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# Entrepreneurs and the Emergence of New Industry Structures

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## Introduction

Mighty oaks from tiny acorns grow. Although acorns all look much alike, the fully grown oaks differ widely in their shape and stature. Their growth occurs in a highly path-dependent way, where initial conditions matter very much. The acorn that falls in sandy soil and receives many years of bright sun and gentle rains becomes majestic, while the acorn that falls on sterile soil or that receives years of shade and drought amounts to little. The same can be observed for the sprouting and growth of new industries in the economy. The technological innovation or market discontinuity that gives birth to an industry is similarly dependent on initial conditions to set its evolution on a path towards high growth and significant social and economic benefit. At the time of industry germination, these initial conditions are created largely by entrepreneurs, individuals who recognize the latent opportunities and take disruptive actions to exploit their growth potential.

Research into institutional entrepreneurship has shed light upon the role that entrepreneurs play in the evolution of already existing industries within extant institutional fields and upon the mechanisms by which entrepreneurs participate in the structuration of their local environments (Luksha 2008; DiMaggio 1988; Lawrence 1999). This research has been largely focused on emergence at the firm level (Busenitz 2003; Venkataraman 1997; Lichtenstein, Dooley, and Lumpkin 2006; Lichtenstein et al. 2007). Some recent research has suggested that emergence can instead be viewed as a multi-level phenomenon where the actions of individuals also matter (Chiles, Meyer, and Hench 2004).

Many studies into the industry effects of entrepreneurship continue to take the existence of major industry artifacts as given, (Sarasvathy 2001; Fligstein 1997; Maguire, Hardy, and Lawrence 2004) and insufficient attention has been paid to their initial development and the potential role of individual entrepreneurs. As a result, the emergence and formation of new industries and institutional fields remains relatively poorly understood. In this article we therefore attempt to address this gap by examining the actions of entrepreneurs during emergence and the causal effects they have on the generation of structure within newly sprouting industries, by which we mean firm boundaries, networks, schemas, rules, norms, contractual relationships, and routines (Scott 2004). By synthesizing concepts from institutional theory and complexity theory, we aim to enrich the explanation of how the initial structures of new industries emerge and how theoretical perspectives from entrepreneurship and strategic management can offer complementary perspectives. Our goal is to propose a conceptual model, based on complexity perspectives, that examines emergence and organization at the industry level to highlight the critical role that entrepreneurship plays in the initial conditions and paths of industry emergence. With this proposal we are responding to the call of Meyer et al (2005) to extend organizational theorizing to adopt nonlinear approaches and concepts during times of system upheaval and emergence and to especially study systems that are in flux.

## Literature Review

The effect of industry structures and their relationships to is often examined from the perspective of institutional theory[1]. We adopt this perspective over the more common Structure-Conduct-Performance alternative paradigm (Bain 1956) because we are interested primarily in the initial emergence and development of industry structures rather than their subsequent effects on industry conduct and performance levels. Institutional theory suggests that social and political context can have ongoing influence on the decisions of individual actors. This influence arises because the behavior of individuals is governed by institutions and social conventions, not just economic utility maximization (Veblen 1898). Institutions can be thought of in several ways: as shared mental models (North 1981), as 'rules of the game' (Shepsle 1989; DiMaggio and Powell 1983), as a set of taken-for-granted understandings (Berger and Luckmann 1966), as systems of social relations (Granovetter 1985), or as coordinating mechanisms for rational political choice (Commons 1934). Scott (2001, : 48) describes institutions as "social structures that have attained a high degree of resilience…composed of cultural-cognitive, normative, and regulative elements that…provide stability and meaning to social life". All of these perspectives share the view that institutions can influence individual decisions taken by actors.

In the context of a mature industry, institutional theory helps explain the great degree of isomorphism and similarity of behaviors and strategies among firms by suggesting that three types of forces act to cause firms to become similar within an industry (DiMaggio and Powell 1983):

- Coercive isomorphism – Social sanctions or laws effect an exogenous imposition of structure and order. Firms within the industry adopt similar structures and behaviors in response to this shared coercion.
- Mimetic isomorphism – Firms observe the structure and performance of each other (e.g., benchmarking). Successful Firms within the industry adopt similar structures and behaviors because they attempt to copy the successes of their rivals, often in response to high uncertainties.
- Normative isomorphism – Values are socialized through extra-firm organizations (e.g., professional associations) to encourage the adoption of selected structural features. Firms within the industry adopt similar structures and behaviors because their managers adhere to the professional values and norms shared by the managers of other firms.

Such traditional organizational perspectives have much less to say about the initial emergence of the industry – how organizational fields are constructed, how the artifacts of the industry (firms, markets, and value chains, etc.) are initially produced and organized, and how these result over time from the decisions and behaviors of the early actors (Chiles, Meyer, and Hench 2004). Institutional theory has therefore been criticized as overly rigid and mechanistic when applied to the emergence of new industries and the behaviors of entrepreneurs at that time of emergence (Welter and Smallbone 2011).

Much of the recent strategy literature on change and evolution in industries has drawn from institutional theory's conception of path dependency, which argues that institutions are the culminating result of specific historical processes (North 1981). These historical processes can involve actions that initiate feedback mechanisms that make going back politically impractical, so that paths that were once viable options become lost (Pierson and Skocpol 2002). Such path-dependent mechanisms are characterized by great sensitivity to initial conditions, with contingency and indeterminacy in the early historical events but relative determinacy or 'inertia' in the later events (Mahoney 2000). One such example can be seen with the QWERTY keyboard. The original purpose of this strange keyboard layout was to slow the human typists so that the initial mechanical typewriters would not become jammed. However, as subsequent generations of technological improvement overcame the initial limitations in the operating speed of these mechanisms and led to modern computer keyboards with no mechanical limitations at all, the QWERTY keyboard layout has remained firmly entrenched – this despite the availability alternative layouts with superior performance and the technical ease with which computer keyboards may be switched (David 1986).

Path dependency suggests that institutional effects can be bi-directional – that individual decisions taken by actors can also influence the formation and evolution of the institutions themselves. For example, the localization of R&D search behaviors and the resulting technology trajectories lead to a path-dependent structuring of the innovative capabilities of firms (Stuart and Podolny 1996). In the early stages of a new industry, collaboration and structuration by individual actors can form the basis for 'proto-institutions' that subsequently develop the facticity to become enduring social forces (Lawrence, Hardy, and Phillips 2002).

As David and Bunn (1987, : 4) describe it, this path dependence is a property of the whole industry viewed as a single system. The evolutionary process of the industry system displays path dependence due to punctuations or discontinuities of radical innovation. These changes destroy the competencies of existing firms in the industry and increase munificence for others (Tushman and Anderson 1986; Abernathy and Clark 1985). Discontinuities are initiated by new firms acting entrepreneurially because these changes tend to destroy significant competencies of existing players, can have large consequences even when the changes are apparently small (Henderson and Clark 1990). This sensitivity to small effects makes the path-dependent evolution of industries a non-ergodic process (David & Bunn, 1987), one where individual agents can abruptly and irreversibly alter the probability distribution of possible future states. As a result, a deeper understanding of these dynamics can be had by adopting a perspective that crosses levels, that attempts to explain industry-level system behaviors by examining the actions of individual entrepreneurs as agents in the system. The macro-scale economic phenomenon of a mature industry has its roots in the micro-scale of individual entrepreneurs acting during the 'fluid' early days of the new industry, particularly when the new industry is based on radical disruption of competencies or linkages and a dominant design has not yet emerged (Abernathy and Clark 1985; Utterback and Abernathy 1975).

Entrepreneurs who are able to spot latent opportunities, commercialize them, and direct the growth of a new industry are well-positioned to capture very large economic gains for their firms and for the society. As institutional theory would also predict, this is a very risky time for early entrepreneurs; the liabilities of newness are especially prominent, and innovative agents typically lack both the cognitive and socio-political legitimacy needed to effect significant changes (Aldrich and Fiol 1994). Moreover, the potential for increasing returns to entrepreneurial innovators can result in situations highly sensitive to random chance or small initial advantages (Arthur 1989). The example of Thomas Edison and the initial emergence of the electrical power industry is frequently used to illustrate this (e.g., McGuire, Granovetter, and

Schwartz 1993). At the end of the 19th Century, when technological innovation had made the replacement of gas lighting with incandescent electrical lighting a feasible opportunity, there were two competing individual entrepreneurs who struggled to define the structure and dominant design for the nascent electricity generation and distribution industry. Thomas Edison held the patents on a DC electrical system, while George Westinghouse was trying to commercialize the AC power system invented by Nikola Tesla. Both sides faced huge uncertainties. Neither system had infrastructure in place, no single compelling technical advantage over the other, or any strong legitimacy among municipal lighting utilities. Moreover, Edison favored an institutional design in which generation, manufacture of lighting equipment, and manufacture of other electrical devices would be separate businesses. He was able to draw upon his individual resources of patents, capital and social networks to influence the institutional field towards establishment of proto-institutions that reflected his personal vision of a nascent electrical utility industry comprising separate lighting utilities, equipment manufacture, and centralized production firms (Granovetter and McGuire 1998; Hargadon and Douglas 2001). On the question of technology standards, the first practical implementation of industrial-scale AC power generation at Niagara Falls eventually tipped the balance away from Edison's preference and towards lock-in of the Westinghouse AC technology.

It is important to note in this example that no external coercive force acted to organize the resulting industry. No technical standards body chose the underlying technology, and no governmental agency imposed the dominant design. Organization emerged through the individual actions of the initial entrepreneurs, in a process due to the emergent holistic behaviors that become possible in sufficiently complex systems.

Complexity theory therefore provides a useful perspective to understand the importance of initial conditions on organizational development and the potential effects of individual early agents (Rivkin 1998; Rivkin and Siggelkow 2002), and so provides a potentially powerful lens for examining the role of entrepreneurs in the emergence of complex industry systems. Complex systems are systems having both many constraints to the interactions among these components. It is the interplay of these two defining characteristics that makes complex systems interesting – a system with few interacting components and few constraint is deterministically simple, and a system with many interacting components and little constraint is chaotic yet statistically simple (Rivkin 1998; Rivkin and Siggelkow 2002).

Complex systems may arise through a process of self-organization among a variety of relatively simple agents. Such self-organization is a process by which the internal organization of a system changes without being guided or managed by an outside entity (Di Marzo Serugendo, Gleizes, and Karageorgos 2005). Complex self-organizing systems typically display emergent properties – holistic properties that cannot be simply predicted through superposition of the properties of the various constituent elements of the system. Such systems typically exhibit nonlinearity, irreducibility, and a surprising range of emergent behaviors, such as the dynamic share-price fluctuations on the public stock market, or the morphogenesis and development of spontaneous spatial patterns in biological systems that arise from intercellular conversations (Kauffman 1993). It is the range of these emergent behaviors that accounts for the increasing use of complexity perspectives to understand very many interesting socio-technical systems and problems. Theories of complexity have been used successfully to better understand biological and physical sciences (Grassberger 1986; Weng, Bhalla, and Iyengar 1999), information processing (Radner 1993; Trevisan and Vadhan 2007), sociology (Byrne 1998; Brewer 2002), market economics (Rosser 1999; Durlauf 2005), strategic management (Brown and Eisenhardt 1997; Houchin and MacLean 2006), and individual firms and organizations (Anderson 1999; Fuller and Moran 2001), as well as the generalized adaptive cycles of innovation and structuration in entire hierarchies of interrelated systems (Holling 2001).

As a result, complexity is now starting to be recognized as a powerful tool in the study of entrepreneurship (Bygrave 1989; Johnes, Kalinoglou, and Manasova 2005; Vogel 1989; Ganco and Agarwal 2009; McKelvey 2004b; Stevenson and Harmeling 1990; Chiles, Meyer, and Hench 2004). It is important to study complexity in the context of entrepreneurial research because complexity science is well-suited to deal with the creation of order during the initial creative phases of a new organization, not just the subsequent evolution of a well-established organization towards a stable equilibrium condition (McKelvey 2004b). This mirrors an important difference between the study of entrepreneurship and the traditional realms of strategic management.

In the case of entrepreneurs as agents, they demonstrate an interplay of equilibrating and disequilibrating forces acting in the economy – enabling the creation and destruction of local pockets of order that approximate economic equilibrium conditions (Baumol 1990; Kirzner 1997). In particular, entrepreneurs act to cause the recognition or creation of new opportunities, the formation of new individual firms, and the creation of new economic processes around these opportunities (Fuller & Moran, 2001). Entrepreneurs and society co-produce via the rules of social order in a process of structuration (Downing 2005). There is no exogenous organizing force – it is self-organized through an emergent process in which the constituent firms of the new industry act independently in pursuing their independent business strategies, yet they collectively achieve the formation and maintenance of the emerging networks and structures (Stuart and Sorenson 2007). From this perspective entrepreneurs may be viewed as economic agents that impose constraints on the emerging industry. These constraints originate through the embeddedness of individual entrepreneurs, which includes their existing cognitive maps (Mitchell et al. 2004), prior institutional settings (Shane 2000), imprinting (Levinthal 1997), and culture (Hayton, George, and Zahra 2002). This process of self-organization and emergent properties has been repeatedly observed at the firm level, since firms are complex systems comprising the individuals and teams within the firm (Coleman 1999). It appears to not have been previously examined at the level of the industry, a complex system comprising many individual firms.

As can be seen from the foregoing, entrepreneurship, institutional theory, and complexity theory intersect at a point of importance. Entrepreneurship research provides insight into the alertness, motivations, and actions of individual entrepreneurs, but has little to say about how such actions can be coordinated into large-scale effects. Institutional theory explains the effects of institutional fields on the behaviors and structures of firms, and on how these evolve in the face of environmental changes, but provides little explanation of the creation of these fields and the emergence of proto-structures during the initial fluid stages. Complexity theory, while providing a generalized explanation of the coordination of multiple agents and the emergence of order and structure, has had very little application to the entrepreneurial domain and has been primarily directed to firm-level phenomena. At the confluence of these three streams of research remains a gap in understanding the role of entrepreneurs in the emergence of new industries as self-organizing structures.

## Self-Organizing Structures

Self-organization can occur when variations due to actions of individual agents result in local pockets of order and constraint. The actions of agents result in state transitions of the system that, under unconstrained conditions, may be undone by subsequent actions of other agents. Hayek (Hayek 1973, : 37) says that there are two kinds of spontaneous order: made or designed order (such as the order imposed by the engineer creating the first typewriter, or the entrepreneur creating a new business venture) and spontaneous grown (such as we shall examine below in the emergence of new industries). In both case, to persevere and grow the initial order, some manner of selection by an asymmetric transition mechanism is required (Ashby 1962) whereby random transitions to states of higher order are more likely and transitions to states of lower order are less likely. The asymmetry in transition likelihoods is essential to permit these local pockets of order to be sustained and eventually interconnected. With both random fluctuations and an asymmetric mechanism, the system transitions into a more ordered state that becomes the new baseline condition. The system can thereby evolve to a more complex and interdependent overall structure – even if the individual transitions were solely directed to the goals of the individual agents (or indeed were completely random). This 'locking in' of emergent pockets of order enhances the path dependency of the emergence of larger scale order in the system. The presence of an asymmetric transition mechanism forms a 'ratchet' that lifts the system into a more organized whole, without need for any exogenous control.

## Learning and Self-Organization

A fundamental problem faced by components in a complex system is the rapid adaptation to changing environmental circumstances. Effective adaptation requires knowledge of the world: the new state of the system, such as the existence of new agents or the formation of new network relationships among agents (Baum, Shipilov, and Rowley 2003; Buchanan 2003; Watts 2004). Complete knowledge of these changes is difficult because social knowledge is typically dispersed idiosyncratically and not available to any single agent and because single individuals may lack the capacity to internalize the degree of complexity required (Dunbar 1993). There is therefore a corresponding need for emergent methods of organization to bring relevant knowledge to bear on the problem – to enable agents to discover the nature of the change and to adapt appropriately (Hayek 1945). By discovering and learning about environmental changes, the individual agents can devise appropriate responses and thereby change the overall system behaviors; the system as a whole changes due to the learning by constituent components.

The foregoing suggests that *learning* on the part of individual agents can be a strong candidate for the asymmetric transition mechanism of the system. The asymmetry of this mechanism is provided by the irreversibility of knowledge transfer – something once learned cannot be unlearned. In particular, agents can learn to improve their coordination and thereby achieve joint objectives. For example, a honeybee colony, as a complex system, is forever changed once a scout brings back news of a nearby nectar supply and dances to communicate the details to the entire hive. Similarly, the structure, scope and roles within the mid-1990s nascent e-commerce retail industry were forever changed once Amazon.com demonstrated both the astute choice of products to sell online and a sustainable business model. With each such change, a new baseline condition is established and exploited and, in turn, used as a jumping off point for the next transition – the ratchet mechanism begins operating. Guerin and Kunkle's example of statistical thermodynamic measures of the explorations of ant colonies (Guerin and Kunkle 2004) provides an example from the domain of natural history of asymmetric transition of a system due to learning by constituent agents, an example of sufficient congruence to suggest institutional equivalents (Webb, Lettice, and Fan 2007). They use their observations to suggest a general four-step mechanism by which a ratchet effect of system organization can be obtained from the combination of random explorations and asymmetric transitions. The mechanism bears strong similarity to Prigogine's theory of dissipative structures (Prigogine and Lefever 1972; Nicholis and Prigogine 1989). Figure 1 illustrates the behavior of this mechanism by showing the average distance covered by an individual ant sojourn away from the colony during each of these steps.

In this model, (1) a newly discovered food source is thoroughly explored (the new system state is discovered and exploited), (2) a consolidation of knowledge occurs about where food is and is not found (the new systems structures are formed), (3) the food resources are mined in an efficient manner (the structures are maintained for so long as they are useful), and (4) the exhaustion of the food supply forces new explorations of increasingly wide range (the process renews with re-exploration from the evolved system state). This force of re-exploration echoes McKelvey's concept of 'adaptive tension', whereby some external trigger drives the system to change into configurations of better fit (McKelvey 2004a). Lichtenstein's recently proposed concept of 'opportunity tension', which integrates exogenous pull factors such as environmental change with endogenous push factors such as goal-seeking intentionality, may also be represented in this stage of the mechanism (Lichtenstein 2009).

**See Figure 1**

This mechanism illustrates how the asymmetry of learning on the part of individual agents can lead to transitions on the part of the system as a whole, provided that the knowledge gained by an individual agent leads to changes in the behaviors of many other agents. Studies of this influence among agents have led to the proposal of five possible processes of self-organization (Di Marzo Serugendo, Gleizes, and Karageorgos 2006):

1. **Direct.** Interactions between agents use basic principles such as broadcast and localization, and employ local computations of individuals, to provide a final coherent global state. The mechanism relies on the ability of agents to establish credibility with others, discuss their common objectives, establish a coordinated approach to achieving these, and communicate this with others (Maguire, Hardy, and Lawrence 2004). This occurs, as a simple example, in the grassroots organization of

political groups in society, as individuals with political objectives communicate directly and thereby discover common purposes.

2. **Stigmergy.** A mechanism of spontaneous indirect coordination between agents, where a trace that is left in the environment by an action of one individual stimulates the performance of subsequent actions by the same or a different agent. In Guerin and Kunkle's ant colony this would be seen in the formation of ant trails, wherein each ant leaves chemical traces on the ground and later ants are influenced by these trace chemicals to follow a similar path. At the human scale, a simple example of similar behavior can be seen the gradual wearing of pathways in the grassy lawns of a new public park.
3. **Reinforcement.** Agent behaviors are positively or negatively reinforced and the agents thereby adapt according to the state of the environment, the current individual state, and the probabilistic calculation of the expected payoff of different future behaviors. This mechanism can be observed in the formation and continuation of social fads and fashions of simple or complex scope and magnitude.
4. **Cooperation.** Agents can deliberately chose to become combined or decomposed in response to changes in environmental demands and communication overhead costs, in order to improve their collective response, such as in the collaboration that generates new proto-institutions (Lawrence, Hardy, and Phillips 2002). For a simple example, when traffic jams occur due to lane closures on a highway individual drivers may choose to combine into queue structures and follow cooperative rules for negotiating the bottleneck.
5. **Generic architecture.** Agents can chose to instantiate some form of extant architectural arrangement by which roles and interrelationships are predefined and self-organization occurs through adoption and modification of this arrangement in response to environmental perturbations. A simple example can be seen in creation of a new recreational league for team sports, where participants organize themselves by adopting the pre-existing rules and roles of the chosen game. Note that we refer to the emergence of complexity at the league level, in contrast to the emergence of complexity in the cooperative efforts of team members as studied by Bokenko (2009).

## Implications

By connecting the mechanism of learning exploration and consolidation of Guerin and Kunkle (2004) with the self-organization processes of De Marzo Serugendo et al. (2005) we establish the basis for our conceptual model for the role of initial agents in the emergence of order and structure in an arbitrary complex system. From this conceptual model we may develop three propositions relevant to the role of entrepreneurs in the emergence of structure and organization in new industries.

*Proposition 1: Learning in social networks is a mechanism for self-organization of systems comprising multiple interdependent agents.*

We first consider the general case of an asymmetric learning mechanism in each of the five processes of self-organization. As an example of direct interaction, exploration is conducted by individual agents seeking their objectives and randomly discovering other agents with compatible objectives, such as may be observed among people with grassroots political objectives. Communications among these agents leads to discovery of the benefits of deliberate and voluntary coordination of their efforts, through the formation of structures such as advocacy groups. The resulting structure is maintained by dyadic rules, social norms and explicit contracts among the agents such as those the govern membership in the advocacy group and stipulate who may speak on behalf of the group. Finally, re-exploration is triggered when the group achieves or abandons its political objective, and members move on to other individual objectives.

An example of stigmergy in the emergence of order can be observed in the development of walkways in a new public park having only grassy fields. Initial visitors to the park may wander about randomly to visit various points of interest. As they walk they begin to wear dirt pathways in the grass, directly between points of interest. The existence of these rough pathways influences subsequent visitors to follow the same routes because they indicate the easy direct routes, or suggest that some point of interest worth visiting must lie at the far end. When the pathways become very well worn, they may be formalized by the park maintenance personnel by paving them or erecting signs or fences to encourage visitor to stay on these walkways and to not wander onto the remaining grassy areas. Such a structure of walkways may endure for a long time in the park, until some new attraction appears in an unserved area so that re-exploration is triggered by visitors who hop over the fence or cross the grass to explore the new attraction.

An example of the reinforcement process can be seen in the development of social fads, such as clothing fashions. The desire of some individuals to be seen as trendsetters motivates them to explore new styles. If these are seen as desirable by others, structure then emerges as followers begin to adopt the same styles – the fad begins to gain momentum. The need for affiliation and social pressures for conformance among that group act to maintain the structure as participation in the fad may be viewed as *de rigueur*. This maintenance may be self-undermining; as the fad becomes mainstream, the trendsetting individuals will be motivated to abandon that fad and being re-exploration for something new and different.

An example of a co-operative process for structure emergence can be seen whenever a lane blockage happens on a busy road, such as at an accident site. The drivers closest to the blockage have independent objectives to get clear of the blockage quickly, and may initially compete fiercely to get ahead of one another, often exacerbating the blockage by getting into traffic snarls. Eventually some drivers will recognize the fundamental symmetry of the situation and realize that everyone benefits if the remaining lanes are keep moving smoothly by instituting some pattern of lane sharing. A variety of structures can then emerge: zippers for the merging of lanes in the same direction, or alternate turn-taking for a single lane that must serve traffic in opposing directions. Once such a structure emerges it tends to persevere because approaching drivers see that it is effective in keeping the remaining lanes flowing, and they recognize the difficulty of replacing this structure with some other (given they have no communications with other drivers), and stopping at the bottleneck to negotiate a new structure is contrary to their primary objective of getting past the obstacle. When the blocked lane finally reopens, the structure dissolves.

Finally, a simple example of the use of a generic architecture process can be seen in the initial creation of a recreational sports league. Individuals who wish to form a new soccer league with dozens of players will view it as impractical to try to organize such a structure through the informal and time-consuming processes described above. Instead they may simply choose to adopt a structure isomorphic to soccer leagues in other towns, copying the game rules, league structure, team structures and so forth. The structure is established by collective fiat and is maintained by explicit enforcement of referees and league officials.

**See Table 1**

In each of these self-organization processes we observe the learning phases of exploration, structure formation, structure maintenance, and re-exploration, which constitute the asymmetric transition mechanism that preserves local order. Table 1 summarizes this general conceptual model. Clearly this shows how learning by interconnected agents can play a significant role in each of the self-organization processes underlying the formation of complex systems, as summarized above in proposition 1.

*Proposition 2a: Learning by entrepreneurs in a mechanism for self-organization of complex new industry structures.*

In arguing for this next proposition we may apply the general conceptual model of proposition 1 to the specific case of entrepreneurs and newly emergent industries (e.g., personal computers, digital media, internet, nanotechnology, biotechnology, and alternative energy production). The primary activities of entrepreneurship entail learning in several dimensions; entrepreneurs learn about opportunities for exploitation, regardless whether these opportunities are recognized, discovered, or developed, and whether this learning occurs through organized search or serendipity (Sarasvathy et al. 2005). They learn about themselves and the culture in which they are embedded, their external environments, the specific business skills needed to launch and operate a new venture, the nature of potential network relationships and the attendant social capital in the new industry (Casson 2010; Cope 2005). On investigation of the opportunity and development of a business plan they learn about markets, customers, competitors, relevant technologies, products, prices, business models, firm structures, and potential profits that may be obtained. The firms that they create serve as a nexus of learning and coordination of new knowledge (Sautet 2000).

On this basis, table 1 may be adapted to the entrepreneurial context of new industry formation by examining how entrepreneurial learning is reflected in each step of the asymmetric transition mechanism, in each of the different self-organization processes. Therefore table 2 gives examples of the five processes of self-organization, as seen in the exploitation of entrepreneurial opportunities and the organization of new industry structures.

**See Table 2**

The direct interaction process now describes entrepreneurs who create order by directly establishing relationships with other firms they view as instrumental to achieving their profit objectives, formalizing these relationships through contracts, and maintaining them for as long as they yield adequate profits (e.g., entrepreneurs learn about a new opportunity, determine what part of the value chain they can fulfill, and establish the partnership relationships necessary to exploit the opportunity). The stigmergy process describes how entrepreneurs create order by achieving initial successes that, while they may themselves be unnoticed, cause ripple effects or environmental traces that stimulate responses by firms in adjacent markets (e.g., Pioneering entrepreneurs begin to exploit a new opportunity by raising capital to launch their firms. These new startups may be unnoticed and “under the radar” of other existing firms, but the act of raising capital may alert other investors to the market potential of the new opportunity and thereby stimulate the funding of other new firms to enter into the newly emerging industry.). The reinforcement process describes how highly visible entrepreneurs act as role models and allow the basis of their success to be visible and learned by others (e.g., entrepreneurs making consumer electronics devices or producing media content learn to copy Steve Jobs and the iTunes model of media distribution). Cooperation describes the case where a group of entrepreneurs recognizes an opportunity that is too large to be individually exploited but that can be exploited by collective effort, and the individual entrepreneurs therefore learn to coordinate their efforts in mutually supporting ways (e.g., entrepreneurs learn to create a new commercial space travel industry by separately developing launch vehicles, spacecraft, engines, launch sites, and so forth). Finally, the generic architecture process describes how extant industry structures and organizations that are known to be successful can be deliberately replicated in other industries or contexts (e.g., entrepreneurs learn to replicate in India the successful Silicon Valley model, or "ecosystem", of venture capital and supporting service firms).

These examples illustrate a close correspondence between knowledge discovery by entrepreneurs in new industries and the generalized learning case discussed above, as summarized above in proposition 2a.

*Proposition 2b: Profit-seeking by entrepreneurs is a mechanism for self-organization of complex new industry structures.*

So far we have argued that a new industry comprising many entrepreneurs is a complex system capable of self-organization, and that this organization occurs through the operation of an asymmetric transition mechanism based on learning. This learning may be motivated by forces operating in the entrepreneurial realm that can drive asymmetric transition mechanisms. One important example of such learning may be the entrepreneurial motive to obtain profits (whether as purely monetary or as other social benefits), since one of the most important things entrepreneurs learn is which business models are most profitable in the new industry. Kirzner noted that entrepreneurs discover errors of over-optimism and over-pessimism and seek to create value by correcting them through arbitrage. The resulting entrepreneurial activity consists of linking up different markets, which cannot fail to produce coordinated activity (Kirzner 1973). The basic asymmetry of this mechanism lies in the observation that an entrepreneur will change strategies and business models if higher profits can thereby be obtained, but will not make the reverse changes that knowingly lead to lower profits. As a result, random experimentation and effectuation processes (Sarasvathy, 2001) on the part of pioneering entrepreneurs will eventually discover profitable configurations, and these will be locked in to form the locally stable pockets of increased order on which the complexity of the industry system and the structuration of industry roles depend.

As an example, consider again the heady days of the early dot-com boom and the discovery of successful e-commerce retail by Amazon.com. Those times were marked by extensive media coverage and hype (Valliere and Peterson 2004) providing ample opportunity for communication and learning among pioneering entrepreneurs. They were, to an even larger extent, times of rampant experimentation with business models. From web retailing of pet food to online market-making in petrochemicals, and using business models developed through both deliberate experimentation and random accident, entrepreneurs thoroughly explored the profit potential of the new industry space, discovered and preserved the most successful approaches, and catalyzed the structuration of the online commerce industry. The primary mechanism of this progression and asymmetric lock-in appears to have been profit-seeking, as summarized above in proposition 2b.

## Conclusions

Industry emergence and structuration follows a variety of processes of self-organization. These processes are highly path-dependent and sensitive to initial conditions. We have argued that entrepreneurs play an important role in establishing these conditions and forming the new proto-institutions through an asymmetric transition mechanism that preserves the initial random emergence of local order and thereby allows it to grow into the new institutional field.

We have further argued that learning by entrepreneurs underpins this ratchet, and occurs through the five processes of direct interaction, stigmergy, reinforcement, cooperation, and generic architecture. Entrepreneurs represent the nexus of learning within the newly emergent industry, where profitable and sustainable structures are discovered and promulgated. The individual actions of entrepreneurs can therefore have irreversible consequences, either arising from knowledge transfer or flowing from the entrepreneurial profit motive. These consequences create the small but significant initial conditions that drive the industry towards one set of future states and away from others.

These initial entrepreneurial conditions create a path dependency in the emergence and formalization of institutional fields in the new industry. Therefore industry evolution cannot be fully understood at only the system level. The emergence of industry structure is a level-crossing phenomenon in which small actions of individual agents can have large effects on the overall system behaviors. These system behaviors in turn enable or constrain further actions by the agents. In this, we argue in support of previous findings of cross-level influences by Chiles et al (2004).

In this paper we have contributed a broad conceptual model, based on complexity-theory perspectives, that integrates the critical role entrepreneurs play in the initial conditions and path dependency for the emergence and organization of new industries. Our conceptual model illustrates how the actions of individual entrepreneurs, acting through five distinct self-organization processes, create the asymmetric transition mechanisms necessary to support self-organization of a new industry. Our model contributes to institutional theory by illustrating the central role that individual entrepreneurs play in establishing new institutional fields and proto-institutions. Institutional theory has previously explained the emergence of these fields and proto-institutions as being somehow carried over by entrepreneurs from their previous work experiences (e.g., by acculturation). Our model now further extends this understanding by proposing the specific mechanisms by which such influences guide the behaviors of individual entrepreneurs and how the collective actions of these entrepreneurs may result in the emergence of order at the industry level.

The potential significance and influence of early entrepreneurial actions on the eventual growth and evolution of new industries underlines the importance of continued research in this area. The asymmetric transition mechanisms described in this paper have been proposed as sufficient but not necessary causes. On the one hand, their sufficiency is in need of empirical validation. On the other, the possible existence of other important mechanisms should also be investigated. Each mechanism found will be significant in that it will provide an important dimension for better understanding the early dynamics of the industry system and the resulting future evolutions, and in that it will also provide new insights into potential policy levers for the facilitation of industry growth and ongoing change.

**Notes**

[1] Institutional theory attempts to explain the actions of individuals in terms of the influence of enacted social structures, such as routines, rules, and norms. It deals with the processes by which these structures become authoritative guides to social behaviour, and how they are created, diffused, and changed over time. Interested readers are directed to Scott (1987) for an overview of the key elements of the theory.

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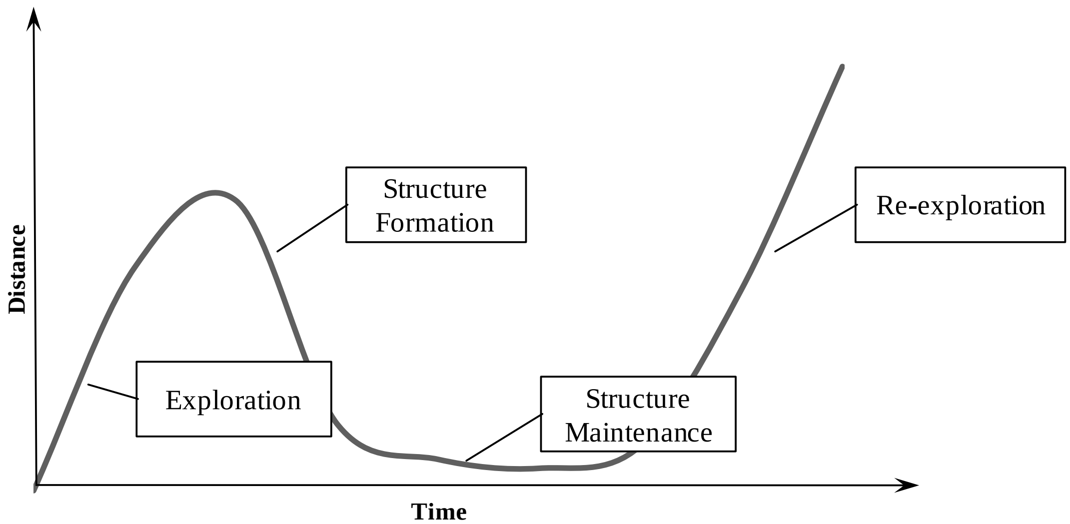
**Figure 1**
***Exploration, Consolidation of Knowledge, and Institutional Structuration***




(Based on Guerin and Kunkle 2004)

**Table 1**
***Asymmetric Learning and Self-Organization***

| | **Self-organization Processes** | | | | |
|---|---|---|---|---|---|
| **Phases of Learning** | *Direct Interaction* (grassroots organizing) | *Stigmergy* (walkways in a park) | *Reinforcement* (social fads) | *Cooperation* (traffic lane blockage) | *Generic Architecture* (soccer league) |
| *Exploration* | Individual experimentation towards goals, local identification of other interested activist parties. | Random walks among areas of interest, constrained by bounded rationality of agents. | Social benefit of being perceived leader, trendsetter, having fun or being cool. | Individual recognition of common objective – allowing *you* to proceed clears the lane for *me*. | Deliberate adoption of existing models and roles (e.g., which game, which league, and which teams and positions). |
| *Structure Formation* | Communication of successes by pioneers and coordination of efforts among local groups (Dal Forno and Merlone 2009), reduced agent ignorance of overall structure. | Influence of environmental traces (footprints and rough paths), widespread copying, and formal structuration (pave the paths). | Need for affiliation and social approval, jumping on the bandwagon. | Emergent identification of agents and roles (queues of cars form), locally negotiated or culturated rules (taking turns). | Adoption of rulebook, enactment of roles and processes (playing positions). |
| *Structure Maintenance* | Local rules govern exchanges for individual benefits, widespread interactions. | Homeostasis of structure regulates agents – 'Keep off the grass' signs erected. | Herd behavior and social costs of non-conformance, co-option by the mainstream society. | Local observation of efficacy (net throughput), recognition of switching costs to create alternative mechanisms | Public tracking of performance (statistics), rule enforcement by appointed referees. |
| *Re-exploration* | Mass communication, assessment of progress and new status quo. | Expanded boundaries through serendipity or noise (e.g., new point of interest discovered, or new shortcut by busier visitors). | Novelty seeking, boredom, desire to be different. | Environmental change (a lane reopens or another lane becomes blocked) triggers revaluation of status quo. | Environmental change (winter comes, players change to ice hockey). |

**Table 2**
***Entrepreneurial Self-organization of New Industries***

| | Self-organization Processes | | | | |
|---|---|---|---|---|---|
| **Phases of Learning** | *Direct Interaction* (direct networking) | *Stigmergy* (indirect networking) | *Reinforcement* (cultural influences) | *Cooperation* (experimentation) | *Generic Architecture* (replication of models) |
| *Exploration* | Small, innovative firms seeking access to large markets dominated by existing players | Serendipitous discovery of opportunity by innovative entrepreneurs; high-growth exploitation of opportunities | Pioneering entrepreneurs seeking first-mover advantage through new venture creation; effects of field frames (Lounsbury, Ventresca, and Hirsch 2003) | Individual recognition of opportunities that require collaboration (complementary products, delivery of 'whole product', co-opetition), specialization and communication (Kogut and Zander 1996) | Opening of a regulated industry opportunity |
| *Structure Formation* | Corporate venturing through strategic alliances with entrepreneurial firms | Strategic responses by entrenched players (e.g., copying new business models). | Recognition of first-mover successes. Copying their strategies, or spotting adjacent emergent opportunities (e.g., supplier, distributor) | Entrepreneurial action to facilitate shared objectives, such as open standards and product architectures, creation of industry associations, deliberate induction of new ventures (Kogut, Walker, and Kim 1995) | Predefined industry participant roles adopted by new and existing firms as they enter the new regulated industry |
| *Structure Maintenance* | Contractual mechanisms established (e.g., hub-and-spoke structures) | Structuration of new norms and expectations of existing players, in light of new entrepreneurial actions. | Successful profit-generation by all industry participants; celebration of managerial leadership | Network effects and increasing returns, exponential growth in switching costs | Enforcement by regulator |
| *Re-exploration* | Interaction and joint discovery through networking, brainstorming, environmental scanning | Declining margins through Kirznerian entrepreneurs, emergent opportunity for Schumpeterian creative destruction | Innovation and environmental change create opportunities for new pioneers | Environmental change (creating new collaborative opportunities) | Environmental change (especially changes in regulatory regime) |