The Impact of Board Interlocks in the Diffusion of Enterprise Resource Planning Systems

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Prière de faire parvenir toute correspondance à Pierre-Majorique Léger.
Abstract
This paper is intended to investigate the extent to which board interlocks contribute to the diffusion of ERP technologies in an interlocked network. Controlling for size, we investigate the effect of two network characteristics on the adoption decision of enterprise systems by organizations: the exposure of a firm to other adopters and the centrality of a firm within an interlocked network. In order to test our models, we gathered board members data of the top 1,000 Canadian public firms and recorded adoption decisions within this network through the analysis of ERP announcements using keywords co-location. Our research findings suggest evidence of the diffusion of ERP technologies in interlocked networks.

Résumé
Cet article vise à déceler jusqu’à quel point les conseils d'administration croisés contribuent à la diffusion de progiciels de gestion intégrés dans un réseau imbriqué. Nous étudions, en tenant compte de la taille des réseaux, l'effet de deux de leurs caractéristiques sur la décision d'adopter des systèmes d'entreprise par des organismes : l'exposition d'une société à d'autres adopteurs et sa centralité au sein d’un réseau imbriqué. Afin d'examiner nos modèles, nous avons recueilli des données des membres de conseils d’administration des 1 000 plus importantes sociétés publiques canadiennes et avons consigné l’information relative aux décisions d'adoption dans ce réseau. Nous avons ensuite analysé les annonces d'implantation de progiciels de gestion intégrés en utilisant la recension synchronisée de mots clés. Nos résultats suggèrent des évidences quant à la diffusion des progiciels de gestion intégrés par le biais des administrateurs de liaison.

Mots-clés
ERP, diffusion, interlocks
1 Introduction

Enterprise Resource Planning (ERP) systems are configurable commercial software solutions that integrate processes and information from all functional areas of an organization. Despite the considerable effort required to implement such systems, many companies have replaced their legacy systems by ERP systems during the last decade, in order to increase employee productivity, improve operations management, and improve information access for decision-making. As of today, ERP systems have been adopted by most Fortune 500 firms and ERP providers are now turning to the middle market to further their growth.

As the adoption of ERP software is usually strategic, involving massive investment of company resources, the final decision is generally supported by the board of directors. Verville and Halingten [1] provide different examples of board involvement in the decision to implement an ERP. In addition, other authors report not only a higher authority approval role for the board of directors, but also a monitoring and overseeing role throughout the implementation process [2].

Directors sitting on more than one board are likely to bring information about partners’ decisions and experience to the table, and consequently, influence the choice. We argue that directors acquire knowledge about ERP technologies through the adoption decision and the monitoring process of the implementation. Not only are they exposed to the reasoning that leads to the selection of one solution over another, but they become aware of how the different technological options fit with current industrial practices.

Many researchers have already demonstrated the importance of the board of directors with regards to the exchange of information among leaders, and the possibility to observe the leadership practices and styles of peers. They have argued that board level relationships could be considered as conduits through which information can flow from one company to another [3]. This flow of information occurs at both tactical and strategic levels between network partners, therefore mutually influencing their business decisions and behavior [4].

With regards to business practices, different authors have found evidence of corporate knowledge transfer at board level. Fong Chua and Petty [5] suggest that interlocks, i.e., directors sitting on more than one board, are a diffusion mechanism for industrial practices such as the adoption of ISO quality standards. Davis [4] found evidence of similar tactical behavior with regards to the adoption of the poison pill strategy to protect against hostile take-overs.

Recognizing that board interlocks may create a conduit through which information and influence on Enterprise Resource Planning (ERP) systems adoption flow, this paper is intended to discover the extent to which board interlocks contribute to the diffusion of ERP technologies in a network. We specifically investigate two main effects on organizations’ decision to adopt enterprise systems: the exposure of a firm to other adopters in the interlocking network and the centrality of a firm within the network. Based on our previous arguments, we pose the following research question: “Does the decision to adopt ERP systems follow a diffusion pattern in industrial networks?” As a first step towards answering this question, we investigated different ways to predict diffusion in the network of Canadian firms.

The remainder of the paper is organized as follows. We first present a brief literature review on quantitative diffusion models. We then present our ERP diffusion model in Section 3 followed by the presentation of our validation methodology in Section 4. Statistical results are then
presented in Section 5. A discussion of the most significant results follows in Section 6. The paper concludes with some prospects for future research.

2 Brief literature review on quantitative diffusion model

The literature on network diffusion has strong roots in many disciplines including economics, sociology, marketing, anthropology, and technology management [6, 7]. Researchers in these fields have generally looked at the vector of diffusion through which new ideas and practice spread across an interconnected population. These diffusion studies have mainly focused on identifying network-based factors that increase or inhibit adoption by community members. In these approaches, network influences are captured by a contagion model where each individual’s likelihood of adoption increases as the proportion of users in the network increases.

So far, a variety of mathematical models has been used to study such diffusion phenomena [7]. Macro models are used to estimate the speed of diffusion and the rate of imitation. In such approaches, the cumulative pattern of diffusion is often modeled by a one- or two-parameter logistic function [8]. While useful for forecasting expected levels of diffusion [9], modeling at the macro level is imprecise because it assumes perfect network mixing as everyone interacts with everyone else [7, 10, 11]. Also, at the macro level, spatial autocorrelation models measure whether diffusion spreads between contiguous areas rather than only estimating the rate of diffusion [7, 12, 13]. However, these models do not demonstrate whether specific individuals are most or least likely to adopt based on their network position.

The inability of macro models to show how the network structure influences diffusion has led researchers to develop network models [14]. These models posit that innovation spreads through the network as adopters persuade nonusers to adopt by exhortation, entreaty, enticement, or example [7]. The validity of these models rests partly on determining whether network exposure or structural positions influence adoption. Empirical validation of such models is difficult however, as it requires the collection of data for an entire network of individuals and over a time period long enough for diffusion to occur. Recording the time of adoption may also be difficult to perform. These difficulties have brought some researchers to do cross-sectional and retrospective studies involving only one time point [14, 15]. As discussed by Valente [7], the following statistical model is adequate when analyzing one time point diffusion network studies:

\[
\log \left( \frac{Pr(Y_i = 1)}{1 - Pr(Y_i = 1)} \right) = \alpha + \sum B_k x_k + B_{(k,i)} \omega Y_i
\]

(1)

where:

- \( Y_i \): binary vector (infected or not)
- \( \alpha \): intercept
- \( B_k \): parameter estimates for vectors of \( k \) sociodemographic characteristics of \( X \)
- \( B_{(k,i)} \): contagion effect
- \( X \): network’s entity (enterprise)
- \( \omega \): weighted adjacency matrix
- \( \omega Y_i \): direct network exposure
Within this model, significant estimates for $B_{t(k+1)}$ indicate a contagion effect by showing that network exposure is associated with adoption. Contagion effects may be modeled in different ways [7]. Multiple sociodemographic characteristics can also be considered within this model. Consistent with this approach, we present our ERP diffusion parameters and model in the following section.

3 Proposed ERP diffusion model

Rapid market penetration is a key success factor for ERP providers as it allows them to obtain detailed knowledge of industry-specific processes and to adapt their solution offering accordingly. Empirical observations in key sectors suggest that ERP vendors that successfully build a significant critical mass of users within an industrial sector generally have an increased adoption rate of their products. Anecdotal evidence suggests that such “winner takes all” phenomena may underlie the diffusion of ERP systems. This has been observed in sectors such as the pharmaceutical, aerospace, and oil and gas industries.

From a diffusion perspective, ERP systems exhibit network externality as their usefulness depends on the number of adopters [16]. This economic phenomenon emerges when the value of goods is directly linked to the installed base of the product. The greater the critical mass of users of a certain network, the more value its product will have for the customers. ERP system adoption is exposed to network externalities for various reasons:

- **Technological standards**: Subsidiaries of the same parent company and business partners in the same supply chain experience operational benefits when they adopt the same software package. Business integration and financial consolidation are easier when common information systems are used;

- **Built-in best practices**: The more a given system is adopted, the broader its coverage in terms of best practices. A later adopter will seek to benefit from all the improvements that are built into the ERP system through its successive implementations in similar organizations; and

- **Information diffusion**: The ERP offering is large and includes hundreds of packaged solutions. The vast majority of firms that consider adopting an ERP system have no previous experience with this type of information system. Their knowledge is often limited to information gained from communication with commercial partners. The probability that they will consider a given solution is therefore higher if their partners have adopted it.

Because of these network externalities, it is likely that the adoption decision of a firm may influence other organizations in the same sector. We may therefore argue that companies evolving in an industry in which a specific ERP system has been adopted by a wide number of members are more likely to adopt the same software. This thesis is based on an epidemiology argument: a company surrounded by business partners “infected” by an ERP system will be more “exposed” to the benefits of adopting the solution from the same software vendor.

The central concept of this argument is the notion of exposure. Exposure of a node in a network at a certain point in time is the proportion of its neighbors who have already adopted and may provide information and influence with regards to some behavior [7]. From a diffusion point of view, exposure can be defined by the proportion of adoption in the surrounding network partners, either directly or indirectly connected. Direct exposure for an individual is simply calculated by summing the number of contaminated neighbors. As we argued that interlocking directorates
may provide a transitive conduit to second degree nodes and therefore contribute to an indirect exposure to the phenomenon, we are interested in measuring the impact of the indirect degree of influence of previous adopters. Thus, our first postulate is that:

**P1. The indirect exposure of an individual node in terms of board interlocks will be positively related to its ERP adoption potential.**

Note that the notion of indirect exposure can be modeled in different ways. For this research, we propose the following measure of indirect exposure (IE):

\[
IE = \left[ (\Omega^2 - \Omega^3 - I + \Omega) \lambda \right] \otimes \left[ (\Omega^2 - \Omega^3 - I + \Omega) i^+ \right].
\]  

(2)

where:

- \( \Omega \) is the adjacency matrix with \( a_{ij} = \omega_{ij} = 1 \), when enterprise \( i \) shares at least one board member with enterprise \( j \);
- \( \lambda \) is the infection vector \( \lambda_j = 1 \), when enterprise \( j \) has adopted;
- \( I \) is the identity matrix \( [i_{ij}] \) such that \( i_{ij} = 1 \) if \( i = j \) and \( i_{ij} = 0 \), otherwise;
- \( i^+ \) is the vector \( [i^+] \) such that \( i^+_{ij} = 1, \forall i \);

\[
A \circ B = \left[ \frac{a_{ij}}{b_{ij}} \right] \text{ is the pair-wise division of } A = [a_{ij}] \text{ and } B = [b_{ij}];
\]

\[
A \bullet B = \left[ \frac{a_{ij}}{b_{ij}} \right] \text{ is the pair-wise multiplication of } A = [a_{ij}] \text{ and } B = [b_{ij}].
\]

Network structure properties, as well as an organization’s position in it, may also influence that organization’s behavior [17]. Indeed, a central organization in a network, as defined by a large number of connections with other organizations, may occupy a position of strategic significance in the overall network [18]. Centrality is therefore a key property of a node within a network and is commonly used to determine the relative importance of a node within a network [19]. The Freeman’s degree of centrality measure (DC) is simply measured by:

\[
DC = \Omega i^+.
\]  

(3)

where:

- \( \Omega \) is the adjacency matrix with \( a_{ij} = \omega_{ij} = 1 \), when enterprise \( i \) shares at least one board member with enterprise \( j \);
- \( i^+ \) is the vector \( [i^+] \) such that \( i^+_{ij} = 1, \forall i \).

Extensive theoretical and empirical results support the argument that highly central organizations are in a good position to innovate [20]. As explained by Liu et al. [20], there are several causal mechanisms underlying this argument. First, if centrality is taken as a proxy for the quantity of
critical resources available to an actor, it may be argued that highly central actors are more likely to have slack resources which foster experimentation [21] and facilitate innovation [6]. Second, a highly central organization is at the confluence of a large number of information sources. Highly central organizations may therefore be more likely to receive ERP related information. Based on this evidence, our second postulate is that:

**P2. The centrality of an individual node in terms of board interlocks will be positively related to its ERP adoption potential.**

Finally, we recognize that, as largely discussed in diffusion research, an organization’s characteristics also influence its adoption potential. Among organizational characteristics, greater size has been most consistently related to adopter innovativeness [22]. As argued by Tornatzky and Fleischer [23], size serves as a proxy for other positively related variables, such as scale, wealth, specialization, and slack resources. Furthermore, the importance of ERP acquisition and implementation costs may limit smaller company’s adoption of such systems [24, 25]. Based on this evidence and on the selection of sales revenue as a measure of size, the last postulate is that:

**P3. Firms with important financial capability as measured by sales revenue are more likely to be adopters of ERP systems.**

Thus, based on the proposed postulates described above and equations (1), (2), and (3), our direct diffusion model takes the following form:

\[
\log \frac{Pr(Y_i = 1)}{1 - Pr(Y_i = 1)} = \alpha + \beta_1\text{Sales}_i + \beta_2\text{IE}_i + \beta_3\text{DC}_i + \beta_4(\text{IE}_i \times \text{DC}_i)
\]

\[
\text{Model 1} \\
\text{Model 2} \\
\text{Model 3} \\
\text{Model 4}
\]

where:

- \(Y_i\): binary vector (infected or not)
- \(\alpha\): intercept
- \(\beta_1\): sales
- \(\beta_2\): network exposition
- \(\beta_3\): degree of centrality effect
- \(\beta_4\): cross products of the degree of centrality by direct exposure effect

In our statistical analysis, we distinctly tested the indirect exposure effect (referred to as Model 2), the centrality effect (Model 3) and the interaction effect between exposure and centrality (Model 4).

### 4 Validation approach

In order to test our models, we gathered interlock data from the Bureau Van Dick Orbis database. Data were extracted in 2005 and represent board information from 2004. Board members of the top 1,000 Canadian public firms were recorded. Adoption decisions within this network were obtained through the analysis of ERP announcements using keywords co-location in Dialog’s PR Newswire database. We collected information in relation to the adoption decisions regarding four ERP systems. In our statistical analysis, we separately tested the socio-demographic effect (referred to as Model 1), the exposure effect (Model 2), the centrality effect (Model 3), and the
interaction effect between exposure and centrality (Model 4). All results were statistically analyzed with UCINET and SPSS software, as presented in the following section.

5 Results

The four models were tested for 4 ERP systems adopted within the top 1,000 Canadian public firms. Our statistical results, obtained with UCINET and SPSS, are presented in Table 1.

Sales revenue appears to have an impact; firms with larger sales revenue are more inclined to adopt enterprise systems. This finding is consistent with previous literature stating that large organizations were the first adopters of this technology.

When we add network exposure in model 2, its impact is significant in each of the four cases. Network exposure adds between 3.9% and 15.1% to the explained variance.

In model 3, we add the centrality variable to the equation. Centrality also exhibits a positive and significant impact on diffusion, adding between 2.8% and 8.6% to the explained variance. Yet, something unexpected happens in model 3. When centrality is included in the model, the beta values of network exposure become negative and significant for ERP A and ERP B technologies, but positive and not significant for ERP C and ERP D technologies. This implies that centrality has a moderating effect on the relationship between network exposure and the dependent variable. This moderating effect is confirmed by the negative and significant cross-product introduced in model 4. This last model adds between 0.5% and 1.1% to the total explained variance.

Overall, model 4 explains between 19.80 and 26.00 percent of the total variance, correctly classifying between 71.4 and 78.3 percent of the cases.

6 Discussion

Our results suggest evidence related to the diffusion of ERP technologies in business networks. It appears that the decision to adopt ERP technologies is correlated with those of close neighboring network partners. This finding is clearly in line with the institutional theory [26] which argues that homogeneity of organizational forms and practices is driven by coercion, norms and, mimesis. In their decision to adopt, firms are likely to look at the behavior of their close partners to make a choice that will be coherent with the industrial logic. As previously explained, there are tangible benefits to adopting an ERP technology that is the norm in an industry.

This research reveals unexpected findings with regards to centrality. We do find evidence that the number of links tying firms to the rest of the network influences the adoption decision. This result suggests that the number of links will lead to a greater probability of “contamination” by the adoption decision of the network partners. Yet, we find what could, at first, look like a contradicting result. The interaction between network exposure and centrality has a negative impact on adoption. In other words, a firm may choose not to adopt or to adopt a different technology in a very homogenous subnetwork when this firm has a high number of links. We could describe such a firm as very independent in its decision-making process. Such a connected firm probably enjoys a dominant role in this subnetwork and the resulting power grants it the freedom to make an independent technological decision. Being able to impose a standard, such a firm probably looks for technology that better fits its business needs, leaving to its partners the responsibility of developing the necessary interface to connect to this non standard technological choice. This result is also consistent with the status-based argument put forward by Rogers [6]
stating that a highly central player is unlikely to imitate widespread practices that are already in use by the followers. Rather, the former will either innovate or imitate other highly central actors [20].

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
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</table>
Finally, sales revenue also appears to have an impact. Firms with greater sales revenue are more inclined to adopt enterprise systems. This finding is consistent with the previous literature stating that large organizations were the first adopters of this technology.

Overall, the models explain between 19.80 and 26.00 percent of the total variance, classifying correctly between 71.4 and 78.3 percent of the cases.

7 Conclusion

Our results suggest that board interlocks influence the diffusion of ERP systems. Specifically, network exposure has a direct influence, while centrality seems to be a moderating factor. It seems that enterprises with high centrality may have enough freedom to select a software solution without being swayed by other firms in their close network.

We recognize the limitations regarding the utilization of the proposed models. Only one internal parameter, namely sales revenue, has been investigated. Also, only one type of tie, board member interlocks, has been analyzed so far.

Nevertheless, the actual results demonstrate the need to study the ERP diffusion process from an epidemiologic perspective. Our next goal will be to improve our analysis by adding the effects of some relevant internal parameters in ERP system adoption and including additional network tie types. We are also planning to enlarge the scope to North America and to segment the analysis by industry, in order to have a better comprehension of the networking adoption behavior. Exploration of homogeneous and heterogeneous industries, like Oil and Gas versus Retail, for example, will be part of our next analysis.
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References


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