CO-CREATION OF VALUE IN A PLATFORM ECOSYSTEM: THE CASE OF ENTERPRISE SOFTWARE*

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ABSTRACT

Platform technology owners often nurture their innovation ecosystems to seek complementary invention and exploit indirect network effects. In this study we examine whether participation in ecosystem partnership creates business value and impacts their business performance for small independent software vendors (ISVs) in the enterprise software industry, and if so, under what conditions the ISVs can better appropriate the value created. By analyzing the partnering activities and performance indicators of a sample of 1210 small ISVs over the period of 1996-2004, we find that joining a major platform owner's innovation ecosystem is associated with an increase in sales and a greater likelihood of issuing an IPO. In addition, we show that these impacts are stronger when the ISVs have greater intellectual property rights or stronger downstream capabilities. This research highlights the value of product compatibility and access to the platform owner's installed base in the platform ecosystem partnership, and stresses that value creation and appropriation are not mutually exclusive strategies in inter-firm collaboration.

Keywords: Platform ecosystem, partnership, business value, sales, IPO, intellectual property rights, downstream capabilities

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1. INTRODUCTION

"Big boys and little boys can't play in the same sandbox."

Campbell "Cam" B. Lanier III, 2006 Distinguished Entrepreneur, The MIT Enterprise Forum

Platform-based technologies such as personal computers, PDAs, and video game consoles are becoming increasingly important in the information economy (Evans et al. 2006). Such systems consist of a core technology platform and interchangeable complementary applications built upon it. To meet the needs of heterogeneous users and to exploit indirect network effects, owners of a platform often seek to encourage complementary third-party innovation from resources located outside the firm, ranging from customers, research companies and business partners to universities (Linder et al. 2003). This approach of complementary innovation has given rise to the model of an innovation ecosystem. A burgeoning body of research has started to theorize about how such ecosystems are formed and their implications for platform owners, complementary providers, and users (Adomavicius et al. 2007; Adomavicius et al. 2008; Eisenmann et al. 2008; Gawer and Henderson 2007; Lee and Mendelson 2008; Mantena et al. 2007; Parker and Van Alstyne 2008; West 2003).

To encourage complementary innovation, owners of IT hardware and software platforms such as Microsoft, IBM, and SAP often have partnership programs for members of their innovation ecosystems. Members of these partnership programs co-create value with the platform owner by developing applications and solutions to be used on the platform. However, despite increasing interest among practitioners and researchers on ecosystems there has been little work in understanding the value of these partnership programs, and under what conditions they are most beneficial to their participants. This is a surprising gap in understanding. For researchers, this

means that there is little systematic measurement of the extent to which partnership programs facilitate the co-creation of value. For example, recent theoretical work on how platform owners can encourage the development of ecosystems (Eisenmann et al. 2008; Parker and Van Alstyne 2008; West 2003) would benefit from empirical evidence on the value of these programs. For practitioners, platform owners and their complementors currently have no systematic means to determine how much to invest in them. In addition, efforts of start-up software vendors to use ecosystem participation as a growth strategy will have meaning only if vendors know who is most likely to benefit from such relationship. In short, accurate measurement of the (co-created) value from ecosystem partnership programs has important implications for both researchers and practitioners.

A related question is the issue of value appropriation in IT innovation networks. Recent studies on inter-firm alliances have emphasized the role of partners' resources and capabilities in value creation (Ahuja 2000; Lane and Lubatkin 1998; Mowery et al. 1996). However, they have generally tended to overlook the effect of appropriation hazards on the co-creation of value by alliance partners. The misappropriation issue is particularly important in the case of platform ecosystem partnerships,[1] as such relationships are often characterized by a conflict between the developers of complementary products and the platform owner due to the risks that the latter may eventually compete in the former's product market space (Gawer and Henderson 2007). The question of how these risks of misappropriation affect the returns to partnership has yet to be answered. Acquiring empirical evidences on these issues has important managerial implications, as it will inform when ecosystems are most likely to grow and succeed.

[1] For example, over the last decade SAP has resolved a number of disputes with its ecosystem partner ISVs, whose claims range from infringement of patents and copyrights, to misappropriation of confidential information and trade secrets (SAP annual report 1998 – 2008).

In this paper we take one step towards addressing these gaps in prior research. Drawing upon theories of innovation commercialization and inter-organizational relationships (IORs), we develop a theoretical framework to predict the relationship between platform ecosystem participation, appropriation strategies and firm performance. We then test the developed hypotheses in the context of the enterprise software industry. Specifically, using a unique data set on the partnering activities of 1210 independent software vendors (ISVs) over the period of 1996-2004, we evaluate the effects of joining the SAP ecosystem on two critical performance measures of entrepreneurial ISVs: sales and the likelihood of obtaining an initial public offering (IPO). We analyze the former because it is strongly correlated with the profitability and overall financial performance of the firm, in particular due to the high fixed cost/low variable cost structure of software firms. We analyze the latter because it is both a measure of the future sales prospects for the firm and a common measure of small firm performance (Cockburn and MacGarvie 2009; Shane and Stuart 2002). We present robust empirical evidence showing that the decision to partner is associated with both an increase in sales and a greater likelihood of an IPO.

We next investigate how appropriability strategies, such as ownership of intellectual property rights (IPR) and downstream complementary capabilities by the ISV, moderate the effects of partnership on ISV performance. A rich literature on appropriating the returns to innovation show that both are conducive to appropriating returns through product markets (Teece 1986) or the markets for technology (Arora and Ceccagnoli 2006; Arora et al. 2001; Gans and Stern 2003), and have a significant effect on firm performance (Ceccagnoli 2009), though as yet there is less understanding of how these may condition the value of partnerships in a platform ecosystem. In particular, we find that the impact of partnership on sales and the likelihood of an

IPO is greatest for those ISVs who are protected by IPR and who have strong downstream capabilities.

Our study contributes to the extant literature on several fronts. First, although prior research on alliance relationships has examined their impact on firm performance (Bae and Gargiulo 2004; Baum and Oliver 1991; Goerzen and Beamish 2005; Mitchell and Singh 1996; Zaheer and Bell 2005), the focus in much of that literature has been on the value of alliances as a mechanism to facilitate learning and access to specialized resources (Porter and Fuller 1986). Our analysis and theory differs from this extant literature in significant ways: in our setting, partnerships are valuable primarily as a way of signaling compatibility with the platform rather than a mechanism of sharing critical information. In that way, our study shares similarities with Chellappa and Saraf (forthcoming), who examine how an enterprise software vendor's structural position in an alliance network is correlated with firm performance. However, while Chellappa and Saraf are primarily interested in how a firm's position in the social network of large enterprise software firms influences firm performance, we examine the impact of ecosystem partnership on performance among small ISVs.

Our research differs from prior alliance literature (including Chellappa and Saraf) in another significant way. With the exception of Lavie (2007), few have simultaneously studied value creation and value appropriation mechanisms in alliance relationships. We bridge this gap by applying theory on innovation commercialization to inter-firm alliance studies. While Lavie (2007) emphasizes the role of bilateral and multilateral competition on value appropriation in alliance relationships, we examine how the benefits of participation in a platform ecosystem vary according to different appropriation strategies. Specifically, our findings imply that appropriability, in particular intellectual property protection, is a critical determinant of the

returns to ISVs from the co-creation of value in the software industry, and that successful and sustainable ecosystems will be found in environments where appropriability mechanisms are strong. In such environments, strong ISV participation in the ecosystem will engender a rich supply of innovative solutions to meet heterogeneous customer needs, igniting a virtuous cycle of indirect network effects that will in turn lead to further value co-creation.

More broadly, while a growing body of literature has examined how platform owners can encourage third-party complementors to stimulate indirect network effects, the current literature on platform technology focuses primarily on the management issues and strategies from the perspective of the platform owners (Eisenmann et al. 2008; Gawer and Cusumano 2002). There is at present little work examining the perspective of the platform participants. In this way, our research builds upon Huang et al. (2009) who study the decisions of ISVs to participate in a partnership program. However, while Huang et al. (2009) study the antecedents of the partnership decision, they do not examine the performance implications of partnering as we do.

The rest of the article is organized as follows. In the next section we present an overview of the literature in related research areas. In section 3 we extend the theories and propose the hypotheses regarding value creation and appropriation in a platform ecosystem. In section 4 we describe the research setting, the data, and methods used in the empirical investigation. We present the results, as well as a set of robustness checks, in section 5. In section 6 we discuss the implications of our findings and conclude.

2. LITERATURE REVIEW

In this section we discuss the connection between our paper and three related streams of the literature: work on technology platforms and innovation ecosystems, research on inter-

organizational relationships and their value creation mechanisms, and studies on appropriating the returns from innovation.

2.1. Technology Platform and Co-Innovation Ecosystem

The demand for a platform is often shaped by indirect network effects; in particular, the value of the platform is increasing in the supply of complementary products (Katz and Shapiro 1994). Positive feedback between user adoption and complementary product provision lead to the interesting dynamics in a two-sided market mediated by the underlying platform (Rochet and Tirole 2003).

Recent research on technology platforms has started to investigate how platform owners utilize an innovation ecosystem strategy as a means to encourage third-party complementary invention and exploit indirect network effects. In particular, prior theory research has focused on the platform owner's decision of the optimal level of openness for an IT platform, which often entails a tradeoff between adoption and appropriability (Eisenmann et al. 2008; Parker and Van Alstyne 2008; West 2003). Others have examined the competitive dynamics between open and closed (i.e., proprietary) platforms (Lee and Mendelson 2008; Mantena et al. 2007). In contrast, empirical studies often seek to relate the rate of innovation to the extent of platform openness (Boudreau 2007) or measure the value of network effects to end users (Brynjolfsson and Kemerer 1996; Gallagher and Park 2002; Gallaugher and Wang 2002; Gandal 1995; Liu et al. 2008; Zhu and Iansiti 2009; Zhu et al. 2006).

Despite the growing interest of researchers and practitioners in platform ecosystem partnerships, it remains unclear whether joining such ecosystems creates value for a complementary solution provider, and if so, how platform complementors can better appropriate the returns to such

partnerships. One particular concern is that the platform owner may eventually enter the complementors product market space by producing a competing product (Gawer and Cusumano 2002; Gawer and Henderson 2007; Iansiti and Levien 2004). While a variety of theoretical work and case studies provide rationale and evidence that the threat of platform sponsor entry influences complementors' platform-specific investments, at present there is little systematic empirical evidence as to how this threat shapes the rent distribution among innovation ecosystem partners. By examining how intellectual property rights and downstream capabilities influence the extent to which a platform complementor can reap the benefits from joining an ecosystem, this paper begins to make some progress on that front.

2.2. Inter-Organizational Relationships and Value Creation

An inter-organizational relationship is an alternative to a market or an organizational hierarchy (Barringer and Harrison 2000) that extends the traditional "make or buy" decision to "make, buy or partner." Prior research has examined various forms of inter-organization relationships, including joint ventures (Inkpen and Crossan 1995; Kogut 1988), alliances (Das et al. 1998; Dickson and Weaver 1997), networks (Alter and Hage 1993; Jones et al. 1997), trade associations (Bresser 1988; Oliver 1990), and supply chain relationships (Clemons et al. 1993; Nolan 2001). A number of theoretical paradigms have been proposed to explain the mechanisms through which an inter-organizational relationship creates value for its participants, including transaction cost economics (Dyer 1997), resource dependency (Das and Teng 1998), strategic choice (Shan and Hamilton 1991), organizational learning (Powell et al. 1996) and institutional theory (DiMaggio and Powell 1983). However, the relationship between a platform owner and its complementary solution providers is different from many other types of inter-organization relationships that have been studied, and may involve different value creation mechanisms.

The relationship has several distinct features. First, an innovation ecosystem is usually formed on the basis of an underlying technology platform, which is characterized by indirect network effect (Katz and Shapiro 1994). The ecosystem usually has a hub-and-spoke structure, and is organized around a key platform technology owner, leading to an asymmetric relationship between the platform owner and complementors (Damsgaard and Truex 2000). Second, the boundary between platform and complementary solutions are not well defined, and platform owners constantly absorb innovative features of complementary applications into the platform (Gawer and Henderson 2007). There may be fierce competition between the platform owner and complementors in multiple market segments, resulting in competitive collaboration (Hamel et al. 1989; Nalebuff and Brandenburger 1997). Third, the primary benefit 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 contrast to other inter-organizational relationships where organizational learning, risk sharing, resource pooling or strategic factors are important (Porter and Fuller 1986). By investigating this platform owner-complementor relationship and how it creates value for its participants, we make a significant contribution to prior research on inter-organizational relationships.

2.3. Appropriating the Return from Innovation

Technology entrepreneurs such as small enterprise software vendors often face a critical challenge of translating their innovation into steady streams of economic returns. When start-up innovators commercialize a new technology, they often face a choice between (1) embedding the innovation into a product and competing with established firms versus (2) earning returns through markets for technology (Gans and Stern 2003). A key determinant to this choice is the ownership of costly-to-build downstream manufacturing, marketing, distribution and other

complementary capabilities that are essential to a firm's value chain and required for successfully launching a product or service (Teece 1986). These complementary capabilities are usually specialized to the innovation, and they cannot be easily contracted for through the market on competitive terms (Teece 1986). In addition, these capabilities are rare, path-dependent and difficult to imitate, and their ownership may constitute of a barrier to entry and provide a sustainable competitive advantage (Barney 1991; Rothaermel and Hill 2005; Teece 1992). Empirical studies have revealed that ownership of downstream capabilities required to commercialize an innovation is one of the most effective means of securing returns from innovation across a wide range of industries (Cohen et al. 2000).

While the ownership of specialized complementary assets is conducive to an appropriation strategy through vertical integration into the product market, securing returns from innovation through technology licensing and the market for ideas depends critically on the possession and strength of IPR (Arora et al. 2001; Gans and Stern 2003). For example, Gambardella and Giarratana (2008) find a positive relationship between the effectiveness of patent protection and technology licensing in the security software industry, while the ownership of downstream specialized capabilities increases the likelihood that firms will launch new products. Recent research has also extended this literature to examine the role of markets for technology in affecting the survival of entrepreneurial firms in the security software industry (Arora and Nandkumar 2008).

The markets for technology literature can be applied and modified to examine the role of appropriability in affecting the performance of startups in the enterprise software industry, especially when they are in collaborative relationships with industry leaders. Partnerships in this industry have as a key objective: to achieve compatibility between innovative software solutions

and the platform. However, likely exchanges of information that occur while forming the partnership mean that the threat of expropriation and appropriability considerations may be crucial drivers of the operational performance of firms involved in such partnerships.

3. THEORY AND HYPOTHESIS

In this section we apply relevant theories and propose hypotheses regarding value creation and appropriation in platform ecosystems. Our hypotheses are motivated by theoretical models of innovation partnerships under appropriability risks developed by Gans et al. (2002) and Huang et al. (2009). In these models, the decision of start-ups to partner with established firms is shaped by the expected payoff from partnership as well as the risks of misappropriation as conditioned by IPR and downstream marketing capabilities. We leverage and adapt these ideas by relating a startup's financial performance with the ecosystem participation decision and its appropriability strategy in the enterprise software industry.

3.1. Participation in Ecosystem and Sales

In technology industries where network effects are important and a dominant standard has yet to be established, small technology firms may initiate an alliance or join a platform ecosystem to achieve technology compatibility with a platform. Technology compatibility is attained when partnering firms align their product interface designs at the data, application and business process levels (Yang and Papzoglou 2000). In the software industry, this process is usually realized through application programming interfaces (API) that are provided by the platform owner, or more recently, through implementing service-oriented architecture and web services, such as those of SAP's NetWeaver platform.

We argue that joining a platform ecosystem, and therefore achieving technology interoperability with an industry leader's portfolio of products, is associated with an increase in expected sales for small ISVs. By ensuring compatibility with the platform, partnership increases the net benefits to potential buyers of the ISV's product: in other words, the ISV and the platform owner co-create value by improving product compatibility. Since platform owners are usually established incumbents with a large installed base, partnership exposes an ISV to a greater potential market that is not served or underserved by the platform owner. The literature on standards competition reveals that technology compatibility is often a prerequisite to gaining access to the user base of the platform owner (Katz and Shapiro 1994; Matutes and Regibeau 1988; Tassey 2000), and there is a large body of empirical evidence on the value of technology compatibility (Brynjolfsson and Kemerer 1996; Kauffman et al. 2000). Successful exploitation of the platform owner's user base is likely to boost the sales of a partnering ISV.

In addition, in order to become a certified complementary solution provider to a platform, an ISV may have to conform to a series of quality specifications in product design and pass a rigorous certification process conducted by the platform owner. As a result, obtaining certification from an industry leader may be perceived by users as a quality signal (Rao and Ruekert 1994), which may enhance the willingness-to-pay of the ISV's potential customers, and in turn has a positive impact on sales revenue. Indeed, prior research has shown that obtaining quality certification such as ISO 9001 enhances software companies' revenue and is associated with higher price per unit of output (Arora and Asundi 1999).

It is important to state how ecosystem partnerships are distinct from other forms of IT value co-creation (Kohli and Grover 2008). Like other settings of IT value co-creation, in our setting IT is "instrumental in creating a product to co-create business value" (Kohli and Grover 2008).

However, in other settings IT is used to co-create value by facilitating standardization of business processes or information flows between heterogeneous systems of individual firms (Markus et al. 2006). In this way, IT facilitates co-creation of value by reducing transaction costs through interorganizational systems that, among other things, strengthen supply chain relationships (Bharadwaj et al. 2007; Clemons et al. 1993; Gerbauer and Buxmann 2000; Melville et al. 2004). In our setting, partnership aids in the standardization of interfaces between software products that are used to co-create business value. In so doing, we add to the evolving work in IS that seeks to understand how firms co-create value through IT platforms (Dhar and Sundararajan 2007).

Therefore, we propose

Hypothesis 1 (H1). *An ISV's participation in an enterprise software platform's innovation ecosystem is associated with an increase in sales.*

A few words are in order about the statement of our hypothesis. As we discuss in section 3.3, while platform participation may be associated with an increase in sales on average, the relationship between participation and sales may vary significantly with ISV characteristics (in particular the appropriation strategies of the ISV) and the market conditions under which the ISV operates. In other words, there may exist considerable heterogeneity in value creation—and for the ISV, value appropriation—across partnerships. Further, ISVs may choose to partner with incomplete knowledge about the future values of these variables that will moderate the effects of partnership. We discuss these variables in detail in section 3.3.

3.2. Participation in the Innovation Ecosystem and IPO

For young entrepreneurial software companies, a crucial dimension of long term performance is the speed at which the company issues an initial sale of securities in the financial market (Hsu 2006; Stuart et al. 1999). An initial public offering (IPO) is a critical milestone which marks the transition of a privately held venture into a publicly owned company. From the perspective of a new venture, selling securities to the public is a less expensive way to raise working capital that is required for future growth and expansion, and it presents an opportunity to the equity holders to exchange their stake in the company for cash.

However, the IPO market is a context in which investors need to assess the quality of relatively new companies with a short track-record and about which investors will have limited information (Pollock and Rindova 2003). We argue that given the significant uncertainty surrounding a new venture's viability and future profit generating capabilities, an ISV's decision to join a platform ecosystem will be an effective way of mitigating uncertainties in the eyes of third party investors. First, the market's evaluation of the firm is based on its expected future cash flow (Kaplan and Ruback 1995), which will be correlated with its current market penetration and sales. Since joining a platform ecosystem is expected to be associated with an increase in sales, such partnerships should be interpreted favorably by the financial markets and boost investors' confidence in the future profitability of the new venture, resulting in a greater likelihood of IPO.

Second, institutional theory (DiMaggio and Powell 1983) suggests that organizations are under the pressure of institutional environments to conform to prevailing social norms and demonstrate legitimacy. Third parties such as investors will be more willing to engage in exchange relationships with firms that have proven social legitimacy (Sine et al. 2007). To the extent that

small ventures have limited history of demonstrating their conformance to prevailing rules, practices and social norms, partnering with large, well-established companies can significantly increase their visibility, reputation, image and prestige. Indeed, studies have examined how endorsements from venture capitalists (Gulati and Higgins 2003; Shane and Stuart 2002), investment banks (Gulati and Higgins 2003; Stuart et al. 1999), alliance partners (Stuart et al. 1999) and media coverage (Pollock and Rindova 2003) can affect impression formation and impart legitimacy to entrepreneurial ventures, and increase the likelihood of raising capital through an IPO. Therefore, we propose

Hypothesis 2 (H2). *An ISV's participation in an enterprise software platform's innovation ecosystem is associated with an increase in the likelihood of issuing an IPO.*

3.3. Participation in the Innovation Ecosystem and Appropriation Strategies

Although joining a platform ecosystem may improve an ISV's sales and likelihood of IPO *on average*, there may be considerable risks associated with such relationships that may lead to variances in the returns to partnership. One particular risk is that the platform owner may begin to offer a competing product, a risk that is likely to increase with partnership. Inter-firm collaborative relationships often lead to unintended knowledge transfer (Khanna et al. 1998; Mowery et al. 1996). Knowledge that is not protected by any appropriation mechanism can therefore be profitably used by collaborators (Bresser 1988; Heiman and Nickerson 2004).

In particular, the partnerships between an ISV and a software platform owner are likely to facilitate such knowledge spillovers. Software certification may require the ISV to disclose proprietary knowledge, the codification of business processes or its best practices that the platform owner could imitate. In this way, the costs of entry for the platform owner into the

ISVs' product market are reduced. In other words, by joining a platform ecosystem an ISV is exposed to a greater expropriation risk.

Firms have a variety of mechanisms at their disposal to protect their intellectual property, such as patents, being first to market, or the ownership of complementary manufacturing, sales, and service capabilities (Cohen et al. 2000). Both patents and copyrights have been shown as common methods of intellectual property protection in the software industry (Bessen and Hunt 2007; Graham et al. 2009). In particular, in the presence of patents and copyrights, an ISV may be able to deter imitation or exercise its IPR and prevent entry once imitation has occurred (Gans et al. 2002). We expect that stronger IP protection from patents and copyrights will increase the payoff to partnering by decreasing the risks of imitation. As a result, the effect of partnership on sales and the likelihood of issuing an IPO will be higher in the presence of IP-based appropriability strategies.

Technology commercialization strategies and firm profits from their innovations are critically affected by the ownership and strength of specialized downstream capabilities (Arora and Ceccagnoli 2006; Ceccagnoli and Rothaermel 2008; Gans and Stern 2003; Rothaermel and Hill 2005; Teece 1986). The effect of partnering on the ISVs' returns will be higher in the presence of downstream capabilities for two reasons. First, the returns to accessing the platform owner's installed base will be greater if the ISV has an established brand image or strong marketing, distribution and service capabilities. Second, an ISV with strong downstream capabilities will be better able to defend its territory in the presence of platform owner entry than firms without such capabilities. Knowledge embedded in business practices or downstream service and consulting activities is difficult to codify and therefore will be more difficult for the platform owner to imitate (Barney 1991; Dierickx and Cool 1989). For example, implementation of enterprise

software often requires extensive effort to configure it to meet the user's idiosyncratic needs (Hitt et al. 2002; Ko et al. 2005). Knowledge of how to conduct such configurations will typically reside in the consulting and service activities of the ISV. Such downstream knowledge and capabilities are difficult to transfer across firm boundaries (Brown and Duguid 2001; Von Hippel 1994) and may also act as a barrier to entry.

In summary, we argue that the extent to which an ISV may benefit from joining a platform ecosystem is likely to vary according to the ISV's ownership of IPR and downstream capabilities. Particularly, we propose

Hypothesis 3 (H3). *The positive effect of an ISV's participation in an ecosystem on sales is greater when the ISV is better protected by intellectual property rights such as patents and copyrights, and has stronger downstream capabilities.*

Hypothesis 4 (H4). *The positive effect of an ISV's participation in an ecosystem on the likelihood of issuing an IPO is greater when the ISV is better protected by intellectual property rights such as patents and copyrights, and has stronger downstream capabilities.*

4. METHODS AND MEASURES

4.1. Research Context

Enterprise software is often considered to be the organizational operating system (Chellappa and Saraf forthcoming; Cotteleer and Bendoly 2006), which consolidates the diverse information needs of an enterprise's departments together into a single, integrated software that operates on a shared database. In this study we are interested in the partnership between an enterprise software platform owner and the ISVs that develop complementary applications that are integrated with

the owner's 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 and Van Alstyne 2008). ISV applications extend the functionality of the platform and co-create value for customers who adopt the platform. SAP is chosen as the focal enterprise software platform owner because SAP is the world's largest business software company. 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).

To join SAP's partner program, ISVs develop a product and then obtain a certification from SAP which endorses the interoperability between the product and the SAP platform. In particular, ISVs that plan to achieve software integration with the SAP solutions work with one of the local SAP integration and certification centers (ICCs) to have their product certified. The process typically involves a feasibility study, service offer processing, and extensive testing by SAP. If successful, SAP issues a formal SAP ICC contract for the ISV to sign and applicable fees are paid by the ISV and the certified integration is publicly listed online in the SAP partner information center.

By making its product SAP-certified, the ISV effectively signals its compatibility with the SAP platform. This will strengthen the ISV's ability to sell to SAP's large customer base. In addition, by teaming up with a prestigious industry leader, those small ISVs gain endorsements, enhance their social legitimacy, and signal their technological excellence (Stuart et al. 1999). The reputation consequences of strategic partnership are particular important in high-technology industries, which are noted for pervasive uncertainty (Tushman and Rosenkopf 1992). On the

other hand, joining the SAP's platform ecosystem is not costless for ISVs. Besides the fixed cost of developing a platform-compliant version of the software solution, certification application fees and yearly membership fees, there are considerable misappropriation risks for ISVs due to the 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 interest as the platform owner may enter the application development arena and compete with the ISV.

4.2. Data

We test our theoretical predictions using a longitudinal data set of 1210 small independent software vendors over the period of 1996 - 2004. We collect information on both the ISVs' decisions to join SAP's innovation ecosystem and information on their business performance. The sampling period starts from 1996 as we find virtually no such partnership activities between SAP and small ISVs in the sample before 1996 (more details will be provided later in the section on variable definitions).

Our primary data source is represented by the CorpTech database, which has detailed information on over 100,000 public and private firms, including sales, employees, product offerings, source of funding and executives. It is well known that studies related to firm performance solely based on public firms may suffer from severe sample selection bias (Cockburn and MacGarvie 2006; Shan 1990). The inclusion of private firms is particularly important in the software industry, since the majority of ISVs fall into private segments. In addition, using a sample comprising public software firms alone may fail to capture important industry dynamics such as entry, exit or IPOs.

To construct a representative sample of entrepreneurial ISVs that could potentially form partnerships with SAP, we first select from CorpTech firms operating in the United States and primarily in the computer software industry. To further identify firms in the enterprise software industry we examine the product portfolios of current SAP software partners, and then find all software firms in the CorpTech dataset that produce similar products. 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 search using the terms "*Country: United States*" and "*Partner Category: Independent Software Vendor*" yields a list of 411 software firms that are current 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 current SAP software partners, and find that SOF-MA (manufacturing software, 61 firms) and SOF-WD (warehousing/distribution software, 44 firms), are the most frequent software product codes in the product portfolios of the partnering firms. We subsequently define our sample as firms that have ever produced SOF-MA or SOF-WD products during the sample period.[4] The final query retrieves 2175 ISVs from the CorpTech database. We further exclude established incumbent and restrict our sample to firms with less than 500 million in sales and 1000 employees, and those are established after 1980. Our final sample consists of 1210 ISVs with

[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".

[4] 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 produce enterprise software applications, and delete those that do not fit the profile.

6578 observations related to the 1996 - 2004 time period. The typical ISV in the final sample has about 12 years of age, 56 employees, and average sales of 7 million dollars.

4.3. Dependent Variables

Sales. Sales data for each company-year are retrieved directly from the CorpTech database, and are measured in millions of US dollars. We take the log form of the sales variable (that is, log (1+x) to avoid taking log of zeroes) as the dependent variable in the regressions because this variable is highly skewed.

IPO. We search the Securities Data Company (SDC) platinum database to retrieve the list of ISVs in our sample that issued an initial public offering in the US market during the sample period. We also obtain the date of IPO. The variable is set to 1 if an IPO is issued for a firm during a year, 0 otherwise.

4.4. Independent Variables

Partnership. The independent variable of interest is whether an ISV is an SAP-certified software solution provider 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. Second, the enterprise software industry experiences considerable entry and exit during the sampling period; many firms who partner are eventually acquired by or merge with other companies. Third, information about the exact date on which the partnership is formed is missing from SAP's web portal, which makes determination of the year of partnership formation impossible.

As an alternative to overcome the aforementioned difficulties, we identify the partnership formation events with SAP through press releases. To test the viability of this approach, we examined the existing partner list retrieved from the 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'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 partnerships. 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 2004 from the list. In addition, for ISVs that have multiple SAP alliance press releases (due to certification for multiple products, new versions of same product, or different interface certifications), we use the first instance of such events to indicate the time that the ISV joins SAP's platform ecosystem.

The *partnership* variable is set to 1 if a first-time partnership is formed in that year and remains 1 for the rest of the years, and is 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.

Patents. We generate ISVs' patent stock variable by using the USPTO CASSIS patent BIB database. Although diversified software vendors may have patented innovations in related areas such as manufacturing control or data acquisition equipments, we are primarily interested in their

software patents. The universe of software patents are identified using the intersection of the patent sets defined by Hall and MacGarvie (2006) and Bessen and Hunt (2007). The first is defined using the software-related U.S. Patent Office technology classes, whereas the latter is based on Boolean queries that search for keywords in the text of issued patents[5]. For a survey of different ways to identify software-related inventive activities see Arora et al. (2008). We also weight the resulting stock of software patents using each patent's forward citations, to account for the heterogeneity in the value of an innovation protected by the patent (Hall et al. 2001).[6]

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. As we are interested in software copyrights, we retrieve only those copyrights that are described as "computer file" within the TX (monograph including books, maps and software) class.

Downstream capabilities. Following prior literature, we use the stock of software trademarks registered in the U.S as a proxy of for the ISV's effort to build brand, reputation for quality, and distribution channels (Gao and Hitt 2004). According to the USPTO definition, a trademark 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." The data have been obtained from the USPTO CASSIS Trademarks BIB database. We use only software trademarks that are active for the firm-year.

[5] As a robustness check, we also use the union of the two software patent sets and derive alternative measures, and find that all the empirical results are robust to this alternative measure.

[6] Use of patent data is becoming increasingly common in IS research. For one example, see Kleis et al. (2009).

4.5. Control Variables

We control for a number of firm characteristics that could potentially influence operational performance. In particular, we control for an ISV's basic R&D capabilities by including its yearly stock of *publications* in academic journal or conferences in both the sales and IPO equations. We obtain this variable from the ISI Web of Knowledge database, by searching for the ISV's name as organization and ("article" or "proceedings paper") as document type. We weight the number of publications by the number of forward citations obtained by each article, to account for heterogeneity in their importance.

Software firms' funding sources are likely to impact their operations. We therefore control for the effect of firms' source of funding on both sales and the likelihood of issuing an IPO. We create 3 dummy variables, *cinvest*, *pinvest* and *vinvest* following the CorpTech database classification of funding sources into corporate investment, private investment or venture capital investment.

We also control for firm *age* in both performance equations based on the year in which an ISV was established, as well as its quadratic term, to account for nonlinear effects. As typically done for IPO equations, we control for firm size by incorporating the number of *employees*, which is obtained directly from the CorpTech database. Due to the high correlation (>0.9) between *sales* and *employees* we exclude *sales* in IPO equation to avoid multicollinearity (Hsu 2006). The variable *employees* is not included in the sales equation due to endogeneity concerns. To control for performance differences between public and privately held companies we instead add an ownership indicator variable in the sales equation.

Investments in product and process innovations are driven in part by expectations about the potential size of the market and its future growth (Acemoglu and Linn 2004; Cohen 1995; Schmookler 1966). In other words, industry sales growth should be associated with unobserved innovative capabilities resulting from innovative investments that will drive a firm's success. To control for this effect, we obtain the target industries that each ISV serves from the CorpTech database and classify them into 40 categories (such as banking, chemical, oil and gas). Next, we calculate the industry growth rate by averaging the sales growth rates of all the ISVs that serve the industry. We then map the industry growth to individual ISVs and derive the variable *industryGrowth* as a control. Table 1 presents the summary statistics of all of our variables, as well as the correlation among them[7].

[Insert Table 1 about here]

4.6. Methods

Main effect of partnering. Cross-sectional analysis of the effect of partnering on an ISV's performance is likely to suffer from unobserved firm heterogeneity which may be correlated with partnering decisions, resulting in inconsistent estimates. We choose panel data methods with fixed effects as a starting point for the empirical analysis. Specifically, for firm sales we estimate the following equation:

[7] Notice that the correlations need to be interpreted with caution due to the panel structure of the data. For example, the correlation coefficient between partner and IPO is 0.06. If the data are collapsed at the firm level the correlation increases to 0.24, which reflect variation *between* firms. Similarly, the correlation between trademarks and IPO is 0.005 overall, but jumps to 0.11 in the between sample. It is difficult to describe the correlation between variables *within* firms.

$$
\begin{aligned}
Log(sales_{it}) = {} & \alpha + \beta_1 partner_{it} + \beta_2 patent_{it} + \beta_3 copyright_{it} \\
& + \beta_4 trademark_{it} + \beta_5 age_{it} + \beta_6 age_{it}^{\,2} + \beta_7 public_{it} \\
& + \beta_8 cinvest_{it} + \beta_9 pinvest_{it} + \beta_{10} vinest_{it} \\
& + \beta_{11} publication_{it} + \beta_{12} industryGrowth_{it} + year_t + c_i \\
& + u_{it}
\end{aligned} \tag{1}
$$

where $year_t$ is a set of year dummies, and c_i denotes firm fixed effects. The variables patent, copyright, trademark and publication are entered in log form (that is, log (1+x) to avoid taking log of zeroes) because their distributions are highly skewed.

Following prior studies (Forman et al. 2009; Gowrisankaran and Stavins 2004; Tucker 2008) we estimate the IPO regression using a linear probability model with firm fixed effects, due to the known difficulty of controlling for unobserved heterogeneity using panel data probit or logit models.[8] In particular, we estimate:

$$
\begin{aligned}
& p(IPO_{it+1} = 1) \\
& \quad = \alpha + \beta_1 partner_{it} + \beta_2 patent_{it} + \beta_3 copyright_{it} \\
& \quad + \beta_4 trademark_{it} + \beta_5 age_{it} + \beta_6 age_{it}^{\,2} + \beta_7 cinvest_{it} \\
& \quad + \beta_8 pinvest_{it} + \beta_9 vinest_{it} + \beta_{10} publication_{it} \\
& \quad + \beta_{11} industryGrowth_{it} + \beta_{12}\, employee_{it} + year_{t+1} + c_i \\
& \quad + u_{it+1}
\end{aligned} \tag{2}
$$

Note that only private firms are included in the IPO regression. The observations after a firm goes public are dropped from the sample as the firm is no longer exposed to the hazard of issuing

[8] For a full discussion of these issues, see Wooldridge (2001). Unconditional fixed effects provide inconsistent estimates using probit or logit models because of the well-known incidental parameters problem. Further, conditional fixed effects models drop panels where there is no variation in the dependent variable — in our setting, this would include any ISV that does not eventually issue an IPO.

an IPO. We lag all the independent variables by one year to further mitigate for potential endogeneity of the right-hand-side variables. Number of employees is entered into the regression equation in log form.

Moderating effects of appropriation mechanisms. In order to evaluate Hypotheses 3 and 4, we add interactions between ISVs' partnering statuses with their IPR and downstream capabilities. To enable a more intuitive interpretation, we create discrete measures of IPR and downstream capabilities. Particularly, the variables *highCopyright* and *highTrademark* are set to 1 if an ISV's cumulative number of copyrights and trademarks are in the first quartile, respectively. Because less than 15% of the observations have patents, the variable *highPatent* is set to 1 if an ISV has at least one patent during the year, 0 otherwise.

To summarize, we estimate the following two equations to test if the effects of partnering on an ISV's sales and likelihood of issuing an IPO are moderated by appropriation mechanisms.

$$\begin{aligned} Log(sales_{it}) = {} & \alpha + \beta_1 partner_{it} + \beta_2 highPatent_{it} + \beta_3 highCopyright_{it} \\ & + \beta_4 highTrademark_{it} + \beta_5 age_{it} + \beta_6 age_{it}^{\,2} \\ & + \beta_7 public_{it} + \beta_8 cinvest_{it} + \beta_9 pinvest_{it} + \beta_{10} vinest_{it} \\ & + \beta_{11} publication_{it} + \beta_{12} industryGrowth_{it} \\ & + \beta_{13} partner_{it} \times highPatent_{it} + \beta_{14} partner_{it} \\ & \times highCopyright_{it} + \beta_{15} partner_{it} \times highTrademark_{it} \\ & + year_t + c_i + u_{it} \end{aligned} \quad (3)$$

$$
\begin{aligned}
p(IPO_{it+1} = 1) \\
&= \alpha + \beta_1 partner_{it} + \beta_2 highPatent_{it} \\
&+ \beta_3 highCopyright_{it} + \beta_4 HighTrademark_{it} + \beta_5 age_{it} \\
&+ \beta_6 age_{it}^{\ 2} + \beta_7 cinvest_{it} + \beta_8 pinvest_{it} + \beta_9 vinest_{it} \\
&+ \beta_{10} publication_{it} + \beta_{11} industryGrowth_{it} \\
&+ \beta_{12}\, employee_{it} + \beta_{13} partner_{it} \times highPatent_{it} \\
&+ \beta_{14} partner_{it} \times highCopyright_{it} + \beta_{15} partner_{it} \\
&\times highTrademark_{it} + year_{t+1} + c_i + u_{it+1}
\end{aligned} \tag{4}
$$

5. RESULTS

5.1. Effect of Joining Platform Ecosystem on Sales

The results of fixed effects models that use *log(sales)* as the dependent variable are presented in Table 2. Variables are entered into the regressions sequentially. In column 1 we present the baseline model in which only the variables partnering status, IPR and downstream capabilities are included. In column 2 we add the other control variables. In column 3 we include year dummies.

[Insert Table 2 about here]

Examining the results from the final model, we find support for Hypothesis 1, suggesting that joining a platform ecosystem is associated with greater sales. The variable *partner* is significant at the 5% level in all of the models. On average, ISVs enjoy a 26% (=$e^{.23}$-1) increase in sales after they become certified solution partners of SAP. Interestingly, we also find that ISVs'

annual sales are strongly correlated with their appropriability mechanisms, as the coefficients of patent, copyright and trademark are positive and highly significant.[9]

5.2. Effect of Joining Platform Ecosystem on IPO

Hypothesis 2 suggests that joining a platform innovation ecosystem is associated with a greater likelihood of issuing an IPO. The hypothesis is supported by the results in Table 3. As we did for the sales models, we present the baseline model in column 1, the one with the full set of control variables in column 2, and include year dummies in column 3. The variable *partner* is significant at the 5% or 10% level in all of the models. Using the results of the full model in column 3, we find that joining SAP's platform ecosystem is associated with a 5.9 percentage point increase in the likelihood of obtaining an IPO, supporting Hypothesis 2.

[Insert Table 3 about here]

5.3. Robustness Checks

We test a number of alternative models and use different variable definitions to demonstrate the robustness of our findings. The results are presented in Table 4 (sales results) and Table 5 (IPO results).

[Insert Table 4 about here]

[Insert Table 5 about here]

[9] Note that we present two sets of R-squared values in all of our tables. First, we present "within" R-squares that do not include the explanatory power of the fixed effects on the explained sum of squares, and are computed based on the fraction of variance explained within firms. These within R-square values are lower than our R-squared with fixed effects, which are based on the total (within and between) sum of squares and incorporate the explanatory power of our fixed effects. Note that in our IPO regressions, our dependent variable is binary, not continuous, and regressions with binary dependent variables typically have lower R-squared values than continuous variables. For further examples of this, see Forman et al. (2009)

First, in the benchmark models we use forward-citation-weighted patents and publications as independent variables. In column 1 of Table 4 and Table 5 we present a similar specification using a fixed effects model and raw counts of patent stocks and scientific publications that are unweighted by forward citations. Second, although fixed effects models are robust to unobserved heterogeneity and require weaker model assumptions, they are more susceptible to attenuation bias arising from measurement error (Griliches and Hausman 1986). In column 2 of Tables 4 and 5 we present the results from the random effects model. We observe that the estimates of the marginal effects of partnering are very similar to that of the fixed effects model.

It is possible that there exist time-varying omitted variables that affect both the ISV's decision to join the SAP's platform ecosystem and their performance, which are not fully accounted for in our baseline fixed effects model. For example, it is possible that ISVs with superior operational performance choose to join the SAP's platform ecosystem, resulting in the endogeneity of partnering status. We address these endogeneity concerns in several ways. First, as a falsification test we verify that the measured positive impacts of partnering on ISV performances do not occur before the partnering year (Agrawal and Goldfarb 2008). If we expect firms with better financial status to join the SAP's ecosystem, it is likely that we will observe an increase in sales or the likelihood of an IPO in the years preceding their partnership with SAP. To explore whether this is the case, we add as additional controls two dummy variables that are equal to one in the two years prior to the first partnership observation. We present the results in column 3 of Tables 4 and 5. The results show no significant preexisting trend on sales or the likelihood of an IPO for partnering ISVs. The effect only takes place *after* the partnership with SAP.

Second, we use instrumental variables (IV) methods to address the endogeneity concerns. In particular, we use two candidate variables that should be correlated with the partnering decision

but not with financial performance. The first variable describes how many executives of an ISV have personal connection with SAP. From the CorpTech database we retrieve the complete list of executives for every firm-year. We then look up the working experience of each executive on the business-oriented social network website, LinkedIn, to find if he/she has ever worked for SAP as an employee. We then aggregate the number of executive links to SAP at the firm-year level. The rationale for using this variable as an IV is that an executive's past working experience at SAP is likely to establish personal connections that would increase the propensity to partner with SAP. However, it is unlikely to be correlated with unobserved firm-level factors that would increase the performance of the firm where he/she serves as an executive. The second variable describes the propensity of partnering with SAP among ISVs that serve markets similar to those of the focal ISV. The CorpTech database has data on the target industries to which each company sells its products and services, which we broadly classify into 40 categories. We calculate the fraction of ISVs that partner with SAP in each industry-year, and use this to approximate the partnering propensity at the industry level. We then calculate the partnering propensity for each ISV, by weighting these data by the set of industries served by the ISV. If an ISV serves multiple industries, the industry level propensities are averaged to derive the ISV's propensity. The logic for this variable is that it will capture cross-industry differences in the value of partnership. However, conditional on our controls for industry growth, it should be uncorrelated with factors influencing ISV performance. Following prior literature on instrumental variables under binary endogenous variables, we use these instruments to run a probit model of the propensity of a firm-year to be an SAP partner.[10] We then use the predicted probability of partnership from this probit model, and the square of this predicted probability, as

[10] That is, we run the probit model of partnership on our two instruments: social connections and industry propensity to partner.

our instruments. Using nonlinear fitted values of instruments in this way has been shown under some cases to have superior efficiency properties than a traditional linear first stage but still provides consistent estimates (Angrist 2001; Newey 1990).

We present the results from the instrumental variable model in column 4 of Tables 4 and 5. Our results are robust to the use of these models.[11]

Since acquisition by another firm is often considered a successful exit strategy for small start-up firms, an alternative measure of forward-looking performance in the literature is whether the firm issues an IPO or has been acquired (Cockburn and MacGarvie 2009). We also examine how partnership influenced the likelihood of obtaining an IPO or acquisition,[12] and the results were qualitatively similar to our IPO models.[13]

5.4. Moderating Effect of Appropriability Mechanisms for Sales

Hypothesis 3 suggests that the positive effect of joining a platform ecosystem on an ISV's sales is greater when the ISV enjoys greater IPR protection or stronger downstream capabilities. In other words, the effect of partnering on ISV sales is moderated by their appropriability mechanisms. We present the results for the moderating effects in Table 6. As usual, fixed effects panel data models are used. Column 1 presents the baseline model where only partnering status, appropriability mechanisms and their interactions are included. In column 2 we add the control

[11] All the instrumental variable results presented in the paper are supported by tests of instruments validity (available from the authors upon request). Indeed, the p-value related to the tests of the joint null hypothesis of no effect of the instruments on partnership is always lower than 0.001. In addition, the tests of the overidentifying restrictions (Hansen J tests) always suggest that the instruments used are exogenous in all the IV specifications presented in the paper.

[12] We define acquisitions as majority share acquisitions, and we exclude bankrupt acquisitions and liquidation acquisitions. Data are collected from SDC Platinum database.

[13] To save space, the results of these models are not included in a separate table but they are available from the authors upon request.

variables, while in column 3 we include year dummies. Consistent with our expectations, we find that the interactions between *partner* and *highPatent*, *highCopyright* and *highTrademark* are all positive and significant at conventional levels. The results lend support to Hypothesis 3. The results in column 3 suggest that ISVs who partner with SAP on average experience a 43.6% sales increase if they have high patent stocks, a 32% increase if they have high copyright stocks, or a 26.9% increase if they have high trademark stocks. Surprisingly, our results indicate that ISVs whose innovations are not protected by any means of appropriation do not experience any significant improvement in performance. If anything, their sales performance is poorer (though not significantly so) than if they did not partner.

[Insert Table 6 about here]

5.5. Moderating Effect of Appropriability Mechanisms for IPO

We also find that the positive effect of joining a platform ecosystem on the ISVs' likelihood of issuing an IPO is also moderated by their appropriability mechanisms. Table 7 presents the results of this model. Confirming Hypothesis 4 (column 3 of Table 7), we find that the increase in the likelihood of obtaining an IPO will be 19.0 percentage points higher if the ISV also has high patent stocks, and a 15.8 percentage points higher if it also has high copyright stocks. These results are statistically significant at conventional levels. We do not find evidence that ISVs with high trademarks experience greater benefits from partnering. In addition, we find that if the innovations of an ISV are not protected by any appropriability mechanism, there is no evidence that partnering will increase the likelihood of obtaining an IPO. This can be seen from the insignificant (and negative) coefficient of the *partner* variable.

We believe that the lack of result for the interaction of *partner* and *highTrademark* may be due to a feature of our data: the number of IPOs decline dramatically throughout our sample because of the deterioration of financial market conditions in the wake of the dot-com bust. At the same time, the fraction of firms with *highTrademark* increases from 22.0% (in 1996) to 38.0% (in 2004). Thus, it is difficult for us to separate the effects of increasing trademarks from deteriorating financial market conditions on the likelihood of an IPO. In a separate set of regressions, we interacted our *partner* variable with a post-2001 dummy and found that the marginal effect of *partner* on IPO declines substantially post-2001 because of this change in external environment. Thus, we believe our coefficient for the *partner* × *highTrademark* variable is biased downward because of this change in economic and financial conditions.

[Insert Table 7 about here]

While we do use firm fixed effects in all of our models in Tables 7 and 8, one potential concern is that there may exist time-varying omitted variables that may be correlated with *partner* and its interaction with *highPatent*, *highCopyright* and *highTrademark*. If that is the case, then our estimates of these parameters may be biased. However, use of instrumental variables for the complete set of endogenous variables is difficult in our setting: This would require a set of four separate instruments, which would compound the usual problems that fixed effects remove all of the useful cross-sectional variation in the data and in the presence of measurement error give rise to attenuation bias (Angrist and Pischke 2009; Greene 2002). To reduce the number of endogenous variables that we must instrument for, we create a new variable called *highIPR* which is equal to one when *highPatent* or *highCopyright* is equal to one. Since patents and copyrights are used as substitute forms of IPR protection in the software industry (Lerner and Zhu 2007), this variable is a combined measure of IPR protection at the ISV.

Thus, we have three endogenous variables: *partner*, *partner X highIPR*, and *partner X highTrademark*. Following prior literature on the use of instrumental variables in nonlinear (in variables) settings (Gallant 1987, p. 440), we instrument for these variables using the predicted values of partner using the method above, and the interaction of this variable with *highIPR*, *highTrademark*, and other exogenous variables such as age, age-squared, and sales growth. In total, we have eight instruments for three endogenous variables.

Instrumental variables estimates for our sales regressions are included in column 4 of Table 6. Our results are qualitatively robust to the use of instrumental variables and fixed effects. The coefficient estimates show that partnership will only be associated with an increase in sales in the presence of *highIPR* and *highTrademark*. The coefficient for the interaction of *partner* with *highIPR* remains significant at the 10% level. The interaction of *partner* with *highTrademark*, while below conventional significance levels, remains statistically significant at the 12.5% level.

Instrumental variable results related to the IPO equation with interactions are not shown due to the poor fit of the model (negative R-squared) and the inability to identify the effects under study. We believe this is due in part to the difficult data environment: In the IPO regressions our dependent variable is binary, a particularly difficult setting to try to estimate this particular model using nonlinear IV (instrumenting for partnership and its interactions) using only the *within* firm variation (because of our use of firm fixed effects). Further, as noted above, the effect of *highTrademark* is inherently more difficult to identify in this setting because of the aggregate time series trend in *highTrademark* and *partner*.

6. CONCLUSION

Platform-based innovation ecosystems present an interesting setting for studies on the dynamics of inter-organizational collaboration and competition. However, there has been little research that examines the value creation mechanisms along with the appropriation strategies adopted by their various participants, and how the distribution of rents is affected by these strategies. Our study takes initial steps to investigate these issues from the perspective of small, complementary solution providers in the enterprise software industry. We present rich empirical evidence that participants in a platform ecosystem benefit from such relationships as they enjoy greater revenues and are more likely to raise capital through the IPO market after they join the ecosystem. In addition, we find that the extent to which ISVs capture the relational rent depends critically on their appropriation strategies, in that software ventures better protected by IPR or possessing stronger downstream capabilities are better able to capture value from their innovation. These findings extend and complement Huang et al. (2009), who show that highly innovative ISVs are more likely to join a platform ecosystem. More speculatively, our results suggest some conditions under which a "virtuous cycle" may be realized in a software platform ecosystem. ISVs who participate in markets for which appropriability mechanisms like patents are strong will see greater returns from partnership. These greater returns will in turn encourage new partners to join the ecosystem, and will also draw in additional customers (and in turn, more partners).

Our findings have important implications for both platform sponsors as well as those who participate in the platform ecosystem. First, our results suggest that under certain conditions ISVs who join a platform ecosystem will see gains in operational performance. However, ISVs whose innovations are not protected should be cautious about initiating partnerships. To prevent

the threat of invasion from the platform owner, they should actively seek IPR protection, or secure complementary downstream capabilities first. Finally, we believe that it is critical for the platform owners to understand the incentives of complementary product providers. In particular, the appropriate management of the expropriation concerns of its smaller and most innovative entrepreneurial partners represents a potential strategy to sustain the innovation ecosystem.

The current study can be extended in several ways. In particular, future research could test the findings in different industry contexts in which co-innovation is important and the threat of knowledge expropriation represents a critical issue for inter-firm collaboration. Second, one could study the implications of joining platform ecosystems for various performance measures beyond sales revenue and likelihood of IPO, such as survival. As firms often face a trade-off between long-term and short-term performance objectives (Meyer 2002), joining a platform ecosystem may have different effects across different performance measures. Finally, the roles of other ecosystem constituents such as customers, developers and consulting companies remain unexplored and further investigation may reveal key insights as to the formation and evolution of the platform ecosystem.

Table 1. Summary Statistics and Correlation Matrix																			
	Variable	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	$Sales_{i,t}$	7.539	16.219	0.000	206.400	1.000													
2	$IPO_{i,t+1}$	0.004	0.064	0.000	1.000	0.035	1.000												
3	$Partner_{i,t}$	0.017	0.129	0.000	1.000	0.295	0.063	1.000											
4	$Copyright_{i,t}$	1.988	12.841	0.000	498.000	0.253	0.029	0.044	1.000										
5	$Patent_{i,t}$	0.145	0.722	0.000	13.000	0.303	0.038	0.129	0.016	1.000									
6	$Trademark_{i,t}$	0.835	2.011	0.000	23.000	0.377	0.005	0.154	0.282	0.338	1.000								
7	$Age_{i,t}$	12.566	5.830	0.000	24.000	-0.052	-0.059	-0.058	0.069	-0.114	0.004	1.000							
8	$Publication_{i,t}$	0.600	5.259	0.000	137.000	0.044	-0.005	0.003	0.001	-0.005	0.030	0.045	1.000						
9	Corporate $invest_{i,t}$	0.046	0.210	0.000	1.000	0.102	0.010	0.101	-0.019	0.031	0.062	-0.118	-0.016	1.000					
10	Private $invest_{i,t}$	0.501	0.500	0.000	1.000	-0.087	-0.029	-0.039	-0.007	-0.048	-0.053	-0.144	-0.017	-0.068	1.000				
11	VC $invest_{i,t}$	0.122	0.327	0.000	1.000	0.176	0.108	0.171	-0.008	0.155	0.106	-0.339	0.039	0.071	-0.073	1.000			
12	$Employee_{i,t}$	56.248	104.904	1.000	997.000	0.901	0.071	0.283	0.240	0.286	0.385	-0.075	0.049	0.108	-0.100	0.199	1.000		
13	Industry $growth_{i,t}$	1.261	0.342	0.873	6.322	0.007	0.006	0.012	-0.001	-0.012	-0.023	-0.051	0.013	-0.019	-0.015	-0.019	0.011	1.000	
14	$Public_{i,t}$	0.061	0.239	0.000	1.000	0.447	-0.017	0.230	0.059	0.248	0.243	-0.058	0.072	0.075	-0.040	0.157	0.477	0.013	1.000

Notes.
Number of firms: 1210; Number of observations: 6578.

Table 2. Effect of Partnering on Sales			
Variables	(1)	(2)	(3)
	Baseline model	With firm level controls	With year dummies
Partner	0.484***	0.254**	0.231**
	(0.115)	(0.105)	(0.105)
Patent	0.179***	0.121***	0.111***
	(0.032)	(0.026)	(0.027)
Copyright	0.233***	0.167***	0.156***
	(0.034)	(0.031)	(0.031)
Trademark	0.204***	0.102***	0.085***
	(0.025)	(0.024)	(0.024)
Age		0.079***	0.037***
		(0.009)	(0.011)
Age^2		-0.002***	-0.002***
		(0.000)	(0.000)
Publication		0.062	0.048
		(0.065)	(0.065)
Cinvest		0.339***	0.327***
		(0.119)	(0.117)
Pinvest		0.040	0.027
		(0.045)	(0.045)
Vinvest		0.172**	0.171**
		(0.085)	(0.085)
IndustryGrowth		0.048***	0.055***
		(0.015)	(0.016)
Public		0.715***	0.704***
		(0.136)	(0.136)
Year dummies	No	No	Yes
Constant	1.232***	0.476***	0.848***
	(0.019)	(0.071)	(0.090)
Observations	6578	6578	6578
Number of firms	1210	1210	1210
R-squared (within)	0.103	0.183	0.192
R-squared (with fixed effects)	0.906	0.914	0.915

Notes.
Fixed effects panel data models with robust standard errors in parentheses.
*** p < 0.01; ** p < 0.05; * p < 0.1.

Table 3. Effect of Partnering on IPO			
Variables	(1)	(2)	(3)
	Baseline model	With firm level controls	With year dummies
Partner	0.066**	0.060*	0.059*
	(0.033)	(0.034)	(0.034)
Patent	0.004	0.005	0.004
	(0.004)	(0.004)	(0.004)
Copyright	0.019**	0.016**	0.016*
	(0.008)	(0.008)	(0.008)
Trademark	0.002	-0.000	-0.000
	(0.003)	(0.003)	(0.003)
Age		0.000	-0.001
		(0.001)	(0.001)
Age^2		-0.000	-0.000
		(0.000)	(0.000)
Publication		-0.006*	-0.006*
		(0.003)	(0.003)
Employee		0.004***	0.004**
		(0.002)	(0.002)
Cinvest		0.043	0.044
		(0.028)	(0.028)
Pinvest		0.004	0.004
		(0.005)	(0.005)
Vinvest		0.027	0.028
		(0.021)	(0.021)
IndustryGrowth		0.002	-0.001
		(0.002)	(0.002)
Year dummies	No	No	Yes
Constant	-0.005	-0.025***	-0.003
	(0.003)	(0.009)	(0.022)
Observations	6266[1]	6266[1]	6266[1]
Number of firms	1175[1]	1175[1]	1175[1]
R-squared (within)	0.020	0.032	0.037
R-squared (with fixed effects)	0.654	0.662	0.664

Notes.
Fixed effects panel data models with robust standard errors in parentheses.
*** p < 0.01; ** p < 0.05; * p < 0.1.
[1]: only private companies are included. Post IPO observations are dropped.

Table 4. Robustness Check, Sales				
Variables	(1)	(2)	(3)	(4)
	Unweighted patent and publication	Random effects	Years before partner	Instrumental variables
Partner	0.230**	0.232**	0.298***	1.995**
	(0.102)	(0.096)	(0.115)	(0.822)
Patent	0.443***	0.097***	0.110***	0.100***
	(0.091)	(0.022)	(0.027)	(0.029)
Copyright	0.128***	0.173***	0.156***	0.136***
	(0.031)	(0.022)	(0.031)	(0.032)
Trademark	0.080***	0.136***	0.084***	0.057**
	(0.023)	(0.021)	(0.023)	(0.028)
Age	0.035***	0.032***	0.036***	0.037***
	(0.011)	(0.008)	(0.011)	(0.011)
Age^2	-0.002***	-0.002***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Publication	0.062	0.014	0.049	0.089
	(0.060)	(0.044)	(0.065)	(0.068)
Cinvest	0.321***	0.301***	0.328***	0.347***
	(0.118)	(0.082)	(0.117)	(0.125)
Pinvest	0.024	-0.058*	0.028	0.036
	(0.044)	(0.033)	(0.045)	(0.048)
Vinvest	0.166*	0.290***	0.168**	0.033
	(0.086)	(0.059)	(0.086)	(0.108)
IndustryGrowth	0.054***	0.059***	0.055***	0.057***
	(0.016)	(0.016)	(0.016)	(0.017)
Public	0.626***	0.791***	0.705***	0.426**
	(0.137)	(0.105)	(0.136)	(0.217)
One year before partnering			0.070	
			(0.102)	
Two years before partnering			0.122	
			(0.123)	
Year dummies	Yes	Yes	Yes	Yes
Constant	0.868***	0.941***	0.850***	
	(0.090)	(0.067)	(0.090)	
Observations	6578	6578	6578	6578
Number of firms	1210	1210	1210	1210
R-squared (within)	0.197	.	0.193	0.069
R-squared (with fixed effects)	0.915		0.915	

Notes.
Robust standard errors in parentheses.
*** p < 0.01; ** p < 0.05; * p < 0.1.

Table 5. Robustness Check, IPO				
Variables	(1)	(2)	(3)	(4)
	Unweighted patent and publication	Random effects	Years before partner	Instrumental variables
Partner	0.059*	0.058*	0.063*	0.242*
	(0.034)	(0.035)	(0.035)	(0.132)
Patent	0.018	0.006	0.004	0.002
	(0.016)	(0.004)	(0.004)	(0.005)
Copyright	0.015*	0.014**	0.016**	0.014*
	(0.008)	(0.006)	(0.008)	(0.008)
Trademark	-0.000	-0.001	-0.000	-0.003
	(0.003)	(0.003)	(0.003)	(0.004)
Age	-0.001	0.000	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Age^2	-0.000	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Publication	-0.010**	-0.005	-0.005*	-0.002
	(0.004)	(0.003)	(0.003)	(0.002)
Employee	0.004**	0.006***	0.004**	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Cinvest	0.044	0.028	0.044	0.041
	(0.028)	(0.021)	(0.028)	(0.028)
Pinvest	0.004	-0.002	0.004	0.006
	(0.005)	(0.004)	(0.005)	(0.005)
Vinvest	0.029	0.035**	0.028	0.014
	(0.021)	(0.015)	(0.021)	(0.018)
IndustryGrowth	-0.001	-0.001	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
One year before partnering			-0.009	
			(0.030)	
Two years before partnering			0.032	
			(0.050)	
Year dummies	Yes	Yes	Yes	Yes
Constant	-0.002	-0.021*	-0.003	
	(0.022)	(0.011)	(0.022)	
Observations	6266[1]	6266[1]	6266[1]	6266[1]
Number of firms	1175[1]	1175[1]	1175[1]	1175[1]
R-squared (within)	0.038	.	0.040	0.041
R-squared (with fixed effects)	0.664		0.665	

Notes.
Robust standard errors in parentheses.
*** p < 0.01; ** p < 0.05; * p < 0.1.
[1]: only private companies are included. Post IPO observations are dropped.

Table 6. Moderating Effect of IPR and Downstream Capabilities, Sales				
Variables	(1)	(2)	(3)	(4)
	Baseline model	With firm level controls	With year dummies	Instrumental Variables
Partner	0.057	-0.084	-0.149	-0.543
	(0.136)	(0.129)	(0.129)	(1.398)
Highpatent	0.616***	0.383***	0.346***	
	(0.058)	(0.057)	(0.056)	
Highcopyright	0.456***	0.339***	0.310***	
	(0.045)	(0.043)	(0.043)	
Hightrademark	0.199***	0.104***	0.088***	0.070*
	(0.021)	(0.021)	(0.021)	(0.031)
HighIPR				0.285***
				(0.063)
Partner × Highpatent	0.392***	0.323**	0.362**	
	(0.149)	(0.143)	(0.142)	
Partner × Highcopyright	0.251**	0.262**	0.278**	
	(0.127)	(0.121)	(0.121)	
Partner × Hightrademark	0.385***	0.214**	0.238**	1.175
	(0.112)	(0.107)	(0.106)	(0.765)
Partner X HighIPR				2.498*
				(1.323)
Age		0.081***	0.035***	0.029***
		(0.007)	(0.009)	(0.011)
Age^2		-0.002***	-0.002***	-0.002***
		(0.000)	(0.000)	(0.000)
Publication		0.083*	0.066	0.120*
		(0.050)	(0.050)	(0.068)
Cinvest		0.357***	0.339***	0.329**
		(0.069)	(0.068)	(0.136)
Pinvest		0.049	0.035	0.059
		(0.034)	(0.034)	(0.050)
Vinvest		0.165***	0.164***	-0.035
		(0.051)	(0.051)	(0.125)
Public		0.749***	0.730***	0.484*
		(0.061)	(0.061)	(0.225)
IndustryGrowth		0.048***	0.055***	0.058***
		(0.013)	(0.015)	(0.018)
Year dummies	No	No	Yes	Yes
Constant	1.220***	0.430***	0.839***	
	(0.014)	(0.053)	(0.076)	
Observations	6578	6578	6578	6477
Number of firms	1210	1210	1210	1109
R-squared (within)	0.091	0.182	0.192	0.012
R-squared (with fixed effects)	0.904	0.913	0.915	

Notes. Fixed effects panel data models with robust standard errors in parentheses.
*** p < 0.01; ** p < 0.05; * p < 0.1.

Table 7. Moderating Effect of IPR and Downstream Capabilities, IPO			
Variables	(1)	(2)	(3)
	Baseline model	With firm level controls	With year dummies
Partner	-0.077	-0.081	-0.083
	(0.071)	(0.072)	(0.071)
Highpatent	0.002	0.002	-0.000
	(0.008)	(0.010)	(0.009)
Highcopyright	0.016*	0.016	0.016
	(0.010)	(0.010)	(0.010)
Hightrademark	0.004	0.000	-0.000
	(0.004)	(0.004)	(0.004)
Partner × Highpatent	0.194**	0.189*	0.190*
	(0.098)	(0.102)	(0.101)
Partner × Highcopyright	0.162**	0.160**	0.158**
	(0.068)	(0.068)	(0.067)
Partner × Hightrademark	0.005	0.005	0.007
	(0.054)	(0.054)	(0.054)
Age		0.001	-0.001
		(0.000)	(0.001)
Age^2		-0.000	-0.000
		(0.000)	(0.000)
Publication		-0.004*	-0.004*
		(0.002)	(0.002)
Employee		0.004***	0.004**
		(0.002)	(0.002)
Cinvest		0.041	0.041
		(0.028)	(0.028)
Pinvest		0.004	0.004
		(0.005)	(0.005)
Vinvest		0.024	0.026
		(0.021)	(0.021)
IndustryGrowth		0.002	-0.001
		(0.002)	(0.002)
Year dummies	No	No	Yes
Constant	-0.001	-0.026***	0.003
	(0.003)	(0.009)	(0.021)
Observations	6266[1]	6266[1]	6266[1]
Number of firms	1175[1]	1175[1]	1175[1]
R-squared (within)	0.038	0.053	0.058
R-squared (with fixed effects)	0.660	0.669	0.671

Notes. Fixed effects panel data models with robust standard errors in parentheses.
*** p < 0.01; ** p < 0.05; * p < 0.1.
[1]: only private companies are included. Post IPO observations are dropped.

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