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WHEN DO ISVs JOIN A PLATFORM ECOSYSTEM? EVIDENCE FROM THE ENTERPRISE SOFTWARE INDUSTRY

Completed Research Paper

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Abstract

In the enterprise software industry leading firms usually adopt an open platform strategy and nurture their innovation ecosystem to achieve the shared success of the community. In this study we examine the antecedents of small independent software vendors' (ISVs') decision to join a platform ecosystem. Using data of 1208 ISVs' history of partnering activities with a major enterprise software maker from 1996 to 2004, we find that appropriability strategies based on intellectual property rights and the possession of downstream complementary capabilities by ISVs are positively related to the partnership formation, and ISVs use the two mechanisms as substitutes to prevent expropriation by the platform owner. In addition, we show that greater level of competition in the downstream market between ISVs and the platform owner negatively affects the likelihood of partnering. The results highlight the role of innovation appropriation, downstream complementary capabilities and collaborative competition in the formation of enterprise software platform ecosystems.

Keywords: Enterprise software, platform ecosystem, intellectual property rights, downstream capability, co-opetition, partnership

Introduction

Platform-based competition is becoming increasingly a ubiquitous phenomenon in the information economy. The personal computer (Bresnahan and Greenstein 1999), personal digital assistant (Boudreau 2007), and video game console (Zhu and Iansiti 2007) are stylized examples of systems that consist of a core technology platform (Boudreau 2007) and the interchangeable complementary applications built upon it. In the software industry we observe that communities of innovation networks, known as ecosystems, have been increasingly employed by platform owners to meet heterogeneous user needs (Adomavicius et al. 2007; Evans et al. 2006). Industry leaders nurture their ecosystems by coordinating and harnessing the collective power of developers, partners, and others integral to the shared success of the community (Adner 2006).

While platform owners encourage the provision of complementary products in order to take advantage of indirect network effects (Rochet and Tirole 2003), there is often a tension between the developers of complementary products and the platform owner due to risk the latter may eventually compete in the partner's product market space (Gawer and Henderson 2007). To the extent that the platform owner may ex post "squeeze" complementors, the latter may have less ex ante incentive to join the ecosystem in the first place (Choi and Stefanadis 2001; Heeb 2003). Prior research has used analytical models or case studies to investigate this issue from the perspective of the platform owner (Farrell and Katz 2000; Gawer and Henderson 2007). However, as yet there has been no systematic empirical evidence on how the potential for platform owner entry conditions independent software vendors' (ISVs') incentives to participate in innovation ecosystems. Acquiring such evidence has important managerial implications, as it will inform when ecosystems are most likely to grow and succeed.

In this study we try to bridge this gap in prior literature by examining the drivers of small ISVs' decisions to join an enterprise software platform ecosystem and develop platform compatible complementary applications. We stress three distinct features of this type of partnership. First, potential entry into complementary markets by the platform owner, together with uncontrollable knowledge transfer during the partnership, brings the relevance of appropriability regimes such as IPR protection and downstream complementary capabilities (Teece 1986). Second, the major benefit for ISVs to join the ecosystem is to gain market exposure to the platform owner's installed base instead of accessing the platform owner's technological or complementary marketing resources, and therefore the analysis is different from the context of technology commercialization or markets for technology (Arora and Ceccagnoli 2006; Gambardella and Giarratana 2006). Third, the relationship often involves collaboration between competitors, characterized as co-opetition (Hamel et al. 1989; Nalebuff and Brandenburger 1997). In many cases both the platform owner and the ISV provide similar functional modules and compete in multiple product markets, and the formation of partnerships may depend critically on the relative intensity of competition and mutual benefits.

We test our theoretical predictions by assembling a unique data set on 1208 ISVs' history of partnering activities with SAP from 1996 to 2004, and collect data on their intellectual property rights, downstream complementary capabilities, and the intensity of their competition with SAP in product markets. Using discrete time hazard models, we find that small ISVs utilize both intellectual property rights protection and downstream capabilities to prevent expropriation. In particular, we find that ISVs with greater stocks of copyrights, or those with strong downstream marketing capabilities are more inclined to join the ecosystem. Interestingly, the two appropriation mechanisms serve as substitutes to each other and the presence of one weakens the marginal effect of the other on the likelihood of partnering. Finally, we find evidence that ISVs' decisions to join a platform are strongly influenced by the extent of competition between the product offerings of the platform owner and the ISV.

The rest of the article is organized as follows. In the next section we introduce the research setting and briefly describe SAP's partnership program with ISVs. In section 3 we extend prior literature and develop the hypotheses. Section 4 describes the data and empirical models. We present the results, as well as a set of robustness checks in section 5. In section 6 we discuss the implications and conclude.

SAP and Its Ecosystem

Enterprise software is claimed to be the organizational operating system (Chellappa and Saraf forthcoming; Ramasubbu et al. 2008), which consolidates the diverse information needs of an enterprise's departments together into a single, integrated software program that operate on a shared database. In this study we are interested in the partnership between an enterprise software platform owner and ISVs that develop complementary applications that

are integrated with the underlying platform. We adopt the definition of Boudreau (2007) and define a platform as the components used in common across a product family whose functionality can be extended by applications and is subject to network effects (Parker et al. 2008). As noted above, a platform ecosystem is an innovation network that is employed by platform owners to meet heterogeneous user needs (Adomavicius et al. 2007; Evans et al. 2006). Third-party software vendor applications extend the functionality of the platform and add value to customers that adopt the platform in various industries. Those vendors who partner with the platform owner become members of the ecosystem.

Joining a platform ecosystem is different in some important ways from joining other kinds of inter-organizational alliances that have been previously studied in the literature. Prior research has identified a variety of benefits from traditional alliances, including learning, access to specialized resources, risk sharing, and shaping competition (Porter and Fuller 1986; Oxley et al. 2009). However, the primary reason for firms to join a platform ecosystem is to signal compatibility of software applications (Chellappa and Saraf forthcoming) and to thereby gain access to the platform owner's installed base; in particular, in contrast to other forms of alliances the learning and risk-sharing benefits to joining the platform ecosystem are likely to be small, if any.

Second, platform ecosystems differ in significant ways from IT-enabled inter-firm supply chain relationships that are frequently highlighted in the information systems literature, in particular those involve close collaboration among supply chain partners and virtual manufacturing relationships (e.g., Clemons et al. 1993; Nolan 2001). While such supply chain relationships may involve information sharing among partners, they differ in significant ways from a platform ecosystem partnership. First, the purpose of these networks of firms differ significantly—while platform ecosystems are typically formed to facilitate innovation that fill holes in a platform owner's product line (e.g., Evans et al. 2006), supply chain relationships are typically formed for manufacturing purposes. As a result, the payoffs for joining the partnership will also differ—in one case, the potential for additional sales through access to the installed base, and in the other, a fixed payment for manufacturing. Second and related, while suppliers in a supply chain may manufacture some (and in some cases, all) of a buyer's product, they usually do not have the complete set of manufacturing and downstream capabilities necessary to compete with the buyer. In contrast, almost by definition, the platform owner would have the capabilities to market products that compete with ecosystem partners, making the risks of expropriation significantly higher.

SAP is chosen as the focal enterprise software platform owner because SAP is the world's largest business software company which offers a complete business software suite including enterprise resource planning (ERP), customer relationship management (CRM), marketing & sales, manufacturing, warehousing & industrial, and supply chain management (SCM) & logistics software modules. In addition, partnerships are core to SAP's platform strategy and in its 37 years of history the network of software solution providers, value-added resellers, distributors, technology and services partners has developed into a broad ecosystem that is among the industry's largest (SAP 2009).

The partnership usually takes the form of ISVs developing a SAP certified product such as those “powered by SAP Netweaver” or “xApps”, obtaining a SAP certification for a particular interface, or joining SAP's complementary software partner program. The process starts with an ISV filing an application with the assistance of local SAP integration & certification center (ICC) or SAP partner liaison/manager. Then an ISV goes through development, documentation, and testing phases to make sure the product is compliant with SAP's platform specifications. Afterwards SAP issues a formal SAP ICC contract for the ISV to sign and applicable fees are paid by the ISV. SAP ICC will also assign a consultant to work with the ISV on preparing for certification and conducting/documenting a certification test. Once the product successfully completes the certification test, a certification logo will be issued and the solution will be listed on SAP's web portal which is accessible by its customers. Other benefits may include access and exposure to SAP's customer base, access to partner-only portals for product, marketing and sales information, sales/marketing assistance, and technical support, etc.

This partnership creates value for both ISVs and the enterprise software platform owner. By making its product SAP-certified and tapping into SAP's huge customer base, an ISV is exposed to a large market potential for its products and services. In addition, by teaming up with a prestigious industry leader, those small ISVs gain substantial endorsements, enhance their social legitimacy and signal their technological excellence (Stuart et al. 1999). The reputation consequences of strategic partnership are particularly important in high-technology industries, which are contexts noted for pervasive uncertainty (Tushman and Rosenkopf 1992). On the other hand, by attracting large number of ISVs into its innovation ecosystem and creating various value-added applications, SAP can meet the heterogeneous needs of enterprise customers, enhance the value, and therefore the willingness to pay for its own platform, and gain a competitive advantage as it promotes its enterprise suite as industry standard (Rochet and Tirole

2003). Furthermore, by learning from innovative small firms, SAP gains access to a window on the latest technology innovations (Benson et al. 2009), and may overcome its innovative inertia due to its size and bureaucracy, and discover new market opportunities and build new capabilities (Stuart 2000).

However, joining SAP's platform ecosystem is not costless for ISVs. Besides the fixed cost of developing platform compliant version of the software solution, certification application fees and yearly membership fees, there are considerable appropriability issues for ISVs due to extensive knowledge sharing involved in the relationship. The partnership is best characterized as a co-opetition (Hamel et al. 1989) and inevitably involves competition and conflict of interests as SAP also enters functional application development arena in addition to being the platform owner.¹

Theory and Hypotheses

IP Protection

Inter-firm collaborative relationships that involve a technology component are often characterized by extensive knowledge sharing and exchange (Khanna et al. 1998; Mowery et al. 1996). To the extent that one party in the alliance relationship is unaware of the other's knowledge acquisition intentions, or unable to define or control the extent of knowledge leakage, inter-firm collaboration may result in the loss of core competencies and expropriation of its innovation by collaborators if the transferred knowledge is not protected by any appropriation mechanism (Bresser 1988; Heiman and Nickerson 2004).

Such knowledge transfer is likely to occur in partnerships between an ISV and a software platform owner. For example, during the course of certification in the enterprise software industry the ISV may reveal sensitive information on its proprietary technology, its codification of business processes or best practices that embody industry-specific knowledge, or a particular design interface. A platform owner who acquires such knowledge may replicate or invent around the innovations of the ISV, absorb the distinct features of the ISV's application programs into its own software product suite, and compete directly with the ISV by invading its product markets.

ISVs can employ several mechanisms to protect their inventions, including legal mechanisms (patents, copyrights, and trade secrets), first mover advantages, and the ownership of complementary marketing and manufacturing capabilities (Cohen et al. 2000). While surveys suggest that the exploitation of first mover advantages is the most effective appropriation mechanism in the software industry (Graham et al. 2009), this mechanism may be less effective among firms who partner. Historically, copyrights have been commonly regarded as an effective legal form of protection for computer software (Graham and Mowery 2003; Graham et al. 2009; Menell 1989); however a series of legal decisions throughout the 1980s and 1990s has recently strengthened the intellectual property protection afforded by patents, especially for "business methods" (Cockburn and MacGarvie 2006; Graham and Mowery 2003; Lerner and Zhu 2007). As a result, both patents and copyrights can be used by the ISV to defend its intellectual property (Graham et al. 2009). While knowledge leakage may increase the risk of imitation associated with partnering, we expect stronger IP protection to decrease the potential loss of revenues arising from a platform owner's market invasion. Therefore, other things equal, increases in IP protection will be associated with greater expected payoffs to partnering. We hypothesize

H1: *The better an ISV's innovations are protected by intellectual property rights, the more likely that it will partner with the enterprise software platform owner.*

Downstream Complementary Capabilities

Since Teece's (1986) seminal work, strategy research on innovation appropriation has emphasized the importance of the ownership of specialized downstream capabilities (Arora and Ceccagnoli 2006; Ceccagnoli and Rothaermel 2008; Gans and Stern 2003; Rothaermel and Hill 2005). ISVs with downstream capabilities will be more successful in appropriating returns from their innovations, even when potential competitors such as the platform owner

¹ Over the course of last decade, SAP has resolved several disputes with partner ISVs, ranging from misappropriation of patents, copyrights, confidential information and trade secrets (SAP annual report 1998 – 2008). Interestingly, all these ISVs continue their partnerships (i.e., certified or re-certified) during and after the dispute period with SAP, suggesting that the benefit outweighs potential risks for these ISVs.

successfully enter their product space (Graham et al. 2009). For one, in the case of the partnership between ISVs and SAP, strong downstream marketing capabilities will enhance the returns to access to SAP's large installed base. In particular, the success of converting the platform owner's extant users into an ISV's customers will depend on downstream capabilities such as brand image, downstream marketing, distribution and service capability.

For similar reasons, the losses from imitation of the ISV's innovation will be lower in the presence of downstream capabilities. An ISV with brand image and marketing capabilities will be able to better defend their market than firms without such capabilities. Further, these capabilities may be difficult to replicate by the platform owner. While knowledge embedded in products can be codified by physical, formal or formulaic means, knowledge embedded in business practices or downstream service and consulting activities is often stored in human's head and is less susceptible to unintended leakage (Heiman and Nickerson 2004). For example, implementation of enterprise software often requires idiosyncratic adaptations to user needs that will be embedded in the implementation and configuration of the software products, and related consulting and service activities (Hitt et al. 2002). Such downstream knowledge and capabilities are more costly to transfer across firm boundaries (Brown and Duguid 2001; Von Hippel 1994) and may also act as a barrier to entry. Therefore, we propose

H2: *The stronger an ISV's specialized downstream capability, the more likely that it will partner with the enterprise software platform owner.*

Interaction of IP Protection and Downstream Capabilities

Researchers have examined and recognized the substitution effect among different types of IP strategies (Graham and Somaya 2006). For example, filing a patent necessitates information disclosure which makes maintaining the secrecy of an innovation difficult; thus, the use of patents and trade secrecy tend to be substitutes in IPR protection (Friedman and Landes 1991; Horstmann et al. 1985; Teece 1986). In this study we argue that formal IP protection is less crucial to the expected payoff from partnering in the presence of strong complementary downstream capabilities. Indeed, as noted in Hypothesis 1, patents and copyrights reduce the likelihood of knowledge expropriation. However, Hypothesis 2 suggests that the negative effect of potential knowledge expropriation will be weaker in the presence of complementary downstream capabilities. It follows immediately that the benefits of patents and copyrights as a means to protect knowledge when partnering (and, consequently the expected payoff to partnership) will be weaker in the presence of strong complementary downstream capabilities. Therefore, we propose

H3: *The positive effect of an ISV's innovation protection through IPR on partnership formation is lower when an ISV owns strong downstream capabilities.*

Product Portfolio Overlap

The effect of competition on partnership success is well documented in the strategy literature (Gimeno 2004). Although competitive collaboration, or co-opetition, could generate mutual benefits and result in a win-win situation through sharing complementary resources or acquiring new skills and capabilities by organizational learning (Hamel et al. 1989), empirical evidence often suggests the fragility of such inter-firm relationship between rivals. For example, Kogut (1989) argues that competitive conflicts impair the stability of cooperative agreements due to imitation of partners' technology and competition in the downstream market, and cooperative incentives could be offset by industry structural conditions that may promote rivalry among the partners.

In this paper, we examine one facet of competition between the ISV and the platform owner: closeness in product market space. Competition between the ISV and the platform owner will be greater when the products of the two vendors are more similar. Further, the losses from imitation of the ISV's product will be higher when the two vendors offer more similar products. Since partnering increases the probability of imitation by the platform owner, these losses will in expectation be higher with partnering. That is, the expected costs from increased competition with the platform owner will be higher under partnering.

Anticipating these effects, an ISV with a more similar product portfolio to the platform owner will have an attenuated incentive to join the ecosystem. Therefore, we propose

H4: *The greater the extent of product portfolio overlap with the platform owner an ISV has, the less likely the ISV will partner with the enterprise software platform owner.*

Methods and Measures

Data

We test the theoretical predictions using a longitudinal data set comprising the partnering activities of 1208 start-up independent software vendors with SAP over the period of 1996-2005. The sampling period starts from 1996 as we find virtually no such partnership activities between SAP and start-up ISVs in the sample before 1996 (more details will be provided later in the section of variable definition and operationalization).

Studies of alliance relationships within the enterprise software industry based solely on companies in the COMPUSTAT universe is likely to suffer from a serious selection bias: well-established public software companies may have a set of starkly different incentives to form inter-firm linkages from those of privately held new ventures or start-up companies (Cockburn and MacGarvie 2006; Shan 1990), and the majority of the firms in the ISV industry fall into private segments. In addition, using a sample comprising public software firms alone may fail to capture important industry dynamics such as entry and exit. However, collecting comprehensive, reliable information for small firms over an extended time period is an extremely difficult endeavor. In this study we resort to the CorpTech directory of technology companies. The dataset has detailed information on 100,000 public and private firms, including geography, sales and employees, product offerings, industry classification, ownership, funding sources and executives. To construct a representative sample of ISVs in enterprise software industry that could potentially form partnerships with SAP, we compare the product characteristics between existing SAP partners and those in the CorpTech data set. The first step involves retrieving a complete list of SAP's current software partners. SAP publishes the directory of all its certified partners as well as their solution offerings on its Internet portal,² and a searching using the terms "*Country: United States*" and "*Partner Category: Independent Software Vendor*" yields a list of 411 software firms that are existing SAP partners. Comparing this list with the CorpTech directory generates 206 matching records. One of the key advantages of the CorpTech database is that it records the product portfolio of each company and assigns each product into 3-digit product classes.³ We retrieve distinct 2-digit level product classification codes of the 206 existing SAP software partners, and try to find the most frequent software product codes in the product portfolio of the partnering firms. Two product codes, SOF-MA (manufacturing software, 61 firms) and SOF-WD (warehousing/distribution software, 44 firms), emerge as the leading products that partnering firms produce. We subsequently define our sample as firms that operate in the United States, with primary industry of computer software (identified by CorpTech company primary industry code "SOF"), and that have ever produced SOF-MA or SOF-WD products during the sampling period. The query generates 2175 ISVs from the CorpTech database. As we are primarily interested in the drivers of alliance formation for small, entrepreneurial software companies, we further remove established incumbents from our sample firms. Consistent with prior literature (Petersen and Rajan 1994; Puranam et al. 2006), we refine the ISVs to those established after 1980, with sales less than 500 million and number of employees less than 1000 throughout the sampling period. As an additional check, we manually go through the business description field in the CorpTech data set for each company, and visit the website of each firm (if the company no longer exists, we visit the archival web site from www.archive.org instead) to confirm that the ISVs indeed produce enterprise software applications, and delete those that do not fit the profile. Our final sample consists of 1208 ISVs.

Variable Definition and Operationalization

Dependent Variable

The dependent variable is whether an ISV firm enters into partnership with SAP and develops platform compliant application software for the first time in a particular year. As our study is longitudinal in nature, using the list of partnering ISVs retrieved from SAP's web portal as the dependent variable is problematic for several reasons. First, the list of partnering ISVs reflects only the current snapshot but fails to capture historical partnering events. SAP's

² <http://www.sap.com/ecosystem/customers/directories/searchpartner.epx>.

³ CorpTech uses a proprietary, 3-digit level product classification system. For example, a product coded as "AUT-AT-DA" means "factory automation"- "automatic test equipment"- "analog/digital component".

policy requires that partnering ISVs to recertify their products for compatibility and renew the partnership every 3 years. Failure to recertify would result in removal of the company from SAP's web portal. Second, the enterprise software industry experiences considerable entry and exit during the sampling period, with some of the once partnering firms being acquired by or merged with other companies. Third, information about the exact date on which the partnership is formed is missing from SAP's web portal, which makes the determination of the year of partnership formation impossible.

As an alternative to overcome the aforementioned difficulties, we identify the alliance formation events with SAP through press releases. To test the viability of this approach, we experiment with the existing partner list retrieved from SAP web portal to see whether a matching press release could be found for each firm. We use the search term "*COMPANY(SAP) and COMPANY(XYZ) and BODY(certification or certify or certified or partner or partnership or alliance)*" to search against the Lexis/Nexis news wire services database, where "XYZ" is replaced by the ISV firm's name. For a random sample (60 firms) of the 411 existing SAP partners, we are able to find a matching news release for over 98% of the firms, which confirms the validity of using press releases to determine the formation of alliances. We subsequently apply the same algorithm to our sample universe and retrieve 148 alliance events between sample ISVs and SAP. It is notable that there has been no such alliance activity prior to 1996. We further exclude pure joint development, marketing or distribution alliances and alliances after 2005 from the list. In addition, for ISVs that have multiple SAP alliance press releases (due to certification for multiple products, new versions of the same product, or different interface certifications), we use the first such event as the time the ISV firm joins SAP's platform ecosystem. We identify a total of 39 first-time alliance events for the sample ISVs.

The observation unit for the dependent variable is firm-year, with the variable set to 1 if a first-time alliance is formed in that year; 0 otherwise. We treat partnering with SAP as an absorbing state, as there are no obvious reasons for a partnering ISV to make its certified product incompatible with SAP's platform thus quitting from the platform ecosystem. Post-alliance observations are deleted as the firms are no longer exposed to the hazard of forming partnership with SAP. The 1208 sample ISVs generate 6436 firm-year observations. The data is structured as an unbalanced panel.

Independent Variables

Patents: We generate ISVs' patent stock variable by using USPTO CASSIS patent BIB database.⁴ To the extent that diversified software vendors often have technology innovations in related areas such as manufacturing control or data acquisition equipments, we are primarily interested in software patents. Prior research has used USPTO class-subclass combinations (Hall and MacGarvie 2006) and Boolean query that searches for keywords in patent text (Bessen and Hunt 2007) to identify software patent. For a survey of various measures of identifying software inventive activities, see Arora et al. (2008b). We use an intersection of the patent set defined by Hall and MacGarvie, and that of Bessen and Hunt as the basis of software patent universe, and retrieve all the software patents for the sample ISVs. As a robustness check, we also use the union of the two software patents sets and derive alternative measures, and all the empirical results are robust to this alternative measure. To account for the heterogeneity in the impact and importance of innovation, we also use Hall-Jaffe-Trajtenberg weighted stock of patent grants by incorporating forward patent citations as a robustness check (Hall et al. 2001).

Copyrights: The cumulative number of software copyrights for each firm-year is obtained from the United States copyrights office. The US copyright office assigns a prefix to each copyright it issues to indicate the copyright type, which could be one of CSN (periodicals, magazines, journals and newspapers), TX (monograph including books, maps and software), MW (manufacturing design), PA (performing arts), RE (copyright renew), SR (sound records), VA (visual arts), or V (name change and title transfer). As we are interested in software copyrights, we retrieve only those copyrights that are described as "computer file" within the TX class.

Downstream capability: One important measure of a firm's marketing capability is trademarks (Gao and Hitt 2004), which is a word, phrase, symbol or design, or combination of words, phrases, symbols or designs that identifies and distinguishes the source of the goods or services of one party from those of others. A firm's stock of software trademarks is the output and, therefore, a proxy for the firm's effort to build brand, reputation for quality, and distribution channels (Fosfuri et al. 2008). The data have been obtained from the USPTO CASSIS Trademarks BIB

⁴ There is usually a significant time lag between patent filing and patent granting. To account for the time issues, we count a patent from the patent filing year. All results are similar if we use an alternative measure of patent that counts patent from the patent granting year.

database.⁵ For each trademark listed on USPTO, a Live/Dead indicator is assigned, which could be Registered, Pending or Dead. Dead marks may have been abandoned, cancelled, or expired. Application abandonment usually happens as a result of failure to respond to an Office Action or a Notice of Allowance. Canceled trademarks are due to the registrant's failure to file the required continued use affidavit under Section 8 of the Trademark Act. An expired trademark results from the registrant's failure to renew the trademark registration at the end of the registration period. To construct the trademark variable, we first retrieve all the trademark records for the sample ISVs, including pending and dead records. The next step involves devising a search term to be applied to the "goods and services" description of trademark records to retain only those software trademarks.⁶ Afterwards, we determine the life span of each trademark to derive the active trademarks for each firm-year. Pending and abandoned trademarks are removed as a formal trademark registration is never granted. For canceled trademarks, registration date and cancellation date are used to determine the life span. For expired trademarks, we calculate the expiration date as 10 years after the registration date, or 10 years after the latest renew date if there has been any renewal record for the trademark.

Product portfolio overlap: Product portfolio information is obtained from the CorpTech database. We retrieve the distinct 2-digit product codes for each ISV firm in each sampling year, and compare those with SAP's 2-digit product portfolio in the same year. 2-digit product codes are used as a proxy for product lines because they correspond very well to the functional modules of enterprise software. The variable *product overlap* is defined as the ratio of number of common product lines (produced by both an ISV and SAP) divided by the number of SAP's product lines for each firm-year. Note *product overlap* is a time-varying covariate as an ISV firm may have entered into a related software market segment, introduced new software product lines, or exited from certain product markets.

Control Variables

We control for various firm level drivers that could influence an ISV firm's decision to join SAP ecosystem and could be potentially correlated with the independent variables. Firm size is measured by both annual *sales* and number of *employees*, obtained directly from the CorpTech database. Firm *age* is derived by referencing the year that an ISV was established. To allow for nonlinear effect of age, we add both linear and quadratic terms of age. We also add an ownership indicator variable to allow for different incentives of and propensity for alliance formation between public and privately held companies. The variable *public* is set to 1 if an ISV is a publicly traded company; 0 otherwise. Software firms' source of capital is likely to affect their decision to form partnership for several reasons. First, ventures backed up by corporate investment or venture capitalist are more likely to accumulate social capital that is unavailable to other start-ups. In addition, bargaining intermediaries that substantially reduce the cost of forging a contract between the parties, such as venture capitalists, can increase the likelihood of cooperation (Colombo et al. 2006; Gans et al. 2002). The CorpTech database classifies the funding sources into corporate investment, private investment or venture capital investment. We create 3 dummy variables, *cinvest*, *pinvest* and *vinvest* to control for the effect of firms' source of funding on alliance formation.

As a control for ISVs' innovative capability, we obtain the ISVs' cumulative number of *publications* in academic journal or conferences in each year via the Web of Science database. This is achieved by specifying the ISV's name as organization and ("article" or "proceedings paper") as document type, and applying the query. To account for the importance of publications, we also retrieve forward citation data for all the publications and construct citation weighted publications as an alternative measure.

⁵ Unlike copyrights or patents, trademark registration rights can last indefinitely if the owner continues to use the mark to identify goods or services. The term of a federal trademark registration is ten years, with ten-year renewal terms. However, in order to keep the trademark alive, between the fifth and sixth year after the date of initial trademark registration, a trademark owner must file a section 8 affidavit of continued use, and pay an additional fee. A trademark owner must also file an affidavit and pay a fee within a year before the end of every ten-year period. Failure of filing affidavit would result in the trademark being canceled.

⁶ After conducting thorough content analysis of 100 software trademarks, we construct the key words as: "computer application" or "computer software" or "computer program" or "operating software" or "business application" or "software application" or "application software" or "enterprise system" or "accounting system" or "application program".

Model Specification

We use discrete-time hazard model to study event history of ISVs' partnership formation with SAP. Using a hazard model (also referred to in various literatures as survival, duration or event history model) is appropriate since it relaxes normality assumption in most linear regressions and allows corrections for right censoring, truncation, late entry, time-varying covariates and duration dependence (Cameron and Trivedi 2005). Hazard analysis models the underlying and unobserved hazard rate, which is the instantaneous rate at which hazard events occurred at duration t , given that the subject under study have survived until time t .

We chose the Cox proportional model as a starting point of empirical analysis. The Cox proportional hazard model is a semi-parametric specification that makes no assumption about the shape of the baseline hazard over time, and assumes that the covariates multiplicatively shift the baseline hazard function. Applying the hazard model to our specification, we have

$$h_i(t | \mathbf{x}_{i,t-1}) = h_0(t) \exp(\mathbf{x}_{i,t-1} \boldsymbol{\beta})$$

and

$$\begin{aligned} \mathbf{x}_{i,t-1} \boldsymbol{\beta} = & \beta_0 \text{patent}_{i,t-1} + \beta_1 \text{copyright}_{i,t-1} + \beta_2 \text{trademark}_{i,t-1} + \beta_3 \text{patent}_{i,t-1} \times \text{trademark}_{i,t-1} \\ & + \beta_4 \text{copyright}_{i,t-1} \times \text{trademark}_{i,t-1} + \beta_5 \text{product_overlap}_{i,t-1} + \beta_6 \text{sales}_{i,t-1} + \beta_7 \text{employee}_{i,t-1} \\ & + \beta_8 \text{age}_{i,t-1} + \beta_9 \text{age}_{i,t-1}^2 + \beta_{10} \text{public}_{i,t-1} + \beta_{11} \text{cinvest}_{i,t-1} + \beta_{12} \text{pinvest}_{i,t-1} + \beta_{13} \text{vinvest}_{i,t-1} + \beta_{14} \text{publication}_{i,t-1} \end{aligned}$$

where $h_i(t | \mathbf{x}_{i,t-1})$ is the conditional instantaneous hazard rate for ISV firm i in year t , and $h_0(t)$ is the unspecified baseline hazard in year t . We lag all independent variables by one year to allow for any causal interpretation. Note there is no intercept in Cox model as it is subsumed into the baseline hazard function and unidentified.

As an alternative estimation method, event history can also be evaluated using standard binary discrete choice model such as logit model or complementary log-log model (Allison 1982; Tucker 2008). In order to estimate such a model, the data are arranged into cross-sectional time series format. The unit of observation is a firm-year, and the event is the binary decision that an ISV joins the platform ecosystem of SAP. If the event happens for an ISV in a particular year, all post-event observations are removed from the sample as we assume partnering is an absorbing state. Otherwise the observation for the ISV is right censored (event does not occur during the sampling years) and all years of data are included. We estimate the panel logit model as a robustness check.

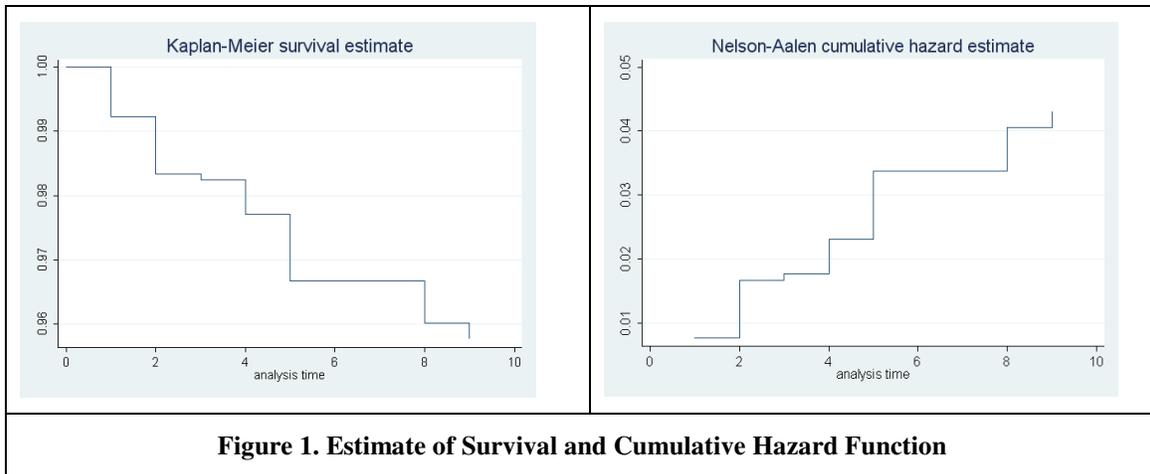
Results

Findings

Table 1 provides summary statistics of the variables and controls, as well as the correlation matrix. The descriptive statistics indicate that ISVs are characterized by significant heterogeneity along key dimensions, such as intellectual property rights (copyright ranges from 0 to 498), downstream capability (trademark ranges from 0 to 23), and product portfolio overlap (ranges from 0% to 100%). It is worth noting that patents are far less frequently used by start-up ISVs in the enterprise software industry (with mean of .13 patent per firm) than copyrights (mean 1.90 per firm), consistent with prior literature that copyrights provide better IP protection for enterprise software as a lot of innovations are in business processes, routines and best practices that may not be amenable to patenting (Mann and Sager 2007; Menell 1989).

Table 1. Summary Statistics																		
Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	
1 Partner _{it}	0.005	0.073	0	1	1													
2 Patents _{it-1}	0.134	0.658	0	13	0.029	1												
3 Copyrights _{it-1}	1.895	12.693	0	498	0.010	0.009	1											
4 Trademarks _{it-1}	0.794	1.959	0	23	0.061	0.335	0.279	1										
5 Product overlap _{it-1}	0.220	0.196	0	1	-0.032	-0.048	0.072	-0.066	1									
6 Age _{it-1}	12.599	5.829	0	24	-0.049	-0.111	0.069	0.003	0.067	1								
7 Sales _{it-1} (millions)	6.897	13.895	0	169	0.077	0.213	0.293	0.357	0.037	-0.045	1							
8 Employees _{it-1}	52.409	95.048	1	900	0.077	0.240	0.268	0.362	0.029	-0.072	0.891	1						
9 Public _{it-1}	0.054	0.226	0	1	0.033	0.227	0.062	0.214	-0.003	-0.048	0.403	0.434	1					
10 Cinvest _{it-1}	0.044	0.204	0	1	0.014	0.042	-0.021	0.045	0.011	-0.119	0.112	0.114	0.054	1				
11 Pinvest _{it-1}	0.503	0.500	0	1	-0.037	-0.042	-0.011	-0.049	0.014	-0.145	-0.094	-0.102	-0.027	-0.062	1			
12 Vinvest _{it-1}	0.115	0.319	0	1	0.080	0.122	-0.008	0.105	-0.014	-0.332	0.153	0.183	0.138	0.073	-0.070	1		
13 Publication _{it-1}	0.598	5.296	0	137	-0.000	-0.003	-0.000	0.032	-0.003	0.045	0.052	0.054	0.079	-0.015	-0.017	0.040	1	

Before we apply the regression models, non-parametric techniques are used to provide intuitive understanding of the event history. Figure 1 presents the Kaplan-Meier estimate for the survival function, as well as the Nelson-Aalen estimator for the cumulative hazard function. It is noticeable that the hazard rate is relatively low (with cumulative hazard less than .05 in the last year), and ISVs’ partnering activity with SAP peaked in 2001 (year 5 in terms of analysis time).



Results from Cox proportional hazard survival models are presented in Table 2. In all regressions we use log transformation of patents, copyrights, and trademarks (i.e., $\log(1+x)$ to avoid taking log of zeros) to control for over dispersion and skewness in these variables. Variables are entered into regressions sequentially with the log likelihood reported for each model. We also report the likelihood ratio test for models 2 and 3, comparing each model with its immediate predecessor to see whether the additional variables increase explanatory power. Model 1 presents the base model where only the control variables are included. In model 2 we add variables for IP protection, downstream capability and their interactions. Model 3 includes the measurement of product portfolio overlap between SAP and ISVs. We observe that adding IP protection mechanisms and downstream assets significantly increases explanatory power ($\chi^2(5)=20.31$, $p=.001$, Model 2 vs. Model 1), and so does product portfolio overlap ($\chi^2(1)=5.58$, $p=.018$, Model 3 vs. Model 2).

Variables	(1)	(2)	(3)
Patents		0.225 (0.656)	0.245 (0.678)
Copyrights		0.714*** (0.213)	0.730*** (0.217)
Trademarks		1.142*** (0.281)	1.104*** (0.284)
Patents × trademarks		-0.245 (0.407)	-0.325 (0.420)
Copyrights × trademarks		-0.591*** (0.209)	-0.581*** (0.210)
Product overlap			-2.154** (0.964)
Public	-0.192 (0.529)	-0.423 (0.521)	-0.299 (0.524)
Age	-0.057 (0.113)	-0.172 (0.117)	-0.160 (0.117)
Age ²	-0.000 (0.005)	0.004 (0.005)	0.004 (0.005)
Employees	0.002 (0.002)	0.001 (0.002)	0.001 (0.002)
Sales	0.013 (0.010)	0.016 (0.011)	0.017 (0.011)
Corporate invest	0.134 (0.616)	0.207 (0.622)	0.183 (0.630)
Private invest	-0.850** (0.366)	-0.723* (0.370)	-0.758** (0.375)
VC invest	1.127*** (0.379)	1.027*** (0.375)	1.117*** (0.375)
Publications	0.353 (0.227)	0.251 (0.242)	0.213 (0.256)
No. of subjects	1208	1208	1208
Observations	6436	6436	6436
Log likelihood	-238.735	-228.579	-225.788
LR test		$\chi^2(5)=20.31$ p=.001	$\chi^2(1)=5.58$ p=.018

*** p<0.01; ** p<0.05; * p<0.1. Standard errors in parentheses.

Examining the results of the final model, we find partial support for H1. Increases in the stock of copyrights are positively associated with an ISV's hazard of forming partnership with SAP, but the effect is not significant for patents, albeit positive. Although there has been recent literature that emphasizes the increasingly important role that software patents plays in IP protection (Graham and Mowery 2003; Lerner and Zhu 2007), our results indicate that copyrights remain the most popular mechanism used by enterprise software vendors to prevent expropriation. In addition, we see a strong positive effect of trademark stock on alliance formation, confirming hypothesis H2. Consistent with our expectation, we find evidence that IP protection and downstream capability act as substitutes for one other in their influence on partnership formation, and the effect is more pronounced for copyrights than for patents, partially confirming H3.

A numerical example based on the full model (Column 3 of Table 2) would illustrate the main effects and interaction effects of IPR protection and trademarks. To examine the marginal effect, we consider a log transformed variables x_i in the Cox proportional hazard model. Suppose we increase x_i by 100%, while holding other variables constant, the hazard ratio

$$\frac{h(t | 2x_i, \mathbf{x}_{-i})}{h(t | x_i, \mathbf{x}_{-i})} = \frac{\exp[\beta_i \ln(2x_i)]}{\exp(\beta_i \ln x_i)} = \exp(\beta_i \ln 2) = 2^{\beta_i}$$

Consider a firm that has the mean value of log transformed copyrights (.378, corresponding to copyrights mean = $e^{.378} - 1 = .46$) and the mean value of log transformed trademarks (.333, corresponding to trademarks mean = .40). If the firm doubles its stock of copyrights while holding other variables constant, the hazard ratio becomes $2^{[.730 + (-.581) \times .333]} = 2^{.537} = 1.451$, which means a 45% increase in hazard. Similarly, if the firm doubles its stock of trademarks while holding other conditions unchanged, the hazard ratio becomes $2^{[1.104 + (-.581) \times .378]} = 2^{.884} = 1.845$, which translates into a 85% increase in hazard rate. However, if the firm doubles both its copyright and trademark, the hazard ratio becomes

$$\begin{aligned} \frac{h(t | 2x_1, 2x_2, \mathbf{x}_{-1,2})}{h(t | x_1, x_2, \mathbf{x}_{-1,2})} &= \frac{\exp[\beta_1 \ln(2x_1) + \beta_2 \ln(2x_2) + \beta_3 \ln(2x_1) \times \ln(2x_2)]}{\exp(\beta_1 \ln x_1 + \beta_2 \ln x_2 + \beta_3 \ln x_1 \times \ln x_2)} \\ &= \exp[\beta_1 \ln 2 + \beta_2 \ln 2 + \beta_3 ((\ln 2)^2 + \ln 2 \times \ln x_1 + \ln 2 \times \ln x_2)] \\ &= 2^{.730} \times 2^{1.104} \times \exp[(-.581) \times ((.693)^2 + .693 \times .378 + .693 \times .333)] = 2.026 \end{aligned}$$

which implies a 103% increase in hazard rate. This is considerably lower than the combination of the direct effect of copyrights and the direct effect of trademarks, $1.451 \times 1.845 - 1 = 168\%$ increase, due to the substitution effect (negative interaction) between copyrights and trademarks.

Hypothesis H4 states that the higher product portfolio overlap with SAP that an ISV has, the less likely the ISV will join SAP's platform ecosystem. We find the hypothesis is supported by the empirical evidence. As an ISV's product overlap with SAP increases by 1%, its likelihood of partnering with SAP decreases by $1 - \exp(.01 \times (-2.154)) = 2.13\%$.

Interestingly, we find evidence that the funding sources of ISVs do influence their inter-firm linkage activities. As expected, ISVs that are backed up by venture capital are more inclined to form partnerships with dominant software platform owners, due to their greater access to social capital, stronger bargaining power and lower contract cost. In contrast, ISVs founded by private investment are less likely to access those resources, and therefore have lower chance of partnering with SAP.

Tests for Robustness

We explore the robustness of our findings through several alternative models, and use different measurements of independent variables to check the robustness of our findings. To account for variation in the significance and impact of innovation, in Model 1 of Table 3 we present the same Cox hazard model by using forward citation weighted patents and publications. We find the set of results is similar to the model that uses unweighted variables.

While Cox hazard model has been commonly used in the literature because of its flexibility of leaving the baseline hazard unspecified and unconstrained, the estimate is not always efficient when compared with full parametric models, if the underlining baseline hazard function is known (Cameron and Trivedi 2005). In Model 2 of Table 3 we present the results from a most commonly used parametric model, the exponential hazard model. Similar results are found as in the Cox proportional hazard model. We also extend the model to account for unobserved heterogeneity, as there could be potential omitted variables that influence alliance formation and which are correlated with the independent variables. Empirically this amounts to the inclusion of a multiplicative idiosyncratic factor, known as a *frailty*, to the hazard function specification (Bruce et al. 2004; Cameron and Trivedi 2005). The unobserved heterogeneity is usually assumed to be gamma or inverse-Gaussian distributed. We present the results of an exponential hazard model with inverse-Gaussian frailty in Model 3 of Table 3. The likelihood ratio test for heterogeneity rejects the null of no heterogeneity at $p=.05$ significance level, which indicates the presence of unobserved heterogeneity.

Finally, we present the results of using a binary choice model in Model 4 of Table 3. We treat alliance formation as a binary outcome for each firm-year observation, and use a panel logistic regression to investigate the determinants of partnership. We allow for firm-level heterogeneity by incorporating random effects. There are two reasons that prevent us from using a fixed effects panel logit model: First, the vast majority of the ISVs in our sample did not join SAP ecosystem throughout the sampling years, therefore the dependent variable remains 0 for all years. This causes those observations to be dropped when a fixed effects logit model is applied. Second, fixed effects models

exploit only longitudinal variations in variables. A number of the variables that we use, such as patents, public/private indicator and funding sources, vary mainly cross-sectionally and have little longitudinal variation, and using a fixed effects model causes great efficiency loss.

The different models listed in Table 3 give consistent estimates of variable coefficients, and confirm the validity of our hypotheses.

Table 3 Alternative Measures and Models				
Variables	(1) Citation Weighted Patent and Publications, Cox Model	(2) Exponential Hazard Model	(3) Exponential Hazard with Unobserved Heterogeneity	(4) Panel Logistic Model with Random Effect
Patents	0.154 (0.172)	0.095 (0.677)	0.256 (0.882)	0.297 (0.903)
Copyrights	0.739*** (0.216)	0.799*** (0.216)	0.915*** (0.294)	1.030*** (0.362)
Trademarks	1.121*** (0.290)	1.096*** (0.284)	1.337*** (0.354)	1.197*** (0.426)
Patents × trademarks	-0.118 (0.111)	-0.302 (0.414)	-0.468 (0.604)	-0.363 (0.569)
Copyrights × trademarks	-0.587*** (0.211)	-0.647*** (0.215)	-0.754*** (0.272)	-0.744** (0.308)
Product overlap	-2.221** (0.972)	-2.199** (0.966)	-3.070** (1.303)	-3.406** (1.436)
Public	-0.372 (0.539)	-0.293 (0.521)	-0.194 (0.928)	-0.011 (0.764)
Age	-0.149 (0.117)	-0.186 (0.115)	-0.185 (0.140)	-0.240* (0.142)
Age ²	0.004 (0.005)	0.004 (0.005)	0.003 (0.006)	0.005 (0.006)
Employees	0.001 (0.002)	0.001 (0.002)	0.001 (0.003)	0.002 (0.003)
Sales	0.018 (0.011)	0.014 (0.011)	0.031 (0.021)	0.023 (0.017)
Corporate invest	0.147 (0.629)	0.172 (0.626)	0.136 (0.886)	0.171 (0.848)
Private invest	-0.731* (0.374)	-0.796** (0.372)	-0.919** (0.435)	-1.043** (0.508)
VC invest	1.145*** (0.376)	1.098*** (0.375)	1.177** (0.489)	1.328** (0.575)
Publications	0.206 (0.366)	0.207 (0.253)	0.223 (0.348)	0.242 (0.361)
Constant		-4.374*** (0.598)	-4.308*** (0.709)	-4.119*** (1.399)
Year dummies				Yes
No. of subjects	1208	1208	1208	1208
Observations	6436	6436	6436	6436
Log likelihood	-225.744	-161.442	-159.842	-181.921

*** p<0.01; ** p<0.05; * p<0.1. Standard errors in parentheses.

Discussion and Conclusion

Summary of Results and Managerial Implications

Innovation ecosystems have long existed in the computer software industry. Surprisingly, there has been a paucity of empirical studies that examine the incentives and antecedents of the formation of such ecosystems from the perspective of its participants. Our study uses an economic-based perspective to illustrate the facilitators of and barriers to an ISV's partnering with a platform owner in the enterprise software industry. We present robust empirical evidence that ISVs with better legal protections through intellectual property rights and those with stronger downstream marketing capabilities are more likely to partner. Interestingly, protection of upstream capabilities using formal IPRs and downstream appropriation protection through marketing capabilities substitute for each other in shaping the payoff to partnering. Further, when the ISV and the platform owner compete in similar markets, the risks of platform owner entry discourage such partnerships.

We envision several broad implications of our empirical findings for platform sponsors as well as participants in the platform ecosystem. First, while certification from a major platform owner may provide the ISV with a larger market access, an endorsement effect and enhance its social and technical legitimacy (Chellappa and Saraf forthcoming), the ISV may bear considerable knowledge expropriation risks during the process if both IP protection is weak and if the ISV does not possess strong downstream capabilities. In addition, ISVs that compete with the platform owner in multiple product markets should be cautious about proceeding with such a partnership. Finally, for a platform owner that focuses on fostering the rapid growth of its ecosystem to capture indirect network effects and promote the platform as de facto industry standard, understanding the incentives and reservations of its complementary product providers is of paramount importance, and building proper governance mechanisms that alleviate its partners' expropriation concerns will be conducive to the shared success of the community (Gawer and Henderson 2007). Surprisingly, our findings suggest that a strong, well-functioning IPR regime not only protects complementors from expropriation risks, but also works to the benefit of the platform owner in that it encourages the provision of complementary innovation that is based on the platform.

Our results also have implications for where ecosystems are most likely to arise. Ecosystems will be less likely to arise among firms with little formal means of IPR protection and, in particular, will be less likely where the protection afforded by patents is weak. They will be relatively more common when complementors are more effectively able to secure their innovations through copyrights, patents, and downstream capabilities, and when the products of the platform owner and complementor do not directly compete.

Limitations and Future Research

Although patents and copyrights serve as effective measures of IPR regimes, we acknowledge our limited ability to disentangle the effect of innovation from IPR protection on partnership formation, as firms in different industry segments may face different levels of strength of legal IPR mechanisms and have different propensities for employing patents, copyrights, trade secrecy, lead time advantage and other informal innovation protection alternatives (Cohen et al. 2000). For example, prior study has documented that the patent propensity rate varies dramatically across industries, with firms in textiles on average patent only 8.1% of their product innovation while pharmaceutical firms have a patent rate of 79.2% (Arundel and Kabla 1998). Although firms in the industry of interest in this study, enterprise software, are relatively homogeneous, it is possible that patent and copyright propensity varies according to firm size (Brouwer and Kleinknecht 1999), relative effectiveness of patents and copyrights within software submarkets (Arora et al. 2008a; Mann and Sager 2007), or characteristics of the technology (Hall and Ziedonis 2001). We address this issue by including scientific publications of ISVs as a measure of (unprotected) innovation. Future research could benefit from separating the effect of innovation from IP protection, either by controlling for firm R&D spending or explicitly incorporating patent and copyright propensity scores in the analysis.

Another limitation of this study is that we focus on the dyadic relationship between an ISV and the platform owner, while theory and research have advanced to analyze conduct and performance of firms by examining the network relationships in which they are embedded (Bae and Martin 2004; Goerzen and Beamish 2005). In cases that multiple platforms and standards coexist in certain industries, firms face substitutable alliance partners from which they can draw complementary resources from (Bae and Martin 2004). Particularly in enterprise software, studies of what

determines small ISVs to choose or join different platforms sponsored by dominant incumbents such as SAP, Oracle or Infor Global, and how firm performances are conditioned on their structural positions inside the partnership network would provide a much richer understanding of the ecosystem evolution than treating the partnership decision as binary choices.

There is plenty room for further research on the topic of enterprise software ecosystem. Particularly, it is unclear through what mechanisms the partnering ISVs extract relational rent from such inter-firm exchange and how their post-partnership financial performance and exit strategies differ from non-participants. In addition, the roles of other ecosystem constituents such as customers, implementation partners and consulting companies remain largely unexplored and call for further investigation.

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