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Applying open innovation in business strategies: Evidence from Finnish software firms

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ABSTRACT

Our study aims at shedding light on the innovative business strategies in the software sector and understanding better the economics that underlies the supply of Open Source Software (OSS). We use survey data collected from 170 Finnish software companies to investigate how different properties of software firms, such as size, age, intellectual capital, absorptive capacity, and ownership structure affect their decisions to base their business strategies on OSS supply or proprietary distribution of products and services.

Our empirical findings indicate that the adoption of technologically advanced strategies requiring complex legal and managerial knowledge, such as the OSS supply strategy, demands relatively highly educated employees. The support for and development of an education system providing highly skilled people from different fields are essential for the firms' successful adoption of innovative business strategies. We also find that market entrants have largely driven the OSS adoption, but there are no significant age-related differences in the adoption behavior of incumbent software firms.

1. Introduction

Software producers are provided with appropriation regimes that are stronger than ever and can protect their products as intellectual property by both patents and copyrights (Cowan and Harison, 2001). By establishing monopoly rights over new applications, firm developing software expect to recoup their investments in R&D and product distribution, generating revenues for long periods.

Open Source Software (OSS)[2] is a privately produced public product and its source code can be downloaded from the Internet and used free of charge. In theory, we should not see many commercial OSS products and their OSS development should be rather limited, as OSS attempts to go against economic logic by not exploiting the legal framework to generate monopoly revenues from proprietary products. However, in reality, the number of OSS projects (both voluntary and commercial) continuously increases, ranging from ones focusing on small utilities and device drivers to those targeted to develop large and complex packages, such as Apache, Open Office, and MySQL. OSS has proved to be a viable mode of innovation and software production: some OSS projects capture substantial market shares from commercial competitors, introducing novel features and superior performance.[3] The Linux operating system, initially developed by the Finn Linus Torvalds, is a paragon of an OSS product that successfully competes with rival proprietary products (such as Microsoft's operating systems) and it is continuously improved by a large community of programmers and users.

In the past few years, OSS development has rapidly shifted from a model driven purely by communities of developers and applications supported mainly by the academic milieu toward commercial environment as many software companies have adopted the OSS supply-based business strategies. The possibilities offered by the

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[2] OSS is freely distributed online, can be used and developed by all and hence it is non-excludable like other public goods. OSS relies on volunteers for the provision of new code, bug fixes of the existing code, online help with problems running and installing the program. See http://www.opensource.org/docs/definition_plain.html for the definition of the Open Source. Taxonomy of Open Source licenses is at http://www.opensource.org/licenses/.

[3] For instance, Kuan (2001) suggests that OSS outperforms commercial proprietary software by comparing bug resolution rates in OSS and proprietary applications as a proxy for quality.

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OSS have attracted new SMEs providing products and services by applying freely available products. Importantly, OSS has also reshaped the business models and strategies of large firms, including such major industrial players as IBM, Oracle, Philips, Nokia, and SAP, which have chosen to integrate OSS applications into their R&D activities, core products, and services.[4]

There is a vast literature on Open Source focusing on the technological and business aspects of OS applications[5] (Raymond, 2001; Feller and Fitzgerald, 2002; Fink, 2003) and on cost-saving effects achieved by substituting proprietary programs with equivalent OSS applications (see, for example, Fitzgerald and Kenny, 2003a). Only relatively recently have economists begun analyzing the economic mechanisms underlying Open Source communities and the incentives that facilitate OSS development[6]. For example, Lerner and Tirole (2005) explore the properties of OSS licenses using data from 40,000 OSS projects. They conclude that projects geared toward end-users tend to have relatively restrictive licenses, while those oriented toward developers, the Internet, or commercial operating systems use less restrictive terms. Bonaccorsi and Rossi (2003a,b) conducted a large-scale survey of Italian firms that supply and implement Open Source solutions. They analyzed how different sources of motivation (related to social, economic, and technological aspects) determine the involvement of various groups of developers in OSS activities. However, these studies mostly aim at identifying the internal structure of OSS communities and the motives of individuals participating in them.

Some recent empirical studies shed light on the OSS business model strategies of the firms (see, e.g., Bonaccorsi et al., 2006). The study of Bonaccorsi et al. (2006) implies that firms that have adopted OSS-based business strategy tend to choose a hybrid business model comprising both OSS and proprietary software supply. It further finds that the degree of openness of the firm's business strategy is negatively related to the switching costs on the supply side and network effects on the demand side but not to firm size. The recent empirical study of Koski (2005) that explores the choices of product and license types in Finnish OSS companies is also close to our work. She concludes that firms that focus on the provision of services tend to supply their products under OSS licenses, whereas firms owned by a family or individuals tend to rely on "traditional" proprietary software in their product selection. Moreover, market trends and participation in OSS development projects affect the licensing of individual software products, such that companies developing their products as OSS tend to choose mostly the dominant OSS license type.[7]

Our empirical study aims at shedding further light on the choice of OSS as a commercial strategy by analyzing the differences between software companies that decide to supply OSS products and/or services and those that provide only proprietary software solutions. Those companies that combine OSS in their products (either purely or as part of the hybrid strategy) are denoted *OSS firms*, and those that provide only proprietary software are referred to as *non-OSS firms*. Our approach differs from those of Bonaccorsi et al. (2006) and Koski (2005) analyzing differences in the strategies of the OSS companies as we focus on the differences *between* OSS and non-OSS firms by including both types of company in our dataset. Moreover, Koski (2005) used product-level data of 18 different product categories, whereas we focus on firm-level analyses.

Several case studies also explore why some software companies choose to supply OSS products and services whereas others apply hybrid strategies in which part of the product features are developed and offered as OSS and others are kept proprietary, or they employ merely proprietary supply strategies (McKelvey, 2001). West (2003) studied the shift in IBM, Apple, and Sun's strategies from development of proprietary operating systems to hybrid, Linux, and Solaris-based platforms in response to increasing R&D costs and competitive pressures from software and hardware producers. Harison and Cowan (2004) explain how different firm strategies, measured by the share of features distributed as OSS, affect the firms' profitability and the performance of their products. The results of their model suggest that rent-seeking firms adopt hybrid strategies and increase the share of OSS features in their products when revenues from complementary services and features increase.

We employ systematic data analysis (i.e. econometric analysis) to shed light on the adoption of different software supply strategies. We use survey data collected from 170 Finnish software companies to investigate how different firm characteristics affect the choice of OSS business strategies in the software sector. Our study also assesses the impact of absorptive capacity (i.e. the ability to absorb, apply, and draw commercial benefits from information or innovation produced outside the firm boundaries; Cohen and Levinthal, 1990) on the adoption of OSS-based supply strategies. Absorptive capacity plays an important role in this context, as the availability of OSS source code and applications enables virtually every Internet user to download them and establish software development or service-providing ventures. The interpretation and use of software programs and their source code typically require significant knowledge and long-term experience that most end-users lack. The commercial exploitation of OSS requires certain learning, experience, and assimilation skills. Those competences play a particularly important role in producing new OSS-based products and technologies building upon former know-how shared within and among organizations and OSS communities.[8]

The paper is organized as follows. Section 2 discusses the business strategies of software companies in the light of the economic literature. Section 3 introduces our data and the research methodology. Section 4 discusses the estimation results and Section 5 concludes and provides a summary of our main findings.

2. Software business strategies

A vast number of potential firm-level factors may affect a firm's business strategy regarding the provision of OSS or proprietary software. The contemporary empirical evidence relies, by and large, on case studies and analyses of particular projects (e.g. Dahlander and Magnusson, 2005) with few exceptions (Bonaccorsi and Rossi, 2003c; Henkel and Tins, 2004; Bonaccorsi et al., 2006). Our research aims at assessing how various characteristics of a firm affect its choices of software business supply strategies. The factors chosen for the analysis are based on the economic literature on the dynamics of innovation and firm strategic behavior, particularly those concerning the adoption of new technologies (see e.g. Antonelli, 1995; Freeman and Soete, 1997; Von Westarp, 2003). While building the econometric model, we also use the recent discussion on entrepreneurial activities that are based on provision of OSS prod-

[4] In January 2005, IBM released 500 of its software patents for the use of OSS developers. Moreover, in November 2005, IBM, Novell, Philips, Red Hat and Sony jointly announced a creation of a Open Invention Network (OIN) that offers a collection of patents royalty-free to promote innovation around Linux.

[5] Garzarelli and Galoppini (2003) analyze the development and production process and project organization of the Debian GNU/Linux operating system.

[6] See, for instance, the special issue of Management Science on OSS (Management Science, July 2006, edited by Eric von Hippel and Georg von Krogh, Von Krogh and von Hippel, 2006).

[7] This finding is consistent with the findings of Lerner and Tirole (2005) that more than 70% of the OSS development projects employ the GPL copyleft license.

[8] Scotchmer (1991) describes technological progress as an ongoing innovative process, in which new discoveries are made by "standing on the shoulders of giants" (see also Nonaka et al., 2000).

ucts and services (see, e.g., Young, 1999; West, 2003; Välimäki and Oksanen, 2005).

The *absorptive capacity* of the firm, that is, its ability to absorb, apply, and draw commercial benefits from external information or innovation produced outside its boundaries (Cohen and Levinthal, 1990), is likely to be one of the key factors affecting the adoption of OSS supply as a business strategy. Even though absorptive capacity is essentially a qualitative concept rather than a quantitative term, it can be attributed to many aspects of the organization and its activities. When the technical complexity of the knowledge is too high and most employees lack the necessary degree of absorptive capacity they are likely to ignore it, even though this know-how could have been useful to the firm. Following this argument, when the degree of absorptive capacity rises, the benefits from external innovation (i.e. OSS) that can be implemented by the firm also increase. Consequently, when the firm's level of absorptive capacity increases, we expect higher degrees of adoption of external technologies and business practices, in this case OSS.[9]

A major determinant affecting the absorptive capacity of the firm and its ability to use, and possibly further develop, invention is the firm's *intellectual capital*, which includes its human capital and intellectual property.[10] The strategic use of OSS requires not only technical (computing) skills, which are similarly needed in the development of proprietary software, but also knowledge of certain OSS specific legal issues and business practices. Those practices typically involve high degrees of uncertainty due to the novelty of incorporating OSS in business models.

The education level of employees roughly quantifies their quality and skills and is often used to measure a firm's human capital. Empirical evidence also indicates that the development of major OSS projects was initiated mainly within academic and public research institutes.[11] In turn, it seems possible that the strategies of the firms in which advance degree holders are employed would be more likely to implement the OSS-based strategies. We use the (log) share of employees having at least a university degree to capture the education level of the firm's employees (variable EDUC).

Specific technical or managerial skills are often necessary to foster adoption of new technologies. Software developers are an important part of the specialized human capital that acts as "change agents", fostering OSS development in firms. It seems likely that companies with more developers are more likely to adopt OSS-based strategies. This prediction is based upon several motives of programmers and engineers. First, development of new technologies and functional features, and the provision of solutions to technologically challenging problems, can be intellectually satisfying for programmers (Brooks, 1995). In the case of OSS, those motives are further prompted by accessibility to the programs' source code. Technology-driven motives (often referred to as "self-satisfaction" that employees derive from accomplishing technically advanced or complex tasks) are usually stronger than profit-generating motives (Lerner and Tirole, 2002; Ghosh et al., 2005).[12] Therefore, programmers are likely to encourage the firm to favor OSS-based strategies, in which they can further the performance of programs and continuously be challenged by other professionals, over proprietary policies.

Second, the ambition of programmers to apply OSS in their workplace is also driven by learning. The operation of OSS projects as "communities of practice" and the disclosure of source code enable programmers to acquire valuable knowledge and develop their skills through work done by others.[13] Third, ideologically, programmers are more motivated to participate in OSS projects through which they contribute to communities of software developers and users and express their professional interests and skills. Fourth, developers of OSS receive credits for their developments and can earn a reputation within firms and the professional community, thus enhancing their future career prospects.[14] We assess the impact of developers on firm strategy via the variable DEVELOPER that captures the share of software developers among firm's employees.

The intellectual property of firms includes copyrighted works, trademarks, and patented inventions. Companies managing large portfolios of intellectual property typically manage their knowledge assets more efficiently and hence are assumed to have a higher degree of intellectual capacity enabling them to create greater benefits from acquired know-how. Therefore, we expect that firms with larger intellectual property portfolios would be early adopters of innovations, such as the Open Source methodology and applications.

In the case of software, it is particularly difficult to measure the volume of intellectual property that a firm owns, as most software products are by nature protected by copyrights.[15] Since no statistical data on the size and range of copyrighted software of companies are available, records of trademarks and patent applications of firms in Finland and the United States are used to form an indicator for intellectual capacity. The variable (IPR) gets values from 0 to 3 as a sum of three dummy variables that indicate whether the firm applied the following appropriation methods: (i) patents in Finland, (ii) patents in the United States, and (iii) trademarks in Finland. This is by no means a perfect measure of firms' intellectual property, but it roughly distinguishes between companies that have chosen to patent their innovations and/or protect their intellectual property by trademarks from those that have not.[16] Since some companies in our sample provide only services and do not develop any products, technical innovation usually lies outside the scope of their business activities and the magnitude of patenting activities does not describe well their innovativeness. Therefore, we control for the

[9] Ghosh et al. (2005) indicate that a significant number of software firms allow their workers to participate in OSS projects *during their workday*, as those companies perceive the contribution to OSS projects and knowledge exchange with other developers as an essential source of learning and acquisition of professional skills.

[10] Granstrand (2000) defines intellectual capital as follows: "Intellectual capital comprises all non-material or intangible resources that could be considered as capitalizable assets of an economic agent... decomposed from the point of view of a firm into IPRs in patents, databases, trade secrets, trademarks, relational capital related to qualities in internal and external relations incorporating organizational capital, goodwill and reputation and human capital related to competencies of various kinds". Empirical studies identify positive correlation between firm value and its intellectual capital (see e.g. Hall, 1999).

[11] The economic literature suggests there are strong links between Open Source and academic communities. Various scholars highlight the similarities between Open Source and "open science", as both are driven by community efforts and by reputation and their final results are freely distributed to the public. Feller and Fitzgerald (2002) discuss the relations between Open Source and *open science* and draw analogies between the dynamics of OSS and scientific communities. Dalle and Julien (2003) describe the success of Open Source communities to create a framework for software development in similar terms to those used in the academic world. David and Spence (2003) draw parallels between the Open Source movement and scientific research by analyzing the development of the Open Source *Globus* grid-computing platform.

[12] Ghosh et al. (2005) found that programmers that develop OSS do it mainly in their free time as a hobby or for leisure. Interaction with other professionals and innovativeness were also found to be major motives for participation in those projects.

[13] A common view among developers is that "good programmers know what to write. Great ones know what to rewrite (and reuse)" (Raymond, 2001).

[14] For a detailed discussion of developers' motives to participate OSS projects see, e.g., Lerner and Tirole (2002).

[15] Different from patent protection, creators of artistic and literary works, *including* software, do not have to register them in order to protect their output. In this sense, copyright protection can be viewed as an "automatic right", unless it is deliberately abolished by the authors, as most OSS licenses do.

[16] Only about 9% of sampled firms have applied for one or more patents and about 15% of them applied for one or more trademarks.

pure service companies by a dummy variable, PURE_SERVICE that gets value 1 when the firm provides only services and 0 otherwise.

We predict that companies with a larger volume of intellectual capital (i.e. human capital and intellectual property) are more likely to adopt OSS, and test the following hypotheses:

Hypothesis 1a. The propensity of the adoption of OSS-based strategies increases with the share of advanced degree holders employed by the firm.

Hypothesis 1b. The propensity of the adoption of OSS-based strategies increases with the share of developers employed in the firm.

Hypothesis 1c. The adoption of OSS-based strategies is positively correlated with the volume of intellectual property that the firm owns.

New companies are often the best exploiters of new business opportunities, including (potentially) radical inventions that make the old business models and technologies obsolete. The economic theory of industrial organization suggests that incumbents may resist technical change not only because of lack of capabilities to apply new methods and techniques, but mainly because they also try to avoid "cannibalizing" existing market niches and their investments in products, facilities, and capabilities (Arthur, 1989; various examples in different technological areas can be found in: David, 1985; Cowan, 1990; Cowan, 1991). In case of the OSS supply, the incumbents may fear cannibalizing their revenue streams from their existing proprietary software solutions.

Further, though it is possible that older firms are better able to adopt the innovative business models due to their greater capital and knowledge assets, insights from evolutionary economics suggest that older firms tend to rely on prior experience and "lock-in" to older market strategies and proven procedures despite changes in their business environment. Younger firms are typically more flexible in adapting their strategies and internal practices to the changing environment (Nelson and Winter, 1982). Firms that fail to adapt their organizational processes and do not update the reservoir of their technological capabilities remain with obsolete know-how and fail to catch up with rivals with advanced technologies (Henderson, 1999). Consequently, the older firms would be more reluctant to offer their products and services under OSS licensing terms and are less likely to adopt OSS-based strategies than recently established companies.

We measure the age of the firm by the (log) year of its establishment (ESTABL_YEAR) and form the following hypothesis:

Hypothesis 2. A firm's propensity to adopt OSS supply strategies is decreasing with the age.

The Open Source model encompasses tangible potential for developing innovation and fostering growth of small and medium enterprises (SMEs) and service firms in the ICT industry.[17] Firms have virtually zero entry and production costs acquiring freely available source code. Also, SMEs may prefer independence from large software vendors, which may further influence their choices between OSS and proprietary products. The Microsoft anti-trust case illustrates how firms' choices are significantly affected by the business practices of a monopolist.[18] Moreover, successful adoption of OSS strategies requires the frequent exchange of knowledge between workers, by forming organizational interaction structures that "resemble a great babbling bazaar of differing agendas and approaches out of which a coherent and stable system could seemingly emerge only by a succession of miracles" (Raymond, 2001). Since the degree of informal knowledge exchange is typically lower in large firms (see, e.g., Dougherty, 1992), we expect that their ability to form complex informal structures of communication that integrate their software development into OSS communities may be limited in comparison to SMEs.

The markets have, however, witnessed that various big players such as IBM have also adopted the OSS-based business strategy. The underlying reasons for the large incumbent software companies to distribute OSS products are typically very different from those of the small firms and market entrants. The large companies, unlike market entrants and small firms, have substantial revenue streams from their existing proprietary products and/or services, and the release of their technology in open source format cannibalizes these revenue streams. However, this may be a profitable strategy if a firm's technology then becomes widespread and forms a de facto standard, and the firm can benefit from compatibility (since it does not need to adapt its products to some other standard), have technology improved by the OSS community, and have revenue streams from the sales of related products and services (see, e.g., West and Callagher, 2006, also for more detailed discussion on individual firm cases). Furthermore, the OSS adoption can generate goodwill further increasing the firm's customer base and demand, and the OSS customers may further become the buyers of the firm's proprietary offerings (like Sun that announced that its software sales grew 13% during the year they aggressively gave away free software[19]). Also, large firms may maintain or even enhance their customer base by supplying, in addition to their high-priced proprietary solutions, low-cost OSS alternatives (for instance, IBM's decision to acquire and provide Gluecode OSS along side its own proprietary WebSphere).

The variable SIZE is the order of magnitude of a firm's turnover and captures the firm size (see Table 1 for a detailed description). Following the above discussion, and the commonly expressed view of the OSS literature based on the real-world observations that there are greater incentives for small firms to adopt the OSS-based business strategy, we form the following hypothesis:

Hypothesis 3. The propensity to apply OSS-based supply strategies decreases with the firm's size.

The ownership structure of firms may also affect the OSS strategies that they adopt. Decision-making processes in family-owned firms largely differ from those of other types of company (Schulze et al., 2001). Family-owned companies typically have fewer problems with managerial incentives than diffusely held companies, as the owner is often either the manager or, due to his major shareholder position, closely monitors the managers' activities. Consequently, there is less chance that managers would make investments that are not in the best interests of the firm and provide some private benefits for themselves, such as improved career opportunities. On the other hand, the managers of diffusely held software companies do not bear the full costs of their strategic decisions. They can personally benefit from adopting OSS supply strategies, for example, in terms of new knowledge, experience, and expanding their career opportunities. Hence, they may be

[17] Lakhani and Von Hippel (2003) argue that Open Source communities have succeeded in addressing the problem of limited IT resources in SMEs by creating efficient online "helpdesks" for OSS users. Those online services successfully substitute formal technical support offered by proprietary software producers.

[18] Whinston (2001) analyzes the case from an economic standpoint and argues that Microsoft relied on two prominent strategies: First, Microsoft established exclusive agreements with hardware vendors to provide its operating system as the sole platform for their products, therefore binding consumers to it. A second and complementary strategy was the bundling of applications (e.g. Microsoft Internet Explorer and Media Player) with its operating system and promoting them by offering distributors reduced licensing fees, co-marketing funds, and other incentives.

[19] See "Inside of Sun's Open Source Strategy", *InfoWorld* August 09, 2007.

Table 1
Explanatory variables.

Variable	Definition	Mean (Std dev)	Min value	Max value
EDUC	Log share of employees having at least university degree	−0.581 (0.653)	−2.944	0
DEVELOPER	Log share of software developers of firm's employees	−1.107 (2.001)	−9.210	0
IPR	Variable that is the sum of three dummy variables that get value 1 if firm has applied for (i) patent(s) in Finland, (ii) patent(s) in the US, iii) trademarks in Finland (and 0 otherwise).	0.252 (0.511)	0	2
SIZE	Variable gets (log) value if firm's turnover in 2003 is (1000 euro)			
	2, 0 3, 1–199 4, 200–399 5, 400–999 6, 1000–1999 7, 2000–9999 8, 10,000–19,999 9, 20,000–	1.525 (0.339)	1.099	2.197
ESTABL_YEAR	Log the year firm was established	7.599 (0.004)	7.583	7.603
FAMILY_OWN	Dummy variable that gets value 1 if firm is owned by a family or an individual and 0 otherwise	0.645 (0.480)	0	1
PURE_SERVICE	Dummy variable that gets value 1 if firm provides only services and 0 otherwise	0.101 (0.302)	0	1
SERVICES	Service variety = number of service categories (S1,. . ., S11 below) provided by firm, variable gets values between 0 and 11	7.276 (3.044)	0	11
S1_Consultancy	Dummy variable that gets value 1 if firm provides consultancy services, 0 otherwise	0.904 (0.206)	0	1
S2_Integration	Dummy variable that gets value 1 if firm provides integration services, 0 otherwise	0.716 (0.452)	0	1
S3_Installation	Dummy variable that gets value 1 if firm provides installation services, 0 otherwise	0.627 (0.485)	0	1
S4_Assistance	Dummy variable that gets value 1 if firm provides assistance services, 0 otherwise	0.754 (0.432)	0	1
S5_Maintenance	Dummy variable that gets value 1 if firm provides maintenance services, 0 otherwise	0.784 (0.413)	0	1
S6_SystemManagement	Dummy variable that gets value 1 if firm provides system management services, 0 otherwise	0.425 (0.496)	0	1
S7_Training	Dummy variable that gets value 1 if firm provides training services, 0 otherwise	0.731 (0.445)	0	1
S8_Application Management	Dummy variable that gets value 1 if firm provides application management, 0 otherwise	0.440 (0.498)	0	1
S9_Adapting codes written by third parties to suit customers' needs	Dummy variable that gets value 1 if firm adapts codes written by third parties to suit customers' needs, 0 otherwise	0.701 (0.459)	0	1
S10_On order software development from the scratch	Dummy variable that gets value 1 if firm does On order software development from scratch, 0 otherwise	0.694 (0.463)	0	1
S11_Generating documentation	Dummy variable that gets value 1 if firm generates documentation, 0 otherwise	0.500 (0.501)	0	1

more likely to apply OSS strategies than managers of family-owned companies ("manager-owners").

OSS supply strategies can be adopted to *signal* to potential investors' valuable innovative capabilities and knowledge that may increase the (future) value of the firm. This is particularly important for diffusely held companies with many small or individual shareholders. Moreover, family- and individually-owned firms tend to be more risk-averse than diffusely held companies, as the private wealth of manager-owners is often tied to the firm's capital. Therefore, as OSS business is a new business model and a relatively risky investment with highly uncertain returns, family-owned companies are usually more reluctant to adopt OSS supply strategies.

Koski (2005) indicates that family-owned software firms *that have adopted the OSS business model* tend to supply proprietary software products or have hybrid OSS strategies biased towards supplying proprietary solutions more than diffusely held OSS companies. Therefore, we expect that family- and individually-owned firms would apply "pure" proprietary strategies more often than OSS and hybrid strategies. In our analysis, the dummy variable FAMILY_OWN distinguishes between family-owned and diffusely held companies. On this basis, we form the following hypothesis:

Hypothesis 4. Family-owned firms are less likely to apply OSS supply strategies than other companies.

In network markets, such as information technologies, complementary products and services have an important role. Since OSS strategies rely on distribution of free products and their source code, provision of complementary services is the major source of revenues. Therefore, the more complementary services for software products the firm offers the more it benefits from the provision of OSS, and thus the more likely it will adopt a business strategy based on OSS supply. We form the following general hypothesis:

Hypothesis 5. A firm's propensity to adopt an OSS strategy increases with a larger variety of services.

We use two types of variables to assess the influence of service provision on the decision to adopt OSS supply strategy. First, we measure the order of magnitude of the variety of services that each firm offers by the variable SERVICE_VARIETY. It receives values on a 0–11 scale by aggregating the number of services offered by the firm (i.e. if a firm offers no services it gets the value 0, and if it provides services in all of the sampled categories it gets the value 11). Second, we test which particular service types affect the adoption of OSS business strategy. For this purpose, we use dummy variables that represent 11 service categories that are applied by the firms in our sample (see Table 1 for a detailed description of the service types).

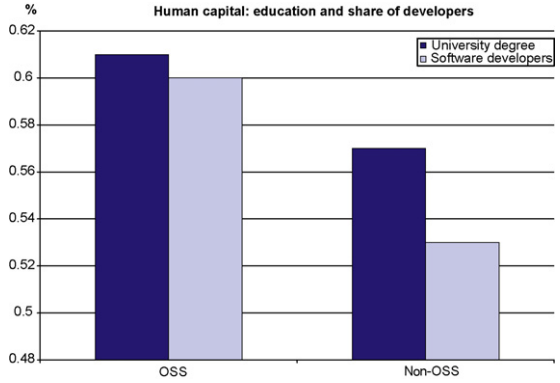

Fig. 1. . Human capital: share of developers and employees with university degree.

3. Empirical analysis

Our data were collected by a web survey during November 2004–February 2005.[20] We approached 591 Finnish software companies by e-mail, asking them to respond to our web questionnaire.[21] The data comprise of responses from 170 firms (circa 30% response rate),[22] which are approximately 8% of all the software firms in Finland. To evaluate the representativeness of our sample in relation to information concerning Finnish software business sector available from other sources, we compared our sampled firms' characteristics to the Finnish software product business companies reached by the National Software Industry Survey (NSIS) 2004 made by Helsinki University of Technology (see Jokinen et al., 2004). On average, there were 118 (median 8) employees per firm in our sample. The NSIS was fairly similar with an average of 123 employees per firm (median 9.5). The average age of a company in our sample is around 9 years (median 8), which is a little lower compared to the NSIS survey, which had an average of 11.2 and a median of 10. Therefore, our sample seems fairly comparable to that of NSIS concerning the size and age of the companies.

In our sample, 73 firms supply OSS products and/or services and 97 offer merely proprietary software or services. Seven of the proprietary software producers had supplied OSS products and services in the past but discontinued their OSS activities.

OSS firms employ, on average, relatively more highly educated developers and employees than companies that provide proprietary solutions. Fig. 1 compares the human capital (i.e. the share of developers and employees with a university degree) of OSS and proprietary firms. About 61% (57%) of the employees of OSS (non-OSS) companies hold a university degree, usually a Bachelor or a Master's degree, and less than 2% of the employees have a PhD. About 60% (53%) of the degree holders in OSS (non-OSS) firms are developers. The statistical significance of these observations was tested in the empirical models.

Only a relatively small share of the companies in our sample applied for patents in Finland or the United States (10% and 11% of the non-OSS and OSS firms respectively). The Open Source movement is strongly associated with opposition to software patents and patenting in general, yet some of the companies that provide OSS solutions are as active in forming intellectual property portfolios as firms that develop and supply proprietary software. Interestingly, an OSS firm filed on average 0.35 patent applications in Finland, whereas non-OSS companies filed only 0.09 patent applications. Providers of proprietary solutions had more trademark applications than OSS firms: about 19% of the non-OSS firms applied for trademarks with 0.59 trademarks per firm, in comparison to 10% of the OSS firms that applied for trademarks with 0.31 trademarks per firm (Fig. 2).

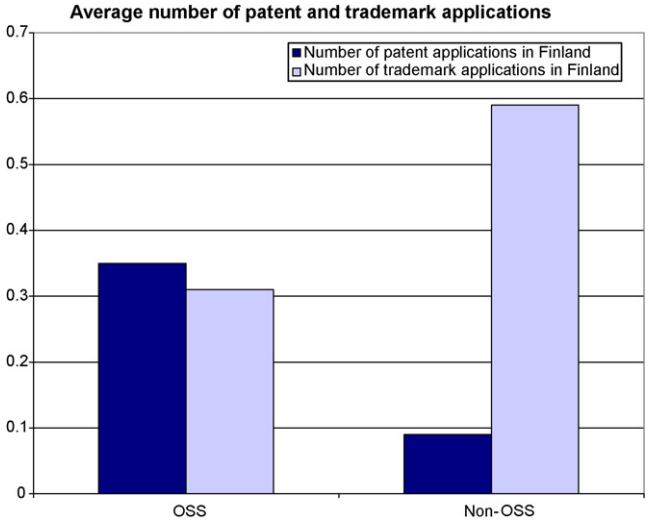

Fig. 2. . Patent and trademarks applications per firm: OSS vs. non-OSS firms.

4. Discussion of the estimation results

First, we estimated the probit model that compares software companies supplying OSS products and/or services (dependent variable gets value 1) with companies that provide only proprietary products and services (dependent variable gets value 0). Table 2 presents the results of the estimated model.[23] As some of the service dummy variables and the service variety variable (SERVICES) were highly correlated, we tested those variables in two separate models. Model 1 includes the SERVICES variable and Model 2 includes individual service dummy variables.

Addressing Hypothesis 1, we find that the firm's human capital affects the adoption of Open Source business strategy among the Finnish software companies. Those companies that have larger academically educated staff applied OSS business strategies more often. This finding is not surprising, considering the close links between OSS and universities.

Unexpectedly though, adoption of an OSS business strategy is not statistically significantly related to the proportion of software developers among a firm's employees. The principles of *absorptive*

[20] The questionnaire used for our web survey was developed in collaboration with the Italian (Cristina Rossi and Andrea Bonaccorsi), Spanish (Clara García), Portuguese (Ines Pereira), and German (Stephan Gauch) partners of the ELISS (European Libre Software Survey) project who undertook a similar survey in their countries (with the exception of few country-specific questions). The questionnaire benefited substantially from the prior questionnaire, developed primarily by Rossi and Bonaccorsi, which they used for surveying the Italian OSS firms (see Bonaccorsi et al., 2006). Further information regarding the questionnaire is available from the authors.

[21] The first e-mail message was followed by several follow-up e-mails and finally by a phone call reminder.

[22] In the regressions that follow, incomplete responses reduce the sample size from 180 to 87 (the number of responses with all the variables present).

[23] We also estimated regression models explaining differences in the firms' degree of involvement in OSS, measured by the share of OSS products (services) of all of a firm's products (services). The sign and statistical significance of the estimated coefficients are very similar – expect that the coefficient of the ownership variable was not significant here – than those in the model for dichotomous variables. These results are probably driven by the inclusion of the non-OSS firms having zero shares of OSS products/services in the sample. We therefore excluded non-OSS firms from the sample. The only explanatory variable that explains differences in the degree of involvement of the OSS firms in providing OSS is the service variety: those OSS firms that provide more OSS services tend to also provide a greater share of OSS products. The estimation results are available from the authors.

Table 2
Estimation results for the probit model: OSS vs. non-OSS firms.

Model Variable	Model 1 Coefficient (*t*-value)	Model 2 Coefficient (*t*-value)
C	−769.32 (−2.00)	−1009.86 (−1.9)
EDUC	0.824 (2.258)	1.129 (2.744)
DEVELOPER	−0.06 (−0.591)	0.018 (0.099)
IPR	−0.031 (−0.095)	0.716 (1.605)
SIZE	−1.653 (−2.620)	−2.660 (−2.716)
ESTABL_YEAR	101.59 (2.013)	133.789 (1.790)
FAMILY_OWN	−0.872 (−2.373)	−1.471 (−2.284)
PURE_SERVICE	−0.601 (−0.985)	−0.853 (−0.977)
SERVICES	0.139 (2.514)	
S1_Consultancy		−3.138 (−2.333)
S2_Integration		0.370 (0.657)
S3_Installation		−0.501 (−0.796)
S4_Assistance		0.135 (0.155)
S5_Maintenance		−0.432 (−0.484)
S6_SystemManagement		1.272 (2.137)
S7_Training		0.450 (0.866)
S8_Application Management		0.889 (1.536)
S9_Adapting codes written by third parties to suit customers' needs		0.223 (0.443)
S10_On order software development from scratch		0.632 (0.126)
S11_ Generating documentation		0.228 (0.430)
Number of observations	87	87
Fraction of correct predictions	72.4%	82.8%
Log likelihood	−44.86	−31.25

capacity (Cohen and Levinthal, 1990) can provide a possible explanation for this finding: the firm should obtain a minimal threshold, in terms of human capital and know-how, to be able to apply new strategic and technological practices. Implementation of an OSS-based strategy is rather complex and requires not only technical and managerial knowledge, but also legal expertise in intellectual property rights—for example, the ability to interpret OSS licensing conditions and to anticipate their impact on the competitive position of the firm.[24] Therefore, even when the number of developers is relatively large (and many of them may be familiar with the OSS), a firm may lack the complementary business and legal know-how required to apply an OSS-based strategy.

The measure of a firm's intellectual property has a positive coefficient, as expected, with the adoption of an OSS supply strategy, but it is not statistically significant. Therefore, our data seem to suggest that human capital plays a greater role than the volume of its intellectual property in the decision to supply OSS.

Our estimation results concerning Hypotheses 2 and 3 indicate that smaller and younger companies tend to apply OSS supply strategies more often than larger and older ones. These findings seem reasonable since by providing OSS solutions, younger firms and SMEs can acquire publicly available know-how and substitute them for the in-house capabilities and R&D that they lack. Also, younger and smaller firms have typically accumulated less knowledge and intellectual property than older and larger companies.

It is possible though that the size and age of a firm are not dependent on innovation but rather firms remain small due to the adoption of the OSS-based strategy and firms are born because of the emergence of the OSS paradigm rather than younger incumbent firms being more inclined to adopt OSS because they have less inertia.[25] We analyzed the data to shed further light on the issue of the underlying reason of the negative sign of the size variable, that is, whether the adoption of OSS hinders the growth of firms and prevents them from becoming large or whether the small firms tend to have greater economic incentives to adopt OSS. We have data on the firm's turnover growth from the year of survey, which we used for analyzing whether the OSS firms differ substantially from those that have not adopted the OSS-based business model. The OSS firms actually had grown, on average, more than the non-OSS firms but according to the *t*-test, this difference was not statistically significant. This allows us to conclude that the negative sign of the size variable is not related to the different growth rates of the adopters and the non-adopters of OSS-based strategies. It seems that smaller firms, indeed, tend to adopt OSS-based strategies more often than the larger ones. Other parts of our survey also affirm that OSS production and provision are desirable strategies particularly for small software companies. According to the respondents, the most important incentives that motivate firms to implement OSS are: "Being independent of the price and license policies of large software producers" and "Exploiting the chance Open Source Software offers to be innovative while staying small".

We also investigated whether younger incumbent firms have been more likely to adopt the OSS-based business model than older ones, or is the firm age negatively related to OSS adoption because many young firms were born because of the emergence of the OSS paradigm. We re-estimated the model excluding the firms that were established in the same year as they adopted the OSS business model. The estimation results concerning other variables did not change substantially, but though the estimated coefficient of the variable ESTABL_YEAR was still positive, it was no longer statistically significant. This means that the software firms that adopted the OSS-based business model when they entered the market differ from the older incumbent companies rather than there being age-related differences in the adoption behavior of the incumbent software firms. Given the economic theory of innovation, it seems logical that incumbent companies are less likely to adopt an OSS supply strategy than markets entrants, because it cannibalizes their license revenues from proprietary software provision, whereas market entrants have no profit flows to lose.

Testing Hypothesis 4, we find that software firms owned by a family or one or two individuals would be less likely to adopt OSS business strategies. Diffusely held companies of which managers are typically less often the owners of the company tend to supply OSS solutions more often than other firms. This result further confirms the empirical findings of Koski (2005). There are various possible explanations for this finding, including the relatively risk-averse behavior of manager-owners, as well as a greater need of managers in diffusely held companies to signal the future potential and value of the company to investors. It is also possible that in diffusely held software firms managers adopt riskier and more uncertain strategies (i.e. OSS supply) more easily than in manager-owned companies, due to personal interests (such as future career opportunities) rather than the best interests of the firm.

The adoption of an OSS business strategy is positively and significantly correlated with the magnitude of the service variety

[24] The adopters of the OSS-based business model not only need to understand the different OSS licensing practices and their practical consequences, but also be aware of various risks involved in the use and supply of the OSS, particularly concerning those OSS distributed with restrictive licenses such as the GPL. So far, for instance, there is no court ruling on how much GPL code needs to be included in a new program before the new program must also be distributed under the GPL license (Evans and Layne-Farrar, 2004). Also, companies using OSS should be aware of the potential security risks and vulnerabilities of OSS, and have sufficient knowledge to take appropriate actions, such as applying risk and coding analysis techniques (Warwick Ashford, "Open Source exposing business to significant risk", *Business Week* 22 July 2008).

[25] We thank an anonymous referee for raising this point.

provided by the firm (variable "SERVICES"; Hypothesis 5). Hence, provision of a wide variety of complementary services is a key attribute in establishing a business strategy and marketing software solutions on the basis of OSS. Firms that offer a wider variety of services in the software markets increase their benefits by widespread diffusion of free software products and by forming network externalities.[26] In this respect, complementarities play an important role in shaping the strategic business decisions of software companies.

Two service types (denoted by dummies variables) received statistically significant coefficients: "System management services" is positively and "Consultancy" is negatively related to the adoption of an OSS supply strategy. A firm's choice to base its services on OSS programs is largely driven by their success and widespread implementation.[27] The reliability of OSS applications, their zero price tag, and the knowledge involving implementation and use of OSS platforms, such as the Linux operating system and the Apache server application, affect the decisions of software firms to provide particular services supporting system management solutions on the basis of OSS. Proprietary solution providers appear to be more active in general consultation than OSS firms. It is difficult to assess what is the underlying reason for this finding, but it is possible that firms that base their business models by and large on selling licenses have a greater incentive to provide consultancy services concerning the selection of software solutions to their clients in order to promote their own products.

5. Conclusions

This paper addresses the following question, which is of major significance for understanding firms' motivation to adopt and develop OSS: Which types of software firm adopt OSS supply strategies, and what are the firm's attributes that foster or hinder implementation of OSS-based strategies?

This paper is the first to systematically analyze how software firms that have chosen OSS strategy differ from providers of proprietary software solutions by using econometric estimations. Our data were collected from a survey that included Finnish software and service providers.

Our main hypothesis concerns the role that the *absorptive capacity* of software firms plays in their decision to adopt an innovative and relatively risky business strategy, such as an OSS-based supply strategy. The intellectual capital of the firm (i.e. its human capital and intellectual property) determines, by and large, its absorptive capacity with regards to the business and technical know-how of the firm. Our major finding is that the quality of human capital is important for adopting innovative business strategies, such as those that apply OSS. Software companies that have higher proportions of educated employees are more likely to be suppliers of OSS. The share of developers in the firm (i.e. the share of the work force that develops new software products) was not found to be statistically significant in explaining the differences between the OSS and non-OSS firms. Neither did the measure of the intellectual property of the firm explain them.

Concerning the other properties of firms, our study concludes that smaller and more service-oriented companies tend to base their software supply strategies on OSS. We also find that market entrants have largely driven the OSS adoption, but there are no significant age-related differences in the adoption behavior of incumbent software firms. It seems credible that incumbent companies are less likely to adopt OSS supply strategy than market entrants since it cannibalizes their license revenues from proprietary software provision, whereas market entrants have no profit flows to lose.

The study also revealed a significant link between the structure of firm ownership and adoption of OSS or proprietary strategies. Software firms owned by a family or by individuals more often apply proprietary strategies, while diffusely held companies tend to supply OSS solutions. This result can be explained by the relative risk-averse behavior of manager-owners in family-owned firms and by the personal incentives (e.g. new know-how and broader career opportunities) that adoption of OSS strategies offers to managers in diffusely held companies.

The research provides some inputs for policy makers who plan to develop the ICT sectors on a regional or national level. Our study indicates that the adoption of technologically advanced strategies requiring complex legal and managerial knowledge postulates relatively highly educated employees. The support for and development of an education system providing highly skilled people from different fields are essential for firms' successfully adopting innovative business strategies. The diffusion of OSS supply and use may benefit society as freely available and downloadable code simultaneously increases competition by lowering the entry barriers to the software sector and enhances knowledge spillovers and their use. In particularly, the OSS-based strategies based on knowledge disclosure can generate learning effects and knowledge externalities that also enrich the technical and innovative capabilities of other firms.

[26] As the number of users increases, so does the chance for interaction using a single standard ("network externalities"). Market standards allow "secondary markets" (application developers) to devote more resources to the development of a wider variety of applications for a single (standard) platform, instead of allocating resources for the development of similar functionality for rival technologies, interfaces, and converters (Farrell and Saloner, 1992; Givon et al., 1995; Laffont et al., 1998).

[27] Analysis of over 85 million websites shows that the OSS Apache is the leading server application with 61.25% of the hosted websites. Microsoft's Windows server follows with 29.7% market share (Netcraft Server Survey, June 2006; Available in: http://news.netcraft.com/archives/web_server_survey.html).

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