PRODUCT INTEROPERABILITY IN THE ENTERPRISE SOFTWARE SYSTEMS INDUSTRY: A SOCIAL NETWORK APPROACH

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Abstract

An important criterion for organizations when they purchase application software products from different vendors is that these components should adhere to a consistent set of interfaces. These interfaces are typically a part of the organization's IT standards. However, the enterprise software systems (ESS) industry consisting of application software vendors, has established neither open high-level compatibility standards nor a single set of leading standards of a dominant vendor.

While prior research identifies access to user bases as the primary *technical* benefits of these alliances we argue that these alliances also yield other benefits along the *social* dimension such as knowledge spillovers of current technology, reputation transfer and third party investments in integration tools (or expertise). We also argue that benefits from such compatibility are transmitted through both, direct and indirect partners in the alliance network. We use the social network approach to conceptually aggregate alliance benefits into the construct of *Sociotechnical capital*.

Our key proposition is that rather than merely maintaining a higher number of alliances, those vendors that have higher socio-technical capital by virtue of these alliances, perform better. Data on 97 ESS vendors is used to test this proposition where relative *prominence* is used as a proxy measure for socio-technical capital and *outdegrees* indicates the number of alliances in vendor's network. To address the limitations of extant social network measures we develop an alternative theoretically grounded metric for prominence and then use it in our empirical testing. Results indicate that socio-technical capital is indeed strongly related to software licensing revenue. These results suggest that in systems industries, rather than a dyadic level focus, a greater focus on the network mechanism is necessary to understand factors leading to better vendor performance.

Keywords: Technology standards, software industry, enterprise resource planning (ERP), software architecture, partnerships, social network theory, standards competition.

INTRODUCTION

It is well understood that the core of most organizational IT portfolios includes software components provided by *enterprise software systems* (ESS) vendors such as SAP, i2, PeopleSoft, among others (Davenport 1998). Despite the need for these components to interoperate, the ESS industry lacks uniform interoperability standards among vendor products[1]. For the purpose of maintaining interoperability vendors commonly adopt (or interface with) a complementary vendor's *proprietary* standards. We observe that in the ESS industry this interoperability is achieved through alliance formation among vendors. Thus, each vendor makes strategic choices in selection of specific vendors with whom to maintain an alliance with.

This study tests the proposition whether high prominence of an ESS vendor in its alliance network leads to higher performance. Though, this research objective is typical of many industry level studies, our objective poses challenges that are unique to hi-tech *systems industries*[2] with under-developed standards, of which the ESS industry is a prime example. The research questions are: how is interoperability maintained between products of different vendors who are alliance partners? What are the types of resource flows associated with such alliance formation? Access to what type of resources constitutes high prominence of an ESS vendor in its alliance network? What is the impact of these alliances on market performance? We suggest that the above research questions will remain relevant in the long-term because industry-wide standards emergence in the ESS industry is likely to be retarded. This is because IT applications execute business processes, which being *firm-specific*, are of strategic importance. Such specificity is likely to make it difficult to standardize IT applications at the vendor level therefore highlighting the importance of our research questions.

We utilize the insights offered by three streams of literature including the strategy literature, to understand the strategic process through which interoperability across vendor products is maintained. In the IS literature, the term corporate *IT standards* (Kayworth and Sambamurthy 2000) refers to enterprise-wide software rules for integrating the IT portfolio. This literature has primarily focused on the benefits of adopting uniform IT standards within an organization (Goodhue, Wybo et al. 1992; Wybo and Goodhue 1995; Streeter, Kraut et al. 1996; Chatfield and Yetton 2000; Hasselbring 2000; Truman 2000; Yang and Papazoglou 2000). While the economics literature has analyzed standards competition extensively using analytical methods (Katz and Shapiro 1985; Matutes and Regibeau 1988) our empirical approach has certain strengths as we describe in the next section. In the strategy literature performance impacts of alliance networks on firms has been examined extensively and therefore provides a theoretical base on which to build our understanding.

We proceed towards addressing our research questions by describing the ESS industry and the role of alliances. Specifically, we present a qualitative understanding of the *content* of the alliance ties between vendors in terms of, for example, how resource flows occur between vendors and how cross-vendor interoperability is maintained. We then identify the social network perspective, commonly used in organizational studies, as an empirical framework to test our proposition that higher prominence in its alliance network should be related an ESS vendor's performance. However, prior to applying the social network perspective, we also develop a measure of prominence of an ESS vendor. Data on 100 ESS vendors is used and analyzed for testing our proposition.

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[1] In contrast to the ESS industry, other sectors in the high technology electronics and computing industry have well-established and uniform industry-wide standards. Examples are the video tape, operating system and telecommunications industries.

[2] In *systems industries* vendors offer multiple components performing different functionality that are then integrated by users into a composite system. A vendor may offer one or more component while competing in a systems industry (Katz and Shapiro 1994).

THE ESS INDUSTRY AND EXISTING QUANTITATIVE FRAMEWORKS

An organization's enterprise system is almost always a collection of software components manufactured by a multitude of vendors (Davenport 1998). For example, a simple payroll system that was programmed in COBOL and housed in a mainframe may now consist of components ranging from an Oracle database, a Web server by Apache, browsers from Netscape and an application component from an Enterprise Resource Planning application (ERP) vendor like SAP. However, in the ESS industry, while there are standards for low level communication (e.g., at the transport level and object stages), there exist no uniform set of high level compatibility standards at the business level (Altman 1998; Yang and Papazoglou 2000). For this reason, two ESS vendors typically adopt a consistent set of interface specifications, to ensure interoperability. This typically requires explicit alliances between ESS vendors that may involve licensing, product development and release agreements, etc. In addition, there are also adapters or consultants in this industry who train themselves to offer integration services to organizational users. These third parties are also influential in social interaction processes such as joint conferences, trade shows, and training sessions.

Behavior of software firms that engage in strategic compatibility decisions has primarily been studied by economists using analytical models (Matutes and Regibeau 1988; Saloner 1990; Axelrod, Mitchell et al. 1995). These contexts include the early VCR industry, where VHS emerged as the winning standard and the operating systems markets where, multiple separate standards such as Unix, Windows, MacOS, etc., still exist(Grindley 1995). The underlying theory for much of this literature is the accumulation of network externality advantages and product complementarities, either by adopting a common standard, or by constructing adapters to enable compatibility. Along these lines, Katz and Shapiro (1985) have argued that firms with small user bases have strong incentives to make their products compatible with products of players will larger user bases. This study is based on a single component market. Others have considered multi-component markets and have argued that in a duopoly (Matutes and Regibeau 1988), or even in a competition between multiple firms of equal size (Economides 1989), compatibility enables competitors to keep prices high and capture a larger market. These economic models provide prescriptions for industries with competing standards and evaluate the benefits of adopting the leading standard in terms of the potentially accessible user bases. However, as against the above analytical studies, an empirical approach becomes useful because extending the above analytical models to a multi-firm context where each firm has linkages with multiple others, becomes an intractable problem. The second feature of the ESS industry that makes it analytically intractable is that there are no clear leaders or leading standards to choose from. Third, these models assume that externality advantages (measured as user bases or market share) due to standards are the only benefits transferred in an alliance network and that these benefits to software vendors are limited to *direct* partnerships. This is a narrow understanding of the benefits accruing from alliance linkages. We note that these drawbacks of an analytical approach are consistent with the observation that using economic models such as conventional game-theoretic analysis to study complex alliance compositions is "especially difficult because payoffs for each firm depend upon the choices made by all other firms" (Axelrod, Mitchell et al. 1995, p. 1497).

We propose that a social network perspective can be useful in analyzing the performance consequences of alliances among ESS vendors. The social network method is used typically in the strategy literature to aggregate the benefits from alliances and their impact on market performance (Nohria and Eccles 1992). In the following section 3.1, we develop a contextual understanding of the *content* of these alliances, i.e., the resource flows across alliance partners. Using this conceptual understanding we state our assumptions that form the basis of our key proposition in section 3.2 and of the prominence measure in section 4. This measures allows us to test our key proposition in section 4.2.

SOCIAL NETWORK VIEW OF ESS INDUSTRY

Research from the social perspective of markets observes that "industrial structures can be represented as a set of positions that are arranged hierarchically according to the prominence of their occupants (Stuart, Hoang et al. 1999, p.318)." In the status-based models of market competition, prominence plays an important role in influencing organizational performance of a firm as well as that of its affiliates (Podolny, Stuart et al. 1996; Benjamin and Podolny 1999; Ahuja 2000; Burt 2000; Stuart 2000). According to this literature, the status of an actor is influenced by its firm specific attributes such as past demonstrations of quality, technological pioneering or higher market share. In addition, in many technological domains, status can also increase through linkages with prominent firms that provide access to knowledge, technological capabilities, newer markets, production know-how and R&D know-how. (Walker, Kogut et al. 1997). Higher prominence of a firm can also serve to further augment its own position, through benefits such as lower transaction costs and risks (Podolny 1993), preferential treatment from suppliers and higher returns from quality (and therefore price) compared to their less prominent counterparts (Benjamin and Podolny 1999), etc. It has also been observed, for example, that firms with low status benefit in their market capitalization and time to IPO due to their partnerships with high status firms (Stuart, Hoang et al. 1999).

The process through which resources flow and therefore prominence accrues to an organizational actor in a network varies across industry contexts. In the following section we describe the nature of benefits that flow from one firm to another in an alliance network of ESS vendors as well as from indirectly connected firms. We term the aggregate resources as *Socio-technical capital*. Thus, firms not only have intrinsic resources and capabilities that are exogenous to the network, but they also acquire network resources due to their structural position in the alliance network. Since social capital is regarded as an umbrella concept we operationalize it as a function of the structural position, relative prominence. That is, we term this structural position as the *relative prominence* of a firm and propose that it is positively related to firm performance.

Social and technical resources transferred between ESS firms

We propose that in the ESS industry, there are two dimensions to the benefits derived from alliances, technical and social. In the *technical dimension*, benefits to each partner result from technical compatibility between two components. Access to user bases of each other is the most significant outcome of technical compatibility as is considered in the analytical models of network externalities. In the telecommunications industry, for example, technical compatibility yields the most immediate impact on the market performance by providing access to larger user bases of another network. In this context, compatibility pertains significantly to the artifact, i.e., the telecom switching equipment. Access to another telecom network (and thus its user base) is instantaneous when the computer controlled telecom switch is manipulated. As another example, Netscape would have had higher access to users of Microsoft Windows if Microsoft makes Netscape browser completely compatible and as tightly integrated with Windows as Internet Explorer[3].

[3] However, Netscape's access to Microsoft user bases is not certain in the longer term due to changing technology. Thus, in a certain respect technical benefits arise largely due to compatibility at the lower levels as per the OSI architectural framework.

In the ESS industry integration between products of different vendors is most often *not* one-shot as in the above examples. For example, even if SAP made its products compatible with the supply chain components of i2, there is no plug and play capability – but instead weeks and months of effort is needed to ensure smooth functioning when these products are implemented in user organizations. A primary requirement is of diverse knowledge domains to configure the firm-specific business rules in these applications. This integration effort can be significantly reduced by alliances and therefore buyers often prefer their ESS vendors to have mutual alliances (Chellappa and Saraf 2002). We term the benefits that accrue through alliances as the *social dimension* of the resource flow. The first type of benefit is the transfer of reputation of the alliance partner. This results in each vendor becoming more preferable than before to buyer organizations because of its alliance with another reputable ESS vendor. The second type of benefit is the accumulation of third-party investments such as those by integrators and consultants. This leads to more resources being devoted to speed up the integration of products offered by the two vendors when, for example, integration vendors begin to offer off-the-shelf integration tools. The third type of social benefit is the spillover of technology-related knowledge and business domain knowledge. Thus, for example striking an alliance with an ESS who is incorporating Web services architecture into its product design benefits its alliance partner in terms of faster adoption of this new technological breakthrough. Similar knowledge flows can also be about the business domain if both vendors are serving the same vertical industry buyers.

The benefits described above can be seen as accruing *directly* by virtue of the alliance. However, *indirect* benefits also accrue because alliance links act as a conveyor of benefits (see Table 1). This indirect effect of alliances is extensively supported in management literature (Nohria and Eccles 1992), where indirect benefits are transferred from partners of directly connected partners. Based on our above description of the content alliances amongst ESS vendors, we next articulate our assumptions. These assumptions form the basis of our rational choice model underlying the measure, relative prominence of an ESS vendor. Due to lack of prior analysis of this industry, we also substantiate our assumptions. This discussion also provides theoretical support for our main proposition.

Assumptions

In the alliance network context, to begin with, every firm by virtue of its own technology and past demonstrations of quality, brings with it a certain amount of resources (including user bases, reputation, access pool of consultants, etc.) to the network, that are now available as potential benefits to its partners. Unlike a private good, these resources are shared, but not to every body, as public goods are. Instead, these resources are available only to those partners who have invested in relationships with the firm. More generally, an alliance increases partner-specific absorptive capacity (Cohen and Levinthal 1990; Dyer and Singh 1998) of each partner because of which know-how and expertise can be exchanged more efficiently (Conner and Prahalad 1996). Furthermore, access to these resources such as knowledge and reputation spillovers is higher if the alliance partners are heavily endowed with these resources.

The above description of how resources flow between firms also applies to industries characterized by network externalities. Here small firms may have significant incentives to make their products compatible with those of larger firms because of the potential *technical* benefits (Katz and Shapiro 1985; Kauffman, McAndrews et al. 2000) such as access to user bases. Similarly, in the ESS industry, access to resources such as knowledge about latest computing technology and standards or about the industry specific business processes, is higher if the alliance partner is a prominent vendor. Thus, we make the first assumption as follows:

Assumption 1: The greater the exogenous (non-network based) resources of the alliance partners, greater are the social and technical benefits derived by the focal software firm."

Alliances that enable flow of network resources not only need initial investment, but like all types of relationships they also incur a maintenance cost (Adler and Kwon 2000). We argue that these costs are increasing with the status of the partner firm in its network because prominent firms are considered to be selective in their partnerships (Benjamin and Podolny 1999). As an alliance partner, a firm has to invest in upgrading its product quality and developing additional capabilities that are complementary and useful to its affiliate. From a technical perspective, firms that wish to make their components compatible with another firm's, incur a cost either in the form of licensing fees or developing (and regularly updating) self-constructed adapters. For example, many ESS vendors offer certification programs and certified Application Programming Interfaces (APIs) to its alliance partners, which are useful for accessing a larger market.

Assumption 2: Higher the relative prominence of the focal ESS firm, higher is the technological and social investment required by its alliance partners to maintain a relation with the focal firm.

A firm's status is damaged if the affiliate has a low quality product. Therefore, firms strive to maintain their reputation and signal quality when forming alliances (Stuart, Hoang et al. 1999). This may involve social signaling through hiring of a high profile CIO, engaging a known and expensive advertisement firm, partnering with specific adapters (integrators), etc. Often these costs are directed at the type of firm they wish to partner with. In order to exploit and sustain the opportunities afforded by relationships with partner firms, organizations also have to invest in continuous learning mechanisms (Metcalfe and Miles 1994) where learning is then dependent on the status of partners in a network. Not only may a prominent ESS firm charge higher licensing fees but it may also require its partner firms to invest in jointly sponsoring user conventions, trade shows, etc. We broadly term these costs incurred to maintain relationships at a non-technical level as investments required to enhance the compatibility between vendors' products.

A unique element of multi component markets is that while firms have to cooperate in some complementary component markets to leverage externality benefits, they may compete with the same firm in other markets. Firms that have more of the same components and less of complementary requirements would choose to form a weak relationship. Thus, we conceptualize the *aggregate tie strength* as the extent to which firms are related net of their competitive posture with respect to each other. The aggregate tie strength represents as the level to which learning mechanisms of one ESS vendor is partner-specific or information-processing structures (Galbraith 1973) are aligned. Thus if a firm chooses to have a very close relationship which may go beyond the licensing of technology to co-development of products as well, then it would naturally have to invest heavily. Consequently, a strong relationship can better facilitate the flow of benefits.

Assumption 3: A software firm's required investment and corresponding benefits from an alliance is related to the strength of the relationship it chooses to maintain with the alliance partner.

The choice of alliance partners is a conscious act by the firms and they incur costs to maintain compatibility with their partners' products. However, if a third firm is indirectly connected to a focal firm through a common partner, then the third firm's components are likely to be more compatible as compared to a completely unconnected firm. For example, if two vendors of niche software components are partners of SAP, then their products are likely to be compatible because SAP may adopt a common platform and API technology. Sometimes vendors also bundle products of their partners and offer these as a complete package. In these cases, consistent interfaces are developed by vendors to achieve better integration. Thus product bundling across different component makers can further enhance benefits derived by an indirect alliance partners. More generally, similar to direct ties, indirect ties also provide access to knowledge and technical breakthroughs, etc. (Ahuja 2000). However, effects from indirect ties are mediated by the intermediate relationships (Holm, Eriksson et al. 1999, p.475). That is, we assume that indirect social and technical benefits are also not fully transitive - rather they are moderated by the strength of the relationship between the firms.

Assumption 4: A software firm derives social and technical benefits from indirectly connected firms at no direct cost to itself. And these indirect benefits are mediated by the intermediate firms."

	Technical dimension	Social dimension
Indirect ties	**Benefits** • Access to user bases from compatibility (Katz and Shapiro 1985; Matutes and Regibeau 1988; Economides 1989)	**Benefits** • Knowledge spillovers and information transfer (Holm, Eriksson et al. 1999; Ahuja 2000)
Direct ties	**Benefits** • Access to user bases due to compatability (Katz and Shapiro 1985; Matutes and Regibeau 1988; Economides 1989) **Costs** • Licensing fees (Kotabe, Sahay et al. 1996) • Constructing and maintaining adapters (Farrell and Saloner 1992)	**Benefits** • Transfer of reputation (Podolny 1993) • Knowledge spillovers and information transfer (Ahuja 2000; Argote and Ingram 2000), e.g., product architectures and new software technology such as web services or encryption. • Stimulating third party investments (Metcalfe and Miles 1994), e.g., by consultants and integration vendors **Costs** • Installing learning mechanisms such as product teams and alliance managers (Metcalfe and Miles 1994) e.g., joint product development teams, alliance manager and technology liaisons.

Table 1: Sociotechnical Resource Transfer Matrix

Sociotechnical Capital as an aggregate resource construct

We term a firm's access to net social and technical benefits (Table 1) from a network of ties as the Sociotechnical capital of a firm. This term is derived from an umbrella concept called "social capital," broadly defined as "the sum of resources accruing to an individual or group by virtue of their location in the network of their more or less durable social relations (Adler and Kwon 2000)." Bourdieu and Wacquant's (1992) define social capital as “the aggregate of the actual or potential resources which are linked to the possession of a durable network of more or less institutionalized relationship of mutual acquaintance or recognition." While many definitions for social capital exist in literature (see Adler and Kwon (2000) for a review), we primarily adopt the view that Sociotechnical capital is a network resource that is created in the alliance network of ESS firms, which can be converted to gain performance advantage. This resource is not a substitute for intrinsic or exogenous capability of a firm or its technology. Rather, as suggested by Portes (1998), it is a complement to these exogenous abilities of the firm. Also, given that sociotechnical capital is not "free" and requires a maintenance cost, the choice of alliance partners has to be strategic decision.

As discussed in section 3.1, in our context, the relative prominence of a firm in its alliance network is an important factor in determining a firm's strategic performance, i.e., how it is able to utilize other vendors' social and technological resources to enhance its performance. The following proposition tests the performance implications of high socio-technical capital.

<u>Proposition 1:</u> *The relative prominence of an ESS firm arising from its access to social and technical resources from both, directly and indirectly connected partners, is positively related to its performance.*

Social capital has been operationalized using network measures of centrality, betweeness, brokerage and prominence (Burt 2000). To test our proposition we proceed along the following steps. First, we discuss how extant measures of firm prominence are limited in their ability to capture the moderated flow of benefits discussed in assumption 4. Thus, in the following section, after a review of existing network metrics, we present a modified prominence measure that satisfies assumptions 1 through 4. This measure allows us to test proposition 1 in section 4.2

PROMINENCE MEASURES IN NETWORK ANALYSIS

Modified prominence measure for Sociotechnical capital (see appendix A)

A literature search reveals that none of the existing measures of prominence incorporate all our assumptions. Specifically, assumption 4 was not built into any of these measures (see Chellappa and Saraf(2002) for a detailed discussion). Therefore, we extend the rational choice model of status (Braun 1997) as follows. Based on other firms' exogenous resources, the focal firm decides to maintain alliances to enhance its Socio-technical capital. For every alliance, the firm incurs a cost that is proportional to the strength of relationship it chooses to maintain. As discussed in assumption 2, this cost is also a function of the partner firm's relative prominence in the network, as given by eq. A1. The benefits as described in assumptions 1&4, are sum total of benefits from both the direct and indirect alliances, giving us the benefits equation given by eq. A3. Under equilibrium, when all network resources have been distributed, such that the costs incurred equal the network benefits, we obtain the measure of prominence as below:

$$s_i = \frac{\sum_{p=0}^{n-1}\sum_k {z_{ik}}^p}{1+n} + \frac{\sum_{p=0}^{n-1}\sum_k {z_{ik}}^p \sum_j r_{kj} s_j}{1+n}$$

From this equation, we see that the relative prominence of the focal firm is a function of the relative prominence of the firms that it partners with s_j, and the relationship strength, r_{ij}, it maintains with each of the partnering firm. This metric is then obtained by solving simultaneously for the prominence of all firms.

Data – Alliance network of enterprise systems software firms

To test proposition 1, we consider the context of ESS firms manufacturing core enterprise resource planning (ERP) components and the allied complementary software providers (CSPs) as shown in Table 2. We collected data from several sources. Data on the type of components the sample of ESS firms offer and their software licensing revenue (SOFTREV) for the year 1999 was collected using questionnaires to vendors. The questionnaire was administered by a consulting organization that was hired by a vendor-neutral industry group. It was confirmed that the questionnaire was administered to all the firms operating in the industry. The response rate was near 100% for the top ranked firms, and we considered this pool of the top 97 firms and a representative sample is shown in Table 2[4].

Example set of enterprise system vendors *	Software component markets **
SAP America, Oracle Corp., J.D. Edwards, Baan Company, JBA International, System Software Associates, i2 Technologies, PeopleSoft Inc., Trilogy Software, Kronos Inc., EXE Technologies, HK Systems, Intellution, Wonderware Corp., Aspect Development	Advanced Planning and Scheduling (25)
	Customer Response Management (9)
	E-Business (20)
	Enterprise Resource Planning (50)
	Product Data Management (15)
	Component Management (15)
	Groupware (15)
	Supply Chain Planning (31)
	Forecasting & Demand Management (10)
	Supply Chain Execution (24)
	Transportation & Logistics (12)
	Warehouse Management (22)
	Enterprise Asset Management (12)
	Supervisory Control (22)
	Business Intelligence (2)
* This is a list of 15 ESS vendors from the sample of 97. ** The component categories are based on component classification assumed by the data sources. Parentheses in the second column state the number of vendors in the sample offering the particular component.	

Table 2: Enterprise system firms and component markets they compete in

Data was on alliances among the sample of 97 vendors constituted our network data which was collected from various sources, including corporate data-sheets, websites, telephone interviews, etc. An alliance linkage was noted if a firm indicated that it had a partnership with any of the other 97 firms. This yielded a matrix of alliances of the top 97 firms (Figure 1). From this matrix, 29 vendors had no links with other vendors within the pool. By definition, the measure of socio-

[4] Data collection about ESS vendors can pose a significant problem as there is no specific SIC code for enterprise software. For example, the SIC code category 7372 (pre-packaged software) includes not only ESS vendors but also vendors that sell off-the-shelf desktop software. Hence we identified an industry group that specifically collects information on ESS vendors. We compared our sample of 97 vendors with information on ESS vendors from OneSource database and confirmed that no known ESS vendors were excluded.

technical capital of these vendors is zero. A large percentage (60%) of these isolates are small vendors. Further, on running the distance matrix procedure in the network software UCINET IV (Borgatti, Everett et al. 1992), it was found that five vendors had links among themselves but not with the rest of 65 firms. The remaining 65 vendors had a total of 196 alliance links amongst themselves of which 96 were reciprocated links. The 97 vendors offered components from a list of 15 products ranging from Advanced planning and Scheduling to Business Intelligence software (see Table 2). To compute Sociotechnical capital (STC) for each vendor, a software program was created in Matlab using the expression in section 4.1. Employee strength (SIZE) and *outdegree* (OUTDG) (number of alliances struck by a vendor) were included as a control variables. Whereas employee size is commonly used in studies to control for organizational slack, *outdegree* controls for the variation in degree to which ESS vendors form alliances. Since data on employee count for the year 1999 was available for only 92 of the 97 firms, our sample size shrunk to 92.

Variables	Data source
ESS firm's software licensing revenue	MSI index and newsletter
Alliances formed by ESS firms	• Websites • Corporate press releases • Phone
Employee size	• Mergent Online • Securities and exchange commission • OneSource Business Browser

Table 3: Variables and Data Sources

Data Analysis and Results

Table 4 reports the descriptive information on the variables. Typically, since the functional form is not completely specified, performance variables are often log transformed. Similarly, SOFTREV and SIZE are log transformed. Graphical plots of the log transformed variables reveal a normal distribution. The correlation between STC and OUTDG is high at 0.72 but after socio-technical capital is log-transformed (rather Log (STC+1) since the transformation is not valid for those vendors with zero socio-technical capital), the correlation drops to 0.62. When the models are tested, variance information factor (VIF) (Hair, Anderson et al. 1992) for all variables is below 2 which indicates that multi-collinearity is under control. All pair-wise correlations are significant at 0.05 level.

Table 5 presents the results from a multiple regression (OLS) with software licensing revenue as the dependent variable. Models 1 and 2 are the baseline models which validate the use of SIZE as the control variable but OUTDG is not significant. However, including LSTC increases the explained variance (R-square) and parameter estimate for LSTC is also significant at 0.05 level. The F-test also indicates that the increase in R-square is significant for LSTC. Thus, overall the results strongly support our argument that rather than a strategy of increasing the number of alliances, the consideration of whom to align with is more important. This is borne out by the fact that the estimate for OUTDG is not significant at the 0.05 level.

Variable name	Means	Standard Deviations	Log(SIZE)	Log(STC+1)	OUTDG
LREV = Log (SOFTREV)	4.08	1.15	0.822	0.499	0.328
LSIZE = Log(SIZE)[5]	6.2	1.36	-	0.424	0.292
LSTC = [Log(STC+ 1)]	1.13	0.85		-	0.628
OUTDG	2.03	2.88			-

Table 4. Means, standard deviations and Pearson correlations

MODEL	1	2	3
LSIZE	0.696*	0.672*	0.63*
OUTDG		0.038	0.003
LSTC			0.257*
R^2	0.676	0.684	0.704
Adjusted- R^2	0.672	0.677	0.694
Number of observations	92	92	92

Table 5. Regressing Firm Performance of ESS Vendors on Socio-technical Capital

IMPLICATIONS

This paper contributes in several ways. This is one of the first works to study the context of standards and compatibility in the IS area. Specifically, we link the traditional understanding of corporate IT standards to the alliance and compatibility decisions of the software firms themselves. Based on an in-depth understanding of the context we conceptualized the resource flows through alliance linkages as consisting of not only knowledge spillovers, traditionally discussed in strategy literature, but also demand-side mechanisms such as, perceptions of higher compatibility and access to user bases, as characteristics of the ESS industry.

A further contribution of this study is the introduction of social network theory to understand strategic behavior of ESS vendors due to under-developed standards. The social network framework allows empirical tests of the intuitions generated in prior research and thus helps to overcome the limitations of analytical methods in this rich domain. The social network

[5] Data on employee count for only 92 firms was available

framework also enriches the understanding of how alliances may result in the convergence between the technological trajectories of high-technology companies.

This paper also makes a significant contribution to research in social network theory. Burt (2000) says, “Research will better accumulate if we focus on network mechanisms responsible for social capital effects rather than trying to integrate across metaphors of social capital loosely tied to distant empirical indicators”. In our research we identify some of these mechanisms by a contextual study of the software industry alliances.

The understanding developed in this work is also rich enough to help examine a variety of issues in an industry that is dependent on standards but does not enjoy uniform, industry-wide product interoperability. For example, a longitudinal study of a software industry using our model can provide insights into the standards formation process itself. This research can also be extended to understand alliance formation even in the presence of industry-wide standards, as the social dimension becomes the only differentiating basis for competition in the face of rapid technological obsolescence. Particularly, the role of user organizations in shaping standards emergence in the ESS industry is an important contribution that has yet to be made by IS scholars.

Our model can also be applied to structure IS problems in intra-organizational situations. For example, identifying the right amount to invest in systems resources is of great importance in IS (Keen 1991), and our network model can help guide this decision. For example, one can construct an intra-organizational network of workflow and resource inter-dependence (Wybo and Goodhue 1995). Similar to the operationalization of Sociotechnical capital, network measures can be used to explore the fit between prominence in the workflow networks and the system compatibility networks. A high mismatch may be an indication of the need to refocus integration efforts.

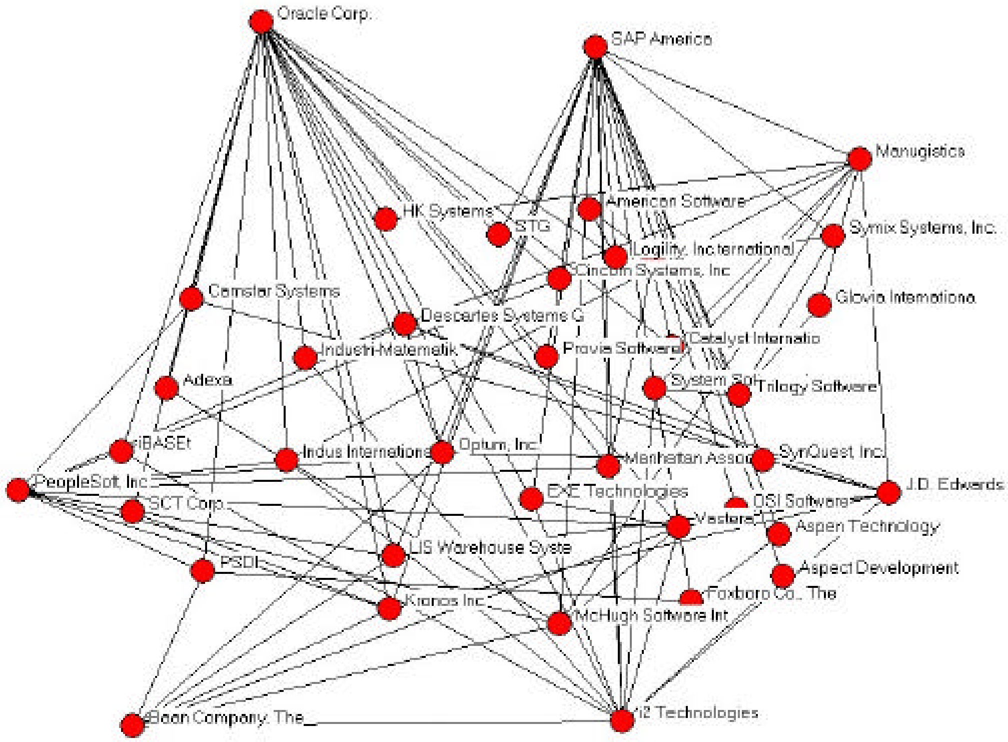

Figure 1: Example Alliance Network of Enterprise System Firms

APPENDIX

In section 3.2, assumption 3, we define the construct of aggregate relationship as representing the extent to which firm j is dependent on i. We can therefore define r_{ij} as "the extent of vendor j's dependence on vendor i as a fraction of vendor j's dependence on all other vendors directly connected to it." The adjacency matrix R is therefore a nXn column stochastic matrix with elements r_{ij}, such that for each j, $\sum_i r_{ij} = 1$. Similarly we also now formally define $s_j \geq 0$ as the relative prominence of vendor j such that $\sum_j s_j = 1$, i.e., s_j is standardized over all vendors in the network. Thus cost c_i can be formalized as

$$c_i = \sum_j r_{ij} s_j \text{ for each } i \qquad (1)$$

Every firm brings with it a certain exogenous value the network. Let this expected value be e_j, such that $e_j > 0$ and $\sum_j e_j = 1$. This value e_j is intrinsic to each firm j, and is representative of resources such as potential users, army of consultants, integrators, implementers, etc. that vendor j may bring to the network. This conceptualization is in line with the observation made by Portes[6]. In the absence of any network or relationship with other firms, a firm j would depend only on its own resources. Thus we can represent $b_j = f(e_j)$

(2)

However from assumptions 1,3,&4 in our network context, benefits for a firm i at any time is constructed as:

$$b_i = \sum_j r_{ij} e_j + \sum_k r_{ij} r_{jk} e_k + \sum_l r_{ij} r_{jk} r_{kl} e_l + \ldots \qquad (3)$$

To simplify equation-3, we use power matrices of R. Let us consider an array of power matrices where $z_{ij}{}^0 = 1_{i=j}(=0)_{i \neq j}, z^1{}_{ij} = r_{ij}, z^2{}_{ik} = \sum_j r_{ij} r_{jk}, \ldots . z^n_{in}$ and in matrix notation $z^2{}_{ik}$ can be represented as $z^2 = R.R$. Similarly, $z^p = R^p$ where power p represents the number path lengths between two firms. Using the power matrix notation we can now represent

$$b_i = \sum_j r_{ij} e_j + \sum_j z^2{}_{ij} e_j + \sum_j z^3{}_{ij} e_j + --- \sum_j z^P{}_{ij} e_j \qquad (4)$$

This can be further reduced to equation

$b_i = \sum_{p=1}^{P} \sum_k z_{ik}{}^p e_k$ for all i and In matrix notation we have, $b = \sum_{p=1}^{n} (Z^p.e)$ (5)

First Order Conditions for Equilibrium: At equilibrium every vendor's resource investments are such that the marginal cost is equal to the marginal benefit. Differentiating equations 1 and 3 with respect to r_{ij} and equating the derivatives we get:

$$s_j = \sum_{p=0}^{n-1} \sum_k z_{jk}{}^p e_k \qquad (6)$$

The above can be represented in matrix notation as $S = \sum_{p=0}^{n-1} (Z^p.e)$ (7)

where S is the column vector of statuses of the vendors.

From equation 5 we have a functional relationship between benefits and intrinsic value of a firm $b_j = f(e_j)$, representing the utility of the firm in the absence of any network investments and resources. At equilibrium the network has stabilized with the actors maintaining a concrete relationship as represented by the adjacency matrix R. Hence we may assume, that benefits are once again functionally related to intrinsic values. However the functional form itself may vary.

If we assume a linear utility function similar to Braun (1997) such as:
$b_i = (1+n)e_i - 1$ (this implies even if $e_i > 0$ we can still have $b_i = 0$)

[6] He clearly distinguishes between resources themselves from the ability to obtain them by virtue of membership in different social structures. Portes, A., "Social capital: Its origins and applications in modern sociology," *Annual Review of Sociology*, 24, (1998), 1-24.

and if we substitute cost for benefit, we have $e_i = \dfrac{1+c_i}{1+n} = \dfrac{1}{1+n} + \dfrac{1}{1+n}.\sum_j r_{ij} s_j$

alternatively for any k we have $e_k = \dfrac{1}{1+n} + \dfrac{1}{1+n}.\sum_j r_{kj} s_j$. Multiplying both sides by $\sum_{p=0}^{n-1} \sum_k z_{ik}{}^p$,

we have from equation 6 $s_i = \dfrac{\sum_{p=0}^{n-1} \sum_k z_{ik}{}^p}{1+n} + \dfrac{\sum_{p=0}^{n-1} \sum_k z_{ik}{}^p \sum_j r_{kj} s_j}{1+n}$

and in matrix notation we have

$$S = \frac{\left(\sum_{p=0}^{n-1} Z^p\right).J + \left(\sum_{p=1}^{n} Z^p\right).S}{1+n} \qquad (8)$$

Equation 8 implies that the prominence of a firm is dependent on s_j, the status measure of other firms and r_{ij}, the corresponding strength of relationship.

Solving equation 8 for S, we have $S = (I - X)^{-1} YJ$ where $Y = \dfrac{\sum_{p=0}^{n-1} Z^p}{n+1}$, $X = \dfrac{\sum_{p=1}^{n} Z^p}{n+1}$

The power series form of $S = (I - X)^{-1} YJ$ would be as follows:

$$S = \frac{1}{1+n}\left(I - \frac{\sum_{p=0}^{n} Z^p}{1+n}\right)^{-1}\left(\sum_{p=1}^{n-1} Z^p\right).J = \frac{1}{1+n}\sum_{l=0}^{l=\infty}\left(\frac{\sum_{p=1}^{n} Z^p}{1+n}\right)^{l}\left(\sum_{p=0}^{n-1} Z^p\right).J \qquad (9)$$

The above power series is valid since $\left\| \dfrac{\sum_{p=1}^{n} Z^p}{1+n} \right\| < 1$

From Kincaid and Cheney (1996), we can confirm the existence of the inverse if the norm $\left\| \dfrac{\sum_{p=0}^{n} Z^p}{1+n} \right\| \le 1 \Rightarrow \left\| \sum_{p=0}^{n} Z^p \right\| \le n+1$, where $\sum_{p=0}^{n} Z^p$ is also a stochastic matrix with column sums equal to n. Therefore, taking $\dfrac{1}{n}\sum_{p=0}^{n} Z^p = G$, the inverse is always said to exist if and only if $\|G\| \le (n+1)/n$. Matrix G, being a column stochastic, its norm is $\|G\| = \dfrac{\max}{1 \le j \le n} \sum_{i=1}^{n} |a_{ij}| = 1$. Since $(n+1)$ is always greater than n, the existence of the inverse is confirmed.

For further empirical studies, e and c can be expressed as:

$$c = Rs = R.\frac{1}{1+n}\sum_{l=0}^{l=\infty}\left(\frac{\sum_{p=1}^{n} Z^p}{1+n}\right)^l \left(\sum_{p=0}^{n-1} Z^p\right).J = \frac{1}{1+n}\sum_{l=0}^{l=\infty}\left(\frac{\sum_{p=1}^{n} Z^p}{1+n}\right)^l \left(\sum_{p=1}^{n} Z^p\right).J \qquad (10)$$

Equation 7 gives $e = \left(\sum_{p=0}^{n-1}(Z^p)\right)^{-1}.S$, and therefore from equation 9 we have

$$e = \frac{1}{1+n}\sum_{l=0}^{l=\infty}\left(\frac{\sum_{p=1}^{n} Z^p}{1+n}\right)^l.J$$

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REFERENCES

Adler, P. S. and S. Kwon (2000). Social Capital: The good, the bad and the ugly. Knowledge and Social Capital. E. L. Lesser. Boston, MA, Butterworth-Heineman**:** 89-115.

Ahuja, G. (2000). "Collaboration, networks, structural holes, and Innovation: A longitudinal study." Administrative Science Quarterly **45**(-): 425-455.

Ahuja, G. (2000). "The Duality of Collaboration: Inducements and Opportunities in the Formation of Interfirm Linkages." Strategic Management Journal **21**(-): 317-343.

Altman, R. (1998). Standards Won't Eliminate Need for Application Integration. -, GartnerGroup**:** -.

Argote, L. and P. Ingram (2000). "Knowledge transfer: A basis for competitive advantage for firms." Organizational behavior and human decision process **82**(1): 150-169.

Axelrod, R., W. Mitchell, et al. (1995). "Coalition formation in standard-setting alliances." Management Science **41**(9): 1493-1508.

Benjamin, B. A. and J. M. Podolny (1999). "Status, quality, and social order in the California wine industry." Administrative Science Quarterly **44**(3): 563-589.

Borgatti, S. P., M. G. Everett, et al. (1992). UCINET IV network analysis software: Reference manual and User's Guide. Columbia, SC, Analytic Technologies.

Bourdieu, P. and L. J. D. Wacquant (1992). An invitation to reflexive sociology. Chicago, IL, University of Chicago Press.

Braun, N. (1997). "A rational choice model of network status." Social networks **19**(-): 129-142.

Burt, R. S. (2000). Structural Holes versus Network Closure as Social Capital. Social Capital: Theory and Research. R. S. Burt. Chicago, Aldine de Gruyter. **2001:** -.

Chatfield, A., Takeoka and P. Yetton (2000). "Strategic payoff from EDI as a function of EDI embeddedness." Journal of Management Information Systems **16**(4): 195-224.

Chellappa, R. and N. Saraf (2002). Firm prominence through sociotechnical capital: A social network perspective of resource transfers in non-standardized software industries. paper presented at the Academy of Management, Denver.

Cohen, W. M. and D. A. Levinthal (1990). "Absorptive capacity: A new perspective on learning and innovation." Administrative Science Quarterly **35**(-): 128-152.

Conner, K. R. and C. K. Prahalad (1996). "A knowledge-based theory of the firm: Knowledge versus opportunism." Organization Science **7**(5): 477-501.

Davenport, T. H. (1998). "Putting the Enterprise into the Enterprise system." Harvard Business Review **July-August**: 121-131.

Dyer, J. H. and H. Singh (1998). "The relational view: Cooperative strategy and sources of interorganizational competitive advantage." Academy of Management Review **23**(4): 660-679.

Economides, N. (1989). "Desirability of Compatibility in the Absence of Network Externalities." The American Economic Review **79**(5): 1165-1181.

Farrell, J. and G. Saloner (1992). "Converters, Compatibility, and the Control of Interfaces." Journal of Industrial Economics **40**(1): 9-35.

Galbraith, J. R. (1973). Designing complex organizations. Reading, MA, Addison-Wesley.

Goodhue, D. L., M. D. Wybo, et al. (1992). "The impact of data integration on the costs and benefits of information systems." MIS Quarterly **-**(-): 293-311.

Grindley, P. (1995). Standards, strategy and policy, Oxford University Press.

Hair, J. F., R. E. Anderson, et al. (1992). Multivariate data analysis. New York, Macmillan.

Hasselbring, W. (2000). "Information system integration." Communications of the ACM **43**(6): 33-38.

Helper, S. and J. P. MacDuffie (2000). Evolving the Auto Industry: E-commerce effects on Consumer and Supplier Relationships. -. **-:** -.

Holm, D. B., K. Eriksson, et al. (1999). "Creating value through mutual commitment to business network relationships." Strategic Management Journal **29**(-): 467-486.

Katz, M., L and C. Shapiro (1994). "Systems competition and network effects." The Journal of Economic Perspectives **8**(2): 93-115.

Katz, M. L. and C. Shapiro (1985). "Network Externalities, Competition and Compatibility." The American Economic Review **75**(3): 424-440.

Kauffman, R. J., J. McAndrews, et al. (2000). "Opening the "Black Box" of Network Externalities in Network Adoption." Information Systems Research **11**(1): 61-82.

Kayworth, T. R. and V. Sambamurthy (2000). "Facilitating localized exploitation and enterprise-wide integration in the use of IT infrastructures: The role of PC/LAN infrastructure standards." The DATA BASE for advances in information systems **31**(4): 54-77.

Keen, P. W. (1991). Shaping the Future. Cambridge, MA, Harvard Business School Press.

Kotabe, M., A. Sahay, et al. (1996). "Emerging role of technology licensing in the development of global product strategy: Conceptual framework and research opportunities." Journal of Marketing **60**(1): 73-88.

Matutes, C. and P. Regibeau (1988). ""Mix and match": product compatibility without network externalities." RAND Journal of Economics **19**(2): 221-234.

Metcalfe, J. S. and I. Miles (1994). "Standards, selection and variety: an evolutionary approach." Information Economics and Policy **6**: 243-268.

Nohria, N. and R. G. Eccles (1992). Networks and organizations: Structure, form, and action. Boston, MA, Harvard Business School Press.

Nonaka, I. and N. Konno (1998). "The concept of "Ba": Building a foundation for knowledge creation." California Management Review **40**(3): 40-54.

Podolny, J., M (1993). "A status-based model of market competition." American Journal of Sociology **98**(4): 829-872.

Podolny, J. M., T. E. Stuart, et al. (1996). "Networks, Knowledge and Niches: Competition in the Worldwide Semiconductor Industry, 1984-1991." American Journal of Sociology **102**(2): 659-89.

Saloner, G. (1990). "Economic Issues in Computer Interface Standardization." Economic Innovation and New Technology **1**: 135-156.

Streeter, L., A, R. Kraut, E, et al. (1996). "How open data networks influence business performance and market structure." Association for computing machinery: Communications of the ACM **39**(7): 62-.

Stuart, T. E. (2000). "Interorganizational alliances and the performance of firms: A study of growth and innovation rates in high technology industries." Strategic Management Journal **21**(-): 791-811.

Stuart, T. E., H. Hoang, et al. (1999). "Interorganizational endorsements and the performance of entrepreneurial ventures." Administrative Science Quarterly **44**(2): 315-349.

Truman, G., E (2000). "Integration in electronic environment." Journal of management information systems **17**(1): 209-244.

Walker, G., B. Kogut, et al. (1997). "Social Capital, Structural Holes and the Formation of an Industry Network." Organization Science **8**(2): 109-125.

Wybo, M. D. and D. L. Goodhue (1995). "Using interdependence as a predictor of data standards: Theoretical and measurement issues." Information & Management **29**(-): 317-329.

Yang, J. and M. P. Papazoglou (2000). "Interoperation support for electronic business." Association for Computing Machinery, Communications of the ACM **43**(6): 39-47.

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