IMPROVING CORPORATE IQ

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Human and social capital development are discussed in the context of increasing corporate IQ, defined as distributed intelligence (DI) in firms, as the basis of economic rent generation. A review of complexity science shows that *adaptive tension* dynamics (energy-differentials) may be used to foster adaptively efficacious DI appreciation. The optimal region for rapidly improving adaptive fitness occurs "at the edge of chaos." This region—in which emergent self-organization occurs—exists between the 1st and 2nd critical values of adaptive tension. Below the 1st value there is little change; above the 2nd value the system becomes chaotic and dysfunctional. Various activities are available to rent-seeking CEOs wishing to create or enlarge the region of emergence are discussed.

Keywords: Order, brain, distributed intelligence, complexity, leadership, emergence, attractors.

1 INTRODUCTION

When share prices fall, CEOs often lose their jobs. The best way to keep share prices high is to produce economic *rents*—defined as profits above the industry average (Besanko, Dranove and Shanley 1996). Porter (1996) says strategy is about finding new niches and then protecting rents by forcing would-be competitors into disadvantageous trade-offs. Prusak (1996, p. 6) says:

> The only thing that gives an organization a competitive edge—the only thing that is sustainable—is what it knows, how it uses what it knows, and how fast it can know something new!

In a brief study of the definitions of knowledge, intelligence, and information, Allee (1997, p. 42), citing the *American Heritage Dictionary*, defines intelligence as "the capacity to acquire and apply knowledge," noting also that the Latin root, *intelligere*, means "*to choose between*."

Zohar titles her 1997 book *Rewiring the Corporate Brain*. "Rewiring" places emphasis on the alteration of the connections among people—substituting for neurons—in the corporate brain. I will refer to this—the corporate brain—as *distributed intelligence* (DI) in firms. DI is a function of strategically relevant human and social capital assets—the networked intellectual capabilities of human agents (Masuch and Warglien 1992, Argote 1999).

What should CEOs do to foster the emergence of DI in their firms, speed up its appreciation rate, and steer it in strategically important directions? My approach rests on taking a "strict constructionist" reading of complexity theory (Mainzer 1994). I translate the concept of "*energy-differentials*" into the notion of "*adaptive tension*" to make the Bénard cell effect more meaningful in an organizational context. Very simply, if a firm is strategically "here" and it needs to be strategically "there" to generate rents, this is adaptive tension. I begin by making the link between DI and Ashby's (1962) definition of emergent order. Then I discuss DI in firms. This is followed with an introduction to basic complexity theory, specifically the Bénard cell effect and the factors defining the region of emergent order "at the edge of chaos." I conclude by outlining several managerial activities and issues pertinent to the creation of emergent order and DI in firms.

2 INTELLIGENCE AS CONSTRAINED ORDER

According to Merriam-Webster's dictionary (1996, p. 818) "*order*" and its synonyms means "…put persons or things into their proper places in relation to each other." Disorder, to natural scientists, means the 2nd law of thermodynamics, namely, inexorable dissipation toward entropy and randomness. Kauffman (1993) and Holland (1995) use the term, *order*, in the titles of their books, respectively *The Origins of Order* and *Hidden Order*. More specifically they focus on emergent order, equating it to spontaneous, emergent, self-organization.

What causes emergent order and self-organization? The Darwin/Wallace theory of natural selection (Darwin 1859) explains speciation in the biological world, that is: Why are there different kinds of organisms? Durkheim (1893) and Spencer (1898) also define order as the emergence of kinds, specifically, social entities. Half a century later, however, Sommerhoff (1950), Ashby (1956, 1962), and Rothstein (1958) define order not in terms of entities but rather in terms of the connections among them.

Ashby adds two critical observations. Order (organization), he says, exists between two entities, *A* and *B*, only if the link is "conditioned" by a third entity, *C* (1962, p. 255). If *C* symbolizes the "environment," which is external to the relation between *A* and *B*, environmental constraints are what cause order (Ashby 1956). This, then, gives rise to his "*law of requisite variety*" (1956). It holds that for a biological or social entity to be efficaciously adaptive, the variety of its internal order must match the variety of the environmental constraints. Furthermore, he also observes that order does not emerge when the environmental constraints are chaotic (1956).

Zohar (1997) starts her book by quoting Andrew Stone, a director of the global retailing giant, Marks & Spencer: "My work is in a building that houses three thousand people who are essentially the individual 'particles' of the 'brain' of an organization that consists of sixty thousand people worldwide" (p. xv). Each "particle" presumably has some intellectual capability—what Becker (1975) terms human capital, *H*. And some of them talk to each other—what Burt (1992) calls social capital networks, *S*. Together, *H* and *S* comprise *distributed intelligence* (DI).

Recent writing about competitive strategy and sustained rent generation parallels Prusak's emphasis on how fast a firm can develop new knowledge—the result of higher corporate IQ. Rents are seen to stem from staying ahead of the efficiency curve (Porter 1996), seeing industry trends (Hamel and Prahalad 1994), winning in hypercompetitive environments (D'Aveni 1994), and keeping pace with high-velocity environments (Brown and Eisenhardt 1998) and value migration (Slywotzky 1996). Dynamic ill-structured environments and learning opportunities become the basis of competitive advantage if firms can be *early* in their industry to unravel the evolving conditions (Stacey 1995). Becker (1975) defines knowledge/skills held by employees and their intellectual capabilities as *human capital* (*H*), and having given knowledge and capability economic value, adds it to the production function.

Human capital is a property of individual employees. Taken to the extreme, even geniuses offer a firm only minimal adaptive capability if they are isolated from everyone else. A firm's core competencies, dynamic capabilities, and knowledge requisite for competitive advantage increasingly appear as *networks* of human capital holders. These knowledge networks also increasingly appear throughout firms rather than being narrowly confined to upper management Norling 1996). Employees have become responsible for adaptive capability rather than just being bodies to carry out orders. Here is where networks become critical. Especially in the last two decades, much of the effectiveness and economic value of human capital held by individuals has been shown to be subject to the nature of the social networks in which the human agents are embedded (Granovetter 1985, Burt 1997), as a reading of the various chapters in Nohria and Eccles (1992) also suggests. Burt (1992) go so far as to move networks into the realm of economic value by terming them *social capital* (*S*), saying that competitive advantage is a function of network relations, not individual knowledge attributes (1992, p. 3).

3 DISTRIBUTED INTELLIGENCE

I draw on both modern brain and distributed computer systems research to demonstrate that Becker and Burt each are half right. Respectively, they naïvely could be interpreted to imply that "isolated geniuses" or "networked idiots" can generate rents. More likely, they would agree that *H* and *S* are *jointly* important. If so, the theory of the firm most relevant to rent generation appears as: $Y = f(K, L, D)$, where D stands for the configuration of *H* and *S* likely to produce optimal DI for a particular firm. DI—in brains and in parallel processing computer systems—is a function of both the knowledge in the nodes (minimal in brains) and in the emergent connections among nodes (primitive in computer systems). Leaving aside nodes for the moment, intelligence is a function of links among nodes.

DI in a brain is entirely a function of its capability for producing emergent networks among neurons. They behave as simple "threshold gates" that have one behavioral option—fire or not fire (Fuster 1995, p. 29). As intelligence increases, it is represented in the brain as *emergent* connections (synaptic links) among neurons. Human intelligence is "distributed" across really dumb agents!

DI in parallel processing computer systems is mostly a function of the built in intelligence capability of computers-as-agents, with minimal DI improvement stemming from emergent networks among the computer/agents. In computer DI systems, computers play the role of neurons. They are more "node-based" than "network-based." Artificial intelligence resides in the *intelligence capability* of the computers as agents, with emergent network-based intelligence rather primitive (Garzon 1995). Garzon's analysis notwithstanding, the distributed computer literature shows only marginal progress toward *emergent* DI, whether at the agent *or* network levels.

Artificial intelligence (AI) models increasingly are used to simulate learning processes in firms, though their intelligence capability is not fully connectionist and the intelligence of their agents is mostly limited to neuronal "on-off" intelligence capability—far below that, even, of PCs (Masuch and Warglien 1992). My focus on DI as emergent order places most of the emphasis on the emergence of constructive networks. Of course, firms that have constructive networks among geniuses usually will fare better than those having great networks among idiots.

4 COMPLEXITY THEORY

How should CEOs accelerate the rate of DI increase? Complexity theory points the way. Complexity theorists define systems in the emergent complexity category as being in a state "*far from equilibrium*" (Prigogine and Stengers 1984) and "*at the* *edge of chaos*" (Kauffman 1993). Prigogine and colleagues observe that energy importing, self-organizing, open systems create structures that in the first instance increase negentropy, but nevertheless ever after become sites of energy or order dissipation. Consequently they are labeled "*dissipative structures.*" Self-organized —and self-contained— dissipative structures may exhibit persistence and nonlinearity. Complexity caused self-organizing structures are now seen as a ubiquitous natural phenomenon (Mainzer 1994) and broadly applicable to firms (Anderson 1999, Maguire and McKelvey 1999).

The boundaries of emergent complexity are defined by "*critical values*" (Mainzer 1994). Nothing is so basic to the definition of complexity science as the Bénard cell—two plates with fluid in between. An *energy* (heat) *differential* between the plates—defined here as '*adaptive tension*', *T*—creates a molecular motion of some velocity, *R*, as hotter molecules move toward the colder plate. The energy-differential in the Bénard cell parallels that between hot surface of the earth and cold upper atmosphere—hotter air molecules move upward and if they move fast enough, create storm cells. Complexity science cannot be understood without appreciating the role that *T* plays in defining the region of complexity "at the edge of chaos." If *T* increases beyond the 2nd critical value, the agent system jumps into the region of chaotic complexity. Here the system is likely to oscillate between different states—centered around different *basins of attraction*—thereby creating chaotic behavior. Definitions of *attractors* are given in Table 1.

Table 1 Definitions of Attractors by Gleick (1987)

"***Point attractors***" act as equilibrium points. A system, even though oscillating or perturbed, eventually returns to repetitious behavior centered around the point attractor—traditional control style management decision structures may act in this manner (appearing as Newtonian complexity);

"***Periodic attractors***" or "*limit cycles*" (pendulum behavior) foster oscillation predictably from one extreme to another—recurrent shifts in the centralization and decentralization of decision making, or functional specialization vs. cross-functional integration fit here (also appearing as Newtonian complexity);

If adaptive tension is raised beyond some critical value, systems may be subject to "***strange attractors***" in that, if plotted, they show never intersecting, stable, low-dimensional, nonperiodic spirals and loops, that are not attracted by some central equilibrium point, but nevertheless appear constrained not to breach the confines of what might appear as an imaginary bottle. If they intersected, the system would be in equilibrium (Gleick 1987, p. 140) following a point attractor. The attractor is "strange" because it "looks" like the system is oscillating around a central equilibrium point, but it isn't. Instead, as an energy importing and dissipating structure, it is responding with unpredictable self-organized structure to tensions created by imposed external conditions, such as tension between different heat gradients in the atmosphere caught between a hot surface of the earth and a cold upper atmosphere, or constraints in a fluid flow at the junction of two pipes, or tension created by newly created dissipative structures, such as eddies in a turbulent fluid flow in a canyon below a waterfall, or "MBA terrorist" structural changes imposed in an attempt to turnaround an acquired firm.

As a metaphor, think of a point attractor as a rabbit on an elastic tether—the rabbit moves in all directions but as it tires it is drawn toward the middle where it lies down to rest. Think of a strange attractor as a rabbit in a pen with a dog on the outside—the rabbit keeps running to the side of the pen opposite from the dog but as it tires it comes to rest in the middle of the pen. The rabbit ends up in the "middle" in either case. With the tether the cause is the *pull* of the elastic. In the pen the cause is *repulsion* from the dog unsystematically attacking from all sides.

Suppose a large firm acquires another firm needing a turnaround and that *T* stays below the 1st critical value—existing management stays in place and little change is imposed by the acquiring firm. There is little reason for people in the acquired firm to create new structures.

If *T* goes above the 2nd critical value, complexity theory predicts chaos. Suppose the acquiring firm changes several of the acquired firm's top managers and sends in "MBA terrorists" to change the management systems "over-night"—new budgeting and information systems; new personnel procedures, promotion approaches, and benefits packages; new production and marketing systems. In this circumstance, two basins of attraction could emerge: one basin defined around demands of the MBA terrorists and the other centered around the comfortable pre-acquisition ways of doing business and resistance to change. The activities of the system could oscillate between these two basins, seemingly exhibiting the characteristics of a strange attractor.

Between the 1st and 2nd critical values lies the region of complexity at the edge of chaos that Brown and Eisenhardt (B/E) (1998) aim at. Here, network structures emerge to solve *T* problems. Using the storm cell metaphor, in this region the "heat conduction" of interpersonal dynamics between sporadically communicating individuals is insufficient to reduce the observed *T*. To pick up the adaptive pace, the equivalent of organizational storm cells consisting of "bulk" adaptive work-flows starts. Formal or informal structures emerge, such as new network formations, informal or formal group activities, departments, entrepreneurial ventures, and so on. Though the *T*s in organization science are unlikely to have the precise values they appear to have in some natural sciences (Johnson and Burton, 1994) it seems likely that a probability distribution of such values will exist for individual firms and each of their subunits.

5 STEPS TOWARD HIGHER CORPORATE IQ[1]

Adaptive Tension. For corporate DI to have its IQ

[1] Due to space limitations I am ignoring other relevant activities such as managing: dysfunctional stress, the coaching (autocatalytic) process, the dissent regime, complexity catastrophe, and modular architecture.

raised, Ashby's definition of order needs to prevail. This means that the constraints, C_i, must be identified and brought to bear on the human "nodes" in the system in addition to fostering emergent networks. Thus, a CEO's first task in improving corporate IQ is to make sure the corporate brain is exposed to the full range of "T_os" "**o**ut there"—that surround the agents—that might energize emergent order. But a T_o that is "out there" but ignored by agents has no impact on agents' behavior. In natural systems, so far as we know, agents—particles, molecules, cells—do not ignore T_os impinging on them. Agents in firms can. At GE, Jack Welch uses "*Be #1 or 2 in your industry*," with a very clear **m**otivational valance. *Respond to the T or your division will be sold!* Thus, T_ms—simply *T*s hereafter—need to have an intrinsic or extrinsic motivational valance attached before they can be expected to be felt as tension by agents. *T*s are the root motivation causing agents to import negentropy—from whatever source available—that is the cause of emergent networks aimed at dissipating them.

While agents in a Bénard cell face just one *T*, the adaptive tension confronting the many agents within a firm—as receivers—appears as countless *T*s. In addition, there are many *T*s reflecting forces and constraints in the environment, not to mention *T*s created by numerous agents within competing firms—from the CEO down to the people in engineering, production, marketing, sales, and so on. An agent network could emerge virtually anywhere in a firm around an initiative to produce a better part, product, marketing approach, new strategy, and so forth. Consequently, there is danger in *a priori* trying to focus certain kinds of *T*s toward specific kinds of agents. This might preclude the emergence of the most effective new networks. But there is an equal danger in trying to flood every agent with every kind of *T*. It is also clear that "selecting" the nature of the incoming *T*s based on preconceived CEO-level notions, as Roger Smith did at GM for a decade (Hunt and Ropo 1998) puts blinders on the corporate brain. Toyota is well known for its system of increasing the awareness of workers about how well their designs and products compete against the competition—a small set of narrowly defined *T*s. Welch accomplishes the same objective by defining *T*s very broadly as, "Be #1 or 2 in your industry!" This is a perfect example of using a simple piece of information to focus attention on a particular aspect of the competitive environment—everything is boiled down to one *T* that *drives* the lower level systems without the command-and-control structure *defining* them. Strong corporate leadership is shown without setting up a suppressive command-and-control-structure or otherwise inhibiting emergent DI.

Critical Values. Assuming agents are confronted by the appropriate *T*s, managing the critical values aspect of adaptive tension requires three basic activities: (1) checking whether behavioral symptoms of *T*s impinging on one or more agents are below, between, or above the critical values; (2) altering motivational valances to move the *T* levels into the region between the 1st and 2nd critical values; and (3) widening the distance between the critical values.

Critical values are not precisely determined in firms—as they are in natural science. Nor does research indicate what levels of *T*s are below, between, or above the critical values. For now we have to rely on behavioral symptoms for evidence about *T* effects. B/E (1998)[2] identify some symptoms. For example, as indications that *T* is *below the 1st critical value*, B/E point to overbearing structure, fiefdoms, little novelty, and reactive strategizing. For evidence that *T* is *above the 2nd critical value* B/E point to random communication, over coordination, politics, modular structures disconnected, and sporadic intense experimentation too narrowly focused.

There are also direct symptoms of emergence. In general *T* between the critical values produces emergent dissipative structures, which then start reducing *T*, at which point they dissipate:

1. Emergent social networks such as dyadic or triadic communication channels, informal or formal teams, groups, or other network configurations;
2. More effective networks within or across groups, more structural equivalence, better proportions of strong and weak ties, increased numbers of structural holes (Burt 1992), more networks emerging between hostile groups—marketing with engineering, or with production, with suppliers, with customers, and so forth;
3. Emergent networks of any kind, networks that produce novel outcomes, new strategies, new product ideas, new directions of knowledge accumulation; and
4. Networks that speed up rates of adaptive-event occurrence.

Widening the region of emergence requires operating on the location of the critical values themselves—lowering the 1st, raising the 2nd—rather than only trying to adjust the *T*s to fall in between. Anything that gets networks to form more easily is essentially lowering the 1st critical value. Raising the 2nd critical value requires training agents to develop (1) more effective emergent structures—so tension stops rising and starts dissipating; and (2) higher 'tension tolerance' to handle higher tension levels before "going chaotic." For example, employees in high-velocity firms in Silicon Valley work routinely in an atmosphere of adaptive tension far higher than might ever appear in

[2] Though the B/E book offers useful advice to practicing managers the impression they give of complexity theory could be misleading to naïve readers. They argue that managers should balance their firms between too much rigid bureaucratic structure and chaos—as if these are God-given and etched in stone. Instead, complexity science shows that a complex adaptive system is caused to exist below, between, or above the 1st and 2nd critical values by an adaptive tension (energy-differential) acting on the system as an exogenous variable, that naturally (as in the weather) or artificially (as with a Bénard cell) is subject to change and/or manipulation. Put simply, CEOs don't respond to complex adaptive systems as fixed entities—they can inadvertently or purposefully create all three kinds of them!

large dinosauric firms or government agencies.

Attractors. The previous two sections work on the "fostering-and-speeding-up-emergence" part. Now I turn to the problem of "steering" without inadvertently fostering the emergence of a suppressive command-and-control-bureaucracy. Recall the definitions of *point* and *strange attractors* in Table 1.

Bureaucratic negative feedback systems center around point attractors. A visionary CEO operates as one—the vision is the goal, which becomes the equilibrium point toward which negative feedback, managerial control processes define the system. Since firms do need strong leaders, and since some people like being strong leaders and behave like strong leaders, it is pointless to think of avoiding point attractors. The trick is to aim these "strong leader types" toward using point attractors that "*drive*" the system toward reducing the *T*s but do not "*define*" it in the command-and-control ways that inhibit emergence. *T*s *are* point attractors. Activities that serve to reduce *T*s, thus, are point attractors.

Remaining strong leader activities are best redefined to be strange attractors. This is probably the best way in which to view Bennis's (1996) "herding cats" metaphor—the "cage" effect of the rabbit and dog metaphor in Table 1. We may use what Morgan (1997, p. 98) refers to as "*cybernetic reference points*" and "*avoidance of noxiants*" to define the reflective cage of a strange attractor without defining goals that act as point attractors. Strange attractor "definitions of the cage" must be created without determining specific or repeating paths—characteristics of point attractors and opposite the definition of novelty.

Incentives should encourage the proper delineation, separation, and development of point and strange attractors. It is easy to define point attractor incentives—"Here is the goal and I will pay more if you achieve it." Saying "No" is all too easy in firms and seldom needs to be encouraged. Setting up "inexpensive experiment" strange attractor systems seems more risky and learning when to say "No" to continuing an experimental product development activity is problematic. Strange attractors also need to be made attractive for agents "inside the cage."

Agency Problem. Economists define the agency problem as the likelihood that managers, as agents of shareholders, will substitute their own personal interests for those of shareholders (Jensen and Meckling 1976). If slack resources (March and Simon 1958) are made available for DI development, then there is the possibility that the slack could be used against shareholder interests. Slack targeted for DI development should be managed by strange attractors rather than allocated to point attractors. Slack imported into basic research parks is adaptive, but the tension is low as the agents are disconnected from market defined *T*s. Connecting slack with specific *T*s, but still steering the DI system by strange rather than point attractors seems optimal. The more market-connected *T*s are used to create the conditions leading to emergent order, the more likely networks will emerge in response to market related adaptive problems rather than in response to the interests of individual agents. In light of my goal of finding ways that CEOs can produce sustainable rents, CEO activities that inhibit DI appreciation actually contribute to the agency problem. DI appreciation depends on staying in the region between the critical values, which in turn depends on "pointing" agents' attention toward the *T*s (defined to include incentives).

6 CONCLUSION

CEOs wishing to generate sustainable rents in a changing world would be more successful if they focused on human and social capital appreciation, that is, distributed intelligence. I use complexity theory and adaptive tension to show how CEOs could speed up the rate of DI appreciation while at the same time suppressing the emergence of bureaucracy—a point elaborated in McKelvey (forthcoming). Complexity science recognizes that kinds of complexity are not immutable; they are the result of adaptive tension. Knowing this, if leaders alter the adaptive tension imposed on a system, its kind of complexity and emergent order changes. Specifically, tuning adaptive tension to between the 1^{st} and 2^{nd} critical values produces emergent network structures.

Theories of bureaucracy and organization (Scott 1998) put intelligence *in the positions* and in the people holding them, and emphasize human capital appreciation as the basis of competitive advantage. Parallel-processing distributed computer systems put intelligence mostly in the agents with primitive emergent connectionism possible. In contrast, theories of the brain and human intelligence say intelligence *is the network*, a view taken up by Burt (1992) with his emphasis of social capital appreciation as the basis of competitive advantage. None of these views is correct by itself. Combined brain and computer-based distributed systems place intelligence both in the agents and in the network. My view of DI in firms, therefore, builds on both brain and computer analogies.

A key part of this paper is the recognition that the use of knowledge in rapidly changing competitive contexts depends on high levels of corporate IQ. Just as IQ in people is a function of neurons and synaptic links, I argue that human and social capital in firms are the basic building blocks of corporate IQ. Since people are spatially distributed throughout a firm, we are necessarily talking about distributed intelligence. Given this, networks are critical. I also draw on a classic article by Ashby (1962) to argue that emergent distributed intelligence in firms is in reality a function of emergent networks among people, with the added Ashby proviso that "order" and self-organization result only in the context of environmental constraints.

Using a strict constructionist interpretation of complexity theory, I develop several activities that CEOs can set in motion to improve corporate IQ by using adaptive tension and incentives to foster emergent order. My analysis elsewhere shows that strong, visionary, charismatic CEO-level leadership may produce levels of group cohesion inhibiting the production of emergent order/intelligence (McKelvey forthcoming). Many of the "complexity-theory-applied-to-management" books reviewed in Maguire and McKelvey (1999) argue that strong command-and-control structures often created by strong visionary CEO leaders also inhibit emergent order/intelligence. In this paper I argue that complexity theory offers guidelines for designing aggressive CEO activities aimed at improving corporate IQ that obviate these well known down-side effects of strong leadership at the top.

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