The Impact of Open Source Software on Firm Value

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Abstract
Although prior research on open source software suggests that it might have complementary effects on proprietary software, its impact on firm value and the appropriation mechanisms that are used to capture the value it creates lack efficient exploration through empirical analysis. In this paper, we try to fill this gap. Our main objective is to explore the interactive effect of firms’ software product portfolios, distinguished between OSS and proprietary software portfolios, together with their stocks of intellectual property protection mechanism, namely software patents and trademarks stocks, on firm value measured through Tobin’s q. We find that, firms commercializing open source software enhance their firm value depending substantially on their trademark stocks. Proprietary software commercialization, on the other hand, is less sensitive to changes in firms’ pre-existing intellectual property protection mechanisms. Yet, we find positive effect of software patenting on the relationship between proprietary software portfolio and firm value despite the controversial existence of software patents. Jelcodes:O31,O34
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Abstract

Although prior research on open source software suggests that it might have complementary effects on proprietary software, its impact on firm value and the appropriation mechanisms that are used to capture the value it creates lack efficient exploration through empirical analysis. In this paper, we try to fill this gap. Our main objective is to explore the interactive effect of firms' software product portfolios, distinguished between OSS and proprietary software portfolios, together with their stocks of intellectual property protection mechanism, namely software patents and trademarks stocks, on firm value measured through Tobin’s q. We find that, firms with large open source software portfolio enhance their firm value depending substantially on their intellectual property protection mechanisms. Proprietary software commercializing firms, on the other hand, is less sensitive to changes in their pre-existing intellectual property protection mechanisms.

Keywords: open source software; intellectual property rights; firm strategy
1. INTRODUCTION

Open Source Software (OSS) has been one of the hot topics drawing the attention of researchers in diverse fields such as sociology, psychology, economics, law, computer science and management throughout the last decade. Without any doubt, the growing body of this literature takes its roots from the great success achieved by OSS projects such as Linux and Apache.

Early studies on OSS centered on the motives driving the contribution of users and developers to OSS projects, the functioning of innovation processes, and the governing issues in OSS communities (Bonaccorsi & Rossi, 2003; Lakhani & von Hippel, 2003; Lakhani & Wolf, 2005; Lerner & Tirole, 2005; Shah, 2006; O’Mahony & Ferraro, 2007). After the transformation of OSS into a commercially viable form, which Fitzgerald (2006) would label as OSS 2.0, a new stream on commercialization of OSS has begun to develop with a focus on for-profit firms, their collaborations with OSS communities, IPR mechanisms used to appropriate returns from such an open business model, and the competitive dynamics introduced by OSS (Bonaccorsi, Giannangeli, & Rossi, 2006; Dahlander & Magnusson, 2005; Dahlander & Wallin, 2006; Henkel, 2006).

OSS has rapidly become a crucial element in commercial settings after IBM put its full corporate support behind Linux a decade ago (Goth, 2005). “Today, large software vendors like IBM, Sun, Dell, HP, and Oracle are making significant amounts of indirect revenue from their activities with and support of OSS. This has greatly aided mainstream adoption and acceptance of OSS. Hybrid business models seem to be increasing. It is likely that this will end up as the most prevalent business model.” reports a global provider of advisory services (Business Wire, 2009).
Considering the rising trend in OSS commercialization activities of incumbent firms and high expectations that are linked to hybrid business models in the near future, we aim to examine the conditions under which OSS might be most beneficial for a firm in terms of value enhancement. Studies focusing on the complementary effect of OSS on proprietary software suggest that they are likely to co-exist in the future. Hybrid models secure to potential adopters a wide range of complementary services meanwhile they play an important role in the diffusion process (Bonaccorsi & Rossi, 2003). West (2003) suggests that under some conditions hybrid strategies might be preferable to either purely open source or purely proprietary alternatives. In the case study, West presents hybrid strategies of three companies - Apple Computer, IBM and Sun Microsystems – that sought “open” strategies to respond to the pressure from Microsoft and its proprietary control of the computer industry.

At first glance, opening up the innovation processes and engaging in OSS might seem tempting as a cost-effective solution. However, releasing a software product with an open source code necessitates a great deal of attention in terms of protecting one’s intellectual property since such a decision can lead to a loss of competitive edge whereas the contrary is aimed. Henkel (2006) depicts the importance of selective revealing for managing the conflict between downsides and benefits of openness. The results suggest that firms reveal only a part of their code while they keep closed at least some part of the software using secrecy and legal protection mechanisms. Likewise, many studies focus on those mechanisms in the form of licenses, copyrights or complementary assets to unravel the dilemma of protecting something, which in fact is open by definition (Behlendorf, 1999; Feller & Fitzgerald, 2002; Dahlander, 2005). Fosfuri, Giarratana & Luzzi (2008) focus on heterogeneity among firms’ intellectual property right endowments for explaining their decisions on incorporating OSS into commercial products.
The results suggest that variations in pre-existing stocks of intellectual property rights, namely patents and trademarks, help to explain why some firms are taking more commercial actions within the OSS paradigm than others.

Although prior research on OSS suggested that it might have complementary effects on proprietary software, its impact on firm value compared to that of proprietary software and the appropriation mechanisms that are used to capture the value they create lack efficient exploration through empirical analysis. In this paper, we try to fill this gap. Our main objective is to explore the interactive effect of firms’ software product portfolios, distinguished between OSS and proprietary software portfolios, together with their stocks of intellectual property protection mechanisms, on firm value measured through Tobin’s q. We argue that the intellectual property protection mechanisms—specifically, software patents and trademarks—of a firm and their interactions with the firm’s software product portfolio, especially for OSS products, affect the level of firm value significantly.

In our analysis, we use a panel data that contains information on 60 companies over 11 years, from 1999 to 2009, which yields a sample of 660 firm-year observations. First, we estimate a base model in order to explore direct effect of OSS and proprietary software products on firm value measured through Tobin’s q. Afterwards, we estimate a full model in which we incorporate multiplicative effects of the variables that correspond to firms’ appropriation mechanisms with the variables that correspond to firms’ OSS and proprietary software portfolios.

We find that intellectual property protection mechanisms of firms are crucial assets in determining the relationship between a firm’s OSS portfolio and its firm value. The empirical analysis reveals that; firms’ stocks of trademarks positively affect the relationship between OSS
portfolio and firm value. On the other hand, the relationship between proprietary portfolio and firm value is enhanced through interaction with large stocks of software patents. Our results assess the importance of suitability of a firm’s appropriation mechanisms to its adopted business model. In line with the classical incentive theory, software patenting works as a protection mechanism that favors proprietary developments. Filing trademarks, on the other hand, is crucial for open business models as a means of differentiation strategy by signaling quality instead of protecting the technology.

The rest of the paper is organized as follows. The second section presents the theoretical background upon which our empirical analysis relies. In section three, we give descriptive statistics on our data and identify the variables used in our estimations. Section four corresponds to the empirical part and presents the results. In the last section, we give a brief discussion and we conclude.

2. THEORETICAL FRAMEWORK

Originating from Teece’s (1986) seminal work on profiting from technological innovation, we conceptualize our theoretical framework on software commercialization and its impact on firm value through complementary assets view and appropriability regimes. First, we try to explain the value creation that result from OSS and proprietary software commercialization from a complementarity view. Afterwards, we elaborate on regimes of appropriability for explaining the variety in the level of firm value captured.

2.1. The relationship between OSS and Firm Value

Do proprietary software and OSS are likely to co-exist in commercial settings in the future or is OSS a trend that eventually will fail due to its controversial existence as a means of
profitability? Peter Yared, founder and CEO of a commercial open source company, states that no commercial OSS companies—excluding Red Hat, MySQL and JBoss—have had liquidity events for the past 6 years (Yared, 2009). On the other hand, firms whose OSS turnover is above 50% between 2000 and 2003 inform remarkable increase in OSS turnovers while those who work with OSS without generating revenues out of it have a notable decrease suggesting the sustainability of a mixed business model (Bonaccorsi, Merito, Piscitello, & Rossi, 2009). How firms make money out of OSS is a long debated issue. Ljungberg (2000) identifies three ways through which firms gain from OSS developments: by distributing the open-source software together with books, manuals, training and support under a trusted brand name (e.g. Red Hat); by adding value to OSS with additional features or extensions in the form of proprietary software (e.g. Sendmail); and by relating to open-source software in different ways, such as bundling it with own products (e.g. IBM). Commercial firms introducing OSS products and proprietary products enjoy higher market value levels combining the advantages of both. For some firms OSS might comprise a basis for further proprietary software developments that adds value to the open source core. It has become a very common strategy for firms to commercialize OSS, distribute it freely and sell extended versions in the form of proprietary software for special commercial applications. In such a way, firms form bundles of own products in a unique way utilizing complementary assets that play an important role in sustaining the competitive advantage (Teece, 1986).

Henkel (2006) groups potential benefits of OSS engagement for a firm into four categories: setting a standard and enabling compatibility; increasing demand for complementary goods and services; benefiting from external development support, and signaling technical excellence or good OSS citizenship. Several other reasons can be articulated for explaining why OSS products
might enhance the value created by proprietary software such as offering a broader product portfolio and sustaining diversification, spurring competition in quality and innovation, weakening of a competitor or the other member of a duopoly, reducing costs, developing dynamic capabilities and gaining competitive advantage (Nilendu & Madanmohan, 2002; Schmidt & Schnitzer, 2003; West 2003; Dahlander & Magnusson, 2005; Bonaccorsi et al., 2006). With regards to our argument on the complementarity view on potential benefits of OSS and proprietary commercialization for a firm, it is reasonable to think that firms with large OSS and proprietary software product portfolios will achieve higher firm value. However, we believe that how much a firm can benefit from its software commercialization depends substantially on the intellectual property right endowments.

2.2. The Role of Intellectual Property Protection Mechanisms

Many large companies have attempted to experiment hybrid strategies with the aim of combining the advantages of open source and proprietary software while retaining control and differentiation (West, 2003). However, the concept of extracting financial benefits from jointly developed software contradicts the core values of OSS movement, in which the code is protected from being appropriated for commercial purposes through the use of legal and normative mechanisms (O’Mahony, 2003). For this reason, following a pure open source strategy might entail the threat of eliminating a company’s historic source of differentiation, namely their proprietary software. Firms, who aim to utilize advantageous attributes of OSS in order to create and appropriate value, have to overcome the challenge of adjusting their respective resources and core competencies in a manner that comply with the core values of OSS (West, 2003).

Studies focusing on OSS and associated appropriating regimes suggest that there are several means of OSS protection ranging from a suitable choice of license (Behlendorf, 1999; Hecker,
1999; Raymond, 1999) to standard means of protections such as copyright, secrecy, lead time and complementary assets (Feller & Fitzgerald, 2002; Dahlander, 2005; Fosfuri et al., 2008). In our analysis we focus on those intellectual property protections in the form of patents and trademarks, which are important firm resources that define the conditions under which OSS might be most beneficial.

Bronwyn & MacGarvie (2010) stress the value creation associated with software patents in the United States and they find positive and significant correlation between software patents and Tobin’s q. They also find evidence that following the expansion of software patentability, in the mid-1990s, software patents have been highly valued in the market compared to ordinary patents. Mann (2006) analyzes the role of property rights in the open source development model, with a particular focus on appropriation mechanisms that are necessary for firms to profit from OSS commercialization in the years to come. The author argues that many major corporate members of the OSDL group (e.g. IBM and HP) continue to make heavy investments in obtaining new software patents primarily to protect themselves from the threat of litigation. The results suggest that, without the intellectual property protection mechanisms, OSS cannot continue to grow in commercial importance and that the proprietary firms who extract the largest benefits out of OSS commercialization will be large firms. Given the argument above, we suggest that high software patenting activity will have a positive effect on the relationship between a firm’s software product portfolio, distinguished between OSS and proprietary software portfolio, and its firm value. Although software patents may not provide a direct protection for OSS products, they may be utilized to capture the value created from OSS releases by providing protection for their complementary assets in the form of proprietary products.
H1a: A firm’s stock of software patents positively affects the relationship between its OSS product portfolio and its firm value.

H1b: A firm’s stock of software patents positively affects the relationship between its proprietary software product portfolio and its firm value.

Although pros and cons of patents have been a long-debated issue from the perspective of classical incentive theory, trademarks have received the attention of researchers only very recently. Mendonça, Pereira & Godinho (2004) test trademarks as a complementary indicator of innovative activity, which is generally proxied by R&D expenditures and patents. While patents protect the underlying technology, trademarks serve more as a differentiation mechanism that aims at distinguishing the brand of a service or a product by leveraging the holder’s reputation. For instance Linux, Apache and Debian have trademarked their names for both differentiation purposes and for preventing proprietary appropriation of the OSS code (O’Mahony, 2003).

Following the argument above, we suggest that trademarks, likewise software patents, will positively affect the relationship between a firm’s software product portfolio and its firm value by the virtue of brand name and reputation they provide. Since protecting the underlying technology, the source-code, is not possible in OSS commercialization, trademarks may work as a key factor in appropriating value for those firms commercializing OSS products.

H2a: A firm’s stock of trademarks positively affects the relationship between its OSS product portfolio and its firm value.

H2b: A firm’s stock of trademarks positively affects the relationship between its proprietary software product portfolio and its firm value.
3. DATA & DESCRIPTIVE STATISTICS

We employ empirical analysis by running firm fixed effects model utilizing a panel data that contains information on 60 companies\(^1\) selected from Fortune Global 500 list across 10 software related industries\(^2\), headquartered in three regions\(^3\) and over 11 years, from 1999 to 2009, which yields a sample of 660 firm-year observations. Table 1 presents the definitions of variables used in our analysis.

Table 1. Variable definitions

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobin’s q</td>
<td>((\text{Market Value} + \text{Preferred Stock} + \text{Debt}) / \text{Total Assets}) (Log transformed))</td>
<td>Compustat</td>
</tr>
<tr>
<td>OssPortfolio</td>
<td>(\sum_{1999}^{t} \text{OSS products calculated for year t at a 15% discount rate}) (Log transformed))</td>
<td>PROMT</td>
</tr>
<tr>
<td>ProprietaryPortfolio</td>
<td>(\sum_{1999}^{t} \text{proprietary software products calculated for year t at a 15% discount rate}) (Log transformed))</td>
<td>PROMT</td>
</tr>
<tr>
<td>SoftwarePatents</td>
<td>(\sum_{1999}^{t} \text{software patents calculated for year t at a 15% discount rate}) (Log transformed))</td>
<td>USPTO</td>
</tr>
<tr>
<td>Trademarks</td>
<td>(\sum_{1999}^{t} \text{trademarks calculated for year t at a 15% discount rate}) (Log transformed))</td>
<td>USPTO</td>
</tr>
<tr>
<td>FirmSize</td>
<td>Employees in year t (Log transformed)</td>
<td>Compustat</td>
</tr>
</tbody>
</table>

From Compustat database we extract the financial data such as market value, total assets, total debt and preferred stock needed for our empirical analysis. We use Tobin’s q as our dependent variable in order to proxy for firm value. Tobin’s q is a widely used proxy for firm value that reflects potential growth opportunities. A Tobin’s q having a value greater than 1.0

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\(^1\) Firms that introduce at least five software products during 11 years are included in our sample


\(^3\) America, Europe and Asia.
shows positive outlook for a firm’s growth opportunities. We calculate a modified version of original Tobin’s q using the following formula by Chung & Pruitt (1994):

$$\text{Approximate } q = \frac{(MVE + PS + DEBT)}{TA}$$

where MVE is the product of common shares outstanding and the month-end price that corresponds to the period end date, PS is the liquidating value of preferred stock, DEBT is the sum of total long-term debt and debt in current liabilities, and TA is the book value of total assets of the firm. The approximate q explains 96.6% of the variability of Tobin's original formulation used by Lindenberg & Ross (1981). Firm size, in number of employees, is also provided by Compustat database.

We search press articles that report a “product announcement” or “new software release” or a “software evaluation” in the software sector (Standard Industry Classification (SIC) code 7372) from PROMT database. The press articles reporting a product introduction in the software sector including the words “open source” or “Linux” are treated as possible OSS product introductions. In contrast, those not including “open source” or “Linux” are treated as proprietary software introductions. After reading the text for each article in the possible OSS product introductions set, we distinguish those articles that clearly refer to an open source product introduction in the text as OSS introductions and include the rest with proprietary software introductions. Table 2 shows the distribution of number of product introductions on firm-year basis.

From the data on product introduction announcements we compute cumulative number of OSS products to proxy for a firm’s OSS product portfolio. We calculate this variable by summing up the number of OSS products introduced to the market starting from 1999 at a 15% discount rate\(^4\). The following formula is used to compute $OssPortfolio$:

\(^4\) The Bureau of Industry Economics (BIE) adopted a discount rate of 15% when assessing the private returns to patent holders (1994, p. 44). We adopt 15% discount rate with a similar logic to valuate new products introduced to the market.
\[ OssPortfolio_t = (Oss_t + Oss_{t-1} \times (0.85) + Oss_{t-2} \times (0.85)^2 + \ldots + Oss_{1999} \times (0.85)^{t-1999}) \]

where \( Oss_t \) is the number of OSS introductions in year \( t \). We calculate cumulative number of firms’ proprietary software products in the same way at a 15% discount rate as follows:

\[ ProprietaryPortfolio_t = (Prop_t + Prop_{t-1} \times (0.85) + Prop_{t-2} \times (0.85)^2 + \ldots + Prop_{1999} \times (0.85)^{t-1999}) \]

Table 2. Distribution of number of product introductions by firm-years

<table>
<thead>
<tr>
<th>No. of Products</th>
<th>Proprietary Software</th>
<th>Open Source Software</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of firm years</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>83</td>
<td>0.22</td>
</tr>
<tr>
<td>2-5</td>
<td>127</td>
<td>0.33</td>
</tr>
<tr>
<td>6-10</td>
<td>35</td>
<td>0.09</td>
</tr>
<tr>
<td>11-15</td>
<td>11</td>
<td>0.03</td>
</tr>
<tr>
<td>15-100</td>
<td>57</td>
<td>0.15</td>
</tr>
<tr>
<td>&gt;100</td>
<td>70</td>
<td>0.18</td>
</tr>
<tr>
<td>Total</td>
<td>381</td>
<td>101</td>
</tr>
</tbody>
</table>

The data on patents and trademarks are extracted from USPTO database through Derwent Innovation Index. First, we search for all patents granted to a given firm on a yearly basis (from 1999 to 2009). After constructing the data for all patents, we identify software patents following the algorithm by Graham & Mowery (2003). According to Graham & Mowery, certain International Classification (IPC) classes/subclasses/groups such as “Electric Digital Data Processing” (G06F), “Recognition of Data; Presentation of Data; Record Carriers; Handling Record Carriers” (G06K) and “Electric Communication Technique” (H04L) are considered as software patents. The authors select these classes after examining the patents of six major software producers in U.S. (based on 1995 revenues), namely Microsoft, Adobe, Novell, Autodesk, Intuit, and Symantec, between 1984 and 1995. Patents in these classes account for 57% of the patents assigned to the hundred largest firms in the software industry (Hall &

\(^5\) The groups included are G06F: 3,5,7,9,11,12,13,15; G06K: 9,15; H04L: 9.
MacGarvie, 2010). Trends in these classes are believed to be representative of overall software patenting activity since they include the areas in which patenting appears to have grown rapidly during 1980-2001. Afterwards, from the same source we extract trademark data at firm level on a yearly basis. We search for all trademarks filed by each firm between 1999 and 2009.

We compute cumulative number of software patents, which is calculated at a 15% discount rate, in order to utilize in our analysis. The rationale for doing so is to identify how much software patents in a firm’s patent portfolio affect firm value since software patents intend to protect the underlying technology. Yet, we do not distinguish between software trademarks because we aim to enlighten the impact of trademarks as a means of differentiation strategy by signaling quality instead of protecting the technology. Henceforth, it is more convenient to include any kind of trademarks granted to a firm since they give an intuition to how much a firm invests in brand and reputation for appropriating returns.

Table 3. Proprietary portfolio, OSS portfolio, software patents and trademarks distribution by sector

<table>
<thead>
<tr>
<th></th>
<th>Proprietary Software</th>
<th>Open Source Software</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Firms</td>
<td>Av. Prop Portfolio</td>
</tr>
<tr>
<td>Internet Services</td>
<td>3</td>
<td>1.54</td>
</tr>
<tr>
<td>Electronics</td>
<td>10</td>
<td>1.81</td>
</tr>
<tr>
<td>Network</td>
<td>8</td>
<td>2.37</td>
</tr>
<tr>
<td>Computers&amp;Office Eq.</td>
<td>14</td>
<td>2.93</td>
</tr>
<tr>
<td>Computer Software</td>
<td>7</td>
<td>4.24</td>
</tr>
<tr>
<td>Computer Peripherals</td>
<td>3</td>
<td>2.00</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>4</td>
<td>1.90</td>
</tr>
<tr>
<td>Photo &amp; Control Eq.</td>
<td>2</td>
<td>2.22</td>
</tr>
<tr>
<td>Information Tech. Ser.</td>
<td>2</td>
<td>2.01</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>7</td>
<td>2.09</td>
</tr>
<tr>
<td>Total No. of Firms</td>
<td>60</td>
<td>26</td>
</tr>
</tbody>
</table>
Table 3 displays the distribution of average sizes of product portfolios, software patent and trademark stocks by industry. 26 firms out of 60 firms in our sample introduce open source software products to the market at least once in 11 years. It is worth noting that the average software patent and trademark stocks are larger for firms engaged in OSS than the average of software patent and trademark stocks for the whole sample. Descriptive statistics and pairwise correlations for the variables are presented in Table 4.

<table>
<thead>
<tr>
<th></th>
<th>Obs</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Min</th>
<th>Max</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 TobinsQ</td>
<td>615</td>
<td>0.517</td>
<td>0.837</td>
<td>-1.434</td>
<td>4.362</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 OssPortfolio</td>
<td>660</td>
<td>0.536</td>
<td>0.872</td>
<td>0</td>
<td>3.609</td>
<td>0.063</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 ProprietaryPortfolio</td>
<td>660</td>
<td>2.485</td>
<td>1.308</td>
<td>0</td>
<td>6.566</td>
<td>0.177</td>
<td>0.742</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 SoftwarePatents</td>
<td>660</td>
<td>5.724</td>
<td>2.255</td>
<td>0</td>
<td>9.456</td>
<td>-0.296</td>
<td>0.328</td>
<td>0.285</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Trademarks</td>
<td>660</td>
<td>4.259</td>
<td>1.152</td>
<td>0.420</td>
<td>7.024</td>
<td>-0.141</td>
<td>0.225</td>
<td>0.339</td>
<td>0.631</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>6 FirmSize</td>
<td>658</td>
<td>10.255</td>
<td>1.589</td>
<td>5.817</td>
<td>13.090</td>
<td>-0.454</td>
<td>0.264</td>
<td>0.228</td>
<td>0.586</td>
<td>0.592</td>
<td>1.000</td>
</tr>
</tbody>
</table>

4. EMPIRICAL ANALYSIS & RESULTS

We estimate firm fixed effects model in which we use Tobin’s q as dependent variable after conducting the Hausman test. We run a base model and a full model, which let us investigate the direct effect of firms’ OSS and proprietary software portfolios on firm value as well as their interactive effect together with firms’ intellectual property protection mechanisms. The following base model is estimated:

\[
(1) \quad TobinsQ_{it} = \beta_0 + \beta_1 OssPortfolio_{it} + \beta_2 ProprietaryPortfolio_{it} + \beta_3 SoftwarePatents_{it} + \beta_4 Trademarks_{it} + \beta_5 FirmSize_{it} + \epsilon_{it}
\]

where subscripts \(i\) and \(t\) denote firm-specific and year-specific observations, respectively. We lag the variables of SoftwarePatents and Trademarks for two years. Although, we collect the data
starting from 1999, we run our analysis using the data starting from 2002. Since all of our main explanatory variables are cumulative numbers, we believe that three years of accumulation will let us work with a more reliable data. We, furthermore, use natural logarithms of all the variables in our analysis and control for firm size.

Table 5. Fixed effects model (standard errors in parentheses)

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Main Results</th>
<th>Robustness Checks</th>
<th>Lagged Values</th>
<th>Alternative Dep. Var.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>TobinsQ</td>
<td>-0.104</td>
<td>-0.533*</td>
<td>-0.042</td>
<td>-0.571</td>
</tr>
<tr>
<td>MarketValue</td>
<td>(0.102)</td>
<td>(0.305)</td>
<td>(0.128)</td>
<td>(0.361)</td>
</tr>
<tr>
<td>ProprietaryPortfolio</td>
<td>0.618***</td>
<td>0.898***</td>
<td>0.482***</td>
<td>0.808***</td>
</tr>
<tr>
<td>MarketValue</td>
<td>(0.079)</td>
<td>(0.218)</td>
<td>(0.082)</td>
<td>(0.253)</td>
</tr>
<tr>
<td>Trademarks</td>
<td>0.253***</td>
<td>0.488***</td>
<td>0.148</td>
<td>0.436***</td>
</tr>
<tr>
<td>MarketValue</td>
<td>(0.073)</td>
<td>(0.130)</td>
<td>(0.091)</td>
<td>(0.158)</td>
</tr>
<tr>
<td>SoftwarePatents</td>
<td>0.060*</td>
<td>-0.042</td>
<td>-0.116***</td>
<td>-0.245***</td>
</tr>
<tr>
<td>MarketValue</td>
<td>(0.033)</td>
<td>(0.059)</td>
<td>(0.041)</td>
<td>(0.067)</td>
</tr>
<tr>
<td>OssPortfolio*Trademarks</td>
<td>0.134**</td>
<td>0.145*</td>
<td>0.141</td>
<td>0.067</td>
</tr>
<tr>
<td>OssPortfolio*SoftwarePatents</td>
<td>-0.030</td>
<td>-0.025</td>
<td>-0.124**</td>
<td>-0.146**</td>
</tr>
<tr>
<td>ProprietaryPortfolio*Brand</td>
<td>-0.146**</td>
<td>-0.059</td>
<td>0.046**</td>
<td>0.057**</td>
</tr>
<tr>
<td>FirmSize</td>
<td>-0.306***</td>
<td>-0.326***</td>
<td>-0.267***</td>
<td>-0.281***</td>
</tr>
<tr>
<td>Constant</td>
<td>0.610</td>
<td>0.393</td>
<td>1.976***</td>
<td>1.590***</td>
</tr>
<tr>
<td>Observations</td>
<td>454</td>
<td>454</td>
<td>398</td>
<td>398</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.217</td>
<td>0.236</td>
<td>0.278</td>
<td>0.300</td>
</tr>
<tr>
<td>Number of id</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
***p<0.01, ** p<0.05, * p<0.1

The results from the first model in Table 5 reveal that while the coefficient on _ProprietaryPortfolio_ is significant and large, the coefficient on _OssPortfolio_ is insignificant urging us to investigate the conditions under which OSS might be beneficial in terms of firm value enhancement. Although there is a rising trend in OSS engagement of firms in the
commercial arena, depending solely on an open business model is too risky in such competitive markets. Appropriability mechanisms in the form of software patents and trademarks are crucial for those firms who are willing to open up their innovation processes with the aim of value enhancement.

We estimate a full model in order to disentangle the impact of firms’ intellectual property protection mechanisms on the aforementioned relationship between a firm’s software product portfolio and its firm value. In this model we incorporate interaction terms between our main explanatory variables, OssPortfolio and ProprietaryPortfolio, and the two variables, SoftwarePatents and Trademarks, corresponding to firms’ intellectual property protection mechanisms. The following full model is estimated:

\[
(2) \quad \text{TobinsQ}_{it} = \beta_0 + \beta_1 \text{OssPortfolio}_{it} + \beta_2 \text{ProprietaryPortfolio}_{it} + \beta_3 \text{SoftwarePatents}_{it} + \beta_4 \text{Trademarks}_{it} + \beta_5 \text{FirmSize}_{it} + \beta_6 \text{OssPortfolio}^*\text{SoftwarePatents}_{it} + \beta_7 \text{OssPortfolio}^*\text{Trademarks}_{it} + \beta_8 \text{ProprietaryPortfolio}^*\text{SoftwarePatents}_{it} + \beta_9 \text{ProprietaryPortfolio}^*\text{Trademarks}_{it} + \epsilon_{it}
\]

where coefficients \(\beta_6, \beta_7, \beta_8, \text{ and } \beta_9\) measure the impact of interactions between firms’ software product portfolios and their intellectual property protection mechanisms.

The results from the full model show that; while the coefficient on the interaction term between OSS portfolio and software patents (OssPortfolio*SoftwarePatents) is insignificant, the coefficient on the interaction term between proprietary software portfolio and software patents (ProprietaryPortfolio*SoftwarePatents) is significantly positive. In line with these results, \(H1a\), hypothesizing a positive impact of software patent stocks on the relationship between OSS and firm value, cannot be confirmed. \(H1b\), on the contrary, is confirmed suggesting that software patents positively affect the relationship between proprietary software portfolio and firm value.
We also observe positive and significant coefficient on the interaction term between OSS portfolio and trademarks \((OssPortfolio*Trademarks)\) which is in support for \(H2a\). However, the interaction term between proprietary software portfolio and trademarks \((ProprietaryPortfolio*Trademarks)\) is negative and significant. Thus, \(H2b\) is rejected.

To check for the robustness of our findings, we run the same analysis with the lagged values of our main explanatory variables, \(OssPortfolio\) and \(ProprietaryPortfolio\). The interactive effect of \(OssPortfolio*Trademarks\) and \(ProprietaryPortfolio*SoftwarePatents\) remain significantly positive meaning that firms’ pre-existing stocks of software patents and trademarks have opposite effects on how a firm enhance its value through combining different appropriation mechanisms and business models. We also use an alternative dependent variable, market value calculated as common shares outstanding multiplied by the month-end price that corresponds to the period end date, to proxy for firm value. After analyzing the results of the regressions run with market value as the dependent variable, we observe similar results to our primary regressions supporting the finding that the suitability of a firm’s intellectual property protection endowments to its adopted business model, either open or closed, is vital in order to get the best outcomes in terms of firm value.

Our findings suggest that, firms taking more commercial actions in OSS paradigm achieve higher firm value through complementary appropriation mechanisms, especially, in the form of trademarks. On the other hand, firms commercializing proprietary software products benefit more from software patent stocks despite the controversial existence of software patenting. However, we find negative effect of trademark stocks on the relationship between proprietary software portfolio and firm value. One possible explanation might be that firms, which have already invested heavily in software patenting, will not be able to change their means of
intellectual property protection so easily. Since trademark filing is a more recent way of protecting the innovative activity, firms that are concerned about protecting the technology are more likely to prefer software patenting over acquiring trademarks or it might be the case that adapting to such a change is likely to take more time.

Teece (1986) states that, through the instrumentality of appropriability regimes in which legal mechanisms of protection are utilized, firms advance their capabilities to retain the value they have created. With regards to our findings favoring software patenting and trademark filing activities in different settings, it is possible to assert that the adequateness of a firm’s appropriation mechanism to its business model is crucial in order to capture the value created. OSS commercialization may lead firms suffer in the presence of wrong choices of appropriation mechanisms while the contrary is aimed.

We conduct simulations in which it is possible to observe, setting all other variables to their mean values, how OSS and proprietary software portfolio interact with firms’ stocks of intellectual property protection mechanisms that end up in enhanced firm value. The graphical analysis provides us with a visual understanding of potential complementarities between intellectual property protection mechanisms and business models. In Figure 1a, 1b and 1c, we fix software patents stocks of a firm to the value coinciding with 25th, 50th and 75th percentiles respectively in order to observe partial effect of trademark stocks on the relationship between OSS portfolio and firm value. For firms with larger stocks of trademarks, Tobin’s q increases dramatically as OSS portfolio moves from its minimum to maximum value. The superiority of firms with strong appropriation mechanisms is remarkable in Figures 1a, 1b and 1c in terms of enhanced firm value.
In Figure 2a, 2b and 2c we set trademark stocks to the value coinciding with 25th, 50th and 75th percentiles respectively in order to observe partial effect of software patents on the relationship between proprietary software portfolio and firm value. Firms with large software patent stocks upgrade their firm value achieved through large proprietary software product portfolio. However, the relationship between proprietary software portfolio and firm value is less
sensitive to changes in firms’ pre-existing stocks of intellectual property protection mechanism than the relationship between open source software portfolio and firm value.

5. DISCUSSION AND CONCLUSION

The findings of this study are twofold. First, we find positive relationship between a firm’s proprietary software portfolio and its firm value. On the other hand, we cannot observe a direct
positive effect of OSS portfolio on firm value. Comparing these two results, we are able to tell that the profitability of OSS commercialization is a more complex issue to be determined by other factors such as property rights. Our second finding assesses the importance of firms’ intellectual property protection mechanisms, specifically software patents and trademarks, which favor the desired ends resulting from firms’ OSS and proprietary software commercialization. We find evidence that firms, which are more concerned about protecting the technology, upgrade the level of firm value through large proprietary software portfolios and software patent stocks. On the other hand, firms, which are willing to take on new challenges, follow an alternative approach and file trademarks for appropriating returns under new circumstances of competitive dynamics introduced by OSS commercialization. Since the traditional incentive theory does not work in such an open model, firms invest in reputation and brand for firm value enhancement. It is worth noting that different appropriation mechanisms derive better outcomes through different modes of software commercialization. Given that OSS is a phenomenon that challenges the firms who are aiming to reap the benefits out of it, appropriability regimes are crucial to those firms in achieving their goals. Nevertheless, methods of appropriability vary notably across and within industries (Teece, 1986). Our findings are consistent with the argument of Mann (2006), who suggests the success of OSS commercialization to be intertwined with its incorporation into traditional commercial value chains. Meaning that firms, which aim at profiting from OSS commercialization, should give emphasize on the property rights that are necessary in order to make profits from other points of the value chain.

Our findings have important managerial implications. As competitive conditions in an industry change over time, firms try to catch up with new trends in business strategies meanwhile they face the challenge to adjust their resources to the corresponding new practices exercised.
The transformation of OSS to a commercial form has obliged firms to make a decision on their current business strategy. Either they continue with what they have believed to be proper in terms of profitability or they accept the challenge and undergo new strategies linking their brands with open source products. Consequently, managers should be aware of how much the adequateness of intellectual property protection mechanism to their business model matters for incrementing firm value. The decision of hybridization for benefiting from both proprietary and OS based services and products should be taken with great care. Successful commercialization techniques may enable firms to create value through OSS introductions. However, a firm that creates a value may not be able to capture the value it creates in the long run. Isolating mechanisms in the form of legal barriers are crucial for a value-creating firm in order to retain the value it creates (Lepak, Smith, & Taylor 2007).

The relationship between firms’ attitude towards OSS product releases and intellectual property protection mechanisms also have policy implications. Despite the long debate on the patentability of software, software patents have gained wide usage across several industries. Tight appropriability regimes are believed to hinder the general cumulative technological progress (Levin, Klevorick, Nelson, & Winter, 1987). Nevertheless, our study proposes a different channel for governmental policies by assessing the importance of trademarks as a crucial appropriability mechanism in certain settings. New forms of appropriability mechanisms may benefit individual firms while the general cumulative advance is sustained.

Although our hypotheses have been confirmed partially (H1b and H2a confirmed, H1a and H2b rejected), we believe that our findings give an insight into new trends in OSS and proprietary software product releases and provide an understanding for researchers who are willing to investigate those new forms of commercialization strategies and their interactions with
appropriation mechanisms. Trademarks might be investigated in-depth as an alternative approach for appropriating returns under new circumstances of competitive dynamics introduced by OSS. It would also be interesting to examine the interactive effects of other potential isolating mechanisms, e.g. copyrights, with new product introductions on firm value.

Due to insufficient information on the development processes of new products, we are unable to examine the impact of OSS on value creation as a commonly developed good. It would be helpful to know whether each product (OSS or proprietary) newly introduced to the market is a direct complement of a formerly introduced product of the same company (e.g. plug-in, extension). Such information would enable us to build other explanatory variables that deepen our empirical analysis on firm value through OSS commercialization with a unique data.
REFERENCES


