p value = 0.000). Other structural characteristics discussed below in the paper do not significantly differ across countries.

<insert table 2 about here>

Respondents are usually young. In all the countries, the majority of the firms (50.45%) are born during the Nineties and the entry process seems to continue at a fast pace; about 10% have entered the market after 2002, 20.74% of the Finnish sample. As expected, given their larger size, German companies are slightly older.

In all the countries but Italy and Portugal firms count a considerable share of graduate personnel, this reaches more than 80% of total staff in the case of Spain.

Respondents serve mainly business customers, particularly SMEs, while very few refer to University or end users. This is probably related to firms' size. In general targeting end users requires highly standardised software products whose development fixed costs are amortizable only in presence of large volumes of sales.

Data provide evidence that the offering of OSS solutions by commercial companies is a widespread phenomenon; more than 30% of the firms in the sample are engaged in some ways in OSS activities and 19 even provide only this kind of software[3] (*Pure Open Source firms, POSS*). The remaining 236 companies mix at a different extent the offering of proprietary and open standards. Hence, for the purpose of our analysis a firm using the open production mode only to a limited extent can hardly be treated as a firm that relies mainly on OSS. For this reason the next step will be the identification of homogeneous groups of firms.

3.2. Business models of the firms working with OSS: a cluster analysis approach

Heterogeneity in adoption of open standards is in line with the most recent literature on the competition between open and proprietary standards that predicts the possible emergence of a long run equilibrium in which the two competing technologies coexist on the market (Dalle and Jullien, 2003).

[3] POSS firms have been singled out by combining two indicators: the percentage of OSS products out of the total, and the statement by firms about the typologies of solutions provided to customers. A firm is purely Open Source if it states that all its products are OSS-based and provides only Open Source solutions. It is worth noting that the large majority of the POSS firms (73.68%) benefits also from additional sources of revenues besides the offering of open programs, such as provision of graphical and editorial services. This seems to question the viability of a business model entirely based on open standards.

Focusing on the micro-level, Bonaccorsi et al. (2006) have explored the coexistence of the two kinds of software within the offering portfolio of profit-oriented companies labelling such a situation as *hybrid business model*. Basing on a survey on 146 Italian OSS firms, the authors have detected substantial heterogeneity in the strategic orientation towards the open software (*degree of openness*) that ranges from a pure OSS offering to the opportunistic introduction of few open solutions in a primarily proprietary framework. While the latter strategy benefits from the traditional IPRs-based source of revenues, the former one implies to solve how to hold out on the market given the weak appropriability regime attached to the large majority of their products. Otherwise, a stronger commitment to OSS gives origin to closer relationships with individual developers (Osterloh et al., 2004) whose contributions lower the development cost (Feller and Fitzgerald, 2002). Open Source community provides also a large amount of free software-related services such as user-to-user assistance in the mailing lists (Lakhani and von Hippel, 2003) or program documentation. As a consequence, it appears clear that the degree of openness affects the way in which a firm succeeds in profiting from the new software production paradigm.

In order to group the respondents according to their commitment on Open Source, we apply the same methodology proposed by Bonaccorsi et al. (2006).

It is worth noting that firms adopting a business model entirely based on open code (Pure OSS firms, POSS) form a stand alone cluster. Their choice is likely to be driven by the strong ideological, community-oriented motivations of their founders.

Hybrid firms are grouped through a hierarchical cluster analysis using the Complete Linking Method. The following variables, which are indicative of the business model adopted, were considered in the analysis:

a. Percentage of OS turnover out of total turnover in year 2003 (OS_TURNOVER). This is a categorical variable whose definition is as follows: 0 = 0%, 1 = less than 10%; 2 = between

10% and 30%; 3 = between 31% and 50%; 4 = between 51% and 70%; 5 = between 71% and 90%; 6 = between 91% and 99%, 7 = 100%

b. Share of OS solutions (i.e. products and services) out of the solutions supplied by the firm overall (OS_SOLUTIONS)

c. Types of solutions offered (SOLUTIONS): mainly Open Source solutions (SOLUTIONS=3), indifferently proprietary and Open Source solutions (SOLUTIONS=2), and mainly proprietary solutions (SOLUTIONS=1)

d. Intensity of use of the General Public License (GPL_INTENSITY) as measured by the share of GPLed solutions out of the total. Namely, we count both the licenses under which firms distribute their software and the licenses of the products for which firms provide services.

e. A dummy variable (MOTIVATION) capturing the attitudes of the firms towards the values of the Open Source community. The dummy variable has been defined on the basis of a question about firms' motivations to adopt an OSS-based business model. A list of items[4], chosen in accordance with the literature, was proposed and respondents had to single out their top three incentives. Hence MOTIVATION takes value 1 if the respondents claimed that their involvement in Open Source was driven by the desire of fostering the diffusion of open standards, and zero otherwise.

Since the five variables are correlated (see table A 2 in the Appendix), a principal component analysis (PCA) has been run in order to single out the main drivers of the business model choice and to derive the factors to be included in the cluster analysis. Two components (PCA1

[4] The proposed items are as follows: Being independent from the price and licensing policies of large software producers; exploiting the possibility Open Source software offers to be innovative while staying small; satisfying private customers' demands for Open Source Software; addressing Public Administration customers, who are moving towards the new open standards; getting feedback and contributions from the Open Source community; lowering development costs exploiting the existing Open Source code for new software solutions; gaining access to products which are not available on the proprietary software market; having better pricing options; fostering the diffusion of the Open Source software; making partnerships with other software firms that work with Open Source software; entering markets that otherwise would be out of reach; making clear our own innovative contributions through source code accessibility; thinking that the demand for Open Source software is going boom very soon and whishing to be ready for that.

and PCA2) have been extracted from the data (see table A 3 in the Appendix). The first one is strongly correlated to economic aspects like the revenues generate by open source or the weight of the OSS solutions in the offering profile. The second one is mainly related to ideological concerns as the sample includes respondents that have entered the OSS arena mostly moved by the community-oriented motivations of their partners.

However, our results highlight that GPL_INTENSITY has a positive coefficient in both PCA1 and PCA2. Such finding is not surprising as the inheritance property of the GPL makes its choice driven by forces going behind merely strategic considerations (Rosen, 2001; McGowan, 2001). The inheritance property forces everyone who modifies a GPLed program to release the modifications under the same license scheme. As the GPL is the most widespread[5] Open Source license, it is often an unavoidable choice. However, the license has a strong ideological connotation, its persistence serves the purpose of keeping the code open preventing everyone to turn it into proprietary (Lerner and Tirole, 2002b). Hence its use signals an agreement with the values of the Open Source community.

Cluster analysis revealed two well-characterized sub-groups (table 3 and table 4) that, according to Bonaccorsi et al., we label as More Open Source (MOSS) and Less Open Source (LOSS) oriented firms.

<insert table 3 and table 4 about here>

With respect to MOSS firms, the LOSS ones have a lower share of OSS solutions in their offering portfolio, use less the GPL license, display lower percentages of OSS turnover, and tend to offer mainly proprietary solutions. Only few of them declare they have entered the Open Source arena in order to foster the diffusion of open standards.

Hence, the overall sample is now divided in four groups showing a decreasing degree of openness of the business model, that ranges from a pure OSS (POSS firms) to a pure

[5] On February 17th 2006, above 80% of the fifty most active SourceForge projects were released under the GPL, a fairly similar result is in Lerner and Tirole (2002b).

proprietary one (NOSS firms). Table 5 summarises the distribution of the four groups by country and shows significant differences (Chi square test, pvalue = 0.000).

<insert table 5 about here>

The distribution of sample firms across the four groups does not differ systematically across countries in the case of Finland, Germany and Italy, while for Spain and Portugal the proportion of NOSS is higher.

Significant differences across the four groups emerge as far as structural characteristics are concerned (table 6).

<insert table 6 about here>

Firms with a higher degree of openness (POSS and MOSS) are smaller than the others (LOSS and NOSS). Most of them are SMEs with less than 10 employees (65.17%). However, this result should be carefully evaluated since OSS firms are younger than the others and this might at least partially account for their smaller size. No correlation between firms' age and size is detected in the data (Pearson correlation coefficient = 0.027, p value = 0.447), suggesting an independent effect. This result is interesting, since it suggests a systematic relation between conventional appropriability and growth in size. Controlling for age, firms based on OSS do not grow significantly. The upper bound to firm size lies around 50 employees, perhaps providing some evidence on the role of Open Source in contrasting the tendency of the software industry towards concentration (Shy, 2001; Shapiro and Varian, 1999).

Firms working with Open Source have entered the market only recently; the median year of foundation is 2000 for MOSS firms and 2001 for POSS firms. No significant difference emerges instead in the year of Open Source adoption. As expected, the large majority of the OSS firms (83.56%) adopted the new paradigm after the drawing up of the Open Source

Definition in 1998, explicitly aimed at convening the Open Source movement and commercial software companies.

All the firms target mainly SMEs, while OSS firms work more for the public sector. Policy makers, in fact, tend to encourage the use of open standards by public bodies that then increase their demand for open source software.

Finally, POSS and MOSS have more educated founders and employees. This confirms that the OSS paradigm capitalises on the ability of programmers to inspect the source code and modify it, rather than just applying existing software. Proprietary software, on the contrary, leverages on extensive and hierarchical division of labour, leaving room for lower skilled technicians.

4.Empirical results

In the following we will go through the Teece's model addressing each building block separately.

Appropriability regimes

The pilot study and the pre-test had suggested that information on profitability tend to be considered as confidential; addressing this issue directly would have greatly reduced the response rate. Therefore, as we do not have direct data on profits, we had to tackle the topic of sustainability indirectly.

As already argued, firms can profit even under the unconventional IPRs regime of the OSS paradigm. First of all, we examine the turnover generated by OSS. It emerges that the share of OSS turnover out of the total turnover increases over time. Table 7 summarises the distribution of OSS turnover in 2000 and 2003[6]; the Wilcoxon signed-rank test shows that the median classes of the two variables are different (p value = 0.000). With respect to 2000, in

[6] Firms established after 2001 were asked for their Open Source turnover in their first year of life while firms established after 2003 were asked for their Open Source turnover in the last year.

2003 there are less firms in the two lowest classes and more firms in all the other ones; 48.63% have shifted up of at least one class, 45.10% have remained in the same class and only 6.27% have shifted down. In three years, the percentage of respondents whose OSS turnover is above 50% has raised from 17.25% to 25.49% while those who work with OSS without generating revenues out of it have decreased from 33.33% to 10.98%.

<insert table 7 about here>

Growth of the OSS revenues takes place independently of firms' degree of openness. As expected (although figures are not reported for the sake of space constraints), more OSS-oriented firms have a higher OSS turnover both in 2000 and 2003 (Kruskal Wallis test, p value = 0.000) but no significant difference emerges as for as changes in classes are concerned (Kruskal Wallis test, p value = 0.170). If the OSS business model were not sustainable, we would not observe such an increase.

Second, we examine the orientation of firms towards appropriability. Interestingly, data show that, on a subjective basis, OSS firms do not consider the lack of appropriability as an obstacle to profitability and *do not* consider appropriability as a crucial requirement for innovation.

The questionnaire collected subjective evaluations on the roles that patents and licenses play at the firm level and for the software industry in general[7]. The importance attached by firms to patents as an instrument for increasing revenues has been measured on a Likert scale ranging from 1 (*not at all important*) to 5 (*very important*). All the respondents ticked low scores; the median score is 1 while 3 is the 75th percentile. As expected, firms working only with proprietary software attach more importance to patents than those involved in Open Source (Kruskal Wallis test, p value = 0.000).

[7] Data on firms' evaluation of IPRs are not available for Spanish firms

Firms' assessment on the role played by patents in the software industry is summarised in table 8. Most respondents agree that patents are costly (72.55%), do not constitute a valid barrier to entry (71.70%), need a too long legal procedure (68.81%). Less respondents think that patents reduce information costs on innovations (25.85%) and such an effect is not compensated by the capacity of providing incentives to innovators (only 32.09%). Not only OSS firms but even the majority of proprietary ones have stated that patents do not promote innovation; MOSS and LOSS firms agree that they even hamper innovation.

<insert table 8 about here>

These results are in line with the literature claiming that patents increase the cost of innovations while the impact on the expected revenues may be dubious (Levin et al., 1987; Mansfield et al., 1981). The issue of the actual efficiency of intellectual property rights in promoting creativity is even more heavily debated insofar as information goods are concerned (Lessig, 2002; Wynants and Cornelis, 2005). In general, the software industry has followed (at least in the USA) the policy recommendation to strengthen the appropriability regime, and in recent times the notion of software patentability, previously excluded by patent offices, has been introduced. Latest evidence shows that this strengthening does not necessarily benefit innovation processes (Hall, 2004; Blind et al., 2005). However, software technology has a sequential nature, as each innovator heavily relies on the achievements of previous innovators. As a consequence, negotiating IPRs on a bilateral or multilateral basis (i.e. patent pools), may be exceedingly expensive. Considerations of time-based competition may also have a role: in rapidly moving markets (es. multimedia) competitors may prefer weaker appropriability in order to avoid legal costs and benefit from each others' innovations, relying more on speed as a competitive weapon (Teece et al., 2001).

Results on licenses (table 9) complement the findings above. In general, respondents have a more positive attitudes towards licenses than patents. Once again, the importance for firms' revenues was measured on a Likert scale ranging from 1 to 5. Most of the respondents choose high scores, the median is 4 while the 75th percentile is 5. MOSS firms have attributed significant lower scores than LOSS (Kruskal Wallis test, p value= 0.002) and NOSS ones (Kruskal Wallis test, p value= 0.000).

<insert table 9 about here>

This is not surprising; Open Source licenses are important for the very survival of the movements as they serve the purpose of keeping the code open by preventing everybody to turning it into proprietary. Otherwise, in this framework they are no more a source of revenues, as the Open Source definition explicitly states that *the license shall not require a royalty or other fee for [software] sale*. Hence companies working mainly with OSS attach them less importance than the others.

The answering patterns of the questions dealing with the role of licenses in the software industry are consistent with the previous findings (table 9). The percentage of respondents agreeing that licenses are an appropriate mean of marketing products and recovering R&D investments is decreasing with the degree of openness (from 54.59% to 22.45%, and from 59.19% to 36.73%, respectively). No significant differences emerge as for as the perception of the role of licenses in creating networks of firms and constraining versioning are concerned (Fisher Exact test, p value = 0.733 and p value = 0.586, respectively).

Firms' assessment on the role played by patents in the software industry is summarised in table 8. Most respondents agree that patents are costly (72.55%), do not constitute a valid barrier to entry (71.70%), need a too long legal procedure (68.81%). Less respondents think that patents reduce information costs on innovations (25.85%) and such an effect is not compensated by the capacity of providing incentives to innovators (only 32.09%). Not only OSS firms but even the majority of proprietary ones have stated that patents do not promote innovation; MOSS and LOSS firms agree that they even hamper innovation.

Complementary assets

In presence of significant costs for accessing complementary assets – such as distribution, after sale service or logistic - firms tend to concentrate on a few business lines. As we found evidence that companies working with OSS diversify along several dimensions, adopting a sort of *a contrario* argument, we infer that the *"open innovation"* paradigm smooth the role of such an issue.

Compared with NOSS firms, companies that have adopted the Open Source paradigm have a *broader* product portfolio, as measured by the number of product areas[8] in which the firms are active (see table 10). The largest differences regard MOSS firms and NOSS and LOSS ones, but a significant difference emerges also between LOSS and NOSS companies (Kruskal Wallis test, p value = 0.000). It is worth noting that the width of the products portfolio is not correlated with firms' size (Pearson's correlation coefficient = 0.068, p value = 0.057) and it is slightly negatively correlated with firms' age (Pearson's correlation index = -0.123, p value = 0.000). No significant correlation emerges with the variable measuring the period after the first adoption of OSS. Fairly similar results are obtained as far as the number of OSS products is concerned. Interestingly, firms taking part in the project of the OSS community offer on average more products (9.02 vs. 6.64, Anova F-test p value= 0.000).

<insert table 10 about here>

Table 11 specifies firms' presence in the 18 product categories. The majority of the firms working with proprietary software are active mainly in management and data management software while no other applications involve more than one third of them. The number of supplied products increases with the degree of openness; more than 40% of the LOSS firms are active in ten areas that become 14 in case of MOSS and POSS firms[9].

<insert table 11 about here>

[8] The 18 product areas have been defined and further classified on the basis of extensive discussions with practitioners.
[9] Even looking at the four classes (S, N, W, O) it emerges that OSS firms diversify more than NOSS ones.

Similar results are obtained when considering complementary software services (table 12 and 13). Compared with NOSS, OSS provide *more* complementary services to customers, as measured using a detailed taxonomy built making reference to the literature on the topic (Wichmann, 2002). This corroborates the hypothesis that the increase in the number of product supplied is made possible by the exploitation of the open knowledge base created by the community of developers.

As POSS and MOSS firms are smaller than others (their maximum size being 57 employees), the ability of OSS employees to provide a large range of products and services is unarguably higher. Given the nature of software solutions, their supply implies multi-faceted competencies (marketing, customisation, adaptation and support along their life cycle).

How would this large deployment of capabilities be possible if, for each line of business, OSS firms would be forced to acquire and/or negotiate over complementary assets? Necessarily, their cost should be minimal.

As the *"open innovation"* paradigm remarkably reduces the cost of accessing knowledge, a new business model does emerge, in which fixed costs for products and services are trivial, costs for complementary assets are negligible, all efforts go to customization, and hence to variable costs. Such a model has intrinsically a very low break even point, allowing small firms to prosper.

Dominant design

Table 11 provide evidence that while proprietary firms (NOSS) are active mainly in segments in which a dominant design has already emerged, companies within the *"open innovation"* paradigm do not limit themselves to standardised products but have entered also in segments in which a strong market leader does not still exist. Indeed, NOSS are mainly active in Office Automation, Management Software and Database Solutions. With over a 90% market share, Microsoft Office is the incumbent application suite in Office Automation, while SAP is the market leader in Management and Data Management software.

On the contrary OSS firms are strongly active also in less mature segments, such as Antivirus, Antispam, Firewall and Security Appliances, e-commerce Solutions, Content Management Systems, where a dominant design has not emerged yet. As a matter of fact, in the Antivirus segment 24 companies are competing for leading the market and the worldwide leader, Trend Micro, has a market share of 33% (IDC, 2002; WinterGreen Research, 2004). The same happens in Antispam that is characterised by low barrier to entry (IDC, 2004) or in Firewall and Security Appliances where Cisco, Juniper, and Nokia remain the top three vendors but account for less than 50% of the market (IDC, 2005). The market for e-commerce Solutions is not dissimilar, as traditional proprietary software companies are challenged by OScommerce, while in Content Management Systems the three market leaders (IBM, FileNet and Documentum/ECM) reach only the 40.3% (Gartner Dataquest, 2004).

Moreover, OSS firms are very active in segments in which the emergence of a dominant design resulted from the existence of a wide community of users/producers, even in the absence of a large incumbent. This is the case of the Apache Web server, which is now leading the market (with a share of 68.01%, Netcraft Web server survey, Febraury 2006).

5. Conclusions

The paper discusses under which conditions (technology, market, competition) the open model of innovation can be sustained in the long run (Chesbrough, 2003). Specifically, evidence is provided on how the *"open innovation"* paradigm challenges the three building blocks of the Teece's model calling for their updating.

Although weakening the appropriability regime, the adoption of an Open Source-based business model allows firms to survive, grow, and provide a larger and more customized range of software solutions. However, as OSS reduces costs for accessing complementary assets, firms are not forced to specialize in a few product niches and may prosper even in segments where a dominant design has not emerged yet.

Advances in production and distribution processes within the software industry, coupled with the new opportunities made available by the OSS phenomenon, may allow firms to overcome some of the main difficulties in profiting from their innovation.

Contrary to common wisdom, OSS firms calibrate their *degree of openness* and maintain a mixed product and service portfolio (Bonaccorsi and Rossi, 2006). Firms' Open Source activities are of importance also in the context of public policy (FLOSS Final Report, 2002). Indeed, one could wonder whether firms produce the socially optimal amount of OSS, just like economics asks whether firms engage in a socially optimal amount of basic research. Even if one comes to the conclusion that this amount is sub-optimal, one has to take firms' behaviour into account when designing policy measures intended to foster the use of Open Source software.

With the increasing acceptance of software patents, this potential problem is likely to get more attention. Bessel and Maskin (2000) report about a decrease in R&D investments and in productivity of the American software branch after the explicit introduction of software patents.

The goals of IPRs in software industry are the same as in other industries: promoting innovation and disseminate knowledge but peculiarities of the software good, namely sequentiality (Bessel and Maskin, 2000), network externalities (Katz and Shapiro, 1986), and interoperability (Farrell and Saloner, 1992), shape the debate about their definition (Dalle and Kott, 2002).

Profiting from innovation is difficult. In some cases profiting from open innovation is more effective.

References

Abernathy, W.J., Utterback, J.M., 1978. Patterns of industrial innovation. Technology Review, June-July, 40-47.

Bärwolff, M., 2006. Tight prior Open Source equilibrium: the rise of Open Source as a source of economic welfare. First Monday, peer reviewed journal on the Internet 11(1).

Bessen, J., Maskin, E., 2000. Sequential innovation, patents, and imitation. MIT Working Paper of the Department of Economics No. 1/2000, http://www.researchoninnovation.org/patent.pdf, accessed on September 29th 2003.

Bitzer, J., Wolfram, S., Schroder, P.H.J., 2004. Intrinsic motivation in open source software development. MIT Working Paper, http://opensource.mit.edu/papers/bitzerschrettlschroder.pdf, accessed on January 23rd 2005.

Blind, K., Edler, J., Friedewald, M., 2005. Software patents. Economic impacts and policy implications. Edward Elgar, Cheltenham.

Bonaccorsi, A., Giannangeli, S., Rossi, C., 2006. Entry strategies under dominant standards. Hybrid business models in the Open Source software industry. Management Science, forthcoming.

Bonaccorsi, A., Rossi, C., 2003. Why Open Source software can succeed. Research Policy 32, 1243-1258.

Brusoni, S., Prencipe, A., Pavitt, K., 2001. Knowledge specialisation and the boundaries of the firm: why do firms know more than they make?. Administrative Science Quarterly 46, 597-621.

Chesbrough, H., 2003. Open innovation. Harvard University Press, Cambridge.

Choi, S., Winston, A., 2000. Benefits and requirements for interoperability in electronic marketplace. Technology in Society 22, 33-44.

Cottrell, T., 1997. Computer platforms: competition in microcomputer software, in: Deutsch, L. (Ed.), Industry Studies. M.E. Sharpe.

Dahlander, L., Magnusson, M.G., 2005. Relationships between open source software companies and communities: Observations from Nordic firms. Research Policy 34, 481-493.

Dalle J.M, Kott L., 2002. Plaidoyer pour des logiciels génériques. La Recherche, 349, 70-73.

Dalle, J.M., Jullien, N., 2003. Libre software: turning fads into institutions?. Research Policy 32, 1-11.

Demil, B., Lecocq, X., 2003. Neither market nor hierarchy or network: The emerging bazaar governance. MIT Working paper, http://opensource.mit.edu/papers/demillecocq.pdf, accessed on 30th December 2005.

Farrell, J., Saloner, G., 1992. Converters, compatibility, and the control of interfaces. Journal of Industrial Economics, 40(1), 9-36.

Feller, J., Fitzgerald, B., 2002. Understanding Open Source Software development. Addison Wesley, Boston.

Gandal, N., 1994. Hedonic price indexes for spreadsheets and an empirical test for network externalities. Rand Journal of Economics 25, 160-70.

Gartner Dataquest, 2004. Content Management market share report.

Ghosh, R., Glott, R., Krieger, B., Robles, G., 2002. Survey of developers. Free/Libre and Open Source Software: Survey and Study, FLOSS, Final Report, International Institute of Infonomics, Berlecom Research GmbH, Maastricht.

Gomulkiewicz, R.W., 1999. How copyleft uses license rights to succeed in the Open Source software revolution and the implications for article 2B. Huston Law Review 36, 179-194.

Granstrand, O., 1999. Economics and management of intellectual property. Edward Elgar, London.

Hall, B.H., 2004. On copyright and patent protection for software and databases: a tale of two worlds: in Granstrand, O. (Ed.), Economics, Law, and Intellectual Property. Kluwer, Amsterdam.

Hardin, R., 1982. Collective Action. John Hopkins University Press, Baltimore.

Hawkins, R.E., 2004. The economics of the Open Source Software for a competitive firm. Why give it away for free?. Netnomics 6, 103-117.

Hecker, F., 1999. Setting up shop: the business of Open-Source software. IEEE Software 16, 45-51.

Henderson, R.M., Clark, K.B., 1990. Architectural innovation: the reconfiguration of existing product technologies. Administrative Science Quarterly 35, 9-30.

IDC, 2002. Antivirus software 2002: a segmentation of the market. Document # 27864, http://www.networkworld.com/research/reports/IDC27864.html, accessed on February 28th, 2006.

IDC, 2004. Worldwide antispam solutions 2004-2008 forecast and 2003 vendor shares: whati being done about spam. Document #32650, accessed on February 28th, 2006.

IDC, 2005. Worldwide quarterly security appliance tracker. #IDC_P6272. http://www.idc.com/getdoc.jsp?containerId=IDC_P6272, accessed on accessed on February 28th 2006.

Jordan, J., 2001. Detecting dominant design. Applying the theory in network economies. M. A.Sc. Thesis. http://opensource.mit.edu/papers/jordan.pdf, accessed on December 16th 2005.

Katz, M., Shapiro, C., 1985. Network externalities, competition and compatibility. American Economic. Review 75, 424-440.

Lakhani, K.R., von Hippel, E., 2003. How Open Source software works: “free” user-to-user assistance. Research Policy 32, 923-943.

Langlois, R.N., 2002. Modularity in technology and organization. Journal of Economic Behaviour and Organization 49, 19-37.

Lanzara, G., Morner, M., 2003. The knowledge ecology of Open-Source software projects. 19th EGOS Colloquium. Copenhagen.

Lee, J.R., O’Neil, D.E., Pruett, M.W., Thomas, H., 1995. Planning for dominance: a strategic perspective on the emergence of a dominant design. R&D Management 25, 3-25.

Lerner, J., Tirole, J., 2001. The Open Source movement: key research questions. European Economic Review 45, 819-826.

Lerner, J., Tirole, J., 2002a. Some simple economics of the Open Source. Journal of Industrial Economics 2, 197-234.

Lerner, J., Tirole, J., 2002b. The scope of Open Source licensing. Journal of Law, Economics, and Organisation 21, 20-56.

Lessig, L., 2002. The future of ideas: the fate of the commons in a connected world. Random House, New York, 2002.

Levin, R.C., Klevorich, A.K., Nelson, R.R., Winter, S.G., 1987. Appropriating the returns from industrial research and development. Brookings Papers on Economic Activity 3, 783-820.

Mansfield, E., Schwartz, M., Wagner, S., 1981. Imitation costs and patents: an empirical study. Economic Journal 91, 907-918.

McGowan, D., 2001. Legal implications of Open Source software. University of Illinois Law Review 1, 241-304 .

Osterloh, M., Kuster, B., Rota, S., 2003. Trust and commerce in Open Source – a contradiction?: in Petrovic, O., Posch, R., Marhold, F. (Eds.), Trust in the Network Economy. Springer Verlag, Wien, pp. 129-141.

Pearson, H.E., 2000. Open Source- the death of proprietary systems?. Computer Law and Security Report 16, 151-156.

Raymond, E., 2001. The cathedral & the bazaar. Musings on Linux and Open Source by an accidental revolutionary. O'Reilly & Associates, Sebastopol.

Rosen, L., 2001. The unreasonable fear of infection. http://www.rosenlaw.com/html/GPL.pdf, accessed on June 9th 2003.

Sanchez, R., 2000. Modular architectures, knowledge assets and organizational learning: New management processes for product creation. International Journal of Technology Management 19, 610-629.

Seemayer, W., Matusow, J., 2005. Das Microsoft–shared–source–programm aus der business–perspective: in Lutterbeck, B., Gehring, R.A., Bärwolff M. (Eds.), Open Source Jahrbuch 2005, pp. 185–200.

Shapiro, C., Varian, H.R., 1999. Information rules: a strategic guide to the network economy. Harvard Business School Press, Boston.

Shy, O., 2001. The economics of the network industries. Cambridge University Press, Cambridge.

Simon, H.A., 1967. Motivational and emotional controls of cognition. Psychological Review 74, 29-39.

Smit, F.C., Pistorious, C.W.I., 1998. Implications of the dominant design in electronic initiation systems in the South Africa mining industry. Technological Forecasting and Social Changes 59, 255-274.

Suarez, F.F., Utterback, J.M., 1995. Dominant design and the survival of firms. Strategic management Journal 16, 415-430.

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

Teece, D.J., Dosi, G., Carroll, G.R., Malerba, F., von Tunzelmann, N., 2001. Editorial. Industrial and Corporate Change 10, 815-816.

Torrisi, S., 1999. Firm specialisation and growth. A study of the European software industry: in Gambardella A., Malerba, F. (Eds.), The Organisation of Economic Innovation in Europe. Cambridge University Press, Cambridge, pp. 239-268.

Towse, R., Holzhauer, R., 2002. The economics of intellectual property: in Towse, R., Holzhauer, R. (Eds.), The International Library of Critical Writings in Economics, Vol. I, II, III and IV. Edward Elgar, Cheltenham.

Tushman, M.L., Murmann, J.P., 1998. Dominant designs, technology cycles, and organisational outcomes. Research in Organizational Behavior 20, 231-266.

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

von Hippel, E., 2005. Democratizing innovation. MIT Press, Cambridge.

Wichmann, T., 2002. Firms' Open Source activities: motivations and policy implications. Final Report, Free/Libre and Open Source Software (FLOSS): Survey and Study, International Institute of Infonomics, Berlecom Research GmbH, Maastricht.

WinterGreen Research, 2004. Antivirus market opportunities, strategies, and forecasts, 2004 to 2009. Report # SH29821366. http://www.wintergreenresearch.com/reports/Virus_Protection_Brochure.pdf, accessed on February 28th, 2006.

Wynants, M., Cornelis, J., 2005. How open is the future? Economic, social & cultural scenarios inspired by free & Open-Source Software. Crosstalk, Brussels.

TABLES

Table 1: Country and size distribution of sample firms

	SIZE [a]								*Anova F-test p-value*
COUNTRY	*N*	*Min.*	*Max*	*Mean*	*Std. Dev.*	*p50*	*p75*	*p95*	
Finland	134	1	640	31.03	77.41	7	18	200	
Germany	92	1	1 400	82.72	203.20	21	55	523	
Italy	243	1	140	5.87	12.46	3	6	18	0.000
Portugal	98	1	380	15.82	40.24	7	13	61	
Spain	200	1	1 300	66.80	169.26	17	42	302	
Total	767	1	1 400	36.64	120.40	8	20	160	

[a] *Two outlier values have been detected in the variable SIZE and excluded from the analysis.*

Table 2: Structural characteristics of sample firms

		YEAR OF FOUNDATION						*SKILLS* [a]			*MAIN CUSTOMERS*						
COUNTRY	*N*	*Min*	*Max*	*p50*	*p75*	*p95*	*Kruskal-Wallis test p-value*	*Mean*	*Std. Dev.*	*Anova F-test*	*SMEs*	*Large Firms*	*Universities*	*Public sector*	*End users*	*Others*	*Chi-square test p-value*
Finland	135	1968	2004	1997	2001	2004		61.02	33.16		49.63	37.04	2.96	8.15	0.74	1.48	
Germany	93	1968	2004	1992	1998	2001		50.19	32.12		45.16	41.94	1.08	7.53	2.15	2.15	
Italy	243	1971	2004	1994	1998	2002	0.000	32.30	37.93	0.000	66.67	16.87	1.65	10.29	2.88	1.65	0.000
Portugal	98	1979	2004	1995	2000	2004		36.67	31.07		69.39	20.41	0.00	7.14	2.04	1.02	
Spain	200	1971	2004	1994	1999	2003		83.03	27.99		63.00	21.00	0.50	9.50	1.50	4.50	
Total	769	1968	2004	1994	1998	2003		53.26	38.86		60.47	24.97	1.30	8.97	1.95	2.34	

[a] *The variable SKILLS refers to the share of graduate personnel, data on skills are available only for a subset of respondents (N=682).*

Table 3: Clusters' characteristics, continuous variables

Variable	*More OSS Oriented MOSS (N= 70)*		*Less OSS Oriented LOSS (N= 166)*		*Anova F-test p-value*
	Mean	*St. dev.*	*Mean*	*St. dev.*	
Share of OSS solutions out of the overall solutions supplied	96.56	7.11	85.29	15.97	0.000
Intensity of GPL use	81.33	30.18	49.78	40.09	0.007
Principal component 1	1.54	0.64	-0.65	0.92	0.000
Principal component 2	0.17	1.32	-0.07	0.83	0.088

Table 4: Clusters' characteristics, categorical and binary variables

		Percentage of OSS turnover						*Typology of solutions supplied*						*Attitudes towards the values of the OSS community*		
Cluster	*N*	*Min*	*Max*	*p50*	*p75*	*p95*	*Mann-Whitney test p-value*	*Min*	*Max*	*p50*	*p75*	*p95*	*Chi-square test p-value*	*NO*	*YES*	*Chi-square test p-value*
MOSS	70	0	7	2	5	7	0.000	1	3	1	2	2	0.000	71.43	28.57	0.000
LOSS	166	0	6	1	1	3		1	3	1	1	3		92.17	7.83	

Table 5: Country distribution of the four groups

Country	*POSS*	*MOSS*	*LOSS*	*NOSS*	*Total*
	2	15	40	78	135
Finland	1.48	11.11	29.63	57.78	100
	10.53	21.43	24.1	15.18	17.56
	0	9	27	57	93
Germany	0	9.68	29.03	61.29	100
	0	12.86	16.27	11.09	12.09
	6	22	63	152	243
Italy	2.47	9.05	25.93	62.55	100
	31.58	31.43	37.95	29.57	31.6
	0	3	12	83	98
Portugal	0	3.06	12.24	84.69	100
	0	4.29	7.23	16.15	12.74
	11	21	24	144	200
Spain	5.5	10.5	12.0	72.0	100
	57.89	30	14.46	28.02	26.01
	19	70	166	514	769
Total	2.47	9.1	21.59	66.84	100
	100	100	100	100	100

Table 6: Clusters' structural characteristics

	SIZE[a]					*YEAR*						*YEAR OF OSS ADOPTION*[b]					
Cluster	*Min*	*Max*	*Mean*	*Std. Dev.*	*Anova F- test p-value*	*Min*	*Max*	*p50*	*p75*	*p95*	*Kruskal-Wallis test p-value*	*Min*	*Max*	*p50*	*p75*	*p95*	*Kruskal-Wallis test p-value*
POSS	1	22	5.74	5.21	0.0037	1991	2004	2001	2003	2004	0.000	1991	2004	2002	2003	2004	0.403
MOSS	1	57	9.83	11.60		1979	2004	2000	2002	2004		1985	2004	2000	2003	2004	
LOSS	1	1 400	63.41	210.44		1968	2004	1997	2000	2004		1992	2004	2001	2003	2004	
NOSS	1	800	32.83	84.29		1968	2004	1993	1997	2001		-	-	-	-	-	

[a] *Two outlier values have been detected in the variable SIZE and excluded from the analysis.*
[b] *Data on the year of Open Source adoption are available only for a subset of respondents (N=146).*

Clusters' structural characteristics (continued)

	SKILLS					*MAIN CUSTOMERS*						
Cluster	*Min*	*Max*	*Mean*	*Std. Dev.*	*Anova F-test p-value*	*SMEs*	*Large Firms*	*Univ.*	*Public sector*	*End users*	*Others*	*Kruskal-Wallis test p-value*
POSS	0	100	68.03	34.24	0.077	73.68	10.53	5.26	10.53	0.00	0.00	0.000
MOSS	0	100	60.65	35.83		54.29	20.00	1.43	20.00	0.00	4.29	
LOSS	0	100	54.62	38.21		49.40	30.12	3.01	12.05	3.01	2.41	
NOSS	0	100	51.26	39.46		64.40	24.51	0.58	6.42	1.95	2.14	

Table 7: Distribution of the OSS turnover in 2000 and 2003

Share of turnover generated by OSS	*Year 2000*		*Year 2003*	
	N	*%*	*N*	*%*
0%	85	33.33	28	10.98
< 10%	77	30.2	72	28.24
10% - 30%	42	16.47	60	23.53
31% - 50%	7	2.75	30	11.76
51% - 70%	10	3.92	19	7.45
71%- 90%	10	3.92	17	6.67
91%and 99%	14	5.49	18	7.06
100%	10	3.92	11	4.31
TOTAL	255	100	255	100

Table 8: Firms' assessment on patents

	We think that patents…[a]	*YES (%)*				*Fisher exact test p-value*
		MOSS	*LOSS*	*NOSS*	*TOTAL*	
		N = 49	N = 142	N = 370	N = 561	
1	Promote innovation	4.08	27.46	37.57	32.09	0.000
2	Hamper innovation	73.47	52.82	34.86	42.78	0.000
3	Do not prevent our potential competitors to enter the market	71.35	75.35	67.35	71.70	0.581
4	Need a too long legal procedure	87.76	69.72	65.95	68.81	0.030
5	Are costly	81.63	76.06	70.00	72.55	0.166
6	Constraint versioning	61.22	50.70	35.41	41.53	0.001
7	Provide information about innovations and product development by other firms	18.37	28.87	25.68	25.85	0.055

[a] *Possible answers: YES, NO; MAYBE. Few firms chose MAY BE and this justifies the use of a Fisher exact test.*

Table 9: Firms' assessment on licenses

	We think that licenses…[b]	*YES (%)*				*Fisher exact test p-value*
		MOSS	*LOSS*	*NOSS*	*Total*	
		N = 49	N = 142	N = 370	N = 561	
1	Contribute notably to the sales of our products	22.45	43.66	54.59	49.02	0.000
2	Require complex contractual agreements	28.57	29.58	18.92	22.46	0.021
3	Constraint versioning	22.45	17.61	12.97	14.97	0.351
4	Make us dependent on our supplier licensors	34.69	43.66	39.46	40.11	0.586
5	Help us to control our products	36.73	65.49	67.30	64.17	0.000
6	Create networks of firms with which we share a common knowledge	28.57	29.58	32.16	31.19	0.733
7	Help us to recover our R&D investments	36.73	54.93	59.19	56.15	0.013

[b] *Possible answers: YES, NO; MAYBE. Few firms choose MAY BE and this justifies the use of a Fisher exact test.*

Table 10: Number of product categories supplied by firms

Cluster	*N*	*Min*	*Max*	*Mean*	*p50*	*p75*	*p95*	*Std. Dev.*	*Anova F-test p-value*
POSS	19	3	18	9.10	8	13	17	3.77	0.000
MOSS	70	0	18	9.17	10	14	18	5.46	
LOSS	166	0	18	6.72	5	11	17	5.28	
NOSS	514	0	18	4.82	3	8	12	4.55	
TOTAL	769	0	18	5.65	4	10	16	4.99	

Table 11: Firms' offering in the 18 products categories

ID	*Classes*[a]	*Product category*	*NOSS*		*LOSS*		*MOSS*		*POSS*		*TOTAL*	
			N 514		*N 166*		*N 70*		*N 19*		*N 769*	
			N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
1	S	Web servers	163	31.71	93	56.02	51	72.86	11	57.89	318	41.35
2	S	Other kinds of servers	153	29.77	73	43.98	47	67.14	11	57.89	284	36.93
3	N	Back up Systems	146	28.40	57	34.34	40	57.14	10	52.63	253	32.90
4	N	Firewall	135	26.26	73	43.98	39	55.71	8	42.11	255	33.16
5	N	Antispam	117	22.76	69	41.57	39	55.71	8	42.11	233	30.30
6	N	Antivirus	130	25.29	68	40.96	37	52.86	7	36.84	242	31.47
7	N	User and Identity Management	123	23.93	53	31.93	35	50.00	10	52.63	221	28.74
8	W	E-mail Client	133	25.88	63	37.95	40	57.14	10	52.63	246	31.99
9	W	Instant Messaging	82	15.95	43	25.90	28	40.00	11	57.89	164	21.33
10	W	Web Browser	37	7.20	38	22.89	22	31.43	3	15.79	100	13.00
11	W	Digital Signature Systems	41	7.98	28	16.87	13	18.57	6	31.58	88	11.44
12	W	Content Management System	127	24.71	73	43.98	45	64.29	12	63.16	257	33.42
13	W	E-commerce solutions	150	29.18	70	42.17	38	54.29	10	52.63	268	34.85
14	W	E-learning Tools	63	12.26	39	23.49	27	38.57	10	52.63	139	18.08
15	O	Management Software	333	64.79	84	50.60	38	54.29	13	68.42	468	60.86
16	O	Data Management Software	274	53.31	82	49.40	44	62.86	16	84.21	416	54.10
17	O	Workflow Systems	130	25.29	42	25.30	25	35.71	10	52.63	207	26.92
18	O	Office Automation Packages	140	27.24	67	40.36	34	48.57	7	36.84	248	32.25

[a] *Products have been grouped as follows. S: server products, N: network infrastructure products; W: Web products; O: Other kind of products*

Table 12: Number of service categories supplied by firms

Cluster	*N*	*Min*	*Max*	*Mean*	*p50*	*p75*	*p95*	*Std. Dev.*	*Anova F-test p-value*
POSS	19	4	11	8.58	9	11	11	2.06	0.000
MOSS	70	0	11	9.09	10	11	11	2.17	
LOSS	166	0	11	7.61	8	10	11	2.73	
NOSS	514	0	11	7.44	8	10	11	2.73	
TOTAL	769	0	11	7.65	8	10	11	2.71	

Table 13: Firms' offering in the 11 service categories

ID	Software related services	NOSS		LOSS		MOSS		POSS		TOTAL	
		N 514		N 166		N 70		N 19		N 769	
		N	%	N	%	N	%	N	%	N	%
1	Consultancy	459	89.30	152	91.57	67	95.71	18	94.74	696	90.51
2	Integration	384	74.71	137	82.53	66	94.29	18	94.74	605	78.67
3	Installation	409	79.57	124	74.70	62	88.57	16	84.21	611	79.45
4	Assistance	439	85.41	133	80.12	67	95.71	17	89.47	656	85.31
5	Maintenance	431	83.85	135	81.33	66	94.29	15	78.95	647	84.14
6	System Management	242	47.08	83	50.00	47	67.14	11	57.89	383	49.80
7	Training	368	71.60	110	66.27	54	77.14	10	52.63	542	70.48
8	Application Management	232	45.14	67	40.36	40	57.14	10	52.63	349	45.38
9	Adapting codes written by others to suit customers' needs	219	42.61	99	59.64	54	77.14	17	89.47	389	50.59
10	On order software development from the scratch	356	69.26	129	77.71	62	88.57	14	73.68	561	72.95
11	Generating documentation	285	55.45	95	57.23	51	72.86	17	89.47	448	58.26

APPENDIX

Table A 1: Population (EUROSTAT 2003) and sample size distribution of firms in NACE code 72

SIZE	*FINLAND*				*GERMANY*				*ITALY*			
	POP.		*SAMPLE*		*POP.*		*SAMPLE*		*POP.*		*SAMPLE*	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
< 10	3 805	89.19	71	52.59	37 314	88.52	17	18.28	79 326	94.38	202	83.13
10-19	203	4.76	30	22.22	2 525	5.99	23	24.73	2 921	3.48	28	11.52
20-49	142	3.33	17	12.59	1 478	3.51	26	27.96	1 160	1.38	11	4.53
50-249	101	2.37	12	8.89	699	1.66	17	18.28	537	0.64	2	0.82
≥250	15	0.35	5	3.70	138	0.33	10	10.75	106	0.13	0	0.00
TOTAL	4 266	100.00	135	100.00	42 154	100.00	93	100.00	84 050	100.00	243	100.00

Table A 1, continued

PORTUGAL				*SPAIN*				*TOTAL*			
POP.		*SAMPLE*		*POP.*		*SAMPLE*		*POP.*		*SAMPLE*	
N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
2533	90.37	50	51.02	21 105	90.72	38	19.00	144 083	92.04	378	49.15
130	4.64	31	31.63	1 086	4.67	60	30.00	6 865	4.39	172	22.37
80	2.85	12	12.24	666	2.86	57	28.50	3 526	2.25	123	15.99
52	1.86	4	4.08	313	1.35	30	15.00	1 702	1.09	65	8.45
8	0.29	1	1.02	95	0.41	15	7.50	362	0.23	31	4.03
2803	100.00	98	100.00	23 265	100.00	200	100.00	156 538	100.00	769	100.00

Table A 2: Correlation matrix of the variables used in the cluster analysis

Variable	OS_TURNOVER		OS_OFFERING		SOLUTIONS		GPL_INTENSITY	MOTIVATION
OS_TURNOVER	1.000							
OS_OFFERING	0.177	***	1					
SOLUTIONS	0.478	***	0.254	***	1			
GPL_INTENSITY	0.179	***	0.177	***	0.175	***	1	
MOTIVATION	0.066		0.002		0.072		0.098	1

Table A 3: Factor loadings of the principal component analysis

Variable	*Acronym*	*Principal Components*	
		1	2
Percentage of Open Source turnover out of the total in year 2003	OS_TURNOVER	0.542	-0.076
Share of OSS solutions on the overall products supplied by the firm	OS_OFFERING	0.436	-0.298
Typologies of solutions supplied by the firms	SOLUTIONS	0.571	-0.122
Intensity of the use of GPL	GLP_INTENSITY	0.404	0.226
Firms' attitudes towards the values of the OSS community	MOTIVATION	0.163	0.916