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RESILIENCE OF PROFESSIONAL OPEN SOURCE ECOSYSTEMS

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Abstract

This paper discusses the ability of an open source firm and its surrounding ecosystem to adapt to changing conditions in an effort to survive. Using an explanatory case study methodology, we examine a series of stresses that occurred over the life of a single professional open source ecosystem as its members attempted to adjust to the resultant impacts upon the available capital portfolios and flows. We propose that the resilience of an ecosystem is largely dependent on the ability of its members to enact available mechanisms to redirect or adjust to these changing capital flows in order to satisfy their individual needs. We also propose that the existence of a central stakeholder, such as the professional open source firm itself, to manage a portion of these capital flows.

Keywords: open source software, organizational ecosystems, resilience

1   INTRODUCTION

Professional Open Source (POS) firms are characterized by the use of an open source licensing strategy combined with the use of commercial-grade development and service provisioning models (Watson, Wynn, & Boudreau, 2005)[1]. POS firms capitalize on several advantages of both traditional proprietary software firms and the newer open source model. It has been argued that, as a business model, POS could emerge as a dominant model for open source software development in the coming years (Watson et al., 2007).

POS firms heavily rely on third parties for software development and service provisioning. A key measure of success for these firms is the creation of a network of complementary vendors and developers to provide components of the 'whole product' associated with a given technological product. These complementary members are necessary for both the development and commercialization of a given software package, particularly for enterprise-class software packages. We refer to the network of participants surrounding a given POS product as an *organizational ecosystem;* such a system exists to enable each participant to achieve its individual (or organizational) goals with respect to the market in which the focal product exists. More specifically, a POS ecosystem includes a wide array of individual and organizational participants, including the central POS firm, individual developers (even those developers that are not employed by the firm), users, financiers, analysts, and complementary service providers.

Previous research has demonstrated the necessity of complementary services and skills with respect to the success of knowledge-intensive technologies (Van de Ven, 2005) and the platforms surrounding them (Bresnahan & Greenstein, 1999). Existing research has also developed frameworks outlining strategies for innovating firms to capture value from the complementary assets and services surrounding their product (Teece, 1986), while sharing a portion of the value with complementary vendors (Moore, 1996; Teece, 1986). Recent studies have also focused on the ability of the firms at the center of open source ecosystems to create and appropriate value in accordance with these strategies (West, 2007). In general, these studies have acknowledged the value of the ecosystem and the benefits of its continued existence. However, few studies have investigated the mechanisms underlying the exchanges occurring within an organizational ecosystem, especially as these exchanges contribute to the ecosystem' resilience. By ecosystem resilience, we specifically refer to the ability of the ecosystem's participants to successfully adapt to extenuating circumstances (Sutcliffe & Vogus, 2003), also known as "stresses". In this research, we conducted an explanatory case study of ecosystem resilience, which shed light on how a POS ecosystem was able to survive the positive and negative stresses that impacted its operations and functionality.

In the first section of this paper, we examine ecosystems and the professional open source business model in more depth. Following that, we describe our research setting and methodology. We then present our findings from the case study along with existing research literature on resilience in natural ecosystems and commercial organizations. We conclude by discussing the implications and conclusions of our research.

2   PROFESSIONAL OPEN SOURCE SOFTWARE ECOSYSTEMS

In nature, the survival of an ecosystem is based on the ability of the biotic and abiotic elements of the ecosystem to meet their individual needs, including food, respiration, biochemical needs, and more. This includes more than a food chain (or supply chain) of energy from sunlight to primary producers

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[1] OSS 2.0 (Fitzgerald, 2006), OSSg2 (Watson, Boudreau, Wynn, Greiner, & York, 2007), and the hybrid OSS Model (Bonaccorsi, Giannangeli, & Rossi, 2006) are similar, in essence, to the Professional Open Source business model.

(plants) to consumers (plankton) to larger consumers (animals) to decomposers (bacteria and other creatures). Instead, it also includes inorganic matter such as the soil, water, oxygen, carbon dioxide, etc. in which these energy flows occur. We can draw a parallel by comparing the flow of capital[2] throughout a organizational ecosystem, which includes not only the capital itself and the entities that are involved in the capital flow (and are largely composed of portfolios of capital themselves), but also the contextual environment in which these flows occur.

Based on our understanding of a nature ecosystem, we define an organizational ecosystem as a productive system of participants that interact with each other to contribute, combine, circulate, appropriate, and retain capital of various forms in order to meet the aggregate needs of the various participants. The boundaries of this ecosystem are defined by the participants, the capital retained and circulated among them, and the interactions between them.

In the organizational ecosystem surrounding a POS firm, multiple participants seek to extract revenues from the required service delivery on the customer side which they use to support and fund the efforts of the development community as well as a staff of employees within the POS firm itself.[3] One major problem with providing many of the requisite services is the high cost of delivering these services relative to the cost of providing software licenses. Unlike licensing revenues, which are highly scalable based on the minimal incremental cost of each additional license once the development costs have been incurred, revenues based on service deliveries are dependent on having an employee base large enough to meet the needs of an expanding customer base. POS firms attempt to meet these scaling risks (Watson et al., 2005) by contracting many of these services through third party providers such as system integrators (SIs), value added resellers (VARs), and independent software vendors (ISVs). These providers are able to generate revenues by contracting directly with customers either to provide direct first- and second-tier support for the POS firm's offerings or to provide software for a derivative product into which the POS firm's offerings have been embedded. In return, these providers pay a recurring subscription fee to the POS firm for third-tier support and maintenance. Certainly this does not preclude the POS firm from providing direct support subscriptions to enterprise customers, but it does shield the firm from a portion of the scaling issues that may arise while enabling the firm to focus on more complex strategic and technical issues.
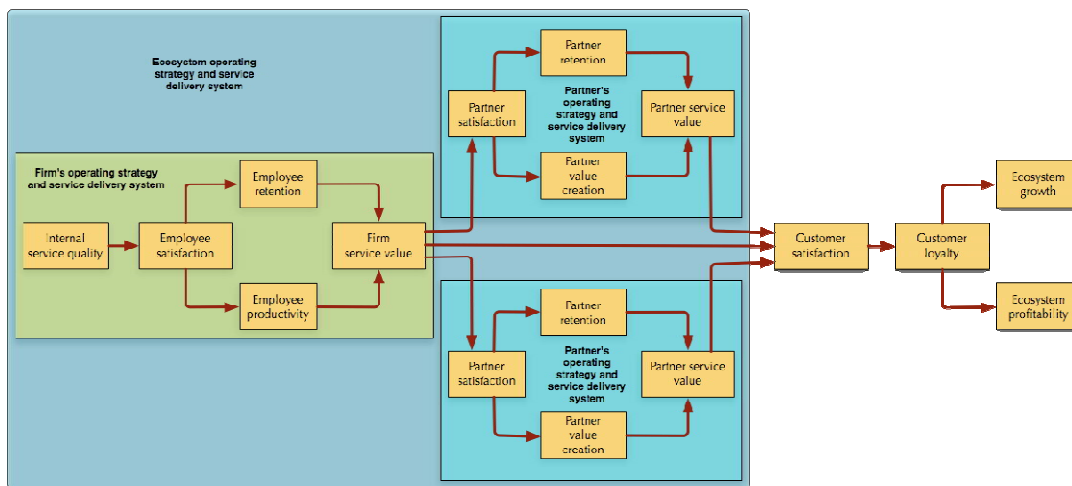
Figure 1 : Service Ecosystem (adapted from Heskett et al., 1994)

In a POS ecosystem, developers, third party service providers, and other parties (such as investors and consultants) together complement the core relationship between the POS firm and its customers. Each participant from a POS ecosystem needs to appropriate value in exchange for their contributions. Because of the varying needs of the different classes of participants (Franck, 2003; Hars, 2002; Shah, 2006), open source ecosystems must be sufficiently versatile and vigorous to enable these returns to be appropriated; otherwise, the level of contribution by the members may be reduced or discontinued. The discontinued participation by any of its contributing members in the POS ecosystem may reduce the level of service value appropriable by the POS firm and service partners as well as the level of customer satisfaction derived by the customer (see **Error! Reference source not found.**).

In this paper, we attempt to explain how POS ecosystems, as an example of these organizational ecosystems, are able to utilize their stored capital and existing capital flows to adjust to the demands introduced by the stresses they face.

3 EXPLANATORY CASE STUDY METHODOLOGY

Building on existing literature on case study methodologies (Yin, 2002), particularly in Information Systems (Dubé & Paré, 2003) and Management (Eisenhardt, 1989), this research was designed to understand the resilience of an open source software ecosystem. One of the strengths of case study research is its applicability in situations where the phenomenon of interest is being investigated "within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2002, p. 13).

The setting for our case study was a professional open source ecosystem that had experienced a number of publicly documented stresses upon it. At the time we began studying the firm at the center of this ecosystem, it had been in existence for approximately five years and had experienced phenomenal growth in the size of its community and the amount of revenues that it was receiving from its customers and through the various partner firms in its ecosystem. At its zenith, the ecosystem was composed of hundreds of partner firms and individuals spread across the globe, engaging in the development and maintenance of the source code as well as the provisioning of related services such as support, training, and integration, This ecosystem growth was paralleled by the central firm, which employed over 150 people directly and established offices in the United States as well as several European countries.

We studied nine distinct stresses (sometimes called "episodes', or "social dramas" (Turner, 1957)) and their effect on the resilience of the POS ecosystem. As Pettigrew (1979) observed, by studying a sequence of social dramas longitudinally, we can gain a better understanding of the "growth, evolution, transformation, and conceivably, decay of an organization over time" (pg. 570); in this case, instead of a specific organization, we are interested in better understanding the ecosystem surrounding the chosen POS firm.

To collect our data, we conducted semi-structured interviews and reviewed secondary data. Seventeen interviews were conducted with individuals spanning the POS ecosystem, including the CEO, outgoing COO, Executive VP (EVP), several developers, end users, analysts, and support providers. These interviews averaged over 45 minutes each and were conducted either via telephone or face-to-face. During the interviews, respondents had to define their involvement with the ecosystem, the contributions they perceive themselves making, the perceived benefits they receive, and the relationships they have with other key roles/participants in the ecosystem. They were also asked to identify and rank a series of stresses; from this list, a few (of their choosing) were used as the basis for discussion of causes, actions, and outcomes, especially in terms of the flows and accumulations of capital. Secondary data was abundant because of the increasingly prominent position of the POS firm

within its niche market. Accordingly, we incorporated many publicly available news reports, analyst studies, and blog postings in our dataset.

For the coding and analysis of the data, which we did with the support of a qualitative data analysis tool called Atlas.ti®, we relied on a template coding (King, 1998). This template included both theory driven and inductively derived codes (Boyzatis, 1998). Inductive codes were generated from evolving insight about the ecosystem's participants, the stresses they encountered, and the circulation, transformation, or accumulation of various forms of capital, and the functional outputs (innovation, marketing, and support). These codes were compared to the emergent raw data and re-evaluated as necessary to assist in the creation of an explanatory model.

4 CASE ANALYSIS

Because of space limitations, the stresses that impacted the POS ecosystem studied in this research will not be discussed in great details. What follows is a brief summary of the early stage of the firm (three stresses), the growth stage (four stresses), and the maturity stage (two stresses), followed by an analysis of the lessons learned.

4.1 Early stage: Creation, Business failure, and Rebirth

The open source software project was founded in 1999 by a software engineer who fell in love with the technology and specifications underlying the software. He decided to write an application engine to take advantage of this technology and release it as an open source project. However, he also decided to take on a financial partner in an attempt to build a company around the software to enable him to support himself financially.

Before long, a number of people were contributing to the project. Initially, there were three classes of participants: users wanting to take advantage of the features of the application engine to build their own derivative applications, developers attracted by the satisfaction of seeing their work implemented and by increasing their knowledge of this relatively new technology, and system administrators who deployed the application engine for their users. In return, the founder attempted to gain revenues by positioning his firm as an application service provider (ASP), including using some of these revenues to fund development and support by the developers who were involved in the open source project.

Unfortunately, the environment for technology start-ups deteriorated around the same time that the open source project was founded. The development community itself was thriving in terms of the number of developers and other participants, the quality and functionality of the software, and the project's perceived credibility among members of the users of the underlying technology. However, the ASP firm which the founder was intending to use as the source for generating revenues to support him and the other core developers of the software was unable to obtain venture capital or additional investors to fund its continuing operations. Thus, the ASP firm went out of business, the founder had completely burned through his savings (leaving him broke), and those contributors that had been hired as employees were suddenly unemployed. However, the software and the open source ecosystem surrounding it survived because it was held separately from the ASP firm and was therefore not directly affected by the failure of a business operating within the boundaries of the ecosystem. Those participants who were attracted by the features of the software's architecture and source code, as well as the expertise and relationships inherent in the community, had not been expecting direct financial returns from their contributions so a lack of financial capital was not a significant detraction. Because the software and at least a core community remained, these people continued to participate.

Although many of the formerly *employed* members of the ASP firm discontinued their participation following the business' failure, development efforts continued. Enough of the firm remained that the founder was able to create a new business revolving around the software that had been developed to date. The business model for the new firm was based on three objectives: the software and the

development community nurturing it needed to remain open source, enabling the skills and expertise in the community to be fully leveraged; the company would need to be immediately profitable since there was little possibility of getting venture funding in the existing climate; and the revenues generated would need to support and sustain a team of developers to provide management and support services such as training, support, and consulting. Building on early revenues from training seminars and documentation sales, the new POS firm was able to generate several hundred thousand dollars the first year which provided a base upon which it could fulfil the three objectives as intended.

4.2 Growth stage: Growth, Defection, Acquisitions, and Funding

In early 2002, the ecosystem had gained significant traction to entice developers and OEMs into deploying the application engine software. By 2003, the software was being downloaded approximately 150,000 times per month. Although the revenues for the POS firm were growing substantially, the conservative strategy of funding the company from revenues and not from taking on additional funding or debt put a cap on the amount of growth that could have been attained.

Much of this changed as the firm hired an experienced software industry professional as EVP to manage its strategy and corporate development. This manager led a number of initiatives within the firm which enabled the firm to mature from a small startup with a conservative, non-scalable business model to a corporation with stable, predictable revenues. At the core of this strategy was the establishment of partner relationships to handle much of the services load and field the majority of the labor expense while enabling the POS firm to focus on development and third-level support, which carries significantly higher margins and dependable revenues.

Also during this period, the firm revamped its compensation strategy for its developers. By 2003 there were 16 fulltime employees of the POS firm along with 18 other 'active core developers'. In total, 37 developers were offered 'economic interest options' and cash bonuses based on their contributions to the software in 2002 and earlier. A group of employees and core developers were dissatisfied with the allocations that they received from this plan, believing their portions of the revenues and the accumulated ownership in the firm should have been larger based on their previous contributions. Based on this dissatisfaction, these members forked the software and established a firm to provide many of the same services offered by the original POS firm. This defection left the POS firm with very few hired developers and consultants within the US and introduced a degree of uncertainty with respect to the survivability of the POS firm and its services provisioning and development activities. Eventually, the defectors realized that the POS firm still held control over the trademarks, code base and contributions, which enabled the firm to essentially isolate the defectors and their new business from the rest of the ecosystem, which would make it difficult to appropriate suitable returns for their efforts. As such, the new firm was closed and the developers moved on to other projects.

Due to the continuing growth of revenues and development as well as the counsel of the new EVP, the firm enacted a number of initiatives which increased the flow of capital into the ecosystem. The firm acquired several complementary open source projects by hiring the developers running them. In so doing, the firm was able to increase the number of contributors participating in the ecosystem surrounding their products while gaining some control over the future direction of these projects. This also provided a larger, more integrated base of software upon which to package service offerings for end users. For the hired developers, the acquisition of their projects enabled them to spend more time on development while leaving much of the administration to the POS firm. The firm was also able to secure venture capital funding, most of which was not spent but instead used to demonstrate a certain degree of stability and legitimacy to potential customers interested in ensuring that the firm was a reliable one. The funding (and the relationships established with the VC firm) also enabled the firm to attract a larger base of professional management talent, including several sales and product management executives.

4.3   Maturity stage: Competitive Actions and Exit Strategy

In 2004, a rival application engine was announced by a competing open source project. This project was created under the auspices of a prominent open source community and was governed by an administrative team consisting of several of the developers who defected from the POS ecosystem months earlier. Although their original intentions were to use the source code they had forked from the POS firm's project, they were unable to use this code as intended because of the protective mechanisms that were put in place by the POS firm. As a result, they created a new application engine which would compete with the POS firm and other proprietary vendors based on the established technological specifications.

Early in 2004, the rival project was sponsored by a small firm interested in providing support and maintenance for corporate customers. The firm also hired several members of the rival development team, which enabled the developers to devote more time to completing the software prior to its release, which occurred in August, 2004. However, because of its entrenched lead in the application engine market, the POS firm was not particularly concerned at that point.

In May of 2005, the small support firm was acquired by a large global firm who had a vested interest in the application engine market. One of its primary business lines revolved around the sale of licenses and support for a proprietary application engine software package which had lost market share to the POS firm's software over the preceding few years. In acquiring the small firm, including the support of the rival project and its developers, the global firm could essentially offer an open source firm to compete directly with the POS firm's software while offering their customers an easier migration path to the more profitable proprietary licenses and support.

For the POS firm, this was a clear attack on the success of their position in the market since the larger competitor had far more resources to devote to further developing the newer rival's software in an effort to compete in this market space. However, it also brought a certain degree of interest in open source offerings since the global firm's entry into the OSS application engine market was seen as a tacit endorsement. As such, the senior management team of the firm considered these developments as a short-term positive in bringing in more participants to their existing ecosystem, including customers, developers, and partners. However, they also recognized the long-term market risks of the combination of the rival project with the resource base of the larger firm.

In addition to the changing competitive landscape, customers had begun to demand that open source vendors provide entire stacks of enterprise software starting with Linux at the operating system level and moving upward through middleware and including some applications as well. In order to meet this demand, the POS firm would need to either acquire other software projects, form loose partnerships to provide this stack, ignore the customer request and remain independent, or be acquired into a software stack provided by a larger firm. Of these options, only the latter seemed to be feasible given the firm's financial position and the existing technology environment.

In 2006, the POS firm was acquired by a larger professional open source firm, enabling the application engine to be integrated into a complete software stack and offered as a single product. The larger POS firm had a similar business model, albeit with more emphasis on sales through the reseller and original equipment vendor (OEM) channels.

For much of the ecosystem, the combination was clearly beneficial. For instance, there was a good fit among the development teams for both firms based on the compatibility of their products, the high degree of technical proficiency, and a familiarity with the open source methodology. Following the ecosystem, the smaller firm's developers noticed a sharp increase in the amount of resources that were available to them. Several customers were already engaged in relationships within both ecosystems, which became a simpler process as the two product lines were integrated into a single stack. However, some ecosystem participants were forced to make tough choices. For instance, some partners within the smaller firm's ecosystem were competitors to the larger firm. Therefore, they would have to either

continue to support a direct competitor's products or cease participation, which several chose to do. Other customers may have had bad experiences with one of the two firms that they were unwilling to revisit, leading them to seek alternative solutions other than those offered by the new firm. Also, several of the participants providing functions that were duplicated across the two ecosystems and firms, such as sales and marketing teams, left the ecosystem following the merger.

Following the acquisition, the smaller POS firm ceased to exist but the ecosystem created by the firm and its founder continued on under the guidance of the larger firm. Several members from the smaller ecosystem discontinued their participation, extracting much of the capital invested in the ecosystem. However, there were many participants, routines, and procedures that remained in the combined ecosystem, assuring its continued existence.

5   DISCUSSION AND IMPLICATIONS

As articulated earlier, resilience is the ability of an ecosystem to adapt; through this adaptation, an ecosystem may not return to its exact structure or level of output after a given stress, but may have to invent a whole new structure to adjust to the changing environment. One model of organizational adaptation to environmental jolts is comprised of three phases: anticipating the stress or jolt, responding to the jolt, and readjusting to the new environmental and internal conditions (Meyer, 1982). In response to a stress in the existing equilibrium of an ecosystem, the participants have three responses available (Gunderson, 2000). First, the participants can do nothing, expecting the stress to be short lived and the system to return to normal. Second, the participants can strive for stability in an attempt to adjust the parameters of the system to return to a desired state. Third, the participants can accede to the need for resilience over stability and adapt to the new conditions or the new environment to create a wholly new equilibrium. Often, these systems are either unable to perceive that a change in their internal structure or environmental conditions is about to occur (or is occurring) or unwilling to accept the strategic and operational changes that successful adaptation would entail (Diamond, 2005). Thus, resilience requires not only the *ability* to react, but the ability to *perceive* the need for change or adaptation often before it is necessary (Hamel & Välikangas, 2003).

An organizational ecosystem depends on the availability of sufficient capital in order to respond to the challenges imposed by the stresses. According to Adam Smith (1937 [1776]), there are four processes for using capital within a social system: procurement of raw capital resources, conversion of these resources into other goods/services, transportation of resources to the point where they are desired/needed, and as appropriation by specific participants. The participant's available capital for use in these processes includes that stored by the participant from previous encounters as well as that which can be shared by other participants (see Figure 2).

To represent the capital available within organizational ecosystems, we have chosen to employ a typology consisting of economic, social, symbolic, human, and organizational capital Economic capital consists of financial, physical, and property related assets. The vast majority of research in the management and economics disciplines discusses the generation and accumulation of economic assets as both a starting point and a target of business organizations. This view is understandable given the ubiquity and near-universality of money and its equivalents. However, the flows and stocks of other capital types are equally important in identifying the contributions made as well as the desired returns to the individuals and organizations involved in exchange relationships. Social capital refers to the ability of an individual or organization to capitalize on the norms, trust, ties, and reciprocity that exist because of the network of relationships a person has within their social structures. Symbolic capital can be described as the degree of honor or prestige held by an entity, including such aspects as reputation, authority, legitimized competence (i.e. degrees or certification), titles, etc. Human capital consists of an individual's skills, knowledge, health, and values (Becker, 1993). Organizational capital consists of the institutionalized knowledge and codified experiences that are owned by an organization, including databases, manuals, routines, systems, and knowledge structures. It has been

described as the "knowledge, skills, and information that stay behind when an organization's people go home at night" (Youndt, Subramaniam, & Snell, 2004 p. 338).

These capital types comprise the available capital which determines the mechanisms or activities that are available to the ecosystem, as seen in Figure 2. We define mechanisms as the entities and activities through which an effect is produced or a purpose is accomplished (Gerring, 2007; Hedstrom & Swedberg, 1998). The mechanisms enacted by participants of the ecosystem subsequently affect the capital that is available for use in adapting to future stresses. As can be seen in figure 2, the enactment of specific mechanisms results in capital output from the system and accumulated capital which is available for later usage. An ecosystem can be considered resilient to the extent that the accumulated capital in combination with subsequent capital inputs is sufficient to enable mechanisms enacted to enable the ecosystem to satisfy the participants needs and thus to survive. Mechanisms which support the resilience of an ecosystem are those which can be enacted to adjust to changes in the operational or structural patterns of the ecosystem or those which attempt to maintain the existing patterns by eliminating these changes. These mechanisms include processes and actions such as disseminating information to bring parties in line with the system's existing patterns and reinforcing participants' beliefs that their actions are leading to the desired results which in turn minimizes their motivation to introduce changes. Other mechanisms include those which directly affect the acquisition, conversion, transportation, and appropriability of capital within the ecosystem.
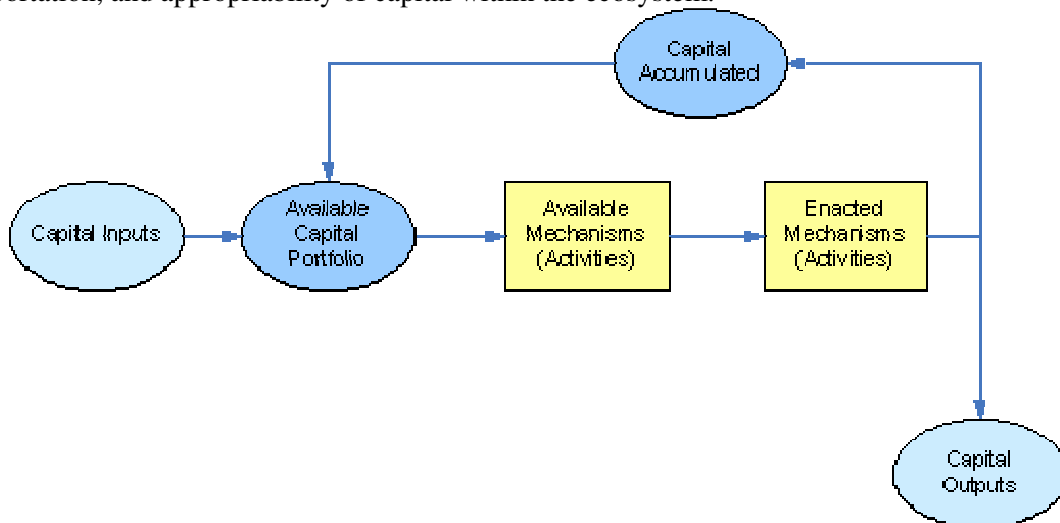
Figure 2: Model of Resilience in Organizational Ecosystems

As shown in Figure 2, the resilience of an organizational ecosystem depends on the continuing capital inputs in the form of contributions from participants, which are contingent upon the expectation of sufficient inducements returned to each participant. This is demonstrated in the case as early as the original founder's decision to participate in the creation of the project in exchange for the working software, which he intended to exploit for financial gain. As the project matured, other people joined and were employed by the original ASP firm, but many of them ceased participation in the POS firm once the expected financial inducements ceased. However, many of the volunteer participants continued to contribute since the non-pecuniary benefits they sought, including expertise, community relationships, and source code access, were still available. As such, the failure of the original firm had little effect on their motivation to continue participating.

When several developers left the POS firm in an attempt to found a competing organization, they did so because of a lack of perceived returns for their contributions. Later, the ecosystem attracted a number of service partners seeking returns (typically financial capital) for their continued participation. However, many of these partners were required to make tough decisions regarding their participation after the POS firm merged with the larger firm, which may have competed directly or indirectly with the partners. By contributing indirectly to their competitors, these partners can

rationally assume that their own comparative position would be weakening which would not be acceptable to most firms. Thus, we can see that one of the primary attributes in the retention of participants within an ecosystem is the ability for these participants to appropriate sufficient inducements to justify continued contributions. The specific forms of capital which are sufficient to attract and retain each participant is dependent on the needs and wishes of each individual participant and the collective needs of the entire ecosystem. As can be seen in several of the above episodes, different participants value each forms of capital relative to their own needs and make decisions regarding continued participation accordingly. As a result, although it is tempting to designate a particular form of capital (typically financial capital) as the most significant form of capital across an ecosystem, we must allow for the production of sufficient capital to enable current and prospective participants to appropriate inducements which would best satisfy specific requirements based on their own self-defined specific criteria or perspectives. We thus suggest the following proposition:

> *P1. The resilience of an ecosystem is determined by the ability of its participants to appropriate sufficient portions of the capital flows to meet their needs.*

When contribution levels falls, the ecosystem may become difficult to sustain depending on the relative necessity of the specific contributions lost. For instance, there was little need to replace or adjust significantly to the lost contributions by the duplicated functions following the acquisition of the POS firm. However, there would have been a different set of adaptive mechanisms enacted if these same participants had left before the acquisition provided the ecosystem with access to similar skills and knowledge.

An example of this is the practice of hiring developers of complementary open source projects by the POS firm. This hiring (procurement) enabled the POS firm to have better control over the direction of these products, which could be integrated into the main product lines of the firm (conversion). It also enabled increased accessibility to the communities surrounding the project and the lead developers, which allowed the human capital contributed by these developers to be more easily delivered where needed (transportation), whether that was to answer a customer support question or to assist in developing code to integrate with another developer's efforts. We can also refer to the *conversion* of the developers' human capital into the finished application itself, followed by making the finished products available for distribution (or *transportation*) to customers at their request.

Having this capital available provides the raw materials needed to embark on improvisational bricolage efforts in order to adapt the business model to meet the participants' changing needs following stress episodes. For instance, the defection and planned fork by participants of the ecosystem was thwarted by the POS firm's control over the customer relationships (social capital), trademark and branding (symbolic capital), and the existing code base (organizational capital). Conversely, the failure of the project fork was directly related to the defectors' lack of control over the resources they needed to deploy toward the creation and conversion of sufficient financial capital to meet their needs.

Over time, a number of participants joined the ecosystem because they expected to receive inducements offered directly from the POS firm rather than from the free-floating exchanges of capital in the remainder of the ecosystem. As discussed earlier, the POS firm is capable of providing services, complementary products, and delivery conditions for the software being developed, which attracts enterprise customers to join the ecosystem. Additionally, the POS firm is able to attract additional funding from external investors, which is used to acquire additional projects, hire additional developers, and attract experienced professional managers to the ecosystem. These efforts not only build up the stock of available capital but also enable the POS firm to direct the flows of this capital in order to reduce the uncertainty between the expected and actual inducements appropriated among the various actors. Reflecting on these ideas, we suggest the following proposition:

> *P2. The ability of the participants of an ecosystem to appropriate capital to meet their needs is enhanced by the ability of a central stakeholder to attract and coordinate these capital flows.*

6   CONCLUSIONS

From the details and analysis of this case, we have identified several requirements for resilience in professional open source software ecosystems. First, there must be sufficient capital available from a combination of ongoing capital contributions and access to capital previously accumulated by the participants. The availability of this capital enables the mechanisms required to adapt to positive and negative changes within the ecosystem or in the surrounding environment. Second, the capital *produced* by the participants within the ecosystem must be sufficient in terms of both type and amount of capital to provide suitable inducements to encourage subsequent participation (including further inputs and access to accumulated capital) from existing and new contributors, particularly those whose contributions are necessary for the benefit of other members. Third, the resilience of an OSS ecosystem is enhanced by the ability of a central stakeholder (in this case, the POS firm) to manage and direct the flows of capital in such a way that each participant has the opportunity to receive benefits in excess of their contributions. This capability is particularly important in response to stresses which attempt to alter the existing balances or flows of capital in the ecosystem.

Although much of the organization and interaction in open source ecosystems is open and unrestricted, a large proportion of the control over the pathways between the development and user communities is enabled by a professional open source firm acting as intermediary. The position of this firm in the center of the ecosystem allows for an increased chance of being able to access the capital accumulated or contributed by any individual participant, to coordinate the combination and conversion of this capital into more desirable forms, and to direct the transportation of this capital to the point where it is needed. For example, POS firms are better able to coordinate the creation of services desired by enterprise software customers. Thus, we can conclude that the resilience of an open source ecosystem is enhanced by the existence of POS firms that can effectively connect the participants of the ecosystem and guide the flow of capital according to their needs and accumulations.

It is worth noting that the above requirements do not necessitate the existence of a POS firm. Many OSS ecosystems have managed to survive for years without a single dominant entity controlling the flows of capital. Instead, many of these ecosystems have core teams which coordinate the developers' efforts toward software production and community building, but leave the customer side of the ecosystem for other parties to exploit. However, several of these ecosystems have benefited from the contributions of these third party vendors and sponsors who have acted as stabilizing forces for other members of the ecosystem. For example, Apache's legitimacy and corporate adoption potential was boosted significantly by the June 1998 announcement that IBM would distribute and support the Apache Web Server. Also, Linux has thrived as many firms, including Red Hat, Suse, Novell, and IBM, have provided support and developer talent to work on the kernel product and the distributions into which it has been integrated. Thus, whereas the existence of these firms is not necessary, it has been a contributing factor in the success of these projects.

The implication of this research is that any developer, investor, user, or distributor considering joining an open source software ecosystem should carefully evaluate the existing levels of capital and the ability to redirect the flows of this capital in response to common stresses such as the loss of key participants or the withdrawal of other capital (including financial capital). In the case of professional open source ecosystems, this evaluation can be focused greatly on the POS firm itself and its interactions and relationships with the development teams, investors, users, and complementary vendors throughout the ecosystem. The ability of these firms to attract and retain other members and their capital contributions is a key factor in the resilience of an ecosystem, which is a necessary part of a long-term value-added relationship on the part of the potential member.

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