Conceptualizing and Modeling Multi-Level Organizational Co-Evolution

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Abstract This chapter stresses the need for research in organizations to reflect the co-evolutionary and complex nature of the changing world we live in today. We argue that key concepts can be abstracted from biological evolution, and used as a starting point for the conceptual development of such approaches. In addition, computational modeling techniques can be used not only as a tool for shaping this conceptual development, but simulating changing behaviors at multiple levels in real organizations. While a number of researchers have developed co-evolutionary accounts of organizational change, these efforts have been constrained by an entity interpretation of the unit of co-evolution. In this latter view, it is assumed that organizations act as vehicles for bundles of routines, being subject to external selection forces only. As a result change occurs largely through the actions of customers or senior executives. We argue that practice-based interpretations offer an alternative approach in the modeling of co-evolution, unpacking the complexity and interconnected agency within and beyond organizations. Building on these conceptual foundations, we outline key conceptual, empirical and ethical challenges in developing related computational models. We argue that such simulation models can be used by managers to help them navigate complex future worlds.

1 Introduction

As we move into the 21st century, organizations find themselves increasingly interconnected with other firms, customers and stakeholders in fast moving business environments. Faced with these turbulent and competitive changes, firms need not only to adapt, but to co-evolve in order to survive (Murmann, 2013). In addition to the pace of environmental change, business environments are increasingly complex and interconnected (McCarthy et al., 2010), and a co-evolutionary approach is well suited to study such regimes of change, with some calling for research to adopt a 'more encompassing, co-evolutionary perspective' (Lewin & Volberda 2012, p. 242). In the co-evolutionary view practices, competences and strategic initiatives are seen to co-evolve through the interaction of individuals, groups, and managers (Rosenkopf & Nerkar, 1999; Lewin & Volberda, 1999; Volberda & Lewin, 2003), as organizations adapt to meet the changing needs of the external environment. In this sense, co-evolution can be defined as the joint evolution of entities at multiple levels (Campbell, 1990; Lewin & Volberda, 1999; Murmann, 2003) where changes of one entity/level influence changes at other entity/levels (Kauffman, 1993; McKelvey, 1999). In this narrative, the focus of the story shifts from that of the visionary, directional entrepreneur or senior executive (that one still finds in the financial and business press), to a complexity of voices,

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interrelationships and co-evolving parts, reflective of what most practicing managers experience in their daily lives.

The notion of co-evolution offers scholars the potential to draw from similar approaches taken in other areas of research beyond organization studies, 'integrating micro- and macro-level evolution within a unifying framework, incorporating multiple levels of analyses and contingent effects, and leading to new insights, new theories, new empirical methods, and new understandings' (Lewin & Volberda, 1999, p.520). A number of researchers have explored the notion of co-evolution (Volberda & Lewin, 2003; Rodrigues & Child, 2003), with studies examining (co)evolutionary processes in internationalization strategies (Koza et al., 2011), off-shoring of business services (Lewin & Volberda, 2011), networks (Dantas & Bell, 2011), organizational adaptation (O'Reilly & Tushman, 2008), organizational learning (Crossan et al., 2013) and organizational practices (Pentland et al., 2010; 2012). Despite these recent calls for a co-evolutionary narrative, few studies have drawn from the theoretical approaches used to study co-evolutionary processes in other scientific domains such as biology, psychology or cultural evolution (Abatecola, 2012; 2014; Breslin, 2014; Murmann, 2013). A number of these latter researchers have used the variation, selection and retention framework from evolutionary theory to put forward conceptual descriptions of multi-level evolution within organizations (Aldrich, 1999; Baum & Singh, 1994; Breslin, 2011a; Murmann, 2003; Rosenkopf & Nerkar, 1999). We argue that this variation-selection-retention framework provides a solid foundation for the conceptual development of organizational co-evolution.

Given the complexity of organizational co-evolution, some researchers have developed computational models as a means of advancing theory, building on the evolutionary concepts of variation-selection-retention (Breslin, 2014; Bruderer & Singh, 1996; Lant & Mezias, 1990, 1992; Mezias & Glynn, 1993). However many of these accounts assume that the organization behaves as one, with an all powerful top management team making choices on behalf of the wider firm (Bruderer & Singh, 1996; Lant & Mezias, 1992; Mezias & Glynn, 1993). As argued above, this latter perspective seems to be at odds with the view that most organizations are characterized by a complexity of interacting parts. Therefore in this chapter, we seek to make a contribution towards this project, exploring the potential of a co-evolutionary approach to study multi-level change in organizations. Given the complex longitudinal nature of changing behavior in organizations, we argue that the development of theory can be further enhanced through the use of simulation models, which allow the researcher to explore these complex processes over time (Carley & Hill, 2001; Lant & Mezias, 1990; Lomi et al., 2010). Such computational models can capture the contextual and historical complexity of changing organizational behavior (March, 2001), as the path-dependant co-evolution of interacting parts is modeled over time. However unlike previous studies of this nature, this study focuses on the co-evolution of behavior at multiple-levels between interacting individuals, based on the evolutionary mechanisms of variation, selection and retention. In addition, we examine key empirical challenges relating to the development of such modeling techniques in the simulation of change in real organizations.

2 Conceptualizing Organizational Co-evolution

In developing theory-led co-evolutionary accounts, Baum and Singh (1994) stress the importance of defining and identifying units of analysis at each level within an organizational hierarchy. This need to explicitly define units of co-evolution becomes even more paramount when developing simulation models. These co-evolving units need to be discrete classes of 'entities' with their own evolutionary path, yet at the same time interact with 'entities' at other levels. As noted above, while a number of scholars have adopted the word co-evolution to describe the multi-level interactions within organizations (see Huygens et al., 2001; Jones, 2001; Rodrigues & Child, 2003; Volberda & Lewin, 2003), few have drawn from other domains of study to further develop the theoretical foundations of such a co-evolutionary approach. Over the past 40 years an emerging group of researchers have explored the possibility of developing a theory-led evolutionary approach to studying organizational adaptation (Aldrich, 1999; Breslin, 2011b; Burgelman, 1991; Campbell, 1965; Hannan & Freeman, 1977; Hodgson & Knudsen, 2004; McKelvey, 1982; Nelson & Winter, 1982; Weick, 1979). As noted above, a number of these have developed the mechanisms of variation, selection and retention to give a conceptual account of evolution in organizations, and populations of organizations. More recently a consensus amongst a group of these scholars has emerged around the use of these three mechanisms and the additional concepts of the replicator and interactor. The replicator-interactors are abstracted concepts from biological evolution, where the replicators is defined as anything in the universe of which copies are made such as genes in the biological world. Interactors have been defined as entities that interact as a cohesive whole with their environment in a way that causes differential replication of these elements (Hull, 1988). The use of the replicator-interactor concept, alongside variation-selection-retention, has been labeled the Generalized Darwinist approach, which argues that at a sufficiently general level of abstraction a core set of general 'Darwinian' principles can be used to describe evolution within a variety of domains (Aldrich et al., 2008; Breslin, 2011b; Campbell, 1965; Hodgson & Knudsen, 2004; Hodgson, 2003), including biology, psychology, culture and economics. In this manner, whilst the details of socio-economic evolution may be different from biological evolution, the concept of Generalized Darwinism can nonetheless be used as the starting point for the development of theory in both.

Scholars who have studied organizational co-evolution through this evolutionary lens have focused on the routine as the unit that co-evolves. In many respects the adoption of the routine dates back to the notion of the 'routine as gene' introduced in Nelson and Winter's (1982) seminal work 'An evolutionary theory of economic change'. While the concept is generally defined as a collective phenomenon, whose enactment results in recurrent patterns of action (Becker, 2005; Nelson & Winter, 1982), different conceptualizations have resulted in quite distinct evolutionary narratives emerging. Some have tended to conceptualize the routine as a capability or entity (Breslin, 2015; Rerup & Feldman 2011), with a focus on how these phenomena influence wider organizational performance (Parmigiani & Howard-Grenville 2011). For instance Nelson and Winter (1982) conceptualized the routine as a reflex-like, automatic process in which individuals within a group respond to certain stimuli with a particular set of repeated actions. Through reinforcement or conditioning certain behavioral responses become associated with certain stimuli over time, resulting in repeated

patterns of actions. Interlocking, conditional, and sequential behaviors between individuals (Hodgson, 2008), and associated socio-political truces and coalitions (Cyert & March, 1963; Nelson & Winter, 1982) act to maintain the status quo. As a result, it is assumed that routines are enacted in an automatic sense, varying little over time, and so their evolution largely depends on external selection forces acting on the organization, as opposed to endogenous change by the individuals enacting them (Feldman & Pentland, 2003). This dualism of the routine and organization is carried over in the conceptualization of the replicator-interactor (Breslin, 2015). It is thus argued that the fate of these routines is inextricably linked to that of the organization (Hodgson, 2008; Hodgson & Knudsen, 2010). Over time organizations coalesce as entities, as founding entrepreneurs gain control of resources, with externals treating it 'as an ecological entity, a social unit with a life of its own' (Aldrich & Ruef, 2006, p.94). The greater the pressures for coherence within the organization, the more change will occur at the 'level of the entire entity' (Aldrich & Ruef, 2006, p.129). Organizational evolution is thus viewed as the study of self-replicating entities (i.e. routines), where replication is affected by external selective pressure (Warglien, 2002), overlooking the internal dynamics of change *within* routines themselves. However this routine-organization dualism (and associated evolutionary accounts) has been criticized, as the voice of the individual and agency is lost, excluding the possibility of intentionality, learning (Witt, 2004), motivation, creativity, imagination and deliberate adaptations (Cordes, 2006).

This routine-as-entity view has been heavily criticized not only from an evolutionary perspective (Breslin, 2011b; Witt, 2004) but from within the routines literature itself (Parmigiani & Howard-Grenville, 2011; Rerup & Feldman, 2011). Some have put forward a 'practice' view of routines (Parmigiani & Howard-Grenville, 2011), in which the focus shifts to parts of routines (Rerup & Feldman, 2011), how they are enacted day-to-day and their internal dynamics. Parmigiani and Howard-Grenville (2011) argue that the practice perspective opens the black box of routines and their internal workings in specific organizational contexts. While the definition of the routine as a repetitive pattern of actions is similar to the entity approach, the emphasis here is on how these patterns are produced and reproduced, and to what extent the patterns remain stable versus change over time (Parmigiani & Howard-Grenville, 2011). Pentland and Feldman (2005) introduced the ostensive-performative duality to conceptualize this adaptive, improvisational nature of routines. They define the performative aspect of the routine as the 'actual performances by specific people, at specific times, in specific places', as opposed to the ostensive aspect of routines which are 'abstract or generalized patterns that participants use to guide, account for and refer to specific performances of a routine' (Pentland & Feldman, 2005, p. 795). Feldman and Pentland (2003) argue that making a distinction between these two levels, captures the interaction between them as they adapt over time to suit changing contexts. Evolutionary accounts have likewise been developed in which the replicator-interactor is defined through the ostensive-performative duality (Breslin, 2008; 2011b; Feldman & Pentland, 2003; Pentland et al., 2010; 2012). In this manner, behaviors (as represented by the performative aspect) are varied and selectively retained through the ostensive aspect over time, or in other words variations in performance are selectively retained through the guiding story or ostensive aspect (Feldman & Pentland, 2003).

This ‘practice’ move marks a conceptual shift in emphasis in the story of organizational change and co-evolution. In the entity approach, change is seen to occur through the selection ‘of’ organizations which act as vehicles ‘for’ the underlying routines (Hodgson & Knudsen, 2010). In this sense, the routine represents the replicator and the organization the interactor (Baum & Singh, 1994; Hodgson & Knudsen, 2010; Murmann, 2003; Nelson & Winter, 1982). In the practice view, change is seen to occur within the routine, with variation-selection-retention acting on the mutually constitutive duality of the ostensive-performative aspect. In this ‘evolution-as-practice’ account, the performances are thus the phenotypic expression of an underlying genotypic logic as represented by the ostensive aspect (Breslin, 2015).

2.1 From Entity to Practice: Implications for the Conceptualization of Co-evolution

In this move from entity to practice, a replicator-interactor duality is proposed with the former interpreted as the ‘stored information’, and the latter it’s behavioral ‘expression’ or enacted ‘manifestation’ (Breslin, 2015; Breslin & Jones, 2012; Plotkin, 1994; Warglien, 2002). In this view knowledge cannot be seen to be accumulated or indeed separated from the specific activity or practice involved (Orlikowski, 2002). As Miner (1994) notes, many evolutionary accounts treat knowledge as entities independent of the individuals enacting them, thus ignoring social interaction. Therefore to link the replicator (as a repository of knowledge) with the socially constructed concept of the organization becomes problematic. For example, accumulated knowledge can pass between organizations and through spin-outs (Aldrich & Ruef, 2006; Breslin, 2011b; Szulanski, 2000; Szulanski & Winter, 2002). ‘So organizational boundaries are not sealed, because cultural norms and practices, institutional requirements, and flows of people permeate them’ (Aldrich & Ruef, 2006, p.130). Moreover, knowledge can be discontinued within organizations, as groups innovate, change and improvise behaviors (Argyris & Schon, 1978). Given differences in personal dispositions and life histories, pockets of knowledge can also form within subgroups, despite the pressure for coherence at an organizational level (Aldrich & Ruef, 2006). As a result organizations are rarely truly monolithic (Aldrich & Ruef, 2006). As a consequence the ‘life’ of the knowledge is not always tied to the ‘life’ of one particular group or organization. Knowledge-in-practice on the other hand is tied to the fate of the practice and not the organization. It cannot be assumed that this continually evolving knowledge-in-practice is a static entity, subject to forces acting beyond the boundaries of the group or even organization. Its maintenance or variation occurs through the continual interrelationship between local performances and abstracted structure (Feldman & Orlikowski, 2011). Therefore, it is through the individuals enacting and participating in the activity, that this knowledge is played out, and not through the actions of some distant managers pulling strings like puppeteers. The ‘replication’ of knowledge can only occur through involvement and participation of others in the activity (Brown & Duguid, 1991; Lave & Wenger, 1990), as opposed to being ‘transferred’ in some entity-like fashion. In sum, in this view the evolution of knowledge is subsumed within the practice, as individuals ‘learn to evolve’ (Breslin & Jones, 2012).

As noted above the entity view of the replicator-interactor concept assumes the organization acts as a vehicle for bundles of replicators (Hodgson & Knudsen, 2010). So with

increasing levels of organizational coherence, selective forces shift from evolving routines and schemata to the organization itself as an entity (Aldrich & Ruef, 2006). The focus of attention thus remains largely at the level of the organization, with at best managers making choices on behalf of the firm (Levitt & March, 1988), and as a result above the level of individual learning (Schulz, 2002). This becomes somewhat problematic when examining the co-evolution of routines within the organization itself. Addressing this problem, some have expanded the entity view by identifying units of evolution at different levels of analysis (Baum & Singh, 1994; Hodgson & Knudsen, 2010). For example Baum and Singh (1994) make a distinction between genealogical entities (replicators) that 'pass on their information largely intact in successive replications', and ecological entities (interactors) that are the 'structural and behavioral expressions of the genealogical entities, interact with the environment and this interaction causes replication to be differential' (Baum & Singh, 1994, p.4) at each level in the organizational hierarchy. So the 'routine-job' represents the micro-level, moving to the 'organization-organization' and 'species-population' at higher levels 2. Nascent and growing organizations can use abstractly-defined idiosyncratic jobs to build organizational knowledge and so develop routines which are better fit to the emerging market (Aldrich & Ruef, 2006). More recently Hodgson and Knudsen (2010) argue that the 'habit-individual' represent the micro-level, with the 'routine-group' and 'routine-organization' representing higher levels.

Despite the multi-level nature of these proposed solutions, there is still an inherent assumption that evolving routines are terminally tied to the individuals, groups and organizations concerned (Breslin, 2015). As noted above in many cases, this link has been focused on the organization as an entity, with the assumption being that integrative forces within the organization result in change largely occurring at the level of the firm (Aldrich & Ruef, 2006). If one assumes however, that organizational cultures are fragmented or differentiated, then clearly the unit of selection shifts within the firm itself. So, selection 'of' these individuals and groups results in the selection 'for' associated ideas, routines and knowledge (Hodgson & Knudsen, 2010). However, such an interpretation of selection downplays choices made by the individuals concerned (Witt, 2005). Selection 'for' routines gives primacy to the selective powers 'of' the world external to the phenomena (e.g. managers, customers etc). In this way, poorly performing routines eventually become extinct as managers select different groups and individuals, or customers select different organizations. On the other hand, if individuals are viewed as 'selecting' habits or routines for enactment through the choices they make, then clearly foresight, anticipation of futures, and the interpretation of feedback from the external world come to the fore.

With practice-based evolutionary accounts, the replicator-interactor concept is represented as a mutually constituted duality of cognitive representations and manifest behaviors. However most of these accounts again tend to focus exclusively on only one level of analysis. For example Pentland et al. (2012) focus on the group as a level of analysis, with routines evolving and adapting in a mutually constitutive relationship between the ostensive guide and performative aspect. However, as noted above some have identified units of analysis at different levels in the development of co-evolutionary accounts (Mesoudi, 2011;

Plotkin, 1994). So individuals and collective cognitive structures represent the replicators at the level of the individual, group and organization respectively (Breslin, 2008). The corresponding interactor depends on the 'micro-environment within which selection occurs, namely the set of actions performed by individuals, groups or firms' (Breslin, 2008, p.412). A simple example of a product design group can help illustrate Breslin's (2008) account of the co-evolutionary processes acting at each level.

Individual Level When completing a task such as an engineering calculation, individuals within the product development group can chose to select either a collective routine associated with that task, such as a 'standard calculation' routine, which they share with other members of the group, or they may chose to carry out a calculation habit which only they use. The individual can also attempt to vary replicators at both levels by changing their individual calculation habit or by persuading others to alter the more collective 'standard calculation' routine. Once selected by the individual, the routine or habit is then enacted through the individual's actions, which in turn receive feedback from external parties, such as other members of the group, managers and customers (Breslin, 2008). Based on the particular strength of these feedback signals, these variants of replicators are retained over time. So for instance if the individual interpreted the use of the calculation habit as resulting in better quality designs, the individual might choose to retain this habit over time. This individual-level evolutionary process is in turn nested within the evolution of collective routines within the group.

Group Level At the level of the group, each individual might choose to enact both individual habits, as outlined above, and collective routines. Again individuals are capable of attempting to vary and select these replicators. However, now the enactment and feedback from other group members is played out within the selection mechanism of the group. Through communication, dialogue and negotiation (Brown & Duguid, 1991; Lave & Wenger, 1990), the individual selection mechanisms are reconciled within the collective selection mechanism, resulting in a set of group actions which then receive feedback from the world external to the group. Each individual will interpret feedback both from other individuals and the world outside the group, including managers and customers (Daft & Weick, 1984; March & Olsen, 1975). In this way whilst one individual might interpret feedback based on the use of the collective standard calculation routine as positive, another individual might interpret this differently and call for a modification in the calculation routine. Over time different interpretations are resolved within the group through dialogue, negotiation and socialization (Lave & Wenger, 1990) as routines are retained.

Organizational Level At a higher level, the evolutionary processes of each group are played out within the context of the organization. The organization will thus be a polythetic collection of individual habits, collective routines, and now organizational routines. This collection of replicators is polythetic in the sense that the existence of routines does not exclude the coexistence of individual habits and after the formation of the routine individuals can continue to adopt both group routines and individual habits. In this way, whilst individuals may be the agents enacting both group routines and individual habits, the replicators at each level are discrete in the sense that selection occurs at both levels, depending on the differential degree of fitness. Therefore whilst different groups within the organization develop routines in the completion of activities such as *idea generation*, *idea screening* and *product development*, they also 'share' broader organizational routines associated for instance with the management of project documentation and information

through the company's information system. Individuals and groups can attempt to persuade others within the company to vary these organizational routines, perhaps by presenting alternative approaches to for instance project documentation. Individuals and groups can also choose to select this organizational routine, or may even choose to select alternative group-level routines or even individual-level habits associated with data management. Again these decisions to retain individual habits, group or organizational routines will depend upon the feedback from other groups, managers and agents external to the organization, such as customers.

In summary, the co-evolutionary narrative one develops differs depending on whether one uses an entity- or practice-based interpretation of the replicator-interactor. In the former account, routines are viewed as repositories tied to the life of individuals and groups. The evolution of these entities is experiential and as a result path dependant. In practice-based narratives, knowledge is viewed as being enacted in practice, and having an existence through those actions. As a result they are not necessarily tied to the fate of the individuals and groups concerned. Individuals can change and learn, with capabilities and knowledge struggling for survival in the collective 'mind space' (Dobson et al., 2013). Examining these differences in approach taken, the choice to use a practice- or entity-perspective depends on the relationship between organizational and environmental change. In the entity view, one largely assumes that the external environment (or that external to the entity in question) changes more rapidly than the associated individual or group. As a result, routines are selected 'for', by the selection 'of' carrying individuals. On the other hand if one adopts a practice view, then one assumes that individuals and groups can adapt dynamically (and indeed prospectively) to external change. So while multi-level narratives can be developed using both approaches, the different positions taken reflect the long-standing dichotomy between deterministic and voluntaristic perspectives (Abatecola, 2012). In the former it is assumed that structural inertia and environmental change have primacy, whereas in the latter adaptation and strategic choice hold sway (Abatecola, 2012; Breslin, 2008).

3 Modeling Organizational Co-evolution

Conceptualizations of organizational co-evolution can be further developed through computational modeling techniques. A variety of computational techniques have been used to simulate evolving behavior in organizations, including nonlinear differential equation modeling (Rahmandad & Sterman, 2008), system dynamics (Larsen & Lomi, 2002) and agent-based approaches. System dynamics models are designed to depict dynamic causal theories in which interacting variables influence each other over time (Sastry, 2001). This approach thus highlights feedback processes, or circular causal relationships in which variables influence and, in turn, respond to each other. Agent-based approaches on the other hand view the organization as a complex social system, and recognize that much of this complexity is due to the interactions between multiple heterogeneous agents. These agent-agent interactions thus shape the emergence and development of wider system-level patterns of behavior. A key advantage in using computational techniques in general is that they can capture the contextual and historical complexity of changing organizational behavior (March, 2001), and as a result help develop formal theories (Lomi et al., 2010; Sastry, 1997). Agent-

based approaches can simulate the path-dependant co-evolution of interacting parts is modeled over time, allowing the researcher to carry out experiments that would be impossible in live organizations. In this manner, one can test for counterfactual conditionals, where the experimenter seeks to identify what would have been the case if the antecedent in a causal relationship were true (although it is not true). In addition to the conceptual advantages of developing computational models, they can also be used to simulate and validate real-life case studies. Models can therefore allow researchers and practitioners to unpack the complexity of organizational life, and uncover 'hidden' generative mechanisms driving or resisting change over time.

A number of scholars have thus used simulation techniques to model change within organizations, both using the variation-selection-retention framework (Bruderer & Singh, 1996; Lant & Mezias, 1990, 1992; Mezias & Glynn, 1993; Pentland et al., 2012) and focusing on the tension between stability and change (Lant & Mezias, 1992), or incremental and radical change (Mezias & Glynn, 1993), in which routines are the focus on analysis. In many of these previous simulation studies, an entity approach has been taken as outlined above. In many respects, conceptualizing organizational change through the mechanisms of variation-selection-retention has many similarities with models of learning (Bruderer & Singh, 1996; Lant & Mezias, 1990, 1992; Mezias & Glynn, 1993). Agency is introduced with managers varying, selecting and retaining routines in response to performance and organizational aspiration levels. So managers search for variations in routines in response to shortfalls between actual and aspired levels of performance. These variants are selected if managers perceive the performance to be favorable (Levitt & March 1988) - though uncertainty and ambiguity surround this interpretation (March & Olsen, 1976). And finally 'successful' routines are retained which in the process can lead to organizational inertia. Given the entity approach taken in these models, the link between the routine and the organization as a level of analysis is still retained. In this sense, the routine-organization might be seen as the replicator-interactor. As in most entity approaches, external selection forces are viewed as the key driving force behind the evolution of the organization over time. It is therefore assumed that the firm behaves as one, with an all powerful top management team making choices on behalf of the wider organization (Bruderer & Singh, 1996; Lant & Mezias, 1992; Mezias & Glynn, 1993). For example, Bruderer and Singh (1996) accommodate both choice and learning by a top management team, and subsequent selection of the organization based on its performance. Thus we have an external 'selected of' organizations and groups, 'for' the underlying routines (Hodgson & Knudsen, 2010; Lant & Mezias, 1992; Larsen & Lomi, 2002; Mezias & Glynn, 1993). More recently researchers have modeled organizational change, shifting the focus of attention onto groups and individuals within the organizations (Breslin, 2014; Kahl, this edition; Holtz, 2014; Miller et al., 2014; Thomsen, this edition). Given the focus of agent-based modeling on multi-agent interaction, the approach is thus clearly well suited to simulating changing patterns of behavior within organizations. Taking a co-evolutionary approach, the mechanisms of variation-selection-retention are now played out in the choices, interactions and behaviors of agents, as represented by the individuals and groups in the organization (Breslin, 2014). In addition, selection is now represented through the choices made by agents based on feedback

received from all others (not just external selection) following enacted behaviors. In this way, a practice-based interpretation of the replicator-interactor is assumed.

Assuming such a practice-based interpretation of organizational change, and following the multi-level conceptualization given above, computational representations can be developed. In such models the co-evolution of routines at different hierarchical levels in the organization is simulated including; the individual-, group- and organizational-levels. Given the practice-based assumptions, all individuals and groups can influence the evolution of organizational routines over time, through the mechanisms of variation-selection-retention as shown in figure 1. Selection therefore is not assumed to occur at the level of the organization or group only, but through the choices made by individuals at all levels. It should be noted that the account presented below, is one of many possible practice-based accounts, and is used here to highlight key empirical issues associated with the development of such approaches. Finally a variety of approaches have been used to represent the routines in these models, ranging from abstract numerical representations (Breslin, 2014), to action sequences (Pentland et al., 2014). For a more complete review of these approaches, please see Kahl's contribution to this volume.

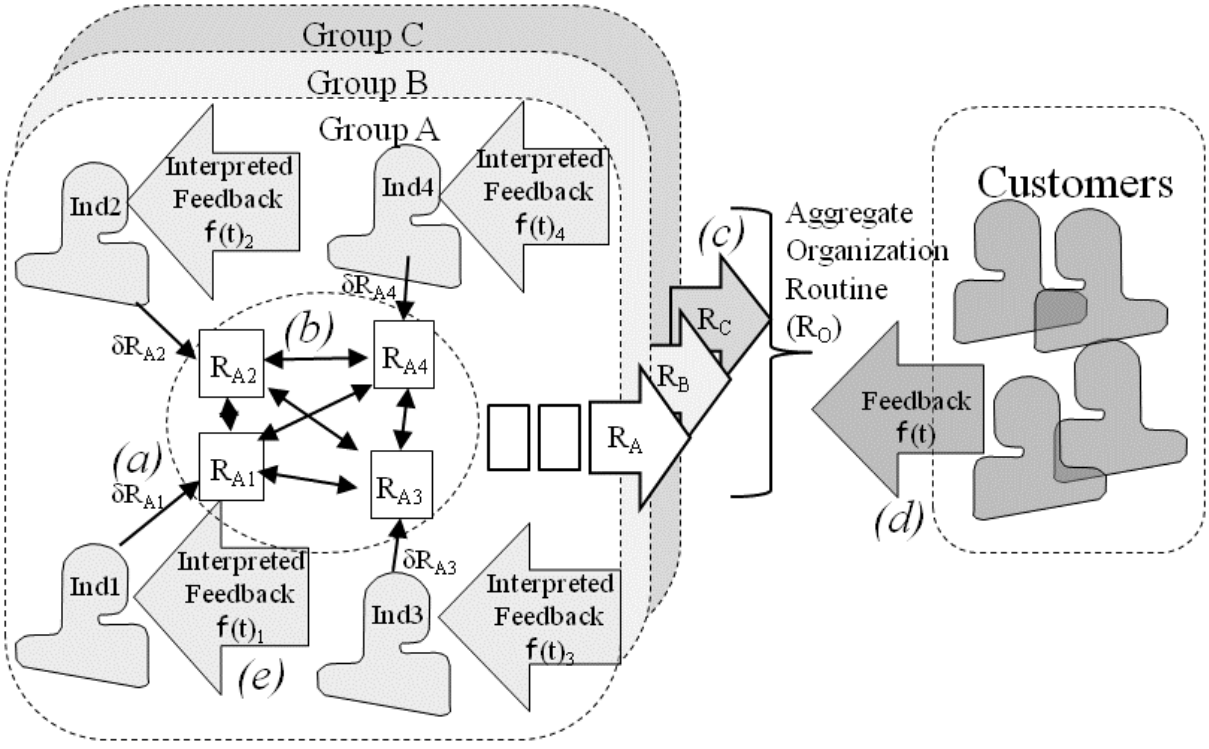

Figure 1 Outline of Co-Evolutionary Model using Variation-Selection-Retention

Variation Each individual in the organization makes a unique contribution to the wider organizational routine. In the first instance however, an individual can only directly influence their immediate group of colleagues. At each iteration of the model, each individual (Ind_i) can potentially change the routine, and he/she differs in their capacity to do so. So a more innovative employee will be more able to alter the routine than a less innovative colleague.

During each iteration of the model, individual 1 (Ind_1) can change the routine by an amount δR_{A1}, as shown in figure 1a. Clearly, these values will be different for each individual, and a group consensus is reached through a process of negotiation (see figure 1(b)). The more influential the individual, the more they influence this group-level choice (Mezias & Glynn, 1993). So if all individuals have equal influence and power within the group, the consensus value is represented by the 'mean' of the individual values. In this way, a negotiated routine R_A emerges (with values R_B and R_C representing groups B and C respectively). Given that these group routines may also differ, a consensus is similarly reached between the groups through a process of negotiation (see figure 1(c)) to arrive at an organizational level routine R_O. Again the degree to which group level routines (R_A, R_B, R_C) influence the aggregate organizational level routine R_O will depend on the influence and power of each group. In this way, individual choices are reconciled within those of the group, whose choices are in turn reconciled within that of the organization as a whole.

Selection The organization routine is then presented to the customer for feedback (see figure 1(d). Past attempts at modeling organizational evolution have used fitness curves or landscapes to represent feedback on organizational performances (Bruderer & Singh, 1996; Lant & Mezias, 1992), with fitness being represented either as a numerical fit (Mezias & Glynn, 1993), or as a match between combinations of gene-like routines (Bruderer & Singh, 1996). As noted above, selection is interpreted in an active sense in this model, with individuals choosing to select routines. So for instance, individual 1 chooses to select practice R_{A1}, which is presented to the group (as outlined above). These choices involve each individual first interpreting customer feedback, and then responding to this, as shown in figure 1(e). The 'accuracy' of this interpretation depends on the closeness of the individual in question to the customer, or customer proximity. The greater the value of customer proximity, then the more accurate the individual's interpretation of feedback (Lant and Mezias, 1990; Bruderer and Singh, 1996). Indeed Abatecola (2012) stresses the importance of management (mis)perception on wider organizational adaptation. So it is assumed that frontline employees are closer to the customer and have a more accurate view of what customer wants. Individuals therefore 'select' practice R_{A1}, if they perceive the associated 'performance' to be favorable - though uncertainty and ambiguity surround this interpretation (Levitt & March, 1988; March & Olsen, 1975). In common with other models of organizational change (Lant & Mezias, 1990, 1992; Bruderer & Singh, 1996; Mezias & Glynn, 1993), individuals are seen to search for variations in response to shortfalls between actual and aspired levels of performance. The greater the shortfall, then the more the individual will act to change the routine (Bruderer & Singh, 1996; Levitt & March, 1988). So if individual 1 interprets customer feedback to be poor, he will act to change the routine by δR_{A1} (as outlined above). Crucially in this multi-level model, the individual can only propose a change at the level of the individual, based on their interpretation of feedback given at the aggregate level of the organization.

Retention 'Successful' routines are retained over time, when an individual interprets feedback as positive. However the exploitation of knowledge in this manner can lead to a build up of behavioral and socio-political inertia within the organization, which can in turn

act to suppress subsequent variations (Miller, 1999), thus impairing the firm's ability to respond creatively to changing external conditions (Aldrich, 1999). In this way, success through positive feedback can lead to over-exploitation of existing knowledge, and an inability to adapt to changing customer expectations. So the longer individual 1 continues to enact the same routine R_{A1}, then the more difficult it becomes for that same individual to initiate change (via δR_{A1}) in subsequent iterations. As with other models, and using the metaphor of the inertial clock, it is assumed that this inertial effect of experiential learning is 'reset' after each innovative change above a given threshold (Mezias & Glynn, 1993). Given the advantages of increasing learning through competence enhancing (Tushman & Anderson, 1986), individuals will only attempt change when the perceived performance is below a certain aspiration level or threshold.

4 Implications for Empirical Investigations

While such multi-level models can be used as a conceptual tool in the development of organizational co-evolutionary theory, they can also be developed to model changing practices in real organizations, provided appropriate representations of those routines are chosen. A number of empirical challenges need to be considered when developing such simulation models. First key characteristics of the organization need to be represented through the model inputs. Second empirical studies need to be designed to capture co-evolving outputs over time.

4.1 Model Inputs

Referring to the model description given above, the following key organizational characteristics at a minimum need to be represented.

Organizational Structure As outlined above, the interaction between individuals and groups is determined by key characteristics of the organizational structure (Breslin, 2014). Therefore, a key input for any model of organizational co-evolution is the structure of the organization, including the identity of individuals and groups, and how they are interconnected. Actual interactions between individual may differ from formal divisional structures, and through techniques such as social network analysis, clearer representations of these interconnections can be made (Dobson et al., 2013; Hanneman, 2001).

Relative Power The negotiation of consensus between individuals and groups, as seen in figure 1(b) and 1(c), is determined by the relative power of individuals within groups (figure 1(b)), and groups within the organization (figure 1(c)). A number of approaches might be taken to capture this. For instance group leaders and managers can be asked to rate the influence of each individual (or group) relative to others within the group (or organization), using a Likert scale. Such data can be gathered via interviews with managers and based on a range of projects worked on, or a typical project worked on over a period of time. Other approaches might be used to capture the actual interactions between individuals over time. For instance sociograms can be developed from social network analysis (Cross and Borgatti, 2004), further supported through qualitative research methods, such as periods of observation

and interviews. These maps can capture key dimensions of interconnectedness, including how individuals are influenced by others across a range of activities.

Creativity As noted above, each individual i can alter the routine by an amount δR_{Ai}, as shown in figure 1a. As a result, a measure of creativity is needed for each individual within the organization. A number of measures might be used to capture this. For example drawing on Holman et al. (2011) a measure for employee creativity is given using self completion questionnaires (see table 1).

Table 1 Measure of Individual Creativity

In the last year, and in a work context, how often have you done the following (1= not a lot to 5 = a great deal)?
1. Thought of new ideas
2. Had ideas about how things might be improved
3. Found new ways of doing things
4. Attempted to get support from others for your ideas
5. Tried to get approval for improvements you suggested
6. Got involved in persuading others to adopt your proposals for doing things differently

Customer Proximity Finally as noted above each individual interprets customer feedback, and then responds to this, as shown in figure 1(e). The 'accuracy' of this interpretation depends on the closeness of the individual in question to the customer, or customer proximity. Drawing on marketing literature, Sin et al.'s (2005) customer proximity measures can be used again using self-completion questionnaires (see table 2).

Table 2 Measure of Customer Proximity

When dealing with the customer to what extent to you agree with the following statements (1= not a lot to 5 = a great deal)?
1. We both try very hard to establish a long-term relationship
2. We work in close cooperation
3. We keep in touch constantly
4. We communicate and express our opinions to each other frequently
5. We can show our discontent toward each other through communication
6. We can communicate honestly
7. We share the same worldview
8. We share the same opinion about most things
9. We share the same feelings toward things around us
10. We share the same values
11. We always see things from each other's view
12. We know how each other feels
13. We understand each other's values and goals
14. We care about each other's feelings
15. My company regards "never forget a good turn" as our business motto

16. We keep our promises to each other in any situation
17. If our customers gave assistance when my company had difficulties, then I would repay their kindness
18. They are trustworthy on important things
19. My company trusts them

Ethical Issues There are clear ethical issues associated with such modeling exercises, and related attempts to represent individuals and groups in simulation studies. Therefore it is imperative that full ethical approval is obtained before embarking on interviews and questionnaires. Crucially the anonymity of individuals must be assured, to ensure that participants complete the questionnaires as honestly as possible. In this respect, it is important that the gathering of data is administered by researchers, independent to the operational activities and management of the organization. Nonetheless, the representation of individuals and groups, and the process through which these individuals interact is key to developing such simulation studies.

4.2 Model Outputs and Validation

While a number of scholars have developed conceptual models of organizational evolution (Bruderer & Singh, 1996; Lant & Mezias, 1990, 1992; Mezias & Glynn, 1993; Pentland et al., 2012), few of these have attempted to validate their results using actual data from organizations. Key to validating the model is the choice of output variable which is used to represent changing behaviors within the organization. While change can be captured through the routine, the practice-view clearly presents some challenges for research design. Considering key elements of the preceded narrative above, a number of core issues come to the fore. First co-evolution is by definition a process which occurs over time (Winter, 2012), and as such this temporal dimension must be captured in proposed research methods and design. As a result, longitudinal studies must be seen as key research method. Indeed Parmigiani and Howard-Grenville (2011) note that in general, scholars exploring a practice-view of routines tend to use single case studies, derived from ethnographies and direct observation (Feldman, 2000; Howard-Grenville, 2010; Lazaric & Denis, 2005; Szulanski, 2000). This longitudinal nature gives researchers the opportunity to explore key aspects of the evolutionary dynamic including the emergence, development and extinction of routines over time (Parmigiani & Howard-Grenville, 2011). In this manner, empirical studies can explore how routines are varied, selected and replicated within the multi-level complexity of the organization.

Second the replicator-interactor concept is a multi-faceted concept, incorporating interpretive frameworks and enacted behaviors. When studying these routines, some give primacy to the study of performative side (i.e. actions) of the replicator-interactor duality (Pentland et al., 2010; Pentland et al., 2012). For instance Pentland et al. (2010) argue that expressed behaviors and not potentialities are the best foundation for empirical research on routines. In the absence of observable patterns of behavior it is impossible to tell if a routine exists, and difficult to ‘observe’ the underlying generative mechanisms (Pentland et al., 2010). Instead they argue that the underlying generative mechanisms (ostensive aspect) can be inferred from

these patterns of action (Pentland et al., 2012). A number of means of inquiry might be used to capture these performances. First detailed observations can record the 'what' and 'how' of enacted performances over time. Such methods require a strict adherence to a set recording system, followed by all researchers involved. Ultimately this method is limited to the exposure of the researcher to expressed behaviors.

Alternatively, the actors themselves can record their actions and behaviors. This can be done either by prompting participants to record behaviors at random or regular intervals. In many cases, actors already record their activities through on-line or off-line daily logs of records. The clear advantage in recording such action sequences is that it allows the modeler to capture details of the changing routine, at multiple levels within the organization. A number of techniques might be used to process this longitudinal data into a form useful for validation purposes. For instance sequential analysis methods (Abbot, 1990) can be used to identify similarities in recorded sequences of activities over time (Salvato, 2009, Turner & Fern, 2012). In this way, each specific activity recorded in daily logs is coded, with similar actions being coded together. Following this coding exercise, each enacted activity is translated into a sequence of coded actions. A distance matrix is generated in which the distances between all pairs of sequences in the data set are computed. Clusters are subsequently generated from this distance matrix to aggregate the sequences into a smaller number of groups, which represent emerging routines (Turner & Fern, 2012). In this manner a detailed log of emerging routines as represented by clusters of action sequences within the organization is captured, which can be compared with outputs from the simulation model via statistical methods.

5 Conclusions

This chapter stresses the need for research which reflects the co-evolutionary and complex nature of changing organizations in the world today. We argue that key concepts can be abstracted from biological evolution, and used as a starting point for such approaches. While a number of researchers have taken this latter approach, these efforts have been constrained by an entity interpretation of the unit of co-evolution. Assuming that organizations are vehicles for bundles of routines, and subject to external selection forces only, seems to draw too close a parallel to related biological analogies (Dawkins, 1976). We argue that the practice-based interpretation of the routine, and related co-evolutionary accounts unpacks the complexity and interconnected agency within organizations. Building on these conceptual foundations computational models can be developed to model and simulate behaviors in real organizations. While there are clear ethical considerations in doing so, such simulation models can be used by managers to help them navigate the complex worlds they face on a daily basis.

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