The interplay of uncertainty, structure and trust on the diffusion of management accounting and control systems: An agent based modeling approach

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Abstract: This study attempts to investigate the interplay of uncertainty, structure and trust on the diffusion of a subset of management information systems, namely management accounting and control systems. The article suggests that under conditions of uncertainty, trust and structure are significantly associated with the success of the implementation process. On the other hand, the importance of trust and structure is less significant when the management accounting and control system is not perceived as threatening to organizational actors. The study draws on social network theory and proposes an agent based modeling approach to study the interplay of uncertainty, trust and structure on the diffusion process.

Keywords: uncertainty, trust, structure, innovation, diffusion, management accounting and control systems, computer simulation, agent-based modeling, social networks.

1. Introduction

In the last two decades, new management accounting and control systems (MACS) (e.g. Activity Based Costing, Balanced Scorecard, Enterprise Resource Planning) have been introduced in organizations. Nevertheless, in spite of being widely recognized as good systems or practices, they have often been perceived as being problematic to implement (e.g. Argyris et Kaplan, 1994; Cooper et al. 1992; Anderson et Young, 1999; Malmi, 1997; Granlund, 2001; Scapens and Roberts, 1993; Kasurinen, 2002) and have acquired a notoriety of being controversial (Vaivio, 2004). The introduction of such innovations threatens operational members, as they dissipate local islands of power and open up a new realm for management accountants in operational units. Granlund (2001) notes that there is always something unpredictable underlying accounting system change and this unpredictability largely involves human factors. Most implementation problems are neither attributable to technical flaws but to organizational issues namely resistance to change (Malmi, 1997). Given the diversity of MACS and contextual factors, different manifestations may emerge (i.e. strong or weak resistance/opposition) and affect the success of the diffusion process. Sulaiman and Mitchell (2005) provided a typology of management accounting change to predict the likelihood of success of implementing management accounting innovations. Based on data collected from case studies, they argued additions and replacements of new techniques are problematic to implement and have a relatively low likelihood of success to implement. On the other hand, management accounting changes as modification of information outputs and operational modifications are less problematic and have a relatively high likelihood of success. Therefore, the more radical and controversial an innovation ought to be, the more employees will resist the change and the less likelihood the success of the implementation process.

To cope with the uncertainty and resistance to change underlying the implementation process, recent studies have highlighted the importance of trust and structural patterns during the change process. Masquefa (2008) argued that the implementation of a MACS depended on the structural position of management accountants and their ability to develop trusted ties with actors in

operational units. When organizational actors are resistant to change, trust operationalized through strong ties are more suitable conduits to implement MACS because the trust component of the relationship helps overcome resistance to change.

In a similar vein, Emsley (2005) posited that the more management accountants interact with operational members, the more the likelihood they develop trust and the higher the likelihood business unit management accountant will implement management accounting systems. This situation is especially relevant for radical innovations. Citing the work of social identify theorists (Janis, 1982; Tajfels, 1978), he argued that resistance to change could be minimized when management accountants with a business unit orientation become a member of the "in" group (i.e. the business unit) and, consequently, will find it less difficult to get their views accepted within the business unit than management accountants with a functional orientation who will be viewed as members of an "out" group. The cited studies (Emsley, 2005; Masquefa 2008) argued that the success of the implementation process is contingent to the development of trust, which, in turn, is affected by an organization's structure.

To model the effect of uncertainty, trust and structure on the success or failure of the diffusion process, we draw on a social network theory, the strength of ties, and the results of a research action that traced the implementation of a MACS in an IT company (see Masquefa 2008).

In organization theory, several authors have emphasized that diffusion of innovations was embedded in the properties of ties. What determines the strength or the weakness of a tie is the relational aspect of two or more persons. Granovetter (1973) defines the strength of a tie as a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie. According to Granovetter (1973), whatever is to be diffused can reach a large number of people, and traverse greater social distance (i.e., path length), when passed through weak ties rather than strong. Weak ties are more likely to link members of *different* small groups than are strong ones, which tend to be concentrated within particular group (Granovetter, 1973, p.1376). Granovetter (1982) notes that weak ties provide people with access to information and resources beyond those available in their own social circles. However, when the innovation is controversial, that is, when it threatens the status quo in terms of standard routines of how decisions are made, then resistance to that change must be addressed before predictions can be made about the success of that change effort (Krackhardt, 1992, p.238). A major resource that is required to bring about such change is trust in the propagators of that change (Krackhardt, 1992, p.238). Granovetter (1982) recognized that strong ties have greater motivation to be of assistance. Citing Pool (1980), he added that strong ties are more likely to be useful to the individual when he is in an insecure position and someone in such insecure positions will develop strong ties to reduce uncertainty and protect himself. Moreover, Krackhardt (1992) and Krackhardt and Stern (1988) posited that in case of severe change and uncertainty, people resist change and uncomfortable with uncertainty, strong ties constitute a base of trust that can reduce resistance and provide comfort in the face of uncertainty. Without current interaction, there is little opportunity to share critical or confidential information. Without the history, there is no experience to know how the other will use the confidential information or who he or she will share it with (Krakhardt, 1992, p.219). Thus, controversial change is not facilitated by weak ties but rather by strong ties.

However, large structures impede the diffusion of innovations through strong ties since individuals tend to interact more with the persons within their sub-unit rather than across sub-units. This is illustrated by Granovetter (1973, p.1364) "*no strong tie is a bridge*… a strong tie can be a bridge, therefore, *only if* neither party to it has any other strong ties, unlikely in a social network of any size (though possible in a small group). In large networks it probably happens only rarely, in practice, that a specific tie provides the only path between two points. When dealing with distant sub-units, people tend to communicate through weak ties. Weimann (1980) suggests weak ties provide "the 'bridges' over which innovations cross the

boundaries of social groups…whereas the influence on the decision making is done mainly by the strong ties network within each group" (1980, p.21). In a similar vain Blau (1974, p.623) argues that since "intimate relations tend to be confined to small and closed social circles…they fragment society into small groups. The integration of these groups in the society depends on people's weak ties, not their strong ones because weak social ties extend beyond intimate circles (Granovetter, 1973) and establish the inter-group connections on which macro-social integration rests." Granovetter (1982) concludes Steinberg (1980) by asserting that there is an existing, intricate interplay between weak and strong ties in structuring outcomes and mediating the competing claims of various community groups. Drawing from social network theory and the strength of ties argument in the diffusion of a management accounting and control system, Masquefa (2008) found that:

-When the management control system innovation was not perceived as threatening, that is when uncertainty was low or without resistance to change, weak ties provided efficient conduits as they provided bridges to distant organizational units. When the degree of controversy of the innovation was low, i.e. when uncertainty was low, the strength of weak ties argument held and individuals transmitted information over weak ties. Under these conditions, information circulated among the dense strong ties within a clique and could freely make the jump over weak tie bridges to adjacent cliques. This rendered weak ties "strong" because they could serve as vital inter-island links (Frenzen and Nakamoto, 1993). Therefore, we proposed the first hypothesis:

H1: MACS innovations that are not controversial will diffuse successfully, regardless the trust level and the amount of structure.

–When the innovation was perceived as threatening, that was when uncertainty was high or with the presence of resistance to change, stronger ties rather than weaker ties, were more suitable conduits to implement management accounting and control systems because the trust component that had been developed through frequent interactions helped to overcome resistance to change. When the degree of controversy was high, individuals were reluctant to transmit the information through weak ties. Information could no longer jump over weak tie bridges to adjacent cliques and instead, became trapped within the clique that first received or originated the information: information flow through the network may then cease. Under these conditions, inter-clique information flow depended on anomalies in the island-bridge structure of the network (see Frenzen and Nakamoto, 1993). In other words, information flow will be observed only in the relatively rare instance where strong (rather than weak) ties link together the members of different cliques. Therefore, we proposed our second hypothesis

H2: MACS innovations that are controversial will diffuse successfully with increasing levels of trust and with lesser amount of structure.

The above theoretical development suggests that successful diffusion is a combination of uncertainty, structure and tie strength. Individual perceptions and tie strength within a social network have a direct effect on the diffusion process of MA change. The success to implement controversial management accounting innovations is more likely to occur when the innovators have strong ties within and between organizational units. Therefore, the study intends to explore simultaneously the interaction of three variables, namely uncertainty, structure and trust on the success or failure of the implementation of management accounting innovations.

2. Methods

In order to explore the interacting effects of uncertainty, structure and trust on the diffusion of a management accounting innovation, the present study introduces an agent based model computation simulation. Simulation is particularly useful for theory development when simple theory exists, that is undeveloped theory with few constructs and related propositions with modest empirical or analytical grounding (Davis et al., 2007). Simulation is useful when the theoretical focus is longitudinal,

nonlinear or processual, or when empirical data are challenging to obtain and enables the elaboration of rough, basic theory that is often derived from inductive cases or formal modeling into logically precise and comprehensive theory (Davis et al., 2007). Simulation involves creating a computational representation of the underlying theoretical logic that links constructs together within these simplified worlds. These representations are then coded into software that is run repeatedly under varying experimental conditions in order to obtain results.
Among the richness in variety of computational simulation, we have chosen agent based modeling because the primary unit of study is the agent, or individual. Agent based modeling is best suited to domains where the natural unit of analysis is the individual and when both micro-level behavior of individuals and macro-level patterns from the interactions of these individuals are of interest. Agent modeling provides a methodology in which these patterns can be replicated (behavioral) and then manipulated to study contingent outcome.

The operationalization of our theoretical constructs, the assumptions that bind the theory and results and the process of the simulation are described as follows:

Our first construct, structure, is represented through a social network composed of organizational agents. Ties or links may exist (positive value) or not (null value) among organizational agents. Our network is composed of n agents, and the strength of the ties between the agents is represented by a n*n matrix. Organizational agents are grouped into organizational sub-units or cliques. Our network is composed of 10 cliques with 15 people in each sub-unit. The organizational structure is modeled through two levels of tie density, one density for ties within cliques and one density for ties between cliques. In accordance with social network theory, organizational actors tend to communicate more with other actors from the same cliques rather than between cliques (i.e. division of labor). However, several organizational structures have been modeled from more mechanistic to more organic (Burns and Stalker, 1994). The first structure “90-10” (cf. figure 1) indicates that within-clique, the density of ties is 90% and between-clique, the density of ties is 10%. This structure[1] is an illustration of a hierarchical, centralized, mechanistic structure with highly cohesive sub-units. Along this continuum, we have modeled structures that tend to be more organic. An illustration is the 65-25 structure with a density of 65% of ties within-clique and 25% of ties between cliques. We are assuming here that the organizational boundaries are becoming blurred and more interactions are taking place between sub-units. We have purposely increased the amount of interactions between subunits and reducing the interactions within sub-units to study their impact on the diffusion process.

Our second construct, trust, is operationalized through the strength of ties. The innovation is interpreted within an existing social context. Each acquaintance has an associated tie strength which is a measure of the strength of the relationship from the agent to her/his acquaintance. The stronger the tie, the closer two organizational agents are likely to be and the greater the likelihood of adoption of the innovation. When a tie exists (value≠0) weak ties and strong ties are randomly assigned through a continuum from 0 (weak tie) to 5 (strong tie) according to two densities: one density for the strength of ties within a subunit and one density for the strength of ties between subunits. Density of strong ties is a proportion of strong ties computed as the actual number of strong ties that a unit engages in divided by the total number of possible strong ties that a unit could engage in. The distribution of the tie strength is modeled with two normal distributions. One distribution refers to within-clique ties and the second distribution refers to between-clique ties. The distribution used for within-clique ties tends to be denser with more strong ties whereas the distribution for between-

[1] An organic structure may be associated as an interconnected structure, agile and learning organization, able to adapt rapidly allowing for cross-pollination and learning. Therefore our 10-90 structure would be the case of an interconnected medium size company that has a low division of labor in which the 150 employees are free to communicate with anyone else to achieve their objectives. On the other hand, a 90-10 structure is hierarchical, centralized and organized around the division of labor in which employees are clustered within groups.

clique ties tends to give more weak ties. Therefore we have imposed at the start of the simulation two values for within clique and between clique average tie strength. These average values are respectively 3.8 for within-clique and 1.6 for between –cliques. The existence of a tie between two individuals is assumed to be symmetric, however the strength of a tie is not.

Our third construct, uncertainty, depends on the controversy of the innovation (see Sulaiman and Mitchell typology). The controversy of the innovation is modeled with a transmission threshold (an arbitrary value). The controversy threshold represents the difficulty that the innovation will be transmitted from an adopter, an organizational agent that is in favor of the proposed innovation, to a non-adopter, a person that has not adopted the innovation. It is the minimal tie strength needed for the innovation to be implemented. For instance, an agent will proselytize other agents in favor of the innovation only if a certain level of tie strength exists. The success of the adoption is a function of whether a tie exists and whether the strength of the extant tie exceeds the transmission threshold. We have arbitrarily selected different degree of controversy for our innovation. The controversy rate ranges from 2.8 (figure 1) to 3.9 (figure 4). We have therefore increased the controversy of the innovation.

Finally, the simulation process is described as follows. Initially, only one organizational agent is an adopter. After successive iterations, the initial adopters will intend to convince non-adopters. If the strength of a tie is above the controversy threshold, the innovation is transmitted through the strong tie and the non-adopter becomes an adopter. We performed successive iterations and when each run converges towards stable values –in terms of intra-clique and inter-clique densities and controversy parameter values, we count the number of adopters and calculate the mean of adopters at the end of each iteration. The simulation is run 20 times with the same parameters. Then we capture the speed and effectiveness, represented by the maximum number of adopters, with diffusion curves.

3. Results and discussion

We postulated that structure, tie strength and transmission threshold will determine the success or failure of the implementation process. This section presents the results of our simulation. We have varied the values of our constructs: uncertainty, structure and trust in order to fully explore the effects of the constructs on outcomes. We purposely present the following most intriguing results. Figures 1 through 4 represent diffusion patterns with controversy rates ranging from 2.8 to 3.9. Each curve depicts a different organizational structure. The S-curve indicates the number of organizational actors and the cumulative number of adopters that have adopted the innovation at every period during 15 successive time periods. The innovation has successfully diffused if the 150 organizational members have adopted it.

Figure 1 represents the diffusion pattern of an innovation characterized by a low degree of uncertainty (i.e. modification of information outputs and operational modifications). The results show that all the organizational actors have adopted the innovation. Indeed, after the third iteration, the innovation diffused within the ten organizational units.

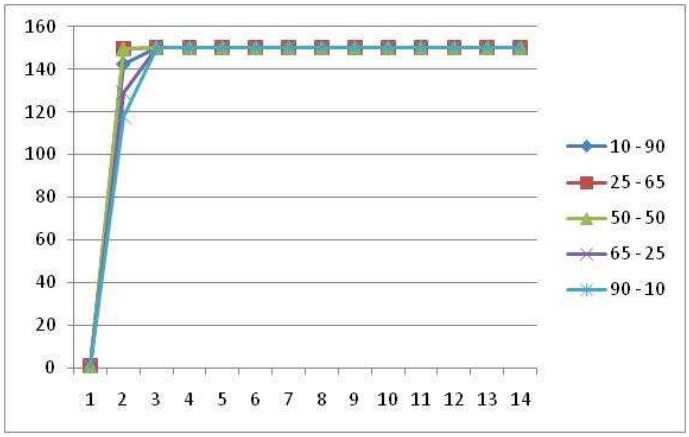

Figure 1: diffusion pattern with controversy rate = 2.8

In this particular case, the innovation diffuses effectively under the four organizational structures and independently of the strength of the ties. Therefore, when management accounting and control systems are perceived with a low degree of uncertainty with relatively low levels of resistance

to change, both weak ties and strong ties provide efficient conduits and propagate management accounting systems because they provide bridges to distant organizational units. The strength of weak ties argument holds. Individuals transmit information over weak ties. Under these conditions, information circulates among the dense strong ties within a clique and can freely make the jump over weak tie bridges to adjacent cliques. This renders weak ties "strong" because they can serve as vital inter-island links. These results support H1, that is, management accounting and control systems that tend to be less controversial have a higher likelihood of being implemented successfully in organizations. Varying the amount of structure and the level of trust are not significantly associated with the success or failure of the diffusion process.

Figure 2 depicts the diffusion patterns of a management accounting and control system with a higher degree of controversy (i.e. additions and replacements of new techniques). As the degree of controversy increases, the importance of the amount of structure and the social context become increasingly important.

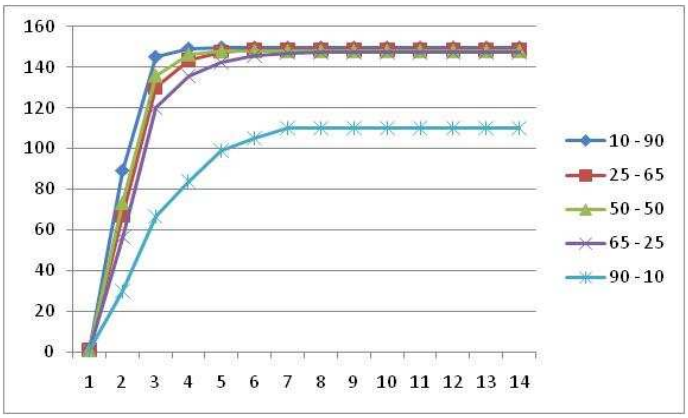

Figure 2: diffusion pattern with controversy rate = 3,5

The diffusion patterns provide support for the importance of structural arrangement and trust in the diffusion process. On one hand, the results suggest that tighter structures (structure 90-10) are ineffective in the implementation of controversial management accounting and control systems. This inverse relationship between the amount of structure and the success of the diffusion process occurs because, when the degree of controversy is high, individuals are reluctant to transmit the innovation through weak ties. The innovation can no longer jump over weak tie bridges to adjacent cliques and instead, becomes trapped within the clique: innovation flow through the network may then cease. Under these conditions, inter-clique diffusion depends on anomalies in the island-bridge structure of the network. In other words, innovation diffusion will be observed only in the relatively rare instance where strong (rather than weak) ties link together the members of different cliques. On the other hand, figure 2 suggests that more organic organizational structures (respectively 50-50 and 25-65) are more effective at diffusing controversial innovations. The increasing amount of connectedness between organizational units is beneficial for the diffusion of the innovation. Organizational agents spend more time with other agents from different sub-units and develop trust relations. Stronger ties rather than weaker ties, are more suitable conduits to implement controversial management accounting and control systems because the trust component that has been developed through frequent interactions helps to overcome resistance to change. These results support H2, that is, controversial management accounting and control systems are more likely to be successfully implemented when organizational structures are organic and when they foster the development of trust between organizational units. Therefore, varying the amount of structure and the level of trust are significantly associated with the success or failure of the diffusion process. These results are also consistent with Emsley (2005) and Masquefa (2008) who argued that the structural position of accountants in organizational network and the relationship they maintained with out-group member had a positive effect on the likelihood of the success of the implementation of management accounting innovations.

The evidences provided above suppose that the lesser the amount of structure, the higher the likelihood of success in implementing MACS. Figure 3 and figure 4 reveal that radical innovations (controversy parameter=3,8 and 3,9) tend to diffuse with different effectiveness.

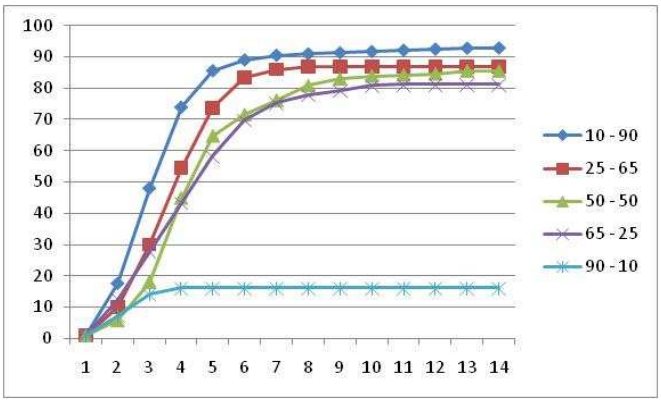

Figure 3: diffusion pattern with controversy rate = 3,8

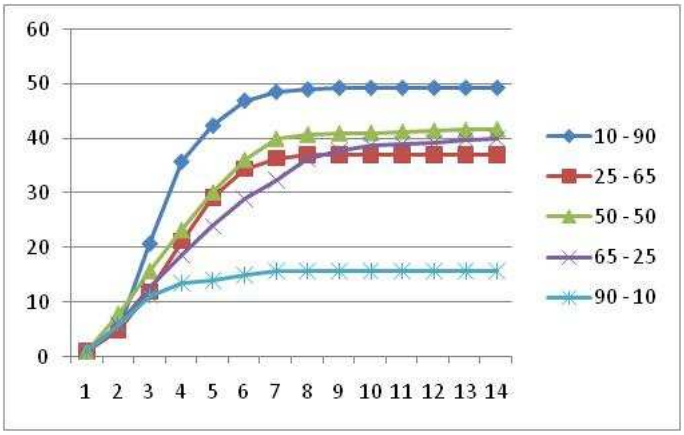

Figure 4: diffusion pattern with controversy rate = 3.9

Although none of the diffusion curves reaches the total number of adopters, more organic structures provide a more effective diffusion process although the increasing benefits of a less amount of structure are not as beneficial as anticipated. Actually, the marginal effectiveness in increasing between-clique ties decreases with the amount of uncertainty. This finding suggests the important role of a moderate amount of inter-clique ties in the success of the diffusion of the innovation.

The above results were obtained with an average value of 3.8 for within-cliques ties strength and 1.6 for between-cliques ties strength. However, if one group increases the number of interactions with other groups then trust is likely to emerge from agents belonging to different groups (inter-clique strong ties). However, strong ties require more time to maintain than weak ties (Granovetter, 1973) and consequently stronger ties within cliques will tend to decrease. To fully capture the effect of the trust between organizational actors, we manipulated the densities of ties of within-cliques and between-cliques ties[2] (see figure 5 and table 1). Interesting results emerge from Figure 5 and table 1. Firstly, the diffusion process in more mechanistic structures is increasingly unpredictable. It suffices that only one agent from one group rejects the MACS innovation so that the whole group rejects the innovation. This argument has been documented in the management accounting literature (Granlund, 2001; Masquefa, 2008). For example, Masquefa (2008) noted that one weak inter-clique tie from the project team and one R&D division could hinder the MACS diffusion to the whole R&D division. Overall, organic structures tend to have less erratic behavior and provide more stability, that is, the likelihood of success in a change process would have more predictable outcomes.

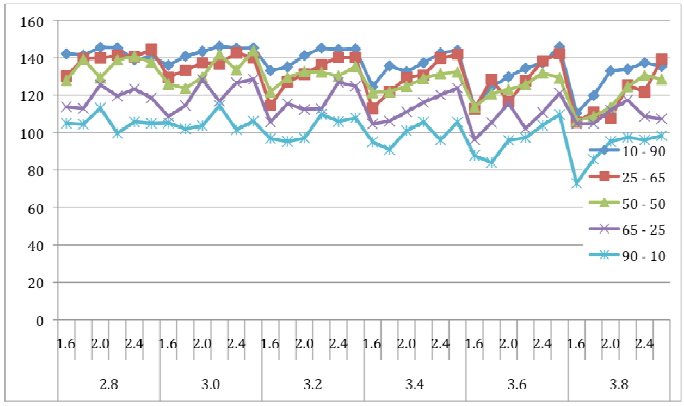

Figure 5: diffusion pattern combining controversy rates of 2.5; 3.5; 3.8; 3.9 and diverse inter- and intra clique densities

	types of structures				
	10-90	25-65	50-50	65-25	90-10
mean	112,626	98,469	94,814	62,969	35,914
standard deviation	22,490	28,602	20,079	19,446	14,640
coefficient of variation	0,200	0,290	0,212	0,309	0,408

Table 1. Statistical analysis for different structures

[2] Figure 5 reads as follows: a 90-10 structure is more centralized, therefore trust densities will be neighboring 4,0 (intra-clique) and 1,5 (inter-clique) while a 10-90 structure is more decentralized and the trust densities will be neighboring 2,8 (intra-clique) and 2,6 (inter-clique).

Secondly, overall, the best performing structures are the 10-90, 25-65, 50-50. However, above the 50-50 structure, decreasing the amount of structure is not as beneficial as anticipated. More organic structures (50-50; 25-65 and 10-90) tend to provide a similar likelihood of success in the diffusion process. Notwithstanding, there is a wide performance gap between the 90-10 and the 65-25 compared to the more organic structures. Finally, surprisingly, organic structures (i.e. 10-90 structure), tend to have a slight decrease of effectiveness as we increase the density of inter-clique strong ties -"wave-like" pattern- within the same range of intra-clique parameter value. Therefore, up to some point, increasing the density of *strong* inter-clique ties is negatively related to the effectiveness of the diffusion process. The marginal benefits of increasing the number of strong inter-clique diminishes the likelihood of successful diffusion.

4. Limitations and conclusion

This article is an attempt to explore the interplay of uncertainty, structure and trust in the diffusion of management accounting and control systems. The results suggest that when uncertainty increases, organic structures are conducive to the development of strong ties between cliques favoring the success of the diffusion process. Overall, more mechanistic structures perform less effectively when MACS innovations are increasingly radical. Furthermore, the study points to the fact that decreasing the amount of structure is not proportionally related to the success of the diffusion process. Therefore, moderate level of inter-cliques ties and inter-clique strong ties increase significantly the likelihood of success on the diffusion process. Therefore managers ought to evaluate the amount of structure, the development of trust and the controversy of the innovation before its implementation process. The study reveals that context (trust and structure) and content (MACS innovation) have a direct impact on the adoption process.

The methodology used in this study is novel in the field of management accounting. Among the many benefits and limitations of simulation methods, one of the often cited limitations is its lack of external validity. The research presented here builds on an action research so that the constructs and the logical underpinnings are drawn from real evidences, therefore, reinforcing our findings. Notwithstanding, our research suggests that resistance to change is inherently linked to the innovative management accounting and control systems. However, resistance may emerge through the process of persuasion and needs to be addressed and extended in future research. Our simulation is based on a building block approach (Harrison et al., 2007). We decided to start our study of the diffusion process with a simple model and then elaborate it and adding complexity in a stepwise fashion (i.e. size, hierarchy and negative relationships). This simulation approach enables the researcher to understand the behaviors of a simple model and then to study the consequences of extending them (Harrison et al., 2007).

A second limitation concerns the inferences drawn from simulation findings (Harrison et al., 2007). Harrison et al. (2007) note that "the simulation findings are only demonstrated for the region of parameter space examined experimentally; generalizations beyond this space can at best be considered conjectures (while inferences based on the parameter values studied can be considered hypotheses of the model)". To avoid the inference limitations, we have attempted to provide a wide range of parameters to increase the validity of our results.

Agent based modeling can be fruitful in a number of areas of management accounting. Potential areas of research are diffusion of innovations, organizational change, the study of Inter-Organizational Relationships (IOR), the dialectic of innovation and control in management accounting and control.

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