Editorial

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Contribution of Complex Systems to Entrepreneurship

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Abstract: The purpose of the research is to demonstrate how recognition of complex systems or complexity science enhances recognition and achievement of entrepreneurial opportunities. A further objective is to provide an integrated source of readily available information about a number of research papers that demonstrate the role of complex systems in entrepreneurial activities. Papers reviewed include those by McKelvey, Andriani, Boisot, Dooley, Siggelkow, Chiles, Plowman, Lichtenstein, Carbonara, Crawford, and others. These papers illustrate how complex systems operate, and how this can be used to develop entrepreneurial emergence. The research also seeks to identify an integrated model of emergence to provide a framework for entrepreneurship researchers and provide assistance to entrepreneurs. Lichtenstein's *Generative Emergence* provides the most comprehensive model found to structure opportunity achievement. While Lichtenstein's comprehensive model has not been tested, vis-a-vis other comprehensive entrepreneurial models, the components of the model have been tested. Overall Lichtenstein's *Generative Emergence* model is strongly endorsed.

Keywords: entrepreneurship, emergence, complex systems, power laws

Executive Summary

The purpose of the research is to demonstrate how recognition of complex systems or complexity science enhances recognition and achievement of entrepreneurial opportunities. A further objective is to provide an integrated source of readily available information about a number of research papers, which demonstrate the role of complex systems in entrepreneurial activities.

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The paper reports on each of these studies in some degree of detail and also provides the authors' comments on the particular contributions that each of these papers make to the subject of the paper. A list of these comments is shown in Table 1 and also graphically in Figure 1.

Table 1: Comments on the contributions of each paper reviewed to contribution of complex systems to emergence and entrepreneurship.

Key elements	Research supporting contribution of complex systems to emergence and entrepreneurship	Authors
1 Operation of power laws to entrepreneurship and the implications	Direct relevance of power laws to entrepreneurship	Crawford et al. (2015)
	The complex systems model provides the best approach	McKelvey and Andriani (2005); Crawford et al. (2015)
	Recognition of emergence and self-organization	Chiles, Meyer and Hench (2004); Plowman et al. (2007)
	Recognition of far from equilibrium conditions and maintenance of dynamic stability	Plowman et al. (2007)
	The Prigogine and Stengers model of far from equilibrium conditions suited the project best	Dooley (1997)
	The entrepreneurial system can be seen as a complex adaptive system	Plowman et al. (2007)
	Interdependent and NOT independent systems operate	Dooley (1997)
2 Recognition of fractals	Recognition of fractals building in scalability	McKelvey and Andriani (2005); Carbonara, Giannoccaro, and McKelvey (2010)
	Scale-free theory of management is based on the premise that a single process – a specific set of sequences, patterns, and behaviors, which drives order creation at <i>every level</i> of specific phenomena.	McKelvey, Lichtenstein, and Andriani (2012)
3 Emergence process	Recognition of the four sequential phases in the emergence process of: Dis-equilibrium State, Amplifying actions, Recombination Self-organization and stabilizing feedback;	Lichtenstein and Plowman (2009)

(continued)

Table 1: (continued)

Key elements	Research supporting contribution of complex systems to emergence and entrepreneurship	Authors
4 Feedback	The model of defining the point at which the system moves from requisite variety to complexity (R_{c1}) and complexity to chaos (R_{c2}) provides a valuable model	McKelvey (2010)
	Evolution toward fit can be achieved	Siggelkow (2002)
	Emergence is an aspect of punctuated equilibrium	Lichtenstein, Dooley, and Lumpkin (2006)
	Adaptive tension provides a common term to explain Prigogine and Stengers' (1984) concept of far from equilibrium and McKelvey's (2001) opportunity tension	Lichtenstein (2007)
	Systems are NOT in equilibrium	Dooley (1997)
	Importance of positive reinforcement to amplify change	Plowman et al. (2007)
	Importance of balancing positive reinforcement with negative reinforcement	Chiles, Meyer, and Hench (2004)
	Spontaneous fluctuation that initiated a new order, positive feedback loops that amplify and reinforce these fluctuations, coordination mechanisms that stabilize the emergent order, and recombination of existing resources that help construct the new order	Plowman et al. (2007)
5 Organizational form	Negative feedback is useful to keep the emergence under control	Plowman et al. (2007)
	The fit between the organizational form and organizational environment, or context, and the organizational structure is crucial to survival and success	Dooley (1997)
	Importance of the core elements reinforcing each other	Chiles, Meyer, and Hench (2004)

(continued)

Table 1: (continued)

Key elements	Research supporting contribution of complex systems to emergence and entrepreneurship	Authors
6 Leadership	Organization systems are not in equilibrium	Dooley (1997)
	Organizational science should treat disequilibrium and disequilibrating change as natural and ongoing rather than exceptional and episodic	Chiles, Meyer, and Hench (2004)
	Emergence is supported by the positive leadership and amplification of change by leaders interpreting and making sense of the change, through symbolic actions and providing supportive making tags	Lichtenstein, Dooley, and Lumpkin (2006)
	Vision is revised by strategic organizing and tactical organizing	Plowman et al. (2007)
	Emergence and entrepreneurship are supported by strong leadership of change; ten principles for the leadership of change are: a. <i>The more that leaders and members embrace uncertainty, the more likely that a Dis-equilibrium state will be initiated and/or heightened in the system.</i> b. <i>Once a system is pushed to a Dis-equilibrium state, the more that its leaders and members surface conflict and create controversy, the more likely that the system will generate novel opportunities and solutions.</i> c. <i>The more that leaders and members allow experiments and fluctuations, the more likely that amplifying actions will be present in the system.</i> d. <i>The more that leaders and members encourage rich interactions, the more likely that Amplifying Actions will be present in the system.</i>	Lichtenstein and Plowman (2009)

(continued)

Table 1: (continued)

Key elements	Research supporting contribution of complex systems to emergence and entrepreneurship	Authors
	<p>e. <i>The more that leaders and members support collective action, the more likely that Amplifying Actions will be present in the system.</i></p> <p>f. <i>The more that leaders and members create correlation through language and through symbols, the more likely that Recombination/Self-organization will be initiated and expanded in the system.</i></p> <p>g. <i>The more that leaders and members recombine resources, the more likely that Self-organization will be supported throughout the system.</i></p> <p>h. <i>When one or a few individuals accept the role or “tag” as a symbol for an emergence process, there is a higher likelihood that Recombination/Self-organization will be increased in the system.</i></p> <p>i. <i>The more that leaders and members integrate local constraints, the more likely that newly emergent order will be stabilized in the system.</i></p> <p><i>The combination of the four sequences – Dis-equilibrium state, Amplifying Actions, Recombination/Self-organization and Stabilizing Feedback – are necessary (but not necessarily sufficient) conditions for the generation of Newly Emergent Order.</i></p>	

(continued)

Table 1: (continued)

Key elements	Research supporting contribution of complex systems to emergence and entrepreneurship	Authors
7 Management style	<p>Draconian incentives have been successful in generating adaptive tension</p> <p>Supporting weak ties, moderate networking, minimum layers of management, job or role changes and physical proximity of disparate groups such as marketing and engineering, support emergence and entrepreneurship; balancing top-down and bottom-up</p>	<p>McKelvey (2010)</p> <p>Carbonara, Giannoccaro, and McKelvey (2010)</p>
8 Business strategy	<p>a. Firms should seek to have their internal complexity less integrated and that of their opponents;</p> <p>b. Firms should seek to keep their internal value chain levels similar to their external value chain in order to maximize matchups with opponents;</p> <p>c. Co-evolutionary systems to firms having K and C values similar to the group average because of the competitive disadvantage of holding K and C values at odds with the group;</p> <p>d. Firms seeking to achieve simultaneous advancements or innovations on multiple value chain competencies have greater competitive advantage if they hold the number of simultaneous changes to just a few.</p>	McKelvey (1999)
9 Nascent entrepreneurs	<p>Concentration of effort, timing of activities, and early activity for nascent entrepreneurs were found to be very relevant variables.</p> <p>High rate, low concentration and even timing were successful whereas the rate of high concentration and early timing were shown to be unsuccessful.</p>	Lichtenstein et al. (2007)

Figure 1 is a graphical depiction of the contents of Table 1.

Figure 1: Contribution of complex systems to entrepreneurship.

1 Introduction

The purpose of the research is to attempt to demonstrate how recognition of complex systems enhances recognition and achievement of entrepreneurial opportunities. The research also seeks to identify an integrated model of emergence to provide a framework for entrepreneurship researchers and to provide assistance to entrepreneurs. A further objective is to provide an integrated source of readily available information about a number of research papers that demonstrate the role of complex systems in entrepreneurial activities.

The significant development of complex systems research has emerged over the last several decades with most of the work occurring in the last ten years. While there is no commonly agreed definition of a complex system, or complexity, among the various elements of science; however, the basic assumption is that each constituent of a complex system has a degree of autonomy as it responds to its extended environment.

Abbott (2001, 7) comments about how the “general linear model” from Newtonian mechanics came to “shape sociologists” thinking:

The phrase “general linear reality” denotes a way of thinking about how society works. This mentality arises through treating linear models as representations of the actual social world. ... The social world consists of fixed entities (the units of analysis) that have attributes (the variables). These attributes interact to create outcomes, themselves measurable as attributes of the fixed entities.

Andriani and McKelvey (2011b, 254) comment further:

Traditional (or linear) sciences are based on one of the following fundamental assumptions West and Deering (1995): (a) theories are and should be quantitative; (b) phenomena can by and large be represented by analytic functions; (c) systems have fundamental scales; and (d) most phenomena are additive – i.e., they satisfy the “Principle of Superposition”. These principles are wide-ranging but not neutral. They are based on a vision of the world that embraces gradualism, linearity, reductionism and equilibrium’. It is concluded that there is absolutely no doubt that complex systems underpins the generation of emergence and entrepreneurship.

Despite the successes of linear science, a large set of problems have proven to be intractable, such as phase transition in physics (Barabási 2002), punctuated equilibria in biology (Kauffman 1993), punctuations in history (Mokyr 1998), increasing returns in economics (Arthur 1994; Warsh 2007), not to mention speculative bubbles and crashes in financial markets (Mandelbrot and Hudson 2004; Cooper 2008; Baker 2009). These are all problems stemming from heterogeneous agents, path dependency and time-dependent connectivity among agents.

Andriani and McKelvey (2011b, 255) go on to comment on the basic principles of nonlinear science:

Nonlinear science is based on five basic principles (quoted from West and Deering 1995):

- 1 Non-quantitative theory statements are as important, and sometimes more important, than quantitative ones.
- 2 Many phenomena are singular in character and cannot be represented by analytic functions.
- 3 The evolution of many systems, although derivable from deterministic dynamical equations, are not necessarily predictable for arbitrarily long times.
- 4 Phenomena do not necessarily possess a fundamental scale and can be described by scaling relations.

- 5 Most phenomena violate the principle of super-position (additivity).
To West and Deering's principles we add one more:
- 6 $N = 1$ research about extreme outcomes is often of more consequence than statistically significant studies of large databases'.

Non-linear science is based on a Pareto rank/frequency distribution plotted in terms of double-log scales and appears as a Power Law (PL) distribution. PLs are based on a rank/size expressions such as $F \sim N^\beta$, where F is frequency, N is rank (the variable) and β , the exponent, is constant (based on Andriani and McKelvey (2011b, 256). Power law behavior is different from nonlinear phenomena due to scalability.

Scalability occurs when the relative change in a variable is independent of the scale used to measure it. Brock (2000, 30) observes that the study of complexity "... tries to understand the forces that underlie the patterns or scaling laws that develop" as newly ordered systems emerge. Theories explaining PLs are also scale-free. This is to say, the same explanation (theory) applies at all levels of analysis. (Andriani and McKelvey 2011b, 256)

These few comments provide an introduction to the different approach being taken in this paper.

2 The Entrepreneurship Journey

2.1 Order Out of Chaos – 1996 – Cheng and Van de Ven

Yu-Ting Cheng and Andrew Van de Ven (1996) take a starting point of assuming that chaos "in the innovation process consists of a new linear dynamical system, which is not the orderly and predictable nor stochastic and random". They test this theory of biomedical innovations in assessing whether they followed either "(1) an orderly periodic progression of stages or phases, or (2) a random sequence of chance 'blind' events, or (3) a seemingly random process of chaotic events".

They found that the actions and outcome experienced by innovation teams exhibit a chaotic pattern during initial period of innovation and development and an orderly periodic pattern during the ending development period.

2.2 A Complex Adaptive Systems Model of Organization Change – 1997 – Kevin Dooley

Dooley (1997) provides a comprehensive paper analyzing and noting how organizations evolve and change over time. Dooley starts by recognizing that the

traditional assumption was that systems were in equilibrium and this reductionist approach allowed prediction of future ventures based on past performance. He notes that management theorists such as Fayol, Mooney, Urwick and particularly Taylor integrated these ideas with the concepts of the scientific method to develop a comprehensive management philosophy. Under scientific management, work tasks are divided into basic skills, and training and standardized methods help to eliminate differences between people's performance. "Organizational controls such as budget, performance review, audits, standards, etc., are used as negative feedback mechanisms for maintaining equilibrium" (Dooley 1997, 70).

Systems theory caused management theorists to see the organization as an organism (Morgan 1986). Fluctuations or contingencies from the environment are adjusted by organizational change (Lawrence and Dyer 1983) – Dooley 1997, 71). Systems theory recognizes that the "fit between the structural form and the environment was key to organisational performance" (Dooley 1997, 72). Organizations evolve through contingencies in the environment. Dooley notes that "the dynamics of innovation adoptions can be better described by assuming that resistance to adoption is caused by institutional (inter and intra-organisational) factors rather than the individual's risk aversion or propensity to imitate" (1997, 73). The growth innovation follows a punctuated equilibrium form.

Dooley notes that Prigogine and Stengers (1984), among others, "use chaos to describe how order can arise from complexity through the process of self-organization" (1997, 76). He notes that "a (*complex adaptive system*) CAS is both self-organising and learning; examples of CAS include social systems, ecology, economics, cultures, politics, technologies, traffic, weather, etc." (1997, 77).

Dooley recognizes that far from equilibrium conditions tend to create a dynamic stability, between randomness and order, freedom and control, learning and unlearning, adaptation to the environment and construction of the environment, where paradox abounds. This dynamic stability can be created by a leader. Dooley notes that Goldstein (1994) advocated the following ways of generating far from equilibrium conditions in businesses:

- (a) Work with (define, discuss, change) organizational boundaries;
- (b) Connect the system to its environment (customers, suppliers, competition);
- (c) Difference questioning (seek divergence in group discussion; based on similar stages first developed in family systems therapy;
- (d) Purpose contrasting (heightening awareness of the state gap);
- (e) Challenge self-fulfilling prophecies;
- (f) Challenge assumptions creatively;
- (g) Develop non-verbal representations of the system;
- (h) Take advantage of chance (Dooley 1997, 79).

Dooley comments that “change does not need to be invoked by catastrophic events. Change occurs when the system has evolved far from equilibrium, which could come from manipulation of small perturbances or cascading, compounding effects of small disturbances while the system is hypersensitive to such disturbances” (1997, 79–80).

Dooley notes Thietart and Forgues (1995), who performed an important analysis of chaos and organization theory, in which they develop six main propositions:

- a. Organizations are potentially chaotic;
- b. Organizations move from a dynamic state to another through a discrete bifurcation process;
- c. Forecasting is impossible, especially at a global scale and in the long term (unpredictability);
- d. When in a chaotic state, organizations are attracted to an identifiable configuration (order out of randomness);
- e. When in a chaotic state, similar structural patterns are found at organizational, unit, group, and individual levels (fractal nature of chaotic attractors);
- f. Similar actions taken by organizations in a chaotic state will never lead to the same result (Dooley 1997, 82).

Dooley’s Table 1 provides a specific list of behaviors that define a CAS.

2.2.1 Dooley’s recognition of complex systems in the entrepreneurial process

1. Organizational systems are not in equilibrium as many theorists have assumed;
2. The fit between the organizational environment, or context, and organizational form and the structure, is crucial to survival and success of the organization;
3. Recognition of self-organization is very important;
4. Far from equilibrium conditions applied to their project and dynamic stability was maintained;
5. Schemas were shown to be important;
6. The entrepreneurial system can be reviewed as a complex adaptive system;
7. Recognition of the elements of Dooley’s table 1 is important.

2.3 NK Landscapes – 1999 – McKelvey

McKelvey (1999) examined the Kauffman concept of landscapes and the approach of assessing these by the NK method. McKelvey sees older fashioned competencies

reflected in the value chain behaviors, effectively aligning competencies of particular employees as single agents, which contributes to total quality function of an organization. This also allows “organisational processes associated with employees having idiosyncratic sense making of their phenomenal world” (p. 298). Kaufmann uses traits that are attributes of parts rather than the actual parts.

Kauffman’s contribution is with fitness landscapes and these landscapes have features causing variation in the ruggedness. Ruggedness is a function of the number of parts constituting the evolving organism N , and the amount of interconnectedness among the parts K . When $K = 0$, the landscape appears as gently rolling ridges coming off a towering volcano. When $K = N - 1$, the landscape is very jagged like peaks, valleys and ridges. As K increases from 0 to $N - 1$, the number of popular peaks increases, the level of precision business increases and the correlation among fitness moves increases and the height of the peaks decrease.

2.3.1 McKelvey’s Recognition of Complex Systems in the Entrepreneurial Process

McKelvey contributed a range of ideas associated with competitive positioning by using Kauffman’s NK methodology to examine competitive advantage. The following provide an illustration, translated in some instances by the authors:

- a. Firms should seek to have their internal complexity less integrated than their opponents (p. 312);
- b. Firms should seek to keep their internal value chain levels similar to their external value chain in order to maximize matchup’s with opponents (p. 312);
- c. Co-evolutionary systems of firms should have K and C values similar to the group average “because of the competitive disadvantage of holding K and C values at odds with the group” (p. 312);
- d. “Firms seeking to achieve simultaneous advancements or innovations on multiple value chain competencies have greater competitive advantage if they hold the number of simultaneous changes to just a few.” (p. 312).

2.4 Evolution Toward Fit – 2002 – Siggelkow

Nicolaj Siggelkow’s approach for organizational development is a gradual evolution in adjusting to the external environment, by addressing a range of parameters that he calls “Evolution toward Fit”. The relevance of internal fit has a long history (e.g., Khandwalla 1973; Drazin and Van de Ven 1985).

This process recognizes the complex systems principle of adapting, using the Vanguard Group as an example. “A new method for determining an organization’s core elements is developed, and four processes are identified that describe the creation and subsequent management of these core elements: *thickening* (reinforcement of an existing core element by new elaborating elements), *patching* (creation of a new core element and its reinforcement by new elaborating elements – p. 140), *coasting* (no further elaboration of a new core element in a given period), and *trimming* (deletion of a core element and its elaborating elements)”.

Siggelkow 2002 describes a punctuated equilibrium pattern of organizational development and comments “a punctuated equilibrium path of development can be described as a sequence of periods in which existing core elements are elaborated, interspersed with brief moments in which all (or almost all) core elements are changed. Siggelkow’s Figure 9 illustrates the pure form of this developmental path.”

2.4.1 Siggelkow’s Recognition of Complex Systems in the Entrepreneurial Process

Siggelkow recognized:

1. Importance of negative reinforcement through pursuit of quality and low-cost solutions;
2. Importance of communication in providing positive feedback;
3. Role of integrated core elements reinforcing each other, that is, providing positive reinforcement.

2.5 Organizational Emergence: Branson’s Musical Theatres – 2004 – Chiles, Meyer and Hench

Chiles, Meyer and Hench (2004) report on the development of the musical theatre initiative in Branson, Missouri, which emerged over a century.

Chiles, Meyer and Hench (2004) provide an empirical test of the dissipative structures model, of “fluctuation, positive feedback, stabilisation and recombination”. The authors interpret the origin and transformation of Branson, Missouri’s musical theatres and illustrate four primary dynamics of emergence: “spontaneous fluctuation that initiated a new order, positive feedback loops that amplify and reinforce these fluctuations, coordination mechanisms that stabilise the emergent order, and recombination of existing resources that help

construct the new order” (Chiles, Meyer and Hench 2004, 500). The model tested positive by use of a Poisson regression analysis.

The longitudinal case study covers the period from 1896 to 1995. The authors comment that “from the inception of the theater population in 1955, until the end of our study in 1995, 135 theatre were founded and 77 failed. In 1995, Branson’s 58 theatres seating 79,400 patrons, nearly twice the capacity of Broadway” (p. 503).

In addition to theatres a special branch train service was established, the local river dammed to create a tourist resort for fishermen, and an ice skating rink established.

The authors identified 76 relationships among 10 key conceptual categories and 48 subcategories in the grounded theory analysis of the Branson emergence process. They tracked tourist demand against entrepreneurial initiatives.

The theatre *foundings* had their second-order effects, including theatre failures: the authors found correlations with theatre density, tourist demand and highway structure improvements were all correlated with $p < 0.015$ with the model. Other initiatives in Branson did not show positive correlations.

Positive feedback dynamics were provided by establishment of the community theatres, restaurants, hotels, shops, theme parks, amusements, two movies being filmed in Branson. A number of retirees moved to Branson. The theatres became increasingly diverse.

Stabilization dynamics occurred by the deep-seated values of local culture being supported, which included Christian ethics, family values, aesthetics, and Osark folkways. “Morality ordinances were enacted to maintain a friendly, wholesome, churchgoing atmosphere” (p. 512). Branson was advertised “as a town with no saloons or gambling houses”. The town was marketed as “the land of a million smiles” (Chiles, Meyer and Hench 2004, 512).

Recombination dynamics provided contributors of organizing systems through “recombining existing elements such as abandon airfields, using folding chairs from area attractions, a skating rink available and vacant theatre buildings, in their efforts to create new theatres” (Chiles, Meyer and Hench 2004, 513).

Empirically the analysis of the Branson musical theatres supported the model. The authors concluded that the variation, selection retention (VSR) “model is not strongly suited to take up the ongoing emergence of novelty” (Chiles, Meyer and Hench 2004, 514), whereas “our study suggested Branson’s organisational collective emerged far from equilibrium, in a state of perpetual disequilibrium”. “Our study suggests that instead of privileging equilibrium and equilibrating change, organizations should treat disequilibrium and disequilibrating change as natural and ongoing, rather than exceptional and episodic” (Lachmann 1986; Tsoukas and Chia 2002; Chiles, Meyer, and Hench 2004, 514).

2.5.1 Chiles, Meyer and Hench's Recognition of Complex Systems in the Entrepreneurial Process

1. Recognition of the dissipative structures model, of fluctuation, positive feedback, stabilization and recombination, explained the emergence process;
2. Spontaneous fluctuation that initiated a new order, positive feedback loops that amplify and reinforce these fluctuations, coordination mechanisms that stabilize the emergent order, and recombination of existing resources that help construct the new order'
3. Organizational science should treat disequilibrating change as natural and ongoing rather than exceptional and episodic;
4. The complex systems model provides the best explanation, because it emphasizes emergence as its central phenomenon, helping explain how system level order spontaneously arises from the action and repeated interaction of lower-level system components without intervention by a central controller;
5. Both positive and negative feedback, or stabilization dynamics, were all very important in both sustaining and controlling the emergence;

2.6 Why Gaussian Statistics are Mostly Wrong for Strategic Organization – 2005 – McKelvey and Andriani

While the papers that have been discussed so far have dealt directly with entrepreneurship, McKelvey and Andriani (2005) provide some important background which leads to influencing the way entrepreneurs think. Their contribution covers the role of fractals and power laws and they note that Gaussian statistics mislead in the study of organizations.

They start by discussing the fact that the coasts of many countries in the world “appear jagged no matter what kind of measurement is used: miles, yards or inches, kilometres, meters or centimetres” (p. 219). Similar patterns exist for rivers. These are fractals. Fractal geometry was generated by Mandelbrot (1983). A cauliflower is an example in that the branches, the sub-branches, and the sub-sub branches all have a similar shape, thus illustrating a fractal.

Fractals are driven by power laws, which “often take the form of rank/size expressions such as $F \sim N^\beta$, where F is frequency, N is rank (the variable) and β the exponent, is constant” (p. 219). They are called power laws because when plotted the log of each expression creates a straight line. Power laws and scale-free theories are related. In scale-free theories, the same theory applies at

different levels, that is, “the explanation of generative process is the same across all levels of analysis.

Many complex systems resulting from emergent dynamics tend to be “self-similar” across levels. The same process drives order-creation behaviors across multiple levels of an emergent system (Kaye 1993; Casti 1994; West, Brown, and Enquist 1997). These processes are called “scaling laws” because they represent empirically discovered system attributes applying similarly across many orders of magnitude (Zipf 1949). Brock (2000, 30) observes that the study of complexity “tries to understand the forces that underlie the patterns or scaling laws that develop” as newly ordered systems emerge. While scale-free theory is something else that is missing in strategic organization, we only deal with the statistical consequences here (McKelvey and Andriani 2005, 220).

Mckelvey and Andriani (2005), in their table 1 (reproduced as Table 2), indicate a range of power law discoveries.

Table 2: Listing of some power law discoveries.

Natural science			
Cities	Traffic jams	Coastlines	Brush-fire damage
Water levels in the Nile	Hurricanes & floods	Earthquakes	Asteroid hits
Sun spots	Galactic structure	Sandpile avalanches	Brownian motion
Bach’s music	Epidemics	Genetic circuitry	Metabolism of cells
Networks in brain	Tumor growth	Biodiversity	Circulation in plants, animals
Langton’s Game of Life	Fractals	Punctuated equilibrium	Mass extinction, explosions
Brain functioning	Predicting premature births	Laser technology evolution	Fractures of materials
Social science			
Language	Social networks	Internet	Blockbuster drugs
Sexual conquests	“Fordist” power	Wealth	Citations
Co-authorships	Actor networks	Job vacancies	Salaries
Firm size	Supply-chains	Growth rates of firms	Growth & internal structure
Casualties in war	Countries’ GDP growth rates	Stock price movements	Delinquency rates
Movie profits	Consumer product sales	Size of villages	Cotton prices
Economic fluctuations	Biotech alliance networks	Entrepreneurship/Innovation	

Sources are given in McKelvey and Andriani (2005).

The assumption behind the laws is that they are *interdependent* whereas Gaussian statistics assumes that events, people, organizations, etc., are *independent* and exhibiting normal distributions. Another key issue about the difference between Gaussian and Paretian statistics is that Paretian statistics include the extreme events, whereas Gaussian statistics seek the mean and standard deviation. In terms of earthquakes, most people are more interested in the very large earthquake that may occur every hundred years or more rather than the hundreds of small earthquakes that people hardly notice. Similar arguments apply to the size of enterprises as Apple and Microsoft have a much greater influence on the market than do the small one or two person organizations working in IT (McKelvey and Andriani 2005, 224).

McKelvey and Andriani (2005) make further critical points about linearity:

Linearity means two things: proportionality between cause and effect; and superposition, that is, when the dynamics of a system can be reconstructed by summing up the effects of the single causes acting on the single components (Nicolis and Prigogine 1989), which allows efficient causality to operate, equations to be solved and forecasting models elaborated. Economics, for instance, is almost theistic in its assumption that economic phenomena trend toward equilibrium (Mirowski 1989). However, this assumption allows linear equations and analytical simplicity (McKelvey and Andriani 2005, 220).

2.6.1 McKelvey and Andriani's Recognition of Complex Systems in the Entrepreneurial Process

- a. They recognized that most social institutions and events are governed by power laws rather than Gaussian statistics;
- b. The assumption of independence in most social activities is inappropriate since people in their relationships are mostly interdependent.

2.7 Measuring Emergence in the Dynamics of New Venture Creation – 2006 – Lichtenstein, Dooley and Lumpkin

Lichtenstein, Dooley and Lumpkin (2006, 154) provide a longitudinal case study of the development of a single entrepreneurial venture, examining the vision, strategic organizing and tactical organizing. They use “longitudinal content analysis and other complexity science methods”. They identified three different modes of organizing: (1) vision, which focused on the business opportunity, (2) strategic organizing, focused on the stream of “decisions, actions and interventions interacted by the entrepreneur”; and (3) tactical organizing, “involved

identifying the time in which particular events, indicative of the real start-up occurred”.

The authors started from Schumpeter’s (1934) definition of entrepreneurship as discontinuous change that destroyed the economic equilibrium’. The authors seek this analysis to be employed to explain the phenomenon of organising, “including the individual, the group-team, the project innovation, the firm, the industry and the macro environment” (Lichtenstein, Dooley and Lumpkin 2006, 157–8). Their analysis was at the level of the firm. Their case data captured many different elements including: cognition and cognitive change, intention, elements of opportunity recognition and development, individual organizing moves that sparks emergence, “various types of strategic organising that occurs as the entrepreneur acquires and creates resources, gains legitimacy and innovates their product/service”, and “specific start-up activities of nascent entrepreneurs” (p. 158).

The authors used Centering Resonance Analysis on the text from transcribed interviews which they endorse as being particularly significant in that they assesses the influence of particular words in “generating coherence within the discourse” (p. 159).

Figure 2: Punctuated change in tactical organizing start-up activities at HealthInfo Lichtenstein, Dooley and Lumpkin 2006.

It can be seen from the authors’ figure 2, and reproduced as our Figure 2, that a substantial change occurred in tactical organizing activities between Data Collection Periods 15 and 17 with further changes following rapidly. This change in tactical organizing produced emergence of entirely new context for the business concept.

The authors comment: “Given the highly interdependent nature of a entrepreneurial organising, we expect that emergent change in one mode would necessarily affect every other mode of organising; thus we argue that change across modes would be nearly simultaneous and punctuated” (p. 167).

Finally the authors comment that “emergence is not a subset of change, it reflects a different type of process. ... Change involves an alteration, a variation, an adjustment, that in some measures refers back to the initial state of the system. In contrast, emergence involved the creation of something genuinely new, the generation of new context within which the previous state of the system still remains” (p. 169).

2.7.1 Lichtenstein, Dooley and Lumpkin’s Recognition of Complex Systems in the Entrepreneurial Process

The authors recognize that:

1. Emergence is an aspect of punctuated equilibrium;
2. Tactical changes can lead to amendment of a strategic vision;
3. If tactical changes can lead to amendment of a strategic vision, there can be substantial progress following;

2.8 Complexity Dynamics of Nascent Entrepreneurship – 2007 – Lichtenstein, Carter, Dooley and Gartner

The authors analyzed the start-up activities of nascent entrepreneurs (Lichtenstein et al. 2007). They point out the importance of this topic because “some forms of organisational emergence (i.e. new business creation) account for up to 1/3 of the variation in economic growth in nearly all industrialised countries” (p. 238).

Analyzing four previous studies they identified 27 start-up activities, which are reproduced from their Table 1, including: “Saved money to invest, Asked for funding, Established credit with suppliers, Hired employees or managers, Developed prototype”, and many others (p. 242).

The authors used three dimensions to assess start-up activities: *rate* (p. 248), which is based on pace, speed or velocity; the authors interpreted these as measuring the number of activities undertaken over a period of time; *concentration* (p. 248), which is defined as the degree to which most of the organizing activities were performed closely together in time; and *timing* (p. 248), which is

the degree to which organizing activities occur earlier rather than later in the time span of the event history.

The results showed *concentration* and *timing* being significant with $p = 0.01$ significance level, early activities being significant with $p = 0.05$ significance level and *rate* being significant with $p = 0.10$ significance level. These results are graphically displayed in the authors' figure 1, which is reproduced in Figure 3.

Figure 3: Visual summary of results comparing emerged vs non-emergent ventures Lichtenstein et al. (2007).

The authors comment (p. 255, 256):

Complexity science does however provide a unique theoretical insight into the genesis of entrepreneurial processes. Current entrepreneurship theory (Shane and Venkataraman 2000; Ardichvili et al. 2003) argues that business opportunities drive entrepreneurial organizing, a perspective that places a primacy on opportunity recognition as the genesis of entrepreneurship (Kirzner 1997). However, that approach is unable to explain why nearly two thirds of the nascent entrepreneurs in the PSED do not start their businesses solely based on a business opportunity; instead, 44.5% said that the desire to start a business came first, and another 20.1% said that both motivations occurred at the same time (Carter et al. 2003, 119).

The findings for concentration – that emergence is improved when organizing activities are spaced apart rather than bunched.

2.8.1 Lichtenstein, Carter, Dooley and Gartner's Recognition of Complex Systems in the Entrepreneurial Process

The authors identified:

- a. Concentration of effort, timing of activities, and early activity for nascent entrepreneurs were found to be very relevant variables.
- b. High rate, low concentration and late timing were successful, whereas the rate, high concentration and early timing were shown to be unsuccessful.
- c. The desire to start a business came before identifying a business opportunity.

2.9 Radical Change Accidentally (Mission Church) – 2007 – Plowman, Baker, Beck, Kulkarni, Solansky and Travis

The Plowman et al. (2007) paper examines the transformation of a traditional and declining downtown silk-stocking church (Mission Church) for the city's wealthiest, which had been declining for 30 years, to a vibrant center for homeless people. This started with offering breakfast to homeless people however, within a short time, full-scale medical, dental, and eye clinics emerged as part of the Sunday morning program and, within a few years, a spin-off (a tax-exempt organization) of the church was receiving city grants, providing a "day center" for several thousand homeless people and serving over 20,000 meals a year. Legal assistance, job training, laundry services, and shower facilities are a few of the programs, in addition to the clinics, that emerged from the initial idea of a hot breakfast. Homeless people began joining the church, singing in the choir, and ushering at the major worship service (pp. 515–516).

The purpose of this research is examination of this radical change. The authors analyzed change at Mission church as:

1. Drivers of radical change: *Major* system instability;
2. Form of radical change: *pattern of adaptations* that is frame bending;
3. Nature of radical change: *Emergent and system wide* as adaptations accumulate into patterns;
4. Radical change system uses *positive and negative feedback* which pull system in two directions – toward a bounded instability
5. Radical change type of connection: *Tight coupling*, which enables amplification of local adaptations into radical change (p. 518).

This change is *continuous and radical* and this "means that both negative and positive feedback loops play important roles in the way change occurs.

Positive feedback reinforces the initial adaptations and, because of the tiny connections, small adaptations can easily accumulate (Maruyama 1963; Weick 1979) and develop into a pattern that attracts attention (Ford and Ford 1994). Negative feedback also plays a role in this quadrant, as a stabilizing mechanism that balances the dynamics of positive feedback (Chiles, Meyer and Hench 2004). Negative feedback can take the form of rules that actors in the system accept and apply to choices (Stacey 1995)” – (Plowman et al. 2007, 519).

Far from equilibrium state: this aspect goes back to Prigogine and Stengers (1984) study of chemical systems. The authors go on to comment:

When organizations move away from equilibrium toward instability, they can display highly complex behavior; that is, they are orderly enough to be stable but also full of surprises (Kauffman 1995), and contradictory forces operate simultaneously, pulling the organizations in different directions’ (Stacey 1992) – (p. 520).

The authors note that “organizations approach this far from equilibrium state when members have enough freedom to experiment with new ways of doing things and their discoveries can lead to disorder capable of moving through the entire organization” (p. 520).

Deviation amplification: Based on the study of cybernetics it has been found that both negative and positive feedback interact. The feedback is the typical feedback of a control process of reducing divergences and “dampening the effects of change and takes a system back to stability” whereas “positive feedback amplifies deviations and moves systems away from a stable state” (p. 520).

Actions amplifying small change: There were three categories of the following actions that follow the initial small change: “(1) acquiring new and rearranging existing resources that enabled and prompted more changes (p. 530); (2) using language that reinforced the emerging pattern of change; examples are ‘becoming holistic’, ‘dying and being reborn’, ‘recovering’ and ‘hell and judgement not included’ (p. 532), and (3) using symbols and signals that reinforced the church’s commitment to its emerging new direction”; examples include the pastors arriving at a meeting with the city officials with 12 freshly showered “marginalized people” to participate in the conversation; and, the pastor’s arrest due to interfering with a police officer who was questioning a homeless person (p. 533).

2.9.1 Overview Comments by Plowman et al.

1. “According to complexity theory, when a small change occurs in a context of destabilizing organizational shifts, other small changes are likely to emerge.

- Specifically, in regions of bounded instability (Stacey 1992), where adaptive tensions (Maguire and McKelvey 1999) or fluctuations (Chiles, Meyer and Hench 2004) are interacting with one another, emergence and self-organization occur” (p. 537). This point illustrates the importance of positive feedback.
2. The leadership was questioned why such changes were effective. “Leadership helped to amplify the small changes” (p. 538). The important role leaders served as sensemakers (Weick and Quinn 1999) “using the tools of language and symbols to give meaning to the changes that were happening” which did not include “the traditional tools of goals, plans, budgets, and strategies” (p. 540.)

2.9.2 Plowman, Baker, Beck, Kulkarni, Solansky and Travis’s Recognition of Complex Systems in the Entrepreneurial Process

The authors recognized that:

1. Complexity theory offers the best basis for an explanation, with its focus on *self-organization, emergence, and far from equilibrium*;
2. Small fluctuations in some variables can have monumental and unpredictable consequences;
3. The Prigogine and Stengers model of *far from equilibrium, with its adaptive tensions providing an import of energy and information, and system transition through chaos from one phase to another*, provides the best model to explain the emergence process;
4. *Positive feedback* is followed by deviations which will be reinforced by *fractal patterns remaining scalability across multiple levels*;
5. Change was amplified by *use of language and symbols that reinforced emerging pattern of change*;
6. Leaders provided sensemaking which contributed to the success of the emergence;
7. Negative feedback provided by recognition of Mission Church’s neighbors and the more conservative members of church leadership, kept the emergence under control.

2.10 Leadership Emergence: A Complex Systems Leadership Theory – 2009 – Lichtenstein and Plowman

Lichtenstein and Plowman take up the important issue about leadership of the emergence process. This involves focusing on the dynamic interactions between all individuals. The research is an analysis of three empirical cases which documents

emergence in different contexts. Four conditions for emergence were identified for each of the cases, these being: “Disequilibrium state, Amplifying actions, Recombination/‘Self-organization’, and Stabilizing feedback” (Lichtenstein and Plowman 2009, 620).

While the research recognizes that formal leaders do play a role in bringing about change the research also recognizes that “leadership may not reside solely within the character or the characteristic behaviours of supervisors (Seers 2005; Uhl-Bien, Marion, and McKelvey 2007), but rather that leadership may emerge from the interactions of all organizational members” (Plowman and Duchon 2007, 2008, 618).

Lichtenstein and Plowman’s Table 1 provides a summary of the three studies (p. 619 with some elements removed) (Table 3).

Table 3: Empirical studies of emergence and their four similar constructs (*table 1 of Lichtenstein and Plowman 2009*).

	Plowman et al. (2007)	Lichtenstein (2000)	Chiles, Meyer and Hench (2004)
Theoretical focus	Radical Emergence in one organization: “new birth”	Emergence (early lift-off) of high-potential ventures	Emergence – across organizations – creation of “agglomeration”
Unit of interest	Single organization (Mission Church)	Four “tech-enabled” high-potential start-up companies.	Organizational collective (Branson, MO)
Longitudinal data	100 years: 1895–1995	9 months of weekly interviews with > 50% of all employees (N = 1,000)	100 years 1895–1995
Dis-equilibrium state	“Initiating Conditions ... Far-From-Equilibrium State”	“Increased Organizing”	“Fluctuation Dynamics”
Amplifying actions	“Actions Amplify Small Change”	“Tension and a Threshold of Change”	“Positive Feedback Dynamics”
Recombination/ self-organization	“Emergent Self-Organization”	“Emergence of a New Configuration”	“Recombination Dynamics”
Stabilizing feedback	“Negative Feedback”	[System-wide Outcomes]	“Stabilization Dynamics”

The comparison of these studies is shown in their Table 1 in which the full constructs, which represent the common conditions for emergence across the

three studies, are shown. The three studies all confirm the same four sequential conditions for emergence, these being: Dis-equilibrium state; Amplifying actions; Recombination/self organization; and, Stabilizing feedback.

Lichtenstein and Plowman (2009) see these factors combining to produce “an entire community of organisations”, in their Figure 1 (p. 621).

While P1 to P9 are shown as propositions in Lichtenstein and Plowman’s paper they are effectively seen as principles by this paper (p. 621):

1. *“The more that leaders and members embrace uncertainty, the more likely that a Dis-equilibrium state will be initiated and/or heightened in the system.*
2. *Once a system is pushed to a Dis-equilibrium state, the more that its leaders and members surface conflict and create controversy, the more likely that the system will generate novel opportunities and solutions.*
3. *The more that leaders and members allow experiments and fluctuations, the more likely that amplifying actions will be present in the system.*
4. *The more that leaders and members encourage rich interactions, the more likely that Amplifying Actions will be present in the system.*
5. *The more that leaders and members support collective action, the more likely that Amplifying Actions will be present in the system.*
6. *The more that leaders and members create correlation through language and through symbols, the more likely that Recombination/“Self-organization” will be initiated and expanded in the system.*
7. *The more that leaders and members recombine resources, the more likely that Self-organization will be supported throughout the system.*
8. *When one or a few individuals accept the role of “tag” as a symbol for an emergence process, there is a higher likelihood that Recombination/“Self-organization” will be increased in the system.*
9. *The more that leaders and members integrate local constraints, the more likely that newly emergent order will be stabilized in the system.*
10. *The combination of the four sequences – Dis-equilibrium state, Amplifying Actions, Recombination/“Self-organization” and Stabilizing Feedback – are necessary (but not necessarily sufficient) conditions for the generation of Newly Emergent Order” (pp. 622–626).*

Some comments on these 10 principles are appropriate:

1. Leaders and members of organizations can surface conflict and create controversy by: questioning differences, fostering relentless discomfort and stating the conflict issues;
2. Amplifying actions can occur through encouraging experiments and supporting new initiatives;

3. Supporting collective action includes introducing others to the group and smoothing out political differences;
4. Correlation through appropriate language includes developing slogans and notices for the public, and identifying and accepting different words, such as replacing the word *homeless* with the word *marginalized*, creating symbols and tags, such as “dying and being reborn”, “Hell and judgement not included”.

A limitation of the study, which the authors readily admit, is that the model has been developed through a total of only five cases.

2.10.1 Lichtenstein and Plowman's Recognition of Complex Systems in the Entrepreneurial Process

The authors contributed the following:

1. Recognition of the four sequential phases in the emergence process of: Dis-equilibrium State, Amplifying Actions, Recombination Self-Organization and Stabilizing Feedback;
2. Combined these into a model of behaviors that generates the conditions for new emergent order shown in Figure 4;
3. Generating ten principles for leadership of emergence.

Figure 4: Behaviors that co-generate the conditions for new emergent order Lichtenstein and Plowman (2009).

2.11 Complexity Leadership and Jack Welch's Success – 2010 – McKelvey

Bill McKelvey analyzed Jack Welch's success at General Electric (GE) finding that he followed a number of complexity principles in his management. Jack Welch was remarkably successful in his 20 years as CEO of GE. He increased the stock value by a record of \$480 billion and was named the *Fortune Magazine's Manager of the Century* (p. 5).

McKelvey analyzing a number of texts and articles about Welch, noting that he followed twelve complexity leadership Action Disciplines (ADs) or principles. These are: imposition of adaptive tension (p. 12); create draconian incentives (p. 12); establish critical values (p. 13); establish co-evolution and scalability (pp. 14–15); introduce heterogeneous agents (p. 15); build human capital (p. 16); create week-tie flooding (pp. 15–17); structure moderate networking (pp. 17–18); create a modular design (p. 18); provide appropriate physical proximity (p. 18–19); establish co-evolution (p. 19); and foster scalability (p. 20).

2.11.1 McKelvey's Recognition of Complex Systems in the Entrepreneurial Process

The author proposed his twelve principles of management for entrepreneurship: These are: imposition of adaptive tension; create draconian incentives; establish critical values; establishing co-evolution and scalability; introduce heterogeneous agents; build human capital; create week-tie flooding; structure moderate networking; create a modular design; provide appropriate physical proximity; establish co-evolution; and foster scalability.

2.12 Making Geographical Clusters More Successful: Complexity-Based Policies – 2010 – Carbonara, Giannoccaro and McKelvey

Carbonara, Giannoccaro and McKelvey (2010) examine geographically based industry clusters and recognized “there is increasing evidence of the adaptive failure of geographic clusters (GCs) ranging across the US, UK, and other parts of Europe” (p. 21). To explain success and failure in GCs, complexity science is used. It holds that successful GC evolution happens only if they behave as effective complex adaptive systems (CASs).

2.12.1 Properties to Foster Efficacious Adaptation to the Changing World Around Them

The seven essential CAS properties are:

- a. Keep a High Level of Heterogeneity (p. 33);
- b. Foster Coevolution (p. 34);
- c. Impose Tension on a GC to Move It into The Melting Zone; (p. 34);
- d. Stimulate Self-Organization and Emergence in GCs (p. 35);
- e. Balance Top-Down and Bottom-Up Effects in The GC (p. 35);
- f. Exploit Butterfly Effects (p. 35);
- g. Build in Scalability (p. 36).

All of these principles are solid complex systems concepts. None are especially particular to networks, although it is recognized that networks obey complex systems behaviors. The paper is a valuable contribution to the study of clusters and networks as such an approach assists identifying the benefits to society of network properties. Consequently this is a valuable paper as significant analysis of networks and clusters is still occurring.

2.12.2 Carbonara, Giannoccaro and McKelvey's Recognition of Complex Systems in the Entrepreneurial Process

Generation of the seven principles for successful operation of a Geographic Cluster, by recognizing all of the following need to be present in a cluster:

- a. Keep a High Level of Heterogeneity (p. 33);
- b. Foster Coevolution (p. 34);
- c. Impose Tension on a GC to Move It into The Melting Zone; (p. 34);
- d. Stimulate Self-Organization and Emergence In GCs (p. 35);
- e. Balance Top-Down and Bottom-Up Effects In The GC (p. 35);
- f. Exploit Butterfly Effects (p. 35);
- g. Build in Scalability (p. 36).

2.13 Managing in a Pareto World – 2011 – Andriani and McKelvey

While this paper provides a reasonably comprehensive analysis of the benefits of a Pareto approach, only one section will be reported since this provides opportunities for entrepreneurs.

Andriani and McKelvey point out that traditional businesses recognizes the 80:20 rule in providing products on the shelves of supermarkets and the 20% of products chosen by 80% of consumers always gain preference. This is due to reducing the cost of marketing, display and supply. This approach is looking at one of the fat tails of the power distribution (p. 97).

However in a situation where the marketing and delivery cost is virtually zero, through the Internet, there is scope for the one-off supplier, who may be supplying from his or her garage in a large city, or who may be supplying from a village in a developing country. So the “emergence of virtual, Internet-based markets, make the distribution of markets fully Paretian”. This turns the traditional world of marketing and supply upside down (p. 97).

2.13.1 Andriani and McKelvey’s Recognition of Complex Systems in the Entrepreneurial Process

Recognition that when marketing costs are virtually zero through the Internet the traditional 80:20 rule is reversed and one-off suppliers can economically do business with one of the users, and hence compete with the mass producers who cater for the 20% of people who buy 80% of mass produced products.

2.14 McKelvey, Lichtenstein and Andriani – 2012 – Requisite Fractality in Firms

Similar to the McKelvey and Andriani (2005), this paper also focuses on the contribution of ideas which underpin emergence, rather than on the emergence itself. McKelvey, Lichtenstein and Andriani (2012) outline the two threads of development of complexity theory with its European roots in Prigogine’s dissipative structures model of phase transitions and the Santa Fe’s School’s focus on self-organized adaptation. The authors attempt to integrate these theories into a broad-based model of organizational design and performance through a law of *requisite fractality*, which provides underpinning for emergence and entrepreneurship. Comments on these two approaches are found in McKelvey and Andriani (2005).

The authors note that Bak’s concept of *organized criticality* is a process represented by a simple power law in which small initial events can lead to complexity cascades of avalanche proportions, which is supported by Arthur (1988, 1990) also focuses on positive feedbacks stemming from initially small

instigation events; as do Casti (1994) and Brock (2000, p. 110). And further in page 111:

In a formal sense, a scale-free theory of management is based on the premise that a single process – a specific set of sequences, patterns, and behaviors (Lichtenstein and Plowman 2009) – drives order creation at *every level* of specific phenomena (Kaye 1993; Casti 1994; West, Brown, and Enquist 1997). This new research program seeks to identify *which* organizational phenomena are scale-free, and find the simplest explanation for all the levels involved (Bak and Chen 1991; Stanley et al. 1996; McKelvey, Lichtenstein and Andriani 2012, 111).

Interpretation of the authors' concept of requisite fractality, in terms of requisite variety, appears to mean, good fractality to deal with the enterprise's business environment. It appears that enterprises are engaged in the power laws in the organizational world and in financial economics, without taking on a particular action. However, these are external fractal systems and this takes no account of the internal environment of the enterprise. What is required is to produce fractality within the enterprise and it assumed this is the authors' intention by their heading to Section 3.1 *From outside in: building from Ashby's law*, and emphasized by the comment in Section 3.1 that *only internal fractality can destroy external fractality* (p. 113).

In doing so this means that the enterprise needs to create an internal scale-free management. The authors also comment that emergent network configurations lead to the emergence of groups and group norms as a second stage. This emergence of levels in organizations, and their benefit in terms of fractal and power law behavior, are illustrated in their Figure 1 (p. 116). The authors are not sanguine about the likelihood of change in their Proposition 1: "The likelihood that any subsequent stage will emerge is the joint probability of emergence of it times all prerequisite stages" (page 116). The authors note that the square/cube law of organisms, absorbing energy growing by the cube, whereas the service increases by the square (p. 117).

The authors provide some guidance on various aspects of internal fractality including the following:

1. The most dangerous competitor firms surrounding a focal firm will be fractally structured (p. 117);
2. Social entities (including enterprises) should increase in size only by building a fractal structure to keep connection costs under control (p. 118);
3. Because of the n/c ratio (number of units/connection costs), the amount of energy going into communication, the organization combines modules which brings the over-communication under control (p. 118);

4. Preferential attachment would normally apply as an organization grows with units attaching themselves to existing large units (p. 119), however note Jack Welch for the problems of this (McKelvey 2010);
5. Adaptive tension is relevant and again Jack Welch provides a model of how he handled this in General Electric (McKelvey 2010, 12).

2.14.1 McKelvey, Lichtenstein and Andriani's Recognition of Complex Systems in the Entrepreneurial Process

The authors contributed:

1. Recognition that Ashby's requisite variety principle can be extended to requisite fractality for effective operation of an enterprise;
2. Recognition that order emerges "as a function of its probability times the joint probability of all prior stages emerging" (p. 116), which indicates that significant managerial effort is required to ensure success.

2.15 Power Law Distribution in Entrepreneurship – 2015 – Crawford, Aguinis, Lichtenstein, Davidson and McKelvey

While the tradition has been to assume that most social systems are governed by independent agents, and hence Gaussian statistics are relevant, the authors analyze a number of examples of social data and find that Paretian or power law statistics apply rather than Gaussian statistics. They provide an explanation noting that "95% of all US businesses employ 20 people or fewer and more than 60% of all new jobs are created by 0.03% of all entrepreneurial start-ups". The basic point here is that Gaussian statistics will be managed by treating organization such as Apple, Google, Facebook and Walmart, with its 2.2 million employees, as outliers and hence neglect the contribution of these large firms. By comparison, power law statistics focus on these large firms which have had such a significant influence on the market (p. 4).

A basis of the authors' criticism is illustrated (p. 3) and includes assumptions of Gaussian statistics as virtually the norm for most organizational studies. Seventy five studies by the authors did not demonstrate Gaussian distributions.

Because many large companies do not fit with the majority of the statistics, researchers make adjustments to the data by excluding some of the large companies which provide the outliers, however in doing so researchers may improve the fit of the data but reduce the validity and accuracy of their

conclusions. “In the entrepreneurial terms, the outliers of high impact firms ... That often transform entire industries” (p. 3).

In order to test their theory the authors comment

Our approach is to test four dozen common input and outcome variables in entrepreneurship, to empirically determine whether they are better characterized by a power law (PL) or a normal distribution. As a form of replication, we select generalizable variables that are central to seminal theories used to explain and predict entrepreneurship, including resource-, cognition, action, and environment-based perspectives. We analyze over 12,000 entrepreneurial firms across four data sets at different stages of development (i.e., nascent, young, and hyper-growing (p. 3).

Explanations provided by the authors

In a Gaussian world, differences in inputs explain different outcomes that remain relatively close to the mean of the distribution. Most of these explanations are based on models of linear causality, which dominate entrepreneurship research (Dean, Shook, and Payne 2007; Delbridge and Fiss 2013; McKelvey 2004a). Unfortunately, these theoretical frameworks have difficulty explaining outcomes where the highest performers are not just six standard deviations away from the lowest, but can be 20 times or even 1,000 times larger (p. 11).

2.15.1 Crawford, Aguinis, Lichtenstein, Davidson and McKelvey’s Recognition of Complex Systems in the Entrepreneurial Process

1. Entrepreneurship research has been largely conducted by using the Gaussian statistical model whereas the Paretian, or power law model, more accurately describes 48 of 49 major research studies of entrepreneurship.
2. By recognizing power laws data about the major entrepreneurial ventures, including growth of Walmart, with its 2.2 million employees, Apple, Google and Facebook, which have enormous influence on the industry, are not treated as outliers and rejected, and thus contribute to the validity of the study.

3 Lichtenstein’s Comprehensive Model of the Contribution of Complex Systems Thinking to Emergence

The papers reviewed in Section 3 provide a basis for contribution to an integrated and comprehensive model of entrepreneurship but none provide an integrated and comprehensive model themselves.

Lichtenstein (2014) has produced a remarkable text, titled “Generative Emergence”. It focuses on the role of complex systems in producing emergence, or entrepreneurship. This is in strong contrast to the traditional areas of study of entrepreneurship, which include firm and market structure.

Lichtenstein uses the word emergence when some might expect him to use the word entrepreneurship. Entrepreneurship is emergence of value.

A large proportion of the 5 unit structure is based on Lichtenstein’s *Generative Emergence* model, which is outlined in Lichtenstein (2014, 231–4). While we consider this work an amazing piece of scholarship, introducing a whole new approach to entrepreneurship modeling, while all the detail is built on complex systems research, including the contributions of the case studies reviewed in this paper, the comprehensive theory or model as a whole is not tested against any other comprehensive entrepreneurship theory or model.

Figure 5: The authors’ representation of the Lichtenstein (2014) regenerative emergence model.

The new model that Lichtenstein (2014, 4) introduces is shown in Figure 5, produced by the authors from Lichtenstein (2014, 231–4).

3.1 Phase 1 – Disequilibrium Organizing

Opportunity tension is the driver of disequilibrium, the initiative gets the entrepreneurial process started. The first driver of the process is the organizing behaviors, or the actions entrepreneurs take themselves to get started with

entrepreneurship. This has been illustrated in the case of Branson Missouri and also the Mission Church. However Lichtenstein (2014) notes that traditionally the “entrepreneur’s goal was to satisfy the needs of a particular market or external constituency”, whereas Sarasvathy (2003, 205) and Lichtenstein et al. (2007) found otherwise. Lichtenstein (2014, 233) comments that “nearly 2/3 of all respondents said that rather than opportunity per se it was their “decision to start” a business that was the primary driver.

Opportunity tension represents an internal drive – the entrepreneur’s intention – that arises in conjunction with his or her perception of the business opportunity, the market need that can be filled through entrepreneurial action (Lichtenstein 2009, 6). Opportunity tension starts when an entrepreneur perceives or enacts a pool of potential resources, creating an opportunity and simultaneously constructing a way to capitalise on the economic potential, through a unique and sustainable organising model (Lichtenstein 2014, 234).

Opportunity tension generates organizing activity that is “taking entrepreneurial action toward, and in favour of, the prospect of creating a new dynamic state” (Lichtenstein 2014, 234). Typical actions include:

- “Developing a prototype
- Doing marketing activities
- Drawing up financials
- Taking a business course
- Getting a telephone number
- Finding and negotiating with suppliers
- Becoming a legal entity” (Lichtenstein 2014, 235).

Empirical studies of emergence have shown that organizing pushes the existing system away from its normal state and “into a state of high dynamism, activity, and intensity, that is, into a far from equilibrium state” (Lichtenstein 2014, 236). Examples of this are provided by Chiles, Meyer and Hench (2004) as well as Plowman et al. (2007) in organizing activities for Mission Church, and Jack Welsh’s *Be #1, or 2, or else*.

Lichtenstein also provides examples of the disequilibrium organizing in the four companies he researched. Some examples provided include:

- Our goal is to become \$100 million company in six years (CEO)
- Take the company to the next level ... from \$7.5 million in sales to \$300 million over the next five years (p 240).

This increase in activity was illustrated in three of the four case studies conducted by Lichtenstein.

3.2 Phase 2 – Stress and Experiments

As the disequilibrium system is ramped up, increased stress occurs in the system. This then “sparks a series of experiments that seek to reduce that stress” (Lichtenstein 2014, 259). The stress being applied is “the intensity of activity, the disequilibrium organising, of entrepreneurs and leaders as they take direct action in their pursuit of an opportunity tension” (Lichtenstein 2014, 259).

This tension is analogous to “the heat” in the Bérnard experiment (p. 259). The author quotes an entrepreneur “the more energy she generates and the more activities she successfully takes, the more the current situation shifts into a disequilibrium state, out of its normal or current situation and into a period of high intensity and rapid change” (Lichtenstein 2014, 260). The stress includes increased workload (p. 260), cognitive and emotional stress (p. 261), low sales and systemic resistance, financial stress (p. 262) and organizational stress (p. 263). These stresses were borne out in the four ventures that Lichtenstein monitored.

3.3 Phase 3 – Amplification and a Critical Event

The greatly increased activity level of the entrepreneur “turns up the heat ... pushing the system into disequilibrium, out of the norm, aiming towards the envisioned state” (p. 279). Lichtenstein comments:

According to studies in several complexity science fields, this system moves farther away from its reference state into disequilibrium, that is an increase in positive reinforcement cycles within it ... With the increase in positive feedback, the occurrence of one action or event increases the likelihood that other similar events will occur in the system, thus pushing the system towards further change. Amplification is thus a natural result of the nonlinear dynamics of disequilibrium, a point Dooley (1997, 87) expresses clearly (Lichtenstein 2014, 279–80).

For social entities, a powerful shift occurs during the increase in disequilibrium organising and stress, amidst a rise in experiments and other fluctuations in the system. Up to a specific threshold a dynamic state will naturally dampen fluctuations so as to remain in its current structure. However, at a threshold point the system moves into a regime of amplification, where experiments can become magnified and extended throughout the system. In system dynamics language, the system shifts from a dampening mode into a reinforcing mode. Usually this starts in specific pockets and then extends throughout the venture (Lichtenstein 2014, 280).

Lichtenstein comments that there usually is a critical event, such as closing the first major deal which sparks such a transition (p. 281). Kauffman (2000, 56–7) “describes the increase of links within a network as an incremental process, until

ratio of links to nodes passes a specific point". Furthermore, "critical thresholds, and the transitions they generate to new organisational regimes, are central to the theory of self-organised criticality (Bak and Chen 1991, p. 281). Lichtenstein's four case studies reinforce these points".

3.4 Phase 4 – New Order through Recombinations

After the critical threshold, catalyzed by the critical event, the entire system will shift out of the previous dynamic state and into a new one, resulting in either first-degree, second-degree, or third degree emergence, or in dissolution whereby the organizing effort (the system) begins to unravel, lose momentum, and ultimately disband. In the brightest outcomes – a third-degree generative emergence – what arises is an all encompassing dynamic state, incorporating a new opportunity tension and core logic for venture' (Lichtenstein 2014, 297).

Lichtenstein provides examples of the degree of emergence in dynamic states. He notes that first degree emergence occurs when one aspect or system within the organizing model is created. He knows that this can include "an emerging relationship with a new partner and key supplier, an emergent routine (process, system) for managing activities, a new strategy for marketing or distribution, or the presentation of an alternative way to position the offering" (Lichtenstein 2014, 298).

"A second degree emergence occurs when an entire category of the dynamic state is (re)made, but still without creating the entire system" (Lichtenstein 2014, 299).

Third degree radical emergence is more than the others, for it is based on the creation of a new core logic for generating a sustainable dynamic state. This core logic pervades the entire firm' (Lichtenstein 2014, 300).

Examples of order creation as re-combinations of system components are found in the four case studies Lichtenstein conducted (2014, 306–13).

3.5 Phase 5 – Stabilizing Feedback and Sustaining the System

Lichtenstein's logic of this section is that:

New emergent order, if it creates value, will stabilise itself by finding parameters that increase its overall sustainability in the ecology. In social systems, as soon as emergence arise, they "test" and adapt their efficacy and legitimacy, so as to become embedded into the core logic and organising model of the dynamic state. Each of these tests is an instance of stabilising feedback' (Lichtenstein 2014, 315).

Lichtenstein notes the stabilizing feedback in Branson Missouri provided by and “usefully kept in check by a strong set of common cultural values, long-standing pro-business policies and the coordination of marketing efforts, through the actions of collective organisations in the area” (2014, 315). Lichtenstein also noted examples of stabilising feedback from his four case studies included:

- “Shift from the cash flow to positive cash flow;
- A licensing deal that starting to go well;
- More appointments;
- Closing out a whole line of business;
- Acceptance of the proposal;
- Completed intellectual property transfer;
- Going into full-scale production” (2014, 318).

Destabilizing feedback includes “comments and actions that call into question the new emergent and/or negate the process of concretizing a new dynamic state” (2014, 319). Other examples include resources being taken away from the project.

Lichtenstein comments that the notion of stabilizing feedback does not come directly from the Bérnard experiment but from recognition of what happened in the Branson Missouri and Mission Church cases (Chiles, Meyer and Hench 2004; Plowman et al. 2007).

4 Conclusions

A review has been conducted of fifteen research studies on the application of complex systems to entrepreneurship, finally examining Lichtenstein’s Generative Emergence model. All studies reviewed illustrate the importance of recognition of complex systems in entrepreneurship. No doubt many other studies could have been reviewed, which would also illustrate the role of complexity models in the development of entrepreneurial ventures.

Clearly, there are some entrepreneurial models that are reasonably comprehensive, such as Lumpkin and Dess’ entrepreneurial orientation (Dess, Lumpkin and Eisener 2008, 432–3) that do not have direct reference to complex systems. Of course, such models have been proven to assist entrepreneurs. However, this point does not counteract or negate the importance of complexity in entrepreneurship.

The study has also emphasized the importance of power law, or Paretian, statistics, which *recognizes* a number of differences including interdependence,

rather than independence, which is appropriate to Gaussian statistics. Probably the most convincing argument is based on the fact that power laws underpin most aspects of society, they recognize the dominant characteristics of a market, such as Apple, Google and Walmart dominating their industry, and being multiple standard deviations from the mean, and hence likely to be rejected as outliers in a Gaussian approach.

The most comprehensive model of all those considered, is Benyamin Lichtenstein's Generative Emergence, which is based on the role of complexity and is a comprehensive five stage model which will assist entrepreneurs in development of *emergence*, and hence entrepreneurial outcomes.

There is significant evidence from a comprehensive literature review provided in this paper that complex systems underpin the generation of emergence and entrepreneurship.

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