Introduction

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In a recently edited volume of a Routledge Great Works Series on *Complexity Concepts*, titled *Power-Law Distributions in Society & Business*, McKelvey and Bragin (2012b) include 45 chapters finding non-Gaussian – that is, Pareto (skewed) distributions – that appear as what are called 'power laws' (PLs) when the skewed data are plotted using log X- and Y-axes.[1] Andriani and McKelvey (2009) list ~100 PL studies relevant to organisations and management. McKelvey and Salmador Sanchez (2011) list another 80 studies of PL distributions in financial economics. All this evidence of PL distributed economic and organisational phenomena shows that management practitioners are embedded in skewed, long-tailed distributions with extreme outcomes that are generally ignored by organisational researchers because of the latter's prevailing presumption of Gaussian (normal) distributions. For this reason, the title of this special issue becomes relevant.

Three of the articles in this special issue were originally presented at the Organization Science Winter Conference of 2008; it had about the same title. As you will see, all the articles in this special issue are quite alien to the thinking of the Gaussian traditionalists dominating current organisation science. The fifth article was originally published in Spanish (McKelvey et al., 2011).[2] Here it appears in English; it translates Ashby's (1956) classic *law of requisite variety* into our *law of requisite fractality*. The latter is based on Per Bak's concept of 'self-organised criticality', as I explain next.

Complexity science recognises that systems can exist or fluctuate between three states – existing order, chaotic, and one in between (Lewin, 1992). Once imposed tension rises above the 'first critical value' (Prigogine, 1962) a phase transition occurs and the system tips over into the region of emergence, what Kauffman (1993) calls the 'melting zone'. In this 'region' – because of the effects of *tension* and *connectivities* among heterogeneous agents[3] – emergent phenomena generate patterns of new order in time and space that are neither static nor chaotic. If the tension rises above the 'second critical value' the system becomes chaotic – the so-called 'edge of chaos' (Lewin, 1992).

Bak (1996) labelled the non-linear interplay of tension and connectivity 'self-organised criticality' (SOC). Under constant *tension* of some kind (gravity, survival, ecological balance, need to change), some systems reach a critical state where they maintain stasis by efficacious adaptive behaviours. Bak illustrates SOC with a sandpile: a system consisting of natural dynamics that drives it towards, and then maintains it, at the *critical state*. Sand is slowly dropped onto a surface, forming a pile. The sand grains move so as to maintain the sandpile's *slope* in a precarious state of equilibrium given the force of gravity and irregularity of the sand grains. Eventually the sandpile becomes high enough and the slope of the sandpile steep enough for sand avalanches of varying sizes to occur. Bak observed that sand-grain movements varied from the frequent but barely perceptible movement of one or a few grains to the rare but large avalanche (the extreme); he found that the size and frequency of falling sand grains form a PL distribution (Bak et al., 1987). SOC theory has been applied across fields as diverse as physics, biology, economics and sociology (Scheinkman and Woodford, 1994; Adami, 1995; Brunk, 2002; Frigg, 2003; Kron and Grund, 2009). The tensions, connectivities, and non-linearities leading to extreme outcomes (the largest avalanches) are key elements of order-creation science. Together, the foregoing serve to cause new order creation in physical systems like Bak's sandpiles and in living systems, whether biological ecosystems (Kauffman, 1988, 1993) or social, organisational and industry ecosystems (Arthur, 1988, 1994; Holland, 1988, 1995; Brown and Eisenhardt, 1998). The chapters in McKelvey and Bragin (2012a, 2012b) present data and make the argument that SOC systems are PL distributed rank/frequency distributions – i.e., are fractal – and that it takes fractal SOC species and organisations to survive within SOC niches and industries.

In what follows I paraphrase the abstracts of the five articles:

- *Nystrom and Soofi:* Probability models for rare, outlier and extreme outcomes are different than the traditional Gaussian (normal) distributions typically used in management research. This paper uses distributional graphs and data on topics relevant to management research and practice to illustrate the theoretical basis and implementation of these concepts. Data on organisational size and CEO compensation are used to illustrate rare and outlier outcomes. Models that fit the size and compensation variables are very different from models fitting Gaussian distributions; means and standard deviations are useless for these variables. Another example focuses on extreme outcomes facing business executives after the 9/11 terrorist attacks on New York City and the Pentagon. A Bayesian approach is used to deal effects of extremely accurate or extremely inaccurate economic forecasts on the strategy of companies. Differentiation between the notions of extreme and rare are also illustrated using data simulated by a Monte Carlo method. The extension of methodology for identifying extremes is illustrated with data on implementation of new technologies.
- *Caiado and Ormerod:* There is considerable evidence of the existence of scaling behaviour (PL relationships) in various kinds of economic activity. Distributions of the connections among different industrial sectors, in terms of the value of outputs that each industry sells to each of the other industries, and also the value of outputs that the other industries sell to it. Information about these connections between industries is available in the input-output tables in the national economic accounts. A database in which the business sector in the UK economy is disaggregated into 123 separate industries is analysed. Although the statistical distributions of the connections are highly non-Gaussian, there are marked departures from PL distributed scaling behaviour, whether in the distribution of the connections from each individual industry to all the others, or in the distribution of connections from all industries into each individual one. Typically, the PL distributions follow the so-called '80–20' rule in that a significant portion of most of the distributions studied fits a PL distribution, but a portion of each often does not.

- *Hazy:* A new multilevel theory is needed that describes an emergent learning algorithm in organisations. A neural network model can be used to describe an organisational network consisting of individuals as nodes, interactions as edges, and influence relationships among them performing a function that is analogous to synaptic weights. This network structure enables organisations to adapt through a process of 'influence process structural learning' that is analogous to back-propagation learning in traditional neural network models. Rather than assuming top management is synonymous with executive function, the proposed model describes top management as facilitating organisational 'learning by doing' by acting as an output layer that expresses an organisation's response to environmental stimuli. Through disambiguation, decision making, and holding people accountable, this output layer selects the responses to be tested in the environment and then by assessing the level of error in the response, back-propagates changes to relative influence among the organisation's members by affecting reputations of individuals and institutionalising relative status. The theory posits that due to the cumulative advantage of network affects, influence relationships in organisations exhibit a PL distribution, which is therefore a potential marker indicating emergent collective agency.
- *Beech, Dowty and Wallace:* This research develops a pioneering approach to study the influence of organisational culture on crisis response. It consists of the development of a computer simulation of the role of different organisations' cultural biases in shaping how they resolve accumulated response tasks and deal with the disruptions of novel tasks. Called ORCiDS, Organizational Response Culture in Disaster Simulation, the simulation is applied to data concerning the responses of four types of organisations to Hurricane Katrina in Louisiana; specifically: the US Coast Guard, Federal Emergency Management Agency (FEMA), the White House, and a group of college-student volunteers. The simulations demonstrate how cultural biases lead to different outcomes for organisations that face similar circumstances but have very different cultural lenses for interpreting the circumstances. Beyond this specific instance of disaster response, this research demonstrates the value of modelling and simulating basic concepts of organisational culture in order to understand organisational behaviours.
- *McKelvey, Lichtenstein, and Andriani:* Complexity science has evolved greatly in the past 30 years, starting from its European roots in Prigogine's dissipative structures model of phase transitions, continuing through the Santa Fe School's focus on self-organised criticality (SOC), self-organised adaptation studied via agent-based computational simulations, and now to it's most recent focus on PLs and their basis in scale-free causes in econophysics. After briefly reviewing these three approaches to complex systems, we attempt to integrate them into a broad-based model of organisational design and performance. Several scale-free theories are applied to organisational phenomena. The law of 'requisite fractality' – an updated version of Ashby's original law for organisations in dynamic environments is defined. It holds that *it takes internal fractality to thwart external fractality*. The fractality law is based on the interaction effects and dynamics of organisational SOC within industry SOC. Fractality is indicated by well-formed PL distributions. Needless to say,

fractality stems from rank/frequency distributions, which show long-tailed distributions and extreme outcomes. Nineteen biological research studies are cited that show evidence of SOC and fractal predator/prey dynamics in ecological systems and, thus, evidence of requisite fractality in biology. Since M&A activities are the organisational equivalent of competition effects in industries, it follows that competition dynamics in organisations and industries produce fractal structures, processes, and dynamics. Implications for organisations and managers are discussed.

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Notes

1 Power laws often take the form of rank/frequency expressions such as $F \sim N^{-\beta}$, where F is frequency, N is rank (the variable) and β, the exponent, is constant.

2 Reproduced by permission.

3 'Agent' refers to semi-autonomous entities (i.e., 'parts' of systems), such as atoms, molecules, biomolecules, organelles, organs, organisms, species, processes, people, groups, firms, industries, etc.