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Complexity: an appropriate framework for development?[1]

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I Prevailing linear paradigm

Kuhn (1970: 6–17) argued that a scientific discipline progresses through 'paradigm shifts' separated by periods of relative calm during which a particular set of rules and assumptions (the paradigm) defines the boundaries for 'legitimate' practices in that field. Capra (1983), amongst others, demonstrated that the natural sciences adhered until recently to the dictates of a linear paradigm that originated from ideas advanced by scholars such as Hobbes, Descartes, Locke and Newton.

Linearity, as typified by the laws of motion, is correlated with order, predictability, linked causes and effects, and knowable universal laws that allow desirable results to be obtained by application of the requisite inputs to a system. The constituent parts of a system give useful indications of the mode of behaviour of the whole. Fundamentally, linear processes are deterministic, mechanistic and finite, as opposed to being evolutionary and open-ended. Consequently, they respond well to hierarchical management structures and to reductionist, rather than integrative, methods of analysis.

In time, linear thinking spread beyond the original scientific discoveries to embrace practically all facets of life. The success of the industrial revolution, in particular, engendered a belief that most problems could be resolved by the positivist application of reason to empirical observations. Following that logic, Smith and Ricardo claimed to have captured the laws of economics, and Marx enunciated his 'immutable' and deterministic laws of capitalist development. More recently, using a similar logic, Bell (1965) predicted an end to ideology while Fukuyama

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(1992) claimed history has come to an end following the triumph of capitalism over communism. As Byrne (1998: 19) put it: 'If we can establish the relationships so that our formalised linear mathematical models are indeed isomorphic with the real world then . . . we can engineer the world . . .'. He added, however, 'much, and probably most, of the world doesn't work in this way'.

The study of development has mainly proceeded within a linear paradigm, although change might be on the way, as discussed later. Rostow (1960) reduced economic development to five distinct stages. For Toye (1987: 11) this was seen as a move 'through a series of stages of development derived essentially from the history of Europe, North America, and Japan . . .'. The World Bank and the International Monetary Fund's (IMF) highly specified structural adjustment and stabilization programmes are more recent examples of linear thinking.

Development was treated as a reasonably predictable activity that should respond to laws of universal applicability; see Elliott (1996: 5–7). Research sought to distil from specific instances lessons useful to the 'developing world' as a whole. Fashions in development have come and gone but the objective of determining laws of general applicability has endured. Reliance on top-down management styles is another indicator of linearity. When development became a global priority after the second world war, it was implicitly viewed as a task that required direction from the top through the United Nations (UN), the World Bank and IMF, world leaders and specialist governmental agencies in developed and developing countries. Numerous programmes ensued, such as the Brandt Commission's *North–South: a programme for survival* (1980), which beamed universalistic elite designed policy packages at nations with diverse problems, potentialities and constraints. Development elites selected grand policies and major infrastructure projects in the belief that the process of development could be initiated and speeded up at will; see Elliott (1996) and Caufield (1997). Recently, development seems to have departed from strict linear thinking, and recent innovations in the natural and social sciences may provide pointers for the form of future change.

II Genesis of the nonlinear paradigm

The success of scientifc discoveries 'led the French scientist the Marquis de Laplace at the beginning of the nineteenth century to argue that the universe was completely deterministic . . . there should be a set of scientific laws that would allow us to predict everything . . . including human behaviour' (Hawking, 1988: 53–61). Scientific determinism was resisted by some 'but it remained the standard assumption of science' until the early years of the twentieth century. In 1926 Heisenberg advanced his uncertainty principle, and then he, Schrödinger and Dirac pioneered quantum mechanics and demonstrated that some phenomena are *probabilistic*. Several scholars, including Capra (1983: 37–89), Davies (1987: 22–39), Gribbin (1987: 5–28), Hawking (1988) and Peat (1991: 9–30), have considered this paradigm shift in the natural sciences.

The drift away from certainty was consolidated during the second half of the twentieth century, with contributions from mathematics, biology, meteorology, as well as the social sciences. Researchers became interested in nonlinear situations where a system exhibits extreme sensitivity to variations in initial conditions. Trivial

events could be magnified, through feedback, into major upheavals. A given cause might lead to more than one outcome, and if the process were repeated the results could be, and often are, different. Basically, *emergent properties* ensure that in this case the whole is not the sum of the constituent parts.

Assimilation of nonlinearity is now well established within the natural and life sciences, as argued by Gleick (1988), Nicolis and Prigogine (1989), Kauffman (1993, 1996), and Gell-Mann (1994). Hawking (1988: 55) has cautioned, however, that 'the uncertainty principle had profound implications for the way we view the world. Even after more than fifty years they have not been fully appreciated by many philosophers . . .'. Nonetheless, complexity theory has begun to spill slowly into the social sciences; see Waldrop (1992), Day (1994), Ormerod (1994, 1998), Lewin (1997) and Byrne (1998).

Byrne (1998: 1–53) supported Reed and Harvey (1992: 354) in arguing that 'societies and institutions can be treated as if they were dissipative entities' and has envisioned a strong link between realism and complexity. Byrne (1998: 8, 39) argued that this combination was fatal to positivism, which assumes total mastery over nature is possible, and to postmodernism, which rejects grand narratives and in essence advocates social inaction. Complexity, in taking a middle course, accepts that human beings could take positive action to improve their condition, but it concedes that there are strict limits to predictability and action. According to Byrne (1998: 45) it is helpful in conceptualizing the relationship to see 'the linear and reductionist as a thesis, postmodernism as an antithesis and complexity as a synthesis.'

III What is a complex adaptive system?

A family of nonlinear systems attracted the attentions of scholars as potentially useful tools in analysing natural and social phenomena. They are variously described as being *complex,* because they have numerous internal elements, *dynamic,* because their behaviour is governed by local interactions between the elements; and *dissipative,* because they have to consume energy to avoid drifting from self-organization into chaos. When such systems are capable of evolution they are also known as Complex Adaptive Systems.

To describe complex systems and consider their relevance to development it is necessary first to understand three regimes of behaviour, *order, chaos* and *self-organized complexity*. These could be illustrated by water in a bathtub. When tap and plughole are closed, the water is in a state of unchanging order. When the tap is open, the movement of the water assumes a regime of chaos that is almost impossible to specify. However, with the water running at a controlled rate and the plug removed, the water *self-organizes* itself into a complex regime represented by a stable vortex (Kauffman, 1996: 21).

Elaborate experiments were conducted using Boolean networks to study the three regimes. Each network has many internal elements with two possible states: active or inactive, for instance light bulbs that could be turned on or off by some or all of the other bulbs depending on the *connectivity* of the network. Kauffman (1993: 36) reported that by simply altering connectivity and the local rules that dictate how the elements interact order, chaos or organized complexity could be created.

As interactions between the elements proceed, a system scrolls through different *states*. In an orderly regime all regions of the system 'freeze in fixed states of activity', as described by Kauffman (1993: 174), while an infinite number of different states are involved in a chaotic regime. In *organized complexity* the system cycles through a large but finite number of similar, but not identical, states (see Kauffman, 1996; Coveney and Highfield, 1996: 166–78), and Byrne, 1998: 26–29). The near-identical states differ but they do so within specific limits that constantly pull them into one *basin of attraction* or *attractor,* as described in complexity parlance. The particular attractor in force at any time gives a complex system its observable global pattern, which remains stable while the states are in the grip of that attractor.

Minor variations between states cause some change but this is normally contained within the attractor. Despite the frenetic internal activity, outwardly the system seems to be unchanging. Occasionally, however, minor variations could trigger a major shift into an altogether different attractor that presents a new global pattern, but there is no way of knowing which initial perturbation would shunt the system into a new pattern. In evolutionary terms the pattern of large upheavals separated by long periods of global stability, but energetic local activity, is sometimes referred to as *punctuated equilibrium (*see Coveney and Highfield, 1995b: 232). The apparent stability of the communist system in eastern Europe that lasted many decades and its rapid collapse within a few years is a good illustration of that concept of change.

To evolve successfully, a complex system has to adapt in response to changing conditions and survive long enough for the next cycle of adaptation to begin. Both activities are dependent on the passage of time. But the system must be able to detect and respond to changes in its environment, including activities by other coevolving systems. Intelligence helps, but is not necessary. Copious internal variety ensures that some elements would survive and prosper under the new conditions. Hence, as a complex adaptive system continues to evolve it develops what appears to be a key facility, in the words of Gell-Mann (1994: 17), for 'acquiring information about its environment and its own interaction with that environment . . .'.

Adaptation, as defined by Coveney and Highfield (1996: 118, 253), is 'any open-ended process by which a structure evolves through interaction with its environment to deliver a better performance', by means of small but effective modifications. In other words, evolution is not a rush to the nearest summit but a leisurely process of exploration of possibilities. Moreover, As Gell-Mann (1994: 244) demonstrated, at each step in evolution 'the greatest complexity represented has a tendency to grow larger with time'. Accumulation of interconnections and adaptations over a long period of time gives the system 'depth'. From the perspective of biological evolution, Dawkins (1989) commented that this process forces all living entities to go down one of only two avenues; increased average complexity or extinction.

In summary therefore, for a system to exist in a state of self-organized complexity, it must have internal elements capable of interacting at an appropriate level of connectivity and in accordance with suitable local rules. Complex adaptive systems exhibit an ability to evolve over time through small but effective modifications, but their evolution is an uncertain and lengthy process that does not lead to an optimal end-state. Finally, average complexity increases over time, and systems with the highest complexity stand to gain the most.

IV A vision of development based on complexity

Kauffman (1993: 173, 232) pointed out that complexity has valid applications in 'living systems, organisations, communities and coevolving ecosystems'. Other authors, such as Ormerod (1998) in the case of economics, and Byrne (1998) in relation to urban development, public policy, health and education, have identified parallels between complex adaptive systems and social phenomena. Rihani (1999) advanced similar arguments in relation to development.

A few examples drawn from the developed countries will help to illustrate the complexity case as it applies to development. First, these nations present a stable common pattern typified by liberal democracy and market economy. Within the uniformity of that global pattern there is massive variety between and within these nations, which gave them stability that has overcome many, expected and unexpected, challenges for several centuries. That setup is remarkably reminiscent of the healthy variety provided by *states* within one *stable attractor* in organized complexity.

Secondly, the governments of the nations concerned have come to appreciate the value of the 'social capital' represented by the widely diverse activities of individuals and groups. Samuelson and Nordhaus (1995: 299–304) reported that the government of the USA is 'the world's biggest enterprise'. Its public spending patterns changed little in recent decades under different administrations. In essence, high spending, on law enforcement, nutrition, health, education and income protection, is dictated by the wish to endow citizens with the freedom and ability to pursue their varied interests without much interference and direction from above. In this context, Summers (1999), secretary of the US Treasury and former chief economist at the World Bank, wrote, concerning the failure of some countries to develop, 'I am convinced that there is a common element of a lack of social connection – a lack of links between people because governments have pre-empted not just all the political and economic space, but also much of the social space'. The language might be different but the meaning in complexity terms is abundantly clear.

Thirdly, as argued by Chandler *et al.* (1997) present-day developed countries followed an evolutionary path characterized by the steady accumulation of modest growth over *very* long periods. It would be most unusual for anyone to argue seriously that they have reached the end of that process. Their evolution is implicitly accepted as being slow and open-ended. Baumol (1991: 1) came to the same conclusion in relation to the rise in labour productivity; a critical ingredient for 'economic welfare'. The process has also exhibited clear signs of punctuated equilibrium and *gateway events*, such as the invention of the steam engine and computers. The parallels with complexity are evident.

Fourthly, development in these countries stemmed largely from uncoordinated efforts by individuals and groups concerned exclusively with their particular businesses, intellectual pursuits and hobbies. The emergence of the industrial revolution in Britain, driven by inventions such as Hargreaves' spinning jenny, Arkwright's use of waterpower, Watt's steam engine and Crompton's spinning-mule, illustrates this feature to perfection. The same is true of the significance of the *zaibatsu*; a diversified business group owned by one family, in Japan's growth prior to the first world war,

and the *chaebol* in the case of South Korea, as discussed by Chandler *et al.* (1997). Yet again, pointers to a complexity view of development are unmistakeable.

Today's developed countries accumulated complexity and acquired 'depth' over several centuries. They are becoming richer, and the gap between them and poorer nations is inexorably widening. But that is precisely what one would expect if the development of nations behaved as a typical complex adaptive system: average complexity increases and the highest complexity stands to gain the most. Basically, developed countries selected, through trial and error, practices that optimized their performance. Recent discoveries in the field of complexity provide possible explanations of why these particular practices proved to be better than others.

It is possible to consider the analogy between development and complexity from the developing countries perspective as well. In this instance conditions are in general the exact opposite of those required for development to assume a stable but evolving pattern of self-organized complexity. Consequently, complexity suggests, the countries involved would find it difficult to develop successfully, which describes their current situation.

The argument is relatively straightforward. Based on a view that the development process is a complex adaptive system, Rihani (1999) argued that the internal elements of the system were interacting human beings, as individuals or groups. Too few interactions result in a state of stultifying order, while too many could lead to chaos. The layer of self-organized complexity that lies at the edge of chaos could only emerge if individuals were *free* to interact and *capable* of interacting, and if their interactions were facilitated by *appropriate rules* that command popular support.

Few of the developing countries meet the *freedom* criterion. State repression, against whole populations or sectors defined by gender, religion or ethnic background, is widespread. The pattern of control by a small and ruthless elite that sets out to stifle diversity of independent action is all too familiar and does not require elaboration. However, it is appropriate to underline the damaging association between repression, corruption, militarism and conflict. Directly or indirectly, all these features stifle healthy interactions between individuals and, therefore, impede development.

The significance of the above impediments to development is well understood. UNICEF declared in the Progress of Nations 1997 'violence against women and girls is the most pervasive violation of human rights in the world today . . . its impact on development profound'. Collier (1998: 18) argued, 'Democratisation is worth around half a century of income growth in terms of its contribution to peace'. And the World Bank (1997) concluded, 'Corruption . . . is negatively correlated with both investment and growth'. The picture from these and other references is, therefore, quite clear. A shift to a complexity viewpoint merely provides a possible scientific explanation of why and how such hindrances affect development.

The factors that affect individuals' *capability*, as opposed to freedom, to interact are equally clear. The main culprits are malnutrition, disease and illiteracy. United Nations Children's Fund (UNICEF, 1998: 9) referred to malnutrition as the 'silent emergency'. Nearly one in six of the Earth's population suffer from chronic malnutrition, which leaves many millions 'crippled, chronically vulnerable to illness, and intellectually disabled'. There is a close link between malnutrition and disease. Shortage of certain micronutrients, such as vitamin A, iodine and iron, and poor standards of sanitation and water supply are just as significant as food shortage.

Lack of iodine, for instance, is critical in inhibiting capability. In 1993 WHO estimated that 1.6 billion people were at risk with 655 million at an 'increasing risk of mental impairment'. Remedial measures, as in the case of vitamin A, amount to no more than a few pence per person per year, see UNICEF (1995: 18). The effects of anaemia caused by shortage of iron in the diet are also crippling. UNICEF (1995: 14) reported that the condition 'lowers the productivity of entire populations'. Illiteracy simply exacerbates the problems of malnutrition and disease. In 1995, adult literacy rates in Chad, Sierra Leone, Afghanistan and Nepal were 62%, 45%, 47%, and 41% for males, and 35%, 18%, 15%, and 14% for females, respectively (see UNICEF, 1998: 106). In addition to illiteracy and loss of indigenous knowledge, poorer nations suffer badly from lack of reliable and relevant information, and inaccessibility to what little information is available, as argued by Timberlake (1991: 30). For a nation to evolve properly as a complex adaptive system, interacting individuals must be able to accumulate knowledge and interpret and respond to opportunities, threats and other events in their environment. In the modern world, most people in the developing countries are hardly capable of fulfilling that requirement.

Apart from being free and able to interact, the actions of groups and individuals, assuming that development performs as a complex adaptive system, would have to be facilitated and protected by an appropriate framework of rules and regulations to enable a nation to achieve a state of evolving self-organization. Yet again, most developing countries are far from meeting this basic condition. There is either chaos, brought about by constantly shifting, unclear and often conflicting rules, or stifling order, created by arbitrary and rigid rules that prevent healthy interactions.

De Soto (2000: 15–20) described the hundreds of bureaucratic steps, and the years, required in Peru, the Philippines, Egypt and Haiti to start a small business or build a modest dwelling. He also highlighted the inadequacy of property rights and legal tools that would permit the conversion of physical possessions, such as land, buildings and workshops, into useful capital assets to trigger development. De Soto (2000: 63) wrote, '. . . property systems become tremendously powerful when they are interconnected in a larger network . . . Only then can government begin to administer development instead of heroically rushing to plug each and every leak'.

On a wider front, research work and policy formulation at the World Bank has refocused in recent years on the urgent need to address institutional reforms. Clearly, the paramount need for popular rules that would provide an appropriate framework to encourage and safeguard interactions is now fully appreciated. Again, adoption of a complexity view of development simply advances cogent reasons why this shift in emphasis is correct. Interestingly, the World Bank, in its research bulletin of July–September 1997, underlined the need to balance regulation against flexibility as 'excessive restraint can lead to paralysis'. That conclusion was arrived at intuitively, but it has specific significance within a complex systems framework as outlined earlier.

V Conclusion

In concluding this paper, it is essential to re-emphasize that recent innovations in the study and practice of development strongly connote a shift of viewpoint, and the

transformation suggests, unintentionally perhaps, a move towards a concept of development based on complexity. Development is increasingly being treated as a long-term process that involves a wide variety of inputs and outputs. Variety is seen as a positive, and unavoidable, feature rather than an aberration to be ignored or eliminated. The Brundtland Commission (World Commission on Environment and Development (WCED, 1987), provided a clear indication of the sea change that took place in the years since the Brandt Commission produced its report. Ideas have emerged, including sustainable development, self-help, participation, focus on basic needs, respect for indigenous knowledge and local coping strategies, and emphasis on institutional improvements and the elimination of extreme poverty, which clearly presage a change in attitudes and direction. The above innovations were adopted as sensible improvements or as moral responses to the consequences of policy failures. However, although they are patently sound they are not yet integrated within a unified theoretical framework. As argued above, complexity seems to offer some interesting possibilities in this respect.

Adoption of the suggested approach, however, would imply acceptance of a few challenging concepts. Firstly, world powers, governments of developing countries, and international institutions would have to accept that development is largely a local affair. Secondly, a balance would have to be struck between the unifying forces of global capitalism and the critical need to maintain abundant local diversity. Thirdly, improving standards of health, nutrition, literacy, democracy and governance could not wait for development to take place. On the contrary, without decisive actions to address these fundamental issues the process of development could not begin.

It is not safe to assume that the above radical shifts would be welcomed necessarily by all, or any, domestic and foreign interest groups. One aspect relating to armed conflict would help to illustrate this point. Much has been said and written about the role of arms transfer to and concentration of civil and interstate wars within the developing countries. However, both activities continue unabated. Significantly, the five permanent members of the UN Security Council, with supposedly a keen interest in peacekeeping, are also the main suppliers of arms, accounting for more than four-fifths of weapons sold (see Stockholm International Peace Research Institute (SIPRI, 1997: 268). Corruption, local interest groups, global business and international power politics, present additional formidable forces against change. The potential benefit in considering a paradigm shift to complexity within the development field lies in its ability to leave little doubt about what would and would not help to drive the development process forward. The shift in itself could not do anything to overcome the forces that seek to preserve the status quo.

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