Complexity Perspectives and Investment Decisions

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly or otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Summary

This thesis investigates investment theory in the light of complexity theory. These insights from diverse fields contain powerful images, metaphors and ways of thinking that allows one to seek new ways of comprehending the nature of the economy and therefore the nature of investment and the related issues of uncertainty and decision making. Complexity theory views the economy as being a dynamic, continuously adaptive, nonlinear system. This is in contrast to traditional or classical economic theory that views the economy as being a simple, linear, equilibrium deterministic system.

This thesis is a conceptual study exploring the implications of a complexity worldview for investment decisions by looking at the nature and characteristics of complexity and then overlaying it on the characteristics of the economy.

It is argued that complexity is caused by three elements: the structure of the system, human behaviour and exogenous factors. Thereafter follows an analysis of how investment decisions are made in the light of complexity by illustrating the investment models of two very successful, yet different investors: Warren Buffet and George Soros.

Buffet's model hinges on value. He realises that emergent phenomenon driven by irrational behaviour of investors leads to intrinsic values of shares to differ widely from perceived value. When quoted or perceived values are low than it is advisable to purchase as you have a margin of safety. Over the long term the market recognises the real value of the share. He tries to ignore the vagaries of the market and to focus on fundamentals. His list of fundamentals include; the franchise value of the company, quality of management and industry dynamics.

George Soros in contrast utilises emergence patterns to locate potential investments. His model is that systems are flawed, human thinking and decision making is flawed and the interaction of the two lead to perturbations and oscillations. He focuses in trying to understand the flaw in systems and in human behaviour and to find some kind of pattern that he could utilise to make a profit. It is shown that both investment models can be understood from a complexity perspective and that these two investors built aspects from complexity into their decision models.

Opsomming

Die tesis ondersoek investeringsteorie in die lig van kompleksiteitsteorie. Met die hulp van metafore en insigte vanuit kompleksiteitsdenke word gesoek na nuwe maniere om die aard van die mark en investering verwante aspekte van onsekerheid en besluitneming te verstaan. Die kompleksiteitsperspektief sien die ekonomie as'n dinamiese en aanpassende nie-lineêre sisteem.

Dit word gedoen deur die implikasies wat kompleksiteit vir investeringsbesluite inhou konseptueel te ondersoek. Die aard en eienskappe van komplekse sisteme word verduidelik en dan op die ekonomie toegepas.

Daar word geargumenteer dat kompleksiteit deur drie elemente veroorsaak word: die struktuur van die sisteem, menslike gedrag en eksogene faktore. Daarna word die praktyk van investeringsbesluite geanaliseer in terme van kompleksiteit duer investeringsmodelle van twee suksesvolle, maar uiteenlopende, investeerders te ondersoek, naamlik Warren Buffet en George Soros.

Buffet se model draai rondom waarde. Hy sien die irrasionele gedrag van investeerders as 'n ontvouende fenomeen wat lei tot 'n gaping tussen intrinsieke en verwagte waarde. Sy investering word gebaseer op die aanname dat oor die langer termyn die mark die intrinsieke waarde herken. Hy ignoreer dus korttermyn skommelinge in die verwagte waarde en fokus op die fundamentele, waaronder die maanwaarde van die besigheid, die kwaliteit van die bestuur, en industrie-dinamika tel.

Soros se model daarenteen gebruik ontvouende patrone en potensiële investeringsgeleenthede te ontbloot. Sy model is dat sisteme inherente teenstrydighede het as ook menslike gedrag en besluitneming. Dit lei tot ossilasies en versteurings. Sy fokus is gerig daarop om hierdie versteurings in die sisteem tot voordeel aan te wend.

Daar word getoon hoedat beide investeringsmodelle vanuit 'n kompleksiteitsperspektief verstaan kan word en dat die twee investeerders sulke aspekte in hulle investeringsbesluite inbou.

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Introduction

1. Complexity and Interconnectivity

We live in a dynamic world that is interconnected and complex. It is not a matter of whether something is connected or not but the degree of connection, that is how close or far apart the connection. It is complex thus what might seem to be a small and trivial intervention can have huge ramifications down the line. It is inhabited by humans, each one of whom is driven by individual motivations and needs. Pure science has laws that have shown to be very consistent and predictable for example the laws of motion. Academics have attempted to utilise these scientific laws to formulate a theory of decision making. These theories are fundamentally flawed as they do not take into account the connectivity and the impact of small events that are not constrained by time or space.

And it is this connectivity that makes prediction impossible. Going back into time before industrialisation when economies were localised and agrarian based, one season followed the other in a predictable fashion. The risk inherent in such an agrarian localised economy was that of external risk. This comes from the outside, from the fixities of tradition or nature, risks such as droughts, tribal warfare and hurricanes. This is in stark contrast to the globalised, interconnected, "runaway world" that we live in today.[1] The level of world trade is much higher than it ever was before and it involves a much wider range of goods and services. But more than this, the difference lies in the level of finance and capital flows with its electronic money – money that exists as digits in computers- the current world economy has no parallel in earlier times. In this new global electronic economy, fund managers, banks, corporations as well as individual investors can transfer vast amounts of money from one side of the world to the other instantaneously- more than a trillion dollars is now turned over each day on the

[1] Giddens Anthony. 1999. *BBC Reith Lectures. Lecture 1*. An interview with Anthony Giddens on the topic "Runaway World" and reflections on globalisation.

http://news.bbc.co.uk/hi/english/static/events/reith_99/week1/week1.htm

global currency markets alone. As they do so, they can destabilise entire economies as what happen in East Asia in 1998.

Globalisation is not incidental and temporary; it is the shift in our very life circumstances. With it comes a second form of risk that of manufactured risk.[2] We need to distinguish this from external risk that we faced in our more closed, localised economy. Manufactured risk is the risk created by the very impact of our developing knowledge of the world. It refers to risk situations which we have very little historical experience of confronting. Most environmental risks, such as those connected to Global warming would probably fall into this category- directly influenced by increasing industrialisation worldwide.

In the past we worried about risks derived from external risk (bad harvest, famine, floods etc), at a certain point however, we started worrying less about what nature can do to us and more about what we have done to nature. This marks the transition from the predominance of external risk to manufactured risk. As manufactured risk expands, there is a new "riskiness" to risk. The concept of risk as we know it has always been related to the possibility of calculation, of being able to assign probabilities as we do in the insurance industry. Every time someone steps into a car, we can calculate the chances of being involved in an accident. This is an actuarial prediction which has a long time series of experience backing it. Situations of manufactured risk are not like this. We simply do not know the level of risk and its impact to other things in the economy given the inter connectivity that we have in a global scenario. For example the mortgage crisis in America has had huge impact on other economies and has led to a rethink on free markets and capitalism. Suddenly the American world view is moving towards policies favouring a more highly regulated government controlled economy. The US government now owns equity in many troubled corporations and financial institutions.

As the world is so interconnected the implications are far ranging. The low interest, easy credit policy of the US Treasury sparked of a liquidity and credit crisis that has led to a consumer recession. The sale of subprime mortgages on the secondary market to other banking institutions around the world has led to large banking losses and loss of jobs leading to a downturn in the world economy. China with a population of 1.3 billion and a substantial domestic market of its own was affected as American purchases declined. This negated the

[2] Giddens A. 1999. *BBC Reith Lectures*. Lecture 2- Risk.

http://news.bbc.co.uk/hi/english/static/events/reith_99/week2/week2.htm

"decoupled economy theory" of some economist who believed that China, India and Brazil with their own large domestic purchasing power would not be affected by the downturn in the US. The fact is everyone's fortunes are tied to everyone else's in the global economy. China needs the US to purchase its goods and keep its people employed and in turn the US needs China to purchase their US Treasury bonds so that they can finance their huge economic deficit. China requires raw materials such as oil and iron ore which it purchases from a range of countries that include Australia, South Africa and Saudi Arabia. Because we are interconnected, a downturn in one economy thus reverberates across the entire world.[3] It is impossible to account for risk in this complex scenario.

Let us move to some conclusions and at the same time try and make sure that our argument is clear. Our age is not more dangerous or risky than those of earlier generations, but the balance of risk and danger has shifted. The hazards created by ourselves are more threatening than those from the outside. As an investor we cannot be blindsided into thinking that we know and can calculate with certainty the risks inherent in our decisions. The past notion of risk and hedging against it via insurance, counter cyclical trade and diversification was supposed to be a way of "regulating the future, of normalising it and bringing it under our dominion".[4] Things have not turned out that way. We have to find new ways to grapple with and understand the emerging risk. We need an improved model that is more realistic and sensitive to view the world. One alternative is a complexity worldview that seems to explain the globalised economy in a more succinct way. Both Warren Buffet and Soros have grappled with this problem of complexity and have found interesting ways to make good decisions in an uncertain world. We need to understand the mindset and the thinking behind their investment decisions if we are to be active risk takers as risk taking is a core element in a dynamic economy and an innovative society.

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[3] Dixon Thomas quoted in Boyce B. 2008. *Why We Need New Ways of Thinking,* states that while "connectivity" is generally thought of as a virtue, in complexity theory, systems with many close connections are said to be "tightly coupled". Tightly coupled systems can act like the proverbial chain of dominoes - a breakdown in one location sends rapidly cascading effects throughout the world. For example, if the few large food growing areas we rely on suddenly experience breakdown at the same time as transport costs increase, a food crisis can develop within days.

[4] Giddens A. 1999. *BBC Reith lectures*. Lecture 1: Globalisation.

2. Layout

In order to explore the implications of a complexity worldview on investment decisions the following will need to be covered:

- In Chapter One I examine complexity theory in order to get an understanding about the characteristics of complexity. Mitleton-Kelly has aggregated ten generic principles of complex evolving systems and gaining an understanding of these ten principles and how they relate to each other, could provide a useful starting point for working with them and applying them to the issue of complexity in the investment arena.

- In Chapter Two I examine the nature of the economy. Investment decisions are made in the context of the economy and is therefore important to understand the nature of the economy. The economy exhibits characteristics of dynamism, non linearity, adaptation, participation and networks that are congruent with complex adaptive systems. I then examine the economy in terms of emergent phenomenon and analyse in some details the impact of emerging phenomenon such as oscillations, punctuated equilibrium and power laws. These are all phenomena that emerge from complex systems and are important constituents of the economy. I examine two theories; the Beer Game and Farmers theory and find that there are three main causes of business cycles namely; the behaviour of participants in the system, the institutional structure of the system and exogenous inputs. Finally I analyse the state of investment theory in terms of complexity. Here I examine the investment decision and limitations of the Efficient Market Hypotheses and the Random Walk Model. I also get to terms with the nature of complex adaptive systems.

- In Chapter Three I examine the investment decision making models utilise by Buffet and Soros and the implications and insights derived in the light of complexity theory and the principle of complex evolving systems. Both investors are highly aware of the nature of risk and utilise models based on human behaviour, laws of emergence and plain common sense. I also examine strategies put forward by academics to aid investors in coping with a complex adaptive world.

  It should be noted that this is purely conceptual study of complexity and its implications on the investment decision. The concepts of risk and the way we make decisions features throughout the thesis as decision making, investment and risk are inherently intertwined. I also make reference in a number of places to a comparison

between traditional theory based on the deterministic, linear concept of the economy and complexity. This comparison is used as a foil purely to highlight and explain the concept of complexity and to appreciate and increase our understanding of the concepts.

Chapter One

Complexity

The nature of complexity

1.1 Introduction

We live in an increasingly complex world driven by globalisation and advances in technology. Dealing with the complex environment requires new tools to analyse and understand implications. Complexity theory focuses attention on the very facets that characterise our economic environment, characteristics such as; disorder, irregularity and randomness and accepts the characteristics of instability change and unpredictability as being an inherent facet of life.[5] In this chapter I analyse the properties of complexity theory with a special focus on the principle of emergence and connectivity.

1.2 Background to Complexity

The realisation that open systems were influenced by nonlinear dynamics and disequilibrium led to a change in methodology and worldview. A network of scientists and researchers have coalesced together to focus on understanding the emergence of self organising structures that create complexity out of simplicity and higher order out of chaos through multiple interactions between basic elements at the origin of the process.[6] The leading knowledge centre for this new perspective resides at the Santa Fe Institute in New Mexico. The important contribution of this 'complexity' school of thought is its emphasis on non linear dynamics as the best approach to understanding the behaviour of living systems both in society and in nature. This perspective is often dismissed by mainstream science as being a non verifiable proposition and has no integrating systemic framework.[7] Castells says that complexity theory could be considered a method for understanding diversity rather than a

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[5] Jackson MC. 2003. Systems Thinking: Creative Holism for Managers. 113.

[6] Castells M. 2000. The Rise of the Network Society. 74.

[7] Castells M. 2000. The Rise of the Network Society. 74.

unified Meta theory and is based on the concept of self organising character of nature and society.[8]

In order to get a deeper understanding of complexity let it is useful to look at the beginnings of this frame of thought:

In 1960 Edward Lorenz at MIT attempted to simulate weather patterns with a computer program and uncovered what we know today as chaotic systems.[9] Lorenz with twelve equations calculated over and over again was able to mimic unpredictability and sensitive dependence on initial conditions. He found that a slight change in one variable no matter how miniscule, had a huge impact on weather patterns. When these points were plotted they displayed a kind of infinite complexity. These points always stayed within certain bounds but never repeated themselves. It traced a distinctive shape of a double spiral in three dimensions, like a butterfly with its two wings. The shape revealed pure disorder, since no point or pattern of points ever recurred. Yet it also signalled a new kind of order, that is, disorder within a larger order.[10]

If I extend this analogy to investment theory and specifically to share price forecasting and assume that they would behave in a similar fashion than small changes in one variable can elicit large changes in the entire system. It is impossible to predict what the share price will be. There are hundreds of variables that could affect the market for coffee beans for instance and investment analysts attempt to utilise a limited number of variables to forecast. Even these limited number of variables can have huge and unpredictable consequences because of the mix soup of variables interacting with each other in various ways in different proportions, some being constant and others fluctuating. Predictability is an illusion as these are chaotic systems and the nature of these systems is different. A number of researchers extended the understanding of chaos and complexity to the behaviour of the economy, which is called Complexity Economics.[11] Their work builds on the view of the economy that is dynamic, that

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[8] Castells M. 2000. The Rise of the Network Society. 74.

[9] Gleick J. 1988. *Chaos Making a New Science*. 11-31.

[10] Gleick J. 1988. Chaos Making a New Science. 30.

[11] Contributors to this field include John Von Neuman, the inventor of game theory and cellular automata, Friedrich Hayek of the Austrian School, Herbert Simon and Daniel Kahneman of the Behavioural School, Douglas North the institutional economist, Richard Nelson and Sidney Winter the evolutionary economist,

never reaches equilibrium and is made up of people interacting with each other in complex ways processing information and adapting their behaviour.[12] The paradigm is holistic in nature and embraces a process view.[13] The parts of the system can only be understood in terms of the relationships with each other and with the whole. The focus of attention is on relationships and it is the pattern of relationships that determine what a system does. It follows a process view as systems are constantly changing due to the interaction of their parts as they seek to process continuous flow of matter, energy and information from the environment. They are therefore best understood as being in constant change in an arena where stable structures are temporarily created. Order is an emergent property of disorder and it is created through self organising processors operating from within the system itself. System and environment change in response to one another and evolve together. A case of the analogy 'we build our houses and then they build us'.[14]

1.3 Characteristics of Complex Systems

1.3.1 Definition

Complex systems can be defined in a number of ways: Cilliers states that in a complex system there are more possibilities than can be actualised and a system that is not only constituted by the sum of its parts but by the intricate relationships between these components.[15] Dent defines complexity science as "an approach to research, study and perspective that makes the philosophical assumptions of the emerging world view."[16] It emphasises a causal, holistic interpretation and feature spontaneous, unpredictable and self

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Robert Axelrod and Thomas Schelling the political scientists and John Holland an Christopher Langton the computer scientists.

[12] The work of these people and many others comprises a new paradigm in the field. It should be noted that Complexity economics is still more of a research program than a single synthesised theory and thus there are many grey areas regarding what falls under this term.

[13] Jackson M. 2003. Systems Thinking: Creative Holism for Managers. 115.

[14] Quote attributed to Winston Churchill, which makes the point that, the structures we create are dynamic and they in turn influence our behaviour in many ways some of which we would not have imagined in the creation stage. Structures influence behaviour (and in turn behaviour influences structure) and we must not underestimate their power.

[15] Cilliers P.1998. Complexity and Postmodernism: Understanding Complex Systems. 2.

[16] Dent E. 1999. Complexity Science: A worldview shift. 5.

organised patterns and behaviours. Complexity theory describes how complex systems can generate outcomes (emergence) that functions as a descriptor of the patterns and properties that are exhibited at the macro level.[17] For example the global economy is made up of many investors. When these individual investors come together they interact and new levels of operation and organisation emerge. Investors differ with respect to time horizons, levels of risk and categories of investment and this mix creates different system reactions and thus dissimilar behaviour within the complex entity. It must be noted that unlike the concept of equilibrium and closed systems, complexity theory views change as a norm not the exception.

1.3.2 Principles of Complex Systems

Mitleton-Kelly has aggregated ten generic principles of complex evolving systems and gaining an understanding of these ten principles and how they relate to each other, could provide a useful starting point for working with them and applying them to the issue of complexity in the investment arena.[18] There is no single unified Theory of Complexity, but several theories arising from various natural sciences studying complex systems, such as biology, chemistry, computer simulation, evolution, mathematics, and physics. This includes the work of scientists associated with the Santa Fe Institute and from Europe.[19]

Fig.1 shows the five main areas of research that form the background to this chapter and the Ten generic principles of complexity that will be discussed.

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[17] Goldstein J. 1999. Emergence as a Construct: History and Issues. 65.

[18] Mitleton- Kelly E. 2003. Ten Principles of Complexity and Enabling Infrastructures. Chapter 2.

[19] The work of scientists such as Stuart Kaufmann, John Holland, Chris Langton, Murray Gell-Mann, Peter Allen and Brian Goodwin on complex adaptive systems; Axelrod on cooperation; Casti, Bonabeau, Epstein and Axtel and Ferber on computer simulation; Ilya Prigogine, Isabelle Stengers and Gregoire Nicolis on dissipative structures; Humberto Maturana, Fransisco Varella on autopoiesis; Gleick on chaos theory and Brian Arthur on Economics and increasing Returns.

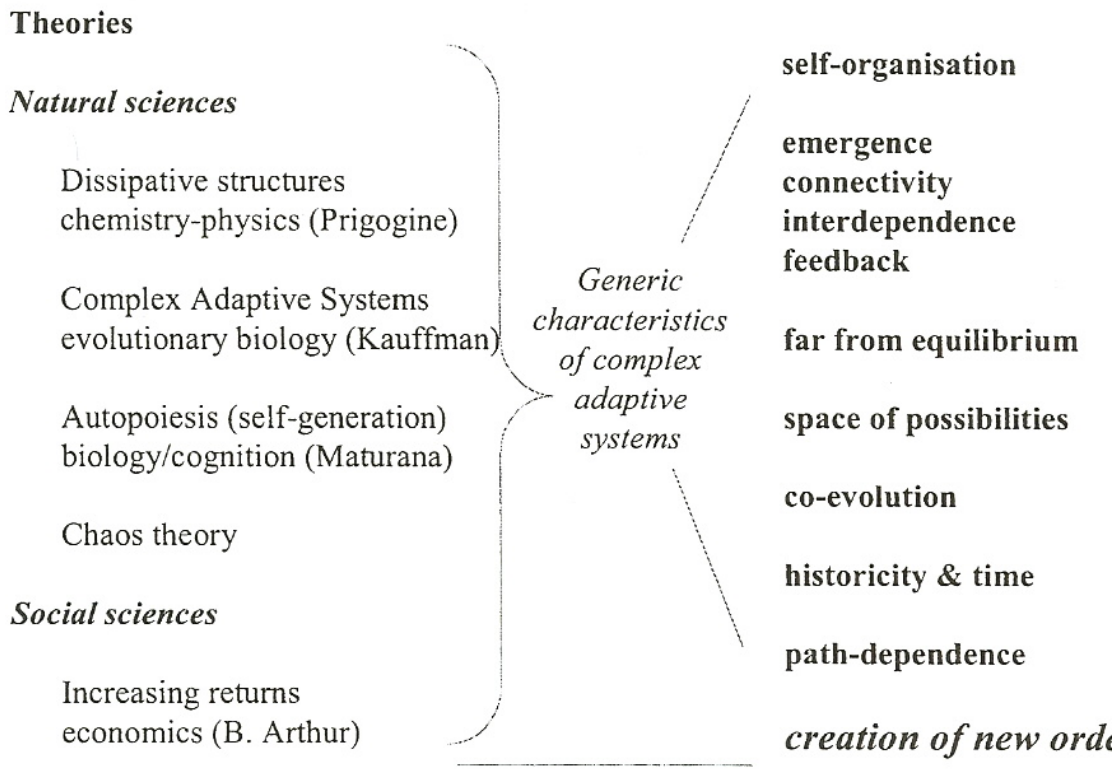

Figure 1:Generic Characteristics of Complex Systems[20]

The four principles grouped together in Fig. 1, namely those of emergence, connectivity, interdependence, and feedback are familiar from systems theory. Complexity builds on and enriches systems theory by articulating additional characteristics of complex systems and by emphasising their inter-relationship and interdependence. It is not enough to isolate one principle or characteristic such as self-organisation or emergence and concentrate on it in exclusion of the others. The approach taken by this chapter argues for a deeper understanding of complex systems by looking at several characteristics and by building a rich inter-related picture of a complex social system. It is this deeper insight that will allow investment strategists to develop better strategies and organisational designers to facilitate the creation of organisational forms that will be sustainable in a constantly changing environment.

The discussion is based on generic principles, in the sense that these principles or characteristics are common to all natural complex systems. A study of these principles explains and helps us understand the nature of the world and the organisations we live in. The theories of complexity provide a conceptual framework, a way of thinking, and a way of seeing the world.

[20] Mitleton- Kelly E. 2003. Ten Principles of Complexity and Enabling Infrastructures. 3.

1.3.2.1 Connectivity and Interdependence

Complex behaviour emerges from the inter-relationship, interaction, and inter- connectivity of elements within a system and between a system and its environment. The implication of connectivity and interdependence in a human system is that a decision or action by any individual (group, organisation, institution, or human system) may affect related individuals and systems. This affect will not have equal or uniform impact, and will vary with the 'state' of each element in the system, at the time. The 'state' of an individual or a system will include its history and its constitution, thereby encompassing its organisation and structure as well. Connectivity applies to the inter-relatedness of individuals within a system, as well as to the relatedness between human social systems. These include systems of artefacts such as information technology (IT) systems and intellectual systems of ideas.

There are limitations to ever-increasing interconnectivity as high connectivity implies a high degree of interdependence. The greater the interdependence between related systems the wider the impact of a perturbation (disturbance) on other related entities. One example of this is the reverberating impact on the global economy from the financial contagion experienced in the USA from the fallout of excessive lending from financial institutions. Institutions worldwide were connected as they repurchased debt from US banks giving good returns on investments. Once these institutions realized that the repayment of debt was doubtful it set of a liquidity crisis as banks stopped lending to each other. The problem was only stemmed by the exogenous input of liquidity by Reserve Banks around the world. Thus, such high degree of dependence may not always have beneficial effects throughout the ecosystem – the attempt by one entity to improve its position, may result in a worsening condition for others imposing associated 'costs' on other entities within the same system or on other related systems.

Complex behaviour arises out of connectivity and interdependence. Another important aspect is that complex systems are multidimensional, and all the dimensions interact and influence each other. In an ecosystem the social, cultural, technical, economic and global dimensions may impose upon and influence each other. Soros (chapter 3.2) utilizes this aspect in his understanding of the investment landscape to find 'flaws' or limitations in the structure of the system itself.

The distinguishing characteristic of a complex evolving system is that it is able to adapt and evolve and thus create new order and coherence. This is one of the key defining features of complexity. Increasing Globalisation has led to the formulation of new strategies such as a

move by organisations towards the use of pull strategies, pursuing flexibility instead of push strategies focusing on efficiency and execution.[21] This leads to the creation of new ways of working, new structures and changes in relationships. It has an impact on companies and institutions that have global orientation and can utilise interconnectivity to their advantage.

Transmission of influence through an ecosystem depends on the degree of connectivity and interdependence. In social ecosystems there are networks of relationships with different degrees of connectivity. Degree of connectivity means strength of coupling and the extent to which the fitness contribution made by one individual depends on related individuals in that context. This is a contextual measure of dependency - the direct or indirect influence that each entity has on those it is coupled with.

The behaviour of the system is not affected by the exact amounts of interactions associated with specific elements. Some elements are more richly connected than others. But if there are enough elements in the system (of which some are redundant) a number of sparsely connected elements can perform the same function as that of one richly connected element. Thus a rich diversity of qualitatively different operating methods/systems exist that the system might adopt. This is a result of the non-linear nature of the relationships that describe the interactivity between the different system constituents.[22]

There are three facets to this concept of non-linearity. First, small causes can have large results and vice versa. The system development is potentially very sensitive to small disturbances; a phenomena popularly referred to as deterministic chaos, as well as being potentially very insensitive to large disturbances; as a result of self-organization or, alternatively, anti-chaos. All possibilities in between also exist. Though chaos still plays a role, anti-chaos (or self-organization) seems to dominate.[23] Second, complex systems exhibit non linear behaviour that is unpredictably related to input. Third, complex behaviour is somewhere between predictability and non- predictability (The edge of chaos). This is the point where there is enough unpredictability to ensure that regularity and predictability is lost, but also enough order and predictability for consistency and patterns to endure. At this edge of chaos undetectable variations in initial conditions (butterfly wings flap at different speeds

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[21] Refer to Chapter 3.7.1 for a detailed analysis of these strategies.

[22] Richardson K, Cilliers P, Lissack M. 2007. *Complexity Thinking: A Middle way for Analyst*. 7.

[23] Richardson K, Cilliers P, Lissack M. 2007. *Complexity Thinking: A Middle way for Analyst*. 8.

or at different altitudes) can lead to the development of behaviour or conditions that may be totally dissimilar. It is here that new and unimagined properties can emerge.

In a social context, each individual belongs to many groups and different contexts. An individual's contribution in each context depends partly on the other individuals within that group and the way they relate to the individual in question. An example is when a new member joins a team. The contribution that individual will be allowed to make will be determined by the skills, knowledge, expertise, etc. brought by the new member. As well as on the other members of the team and on the space they provide for such a contribution.

In economic systems connectivity between agents is not a constant or uniform relationship, but varies over time, and with the diversity, density, intensity, and quality of interactions between human agents. It is the degree of connectivity, which determines the network of relationships and the transfer of information and knowledge.

1.3.2.2. Co-evolution

Connectivity applies not only to elements within a system but also to related systems within an ecosystem. The way each element influences and is in turn influenced by all other related elements in an ecosystem is part of the process of co- evolution. The evolution of one entity is partially dependent on the evolution of other related entities with an emphasis on the interactions and on reciprocity. In human systems, interactions take the form of the relationship between the co- evolving entities. Co-evolution takes place within an ecosystem, and cannot happen in isolation. The social ecosystem includes the social, cultural, geographic and economic dimensions and co- evolution may affect both the form of institutions and the relationships and interactions between the co-evolving entities.

In a an organizational context, each organization is a full participating agent which both influences and is influenced by the social ecosystem made up of all related businesses, consumers and suppliers as well as economic, cultural and legal institutions. Strategies therefore are not simply a response to a changing environment but must be seen as adaptive actions that will affect both the initiator of the action and everyone else influenced by it. In this sense, then no individual or organisation is powerless as each entity's actions influence the social ecosystem. Any action therefore requires a deeper understanding of the possible consequences of an entities action and argues for a deeper understanding of reciprocal change and the way it affects the totality. This has far reaching implications for the investment decision especially as to the use of analytical methods that utilizes the analysis of

independent variables rather than the an awareness of the interdependency and co-evolution of variables that a complex evolving system suggests.

Co-evolution affects both individuals and systems and is operational at different levels, scales, or domains. In such a system there is to be found intricate and multiple intertwined interactions and relationships as well as multi-directional influences and links that are both direct and far removed.

1.3.2.3 Dissipative Structures, Far-from-equilibrium and History

Dissipative structures are the ways in which open systems exchange energy, matter, or information with their environment and which when pushed to a state 'far-from-equilibrium' create new structures and order. The physical sciences have contributed to a great deal of research in this area. The Bénard cell is one such example of a physical-chemical dissipative structure. It is made up of two parallel plates and a horizontal liquid layer of water. The dimensions of the plates are much larger than the width of the layer of water. When the temperature of the liquid is the same as that of the environment, the cell is at equilibrium and the fluid will tend to a homogeneous state in which all its parts are identical. If heat is applied to the bottom plate, and the temperature of the water is greater at the bottom than at the upper surface, at a threshold temperature the fluid becomes unstable. As the system moves further away from equilibrium by increasing the temperature differential, suddenly at a critical temperature the liquid performs a bulk movement which is far from random resulting in the fluid being structured in a series of small convection 'cells' known as Bénard cells.

In the process the following has occurred:[24]

(a) The water molecules have spontaneously organised themselves into right-handed and left-handed cells. This kind of spontaneous movement is called self-organisation and is one of the key characteristics of complex systems; (b) from a condition of molecular chaos the system has emerged as a higher-level system with order and structure; (c) the system was pushed far-from- equilibrium by an external constraint or perturbation; (d) although we know that the cells will appear, "the direction of rotation of the cells is unpredictable and uncontrollable; (e) when a constraint is sufficiently strong, the system can adjust to its environment in several different ways, that is several solutions are possible for the same parameter values; (f) the fact

[24] Mitleton- Kelly E. 2003. Ten Principles of Complexity and Enabling Infrastructures. 10-12.

that only one among many possibilities occurred gives the system "a historical dimension, some sort of "memory" of a past event that took place at a critical moment and which will affect its further evolution."; (g) the homogeneity of the molecules at equilibrium was disturbed and their symmetry was broken; (h) the particles behaved in a coherent manner, despite the random thermal motion of each of them. This coherence at a macro level characterises emergent behaviour, which arises from micro-level interactions of individual elements.

In the Bénard cell heat transfer has created new order. It is this property of complex systems to create new order and coherence. Symmetry breaking in a complexity context means that the homogeneity of a current order is broken and new patterns emerge. This can be understood as a generator of information, in the sense that when a pattern of homogeneous data is broken by differentiated patterns, the new patterns can be read as 'information'. This can be interpreted at different levels from, homogeneous data to exception reporting, when different or unexpected patterns appear to deviate from the expected norms.

In dissipative structures the tendency to split into alternative solutions is called Bifurcation. There may be several possible solutions. An observer could not predict which state will emerge - this will be decided by chance, through the dynamics of fluctuations. The system makes a few attempts to stabilize. Then a particular fluctuation will take over. By stabilizing it the system becomes a historical object in the sense that any subsequent evolution depends on this critical choice. This in a sense creates a platform from which any future evolutions could occur.

When a social entity (organisation or the economy) is faced with a constraint, it finds new ways of operating, because non equilibrium systems (going against established norms) are forced to experiment and explore their 'space of possibilities', and this exploration helps them discover and create new patterns of relationships and different structures. Bifurcation is seen as a source of innovation as it is at this point the system discards a measure of information in order to build a new order.[25]

Increasing competition and slavish following of ever increasing growth objectives has led to increasing outsourcing of production and other services to less developed economies where wages are competitive and flexibility of demand can be met efficiently (pull structures). In

[25] Jalonen H. *The Role of Complexity in Preparing for Municipal Decision Making*. Turku University of Applied Sciences. Research reports 21.

the investment arena, money flows to areas of greater return and opportunity which has seen large inflows of finance into emerging economies. In an organizational context, when an organisation moves away from equilibrium (i.e. from established patterns of work and behaviour) new ways of working are created and new forms of organisation may emerge. These may be quite innovative if choice is allowed and the symmetry of established homogeneous patterns is broken. Soros utilizes this knowledge of disequilibrium and disfunctioning systems to find likely areas where homogenous patters may be broken. These conditions are characterised by wide fluctuations in prices that create investment or speculative opportunities.[26]

It should be noted that there is a fundamental difference between natural and social human systems. Social systems can deliberately create constraints and perturbations that consciously push a human entity far-from-equilibrium. Humans can also provide help and support for a new order to be established. If excessive details are designed for the new order then the support needed might be greater, because those involved have their self-organising abilities restricted, and may thus become dependent on the designer/planner to provide a new framework to facilitate and support new relationships and connectivity. This has implications for policy makers who attempt to 'control' the economy. It is doubtful that this will be effective and from a complexity viewpoint it would be more effective to concentrate on the provision of enabling infrastructures (the socio-cultural, technical and infrastructure) conditions that facilitate the emergence of the intended objective required. Flexibility must be given for new patterns and relationships and ways of working to emerge. New forms of organisations and entities may arise that would be unique more robust and sustainable in competitive environments.

1.3.2.4 Exploration-of-the-space-of- possibilities

A study of complexity suggests the following conclusions: It suggests that to survive and grow an entity needs to explore its space of possibilities and to generate variety. It also suggests that the search for a single 'optimum' strategy may neither be possible nor desirable. Any strategy can only be optimum under certain conditions, and when those conditions change, the strategy may no longer be optimal. Warren Buffet changed his strategy from purchasing 'penny' stocks that were undervalued to purchasing quality, companies with high barriers to entry when conditions changed. With the increase in knowledge and easier

[26] See Chapter 3.4 for an example of how Soros exploited distortions in currency regimes.

information gathering methods, 'penny stocks' now became accessible to many investors nullifying Buffet's advantage. Buffet was forced to look at 'the space of possibilities'. To survive an investor needs to be constantly scanning the landscape and trying different strategies. Unstable environments and rapidly changing markets require flexible approaches based on requisite variety.

Flexible adaptation also requires new connections or new ways of seeing things. Seeing a novel function for a part of an existing entity is called 'exaptation.'[27] When searching the space of possibilities, whether for a new product or a different way of doing things, it is not possible to explore all possibilities. It may, however, be possible to consider change one step away from what already exists. In this sense, exaptation may be considered an exploration of what is sometimes called the 'adjacent possible'.[28] That is exploring one step away, using 'building blocks' already available, but put together in a novel way. According to Kauffman both the biosphere and the econosphere seem to have "endogenous mechanisms that gate the exploration of the adjacent possible such that, on average, such explorations do successfully find new ways of making a living."[29]

In the econosphere adaptations are selected by economic success or failure, at a rate that is sustainable. Any attempt to push for unrealistic growth leads to perturbations that bring back the economy to sustainable conditions that can be assimilated by the market. Although the rate at which novelty can be introduced is restricted, the adjacent possible is indefinitely expandable.[30] Once discoveries from the current adjacent possible have been realised then a new set emerges that include the expanded set that has occurred from the newer adjacent possible. The constant opening up of niche markets in areas that only a few years earlier had not even been thought of, is an example of the ever expanding possibilities of the adjacent possible.

1.3.2.5 Feedback

Feedback mechanisms are related to an engineering concept that is traditionally seen in terms of positive (reinforcing) and negative (balancing, moderating, or dampening) feedback

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[27] Mitleton- Kelly E. 2003. Ten Principles of Complexity and Enabling Infrastructures. 14.

[28] Kaufman S. 2000. *Investigations,* Oxford University Press. 22.

[29] Kaufman S. 2000. *Investigations.* Oxford University Press. 22.

[30] Kaufman S. 2000. *Investigations*. Oxford University Press. 42.

mechanisms. Thus positive feedback drives change and negative feedback maintains stability in the system. There is an abundance of non-linear feedback routes: There are loops in the interactions. The effect of any activity can feed back on itself, sometimes directly and at times after a number of intervening stages. This is called recurrence.[31]

In far-from-equilibrium conditions, non-linear relationships prevail, and a system becomes inordinately sensitive to external influences where small inputs yield huge, startling effects that cause a whole system to re-organise itself. Part of that process is likely to be the result of positive or reinforcing feedback.

In human systems, far-from-equilibrium conditions operate when a system is perturbed well away from its established norms, or away from its usual ways of working. When an organisation as a system is thus disturbed (due to restructuring, merger, crisis etc.), it may reach a critical point and either degrade into disorder (loss of morale, loss of productivity) or create some new order and organisation. That is it may find new ways of working and relating and thus create a new coherence. Positive or reinforcing feedback processes underlie such transformation and they provide a starting point for understanding the constant movement between change and stability in complex systems.

Soros and Buffet are both well aware of and seem to understand this feedback mechanism. Soros in his use of the theory of reflexivity observes and tries to anticipate likely human reaction to events. Buffet understands that markets will from time to time fall into far from equilibrium state due to investor expectations or some exogenous variable causing a re-evaluation of share prices. After a period of time feedback mechanisms lead to changes in sentiment and values rise again.

In social systems, the degree of connectivity (dependency or strength of coupling) often determines the strength of feedback. Feedback when applied to human interactions means influence that changes potential action and behaviour. Feedback is rarely the straightforward engineering concept of linear input –output predictable outcomes. Actions and behaviour may vary according to the degree of connectivity between different individuals, as well as with time and context. Co-evolution may also depend on reciprocal feedback influences between entities.

Kauffman states that he has found evidence that the structure of an ecosystem governs co-

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[31] Cilliers P.1998. Complexity and Postmodernism: Understanding Complex Systems. 3-5.

evolution.[32] We will see this in our analysis of the Beer Game and Farmers Model in Chapter 2.3; where the institutional structure of the system creates dynamics. When this is combined with the behaviour of agents and exogenous inputs leading to perturbations (business cycles) and could lead to the emergence of a new order.

1.3.2.6 Path Dependence & Increasing Returns

Brian Arthur argues that traditional economic theory is based on the implicit assumption of negative feedback loops in the economy, which lead to diminishing returns, which in turn lead to predictable equilibrium outcomes. He cites the example of the oil shocks of the 1970s that encouraged energy conservation and increased oil exploration, leading to an increase in supply and a drop in prices by the early 1980s. Arthur argues that such stabilising forces do not always operate or dominate. Instead positive feedback magnifies the effects of small economic shifts, and increasing returns from positive feedback makes for many possible equilibrium points, depending on the negative feedback loops that may also operate in a system.[33]

In our discussion on dissipative structures we have seen that it is possible to have more than one equilibrium point. The specific paths that a system may follow depend on its past history. The behaviour of a complex system is determined by how it evolves over time and its past history. The dimension of time is important when analyzing the system. A complex system has memory/history captured at both the micro level (e.g. personal experiences, personal opinions, worldview) and macro level (e.g. culture, ritual, value system). Therefore system history plays an important role in defining the state of the system as well as affecting system evolution. Past history affects future development, and there may be several possible paths or patterns that a system may follow. This explains why the precise behaviour of a complex system may be very difficult to predict. Examples of increasing returns resulting from a virtuous cycle of reinforcing growth and path dependence include the gauge of railway tracks, VHS recorders and the English language used as a standard language in air navigation.[34]

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[32] Mitleton-Kelly E. 2003. Ten Principles of Complexity and Enabling Infrastructures. 17. Quotes Kaufmann S. 1993. 279. The Origins of Order: Self Organisation and selection in Evolution. Oxford University Press.

[33] Mitleton-Kelly E. 2003. 17. Ten Principles of Complexity and Enabling Infrastructures. 17. Quotes Arthur B.W. 1990 Positive Feedbacks in the Economy. Scientific American. Feb.1990.

[34] Mitleton- Kelly E. 2003. Ten Principles of Complexity and Enabling Infrastructures.18.

Apart from reinforcing feedback loops, there may be negative feedback or stabilising loops in operation as well. The two processes may be present simultaneously or they may follow each other as the market progresses through various economic cycles. Markets and economies are complex systems that co-evolve, are dissipative (in the sense that they are irreversible and have a history), show self-organisation and emergence, and explore their space of possibilities. As all these characteristics play out, the progression of any technology or market is not smooth.

Arthur looks closely at the development of technology clusters for example with cars come production lines, modern assembly methods, 'scientific management' road systems, oil refineries and traffic control.[35] He shows how they eventually change the way business is done, and that they may even change the way society is conducted. Thus the constant interplay between positive and negative feedback loops moving the markets between periods of expansion and stability.

1.3.2.7 Self-organisation, Emergence and the Creation of New Order

Self-organisation, emergence and the creation of new order are three of the key characteristics of complex systems. Emergence is the way complex systems and patterns arise out of a multiplicity of relatively simple interactions. Emergence is central to the theories of integrative levels and of complex systems. Goldstein defines emergence as "the arising of novel and coherent structures, patterns and properties during the process of self organisation in complex systems."[36] He cites the following six common characteristics of emergence:

- radical novelty (features not previously observed in systems):

  Quantitative incremental changes can lead to qualitative changes that are different from and irreducible to their parts. By their very nature such wholes are unpredictable.[37] Lloyd Morgan argued that the evolutionary process has an underlying advancement tendency, because emergent phenomenon lead in due course to new levels of reality.[38]

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[35] Arthur B.W. 2002. Is the Information Revolution Over? If History is a guide, it is not. Business 2.0 March; http://www.business2.com/articles/mag/o, 1640,37570,00html

[36] Goldstein J. 1999. Emergence as a Construct: History and Issues. 49-72.

[37] Corning P. 2002. The Re –Emergence of 'Emergence': a Venerable Concept in Search of a Theory. 4.

[38] Corning P. 2002. The Re –Emergence of 'Emergence': a Venerable Concept in Search of a Theory. 4.

- coherence or correlation (meaning integrated wholes that maintain themselves over some period of time) :-

  It must be noted that patternmaking itself is not enough to fulfil the requirements of emergence. For example neural networks are patterns that are constructed but are not deemed to be emergent phenomenon. Emergence requires patterns whose stability and reproducibility over time is assured by self organisation.[39]

- A global or macro "level" i.e. there is some property of "wholeness":-

  The higher level reveals itself as a pattern or a special arrangement of entities of the lower. If you were existing at a lower level that you would be unable to grasp or realise the pattern which is only possible to conceive at a higher level. Most emergent phenomenon show this gestalt property (an organised whole that is more than the sum of its parts) of being a pattern in time and space of elements of a lower level.[40] Wholes provide unique combined effects, but many of these effects may be co-determined by the context and the interactions between the wholes and its environments. In fact many of the "properties" of the whole may arise from such interactions. This is the case with living systems. The properties of an emergent phenomenon like water, proteins or people may be codetermined by context.[41]

- It is a product of a dynamical process (it evolves):-

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[39] Emmeche C, Koppe S, Stjernfeldt F.1977. *Explaining Emergence: Towards an Ontology of Levels*. 83-119.

[40] Emmeche C, Koppe S, Stjernfeldt F.1977. *Explaining Emergence: Towards an Ontology of Levels*. 83-119.

[41] Corning P. 2002. *The Re –Emergence of 'Emergence': a Venerable Concept in Search of a Theory*. 12, gives an example of the properties of water and the implications of context: At a micro level hydrogen and oxygen link together to form a bond. To explain the energetic properties of water requires quantum theory. Principles of chemistry are required to account for the state changes that produce water from gas. Thermodynamic principles are needed to understand the dynamics of temperature changes in water. Hydraulics is required to understand how water reacts to a force exerted on it. Thus the problem of understanding the role of water in world climate patterns presents a great research challenge that requires a multi levelled, multidisciplinary modelling approach. Thus the emergent properties of a phenomenon like water may be codetermined by context.

The joining together of complex entities will always synthesise into more complex units. At a certain point in the evolutionary process, the dialectical development will cause quantitative elements to synthesise into qualitative elements.[42]

- It is "ostensive" – emergence can be perceived and functions as a descriptor of the patterns and properties that are exhibited at the macro level. This can commonly be identified by patterns of accumulating change which we call growth.[43]
- It shows supervenience – a kind of dependency relationship between sets of properties.[44] :-

Higher level emergent phenomena occur either from lower level parts and their actions or by downward causation (supervenience). For emergence to occur over different time scales there must exist a causal relationship between different scales – a top down feedback known as interconnectivity. The emergent property or complex behaviour is not a property of any single entity and cannot be predicted from behaviour in lower entities – they are irreducible. By their very nature the levels are inclusive – phenomenon on one level cannot be reduced to a lower level, and cannot change the laws of the lower level.[45]

One of the reasons why emergent behaviour is difficult to predict is the fact that the number of interactions between parts of a system increases exponentially with the number of parts thus potentially allowing for subtle and new behaviour to emerge. For example; the interactions between groups of molecules grow enormously as the number of molecules increase to such an extent that it is not possible for a computer to handle the arrangements for a system as small as 20 molecules.[46]

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[42] Emmeche C, Koppe S, Stjernfeldt F.1997. *Explaining Emergence: Towards an Ontology of Levels*. 83-119.

43 Refer to Smith T.A. 2004. Complexity theory and change management in sport organizations. E: CO Special Double Issue Vol. 6 Nos. 1-2. 2004. 70-79. This research paper is a good example of how complexity theory maybe helpful in understanding organizational changes. This paper specifically deals with organizational change in sports organisations in Australia. It also illustrates examples in a practical sense of identifying and analysing emergent behaviour.

44 If the mental supervenes on the physical properties of a person than if two person are indistinguishable in their physical properties than they must be indistinguishable in their mental properties- downward causation.

[45] Emmeche C, Koppe S, Stjernfeldt F.1997. *Explaining Emergence: Towards an Ontology of Levels*. 83-119.

[46] http://en.wikipedia.org/wiki/Emergence . 2.

At the same time merely having a large number of interactions is no guarantee of emergent behaviour resulting as many of the interactions may be negligible qualitatively, irrelevent or cancel each other out. In certain cases a large number of interactions can work against the emergence of interesting behaviour by creating a lot of "noise" that drowns out an emerging signal. The emerging behaviour may need to be temporarily protected and isolated from other interactions so that it can reach critical mass to be self supporting.[47] Thus it is not only the number of connections between parts but also how the connections are organised. There can be more than one way to generate emergent behaviour. It can arise from a hierarchical organisation or from decentralised organisational structures such as a marketplace. In some cases the system has to reach a combined critical mass of diversity, organisation and connectivity before emergent behaviour appears.

Unintended consequences and side effects are closely related to emergent properties. Luc Steels states that; "A component has a particular functionality but this is not recognisable as a subfunction of the global functionality. Instead a component implements a behaviour whose side effect contributes to the global functionality. Each behaviour has a side effect and the sum of the side effects gives the desired functionality". In other words, the global or macroscopic functionality of a system with "emergent functionality" is the sum of all "side effects" of all emergent properties and functionalities.[48]

Systems with emergent properties or structures may appear to defy entropic principles and the second law of thermodynamics, because they form and increase order despite the lack of central command and control.[49] This is possible because open systems can extract information and order out of the environment.

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[47] Gladwell M. 2002. *The Tipping Point,* uses the term the tipping point to explain the point of critical mass when emergence occurs. He argues that there are three things that converge to bring about dramatic changes in society. These are the context, the idea and the people involved. His point is that small changes in any or many of the context, the quality of the idea or whether the idea reaches a very small group of key people can trigger a dramatic 'epidemic' of change in society.

[48] Steels L.1990. Towards a Theory of Emergent Functionality. 454.

[49] The operation of the Second Law of Thermodynamics in very basic terms is the tendency for closed systems to wear down and dissipate energy that can never be retrieved. Equilibrium is the end state of a closed system, the point at which the system has exhausted all its capacity for change and has reached a state of entropy. This law states that entropy, a measure of disorder and randomness in a system, is always increasing. The Classical Economists were not aware of this fact i.e. the link between closed systems, the

In an organisational context, self-organisation may be described as the spontaneous coming together of a group to perform a task with no one outside the group directing the activities. Emergence in a human system tends to create irreversible structures or ideas, relationships and organisational forms, which become part of the history of individuals and institutions and in turn affect the evolution of those entities: e.g. the generation of knowledge and of innovative ideas when a team is working together could be described as an emergent property in the sense that it arises from the interaction of individuals and is not just the sum of existing ideas, but could well be something quite new and possibly unexpected. Once the ideas are articulated they form part of the history of each individual and part of the shared history of the team - the process is not reversible - and these new ideas and new knowledge can be built upon to generate further new ideas and knowledge.

In terms of the econosphere, emerging patterns of boom and bust are the result of the interaction of the behaviours of many consumers and investors in the context of a structure with history.

In conclusion then if one sees the economy and social systems as complexly evolving systems and can understand the characteristics of these systems than one can gain a better understanding of the issues. One needs to understand the inter relationship of elements in a system to gain a maximum benefit of application of theory. One needs to think about creating enabling environments to foster learning and create positive change. One must remember that there are limits to connectivity. Connectivity cannot be increased indefinitely without experiencing a breakdown.

1.3.3 Emergence and Social Innovation

Wheatley inteprets academic speak on emergence in a very interesting and perceptive way.[50] Her focus is on emergence in a social innovation context. Change begins as local actions occur simultaneously in many different areas. If these changes remain disconnected nothing happens beyond each locale. However when they become connected local actions can emerge as a powerful system with influence at a more large scale or comprehensive (global) level. If you take an example of the collapse of the Soviet Union it was the result of many local

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Second Law of Thermodynamics and equilibrium. They borrowed the concept from early physics not realising its applicability to closed systems such as machines and not to open systems. It is incorrect to apply it to open systems that have the capacity for self-renewal.

[50] Wheatley M and Frieze D. 2008. Using Emergence to take social Innovation to Scale.

actions and decisions, most of which were invisible and unknown to each other and none of which was powerful enough by itself to create change. But when these changes come together new power emerged.

Emergent phenomena have the characteristics of exerting more power than the sum of their parts. They always posses new capacities different from the local actions that engendered them. What will arise cannot be predicted and emergence always results in a more powerful system that has more capacities than could ever be predicted by analysing the individual parts.[51]

Wheatley states that there are three stages to Emergence: Networks, Communities of Practise and Systems of Influence.

Networks are the only form of organisation on this earth used by living systems. These networks result from self organisation where individuals recognise their interdependence and organise in ways that support the diversity and viability of all. They are based on self interest where people usually network together for their own benefit to further their own aspirations. People in networks realise that there are people with similar aspirations out there and they get together to form a community. This leads to a conglomeration of ideas and actions that become 'standard'. Finally the networks and group action coalesce to give rise to a new system at a greater level of scale (Systems of Influence). The System of Influence possesses qualities that were unknown in the individual. They are properties of the system not the individual and the system that emerges is more powerful than planned and incremental change. Emergence is how life creates radical change and takes things to scale.

The stock market is an example of emergence on a large scale. As a whole it precisely regulates the relative share prices of companies around the world, yet it has no leader; there is no one entity which controls the workings of the entire market. Agents or investors, have knowledge of only a limited number of companies within their portfolio, and must follow the regulatory rules of the market and analyse the transaction individually or in large groups. Trends and patterns emerge which are studied intensively by technical analysts.

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[51] Wheatley and Frieze state that we see this in the behaviour of hive insects such as ants and bees. Individual ants possess none of the intelligence or skills that are in the hive. No matter how intently you study the behaviour of the individual ant you will not be able to see the behaviour of the hive. Yet once the hive forms, each ant acts with the intelligence and the skilfulness of the whole.

1.3.4 Limitations to constructing a model of a complex system

Richardson puts forward the following argument about the limitations and problems inherent in attempting to construct a model of a complex system:[52] If a model of a complex system was constructed that captured all the possible behaviours contained (both current and subsequent) by the system being represented then that model must be as complex as the system of interest. The reason for this is that there will always be something outside of the boundary (that is, the boundary inferred by the model) that would affect the system's behaviour in some way at some time.[53] It is very difficult if at all possible to build effective models because complex systems are sensitive to small changes or small errors in our assumptions, i.e. a small error in the placement of the model boundaries, could mean that the model might be wholly inappropriate for the decision that it supposedly supports. To model a complex system accurately, one would have to take into account life, the universe and everything. Acknowledging that there is only one complex system (the universe) is important, however, since it forces the analyst to recognize the narrow scope and the conditional and temporary nature of their representations. Given that no hard enduring boundaries exist in reality the use of the term "system" can be misleading as it suggests the existence of completely autonomous entities. Richardson says that maybe we should rename complexity science as the "science of partial complex systems". This usage would make explicit the fact that when considering any problem we are in fact investigating a part of a complex system. This argument places a large question mark on our financial theories and any systems that investors utilize in making decisions. There are just too many variables and too many things to take into account that is outside the scope of any model or any investor no matter how intelligent and smart he or she might be.[54]

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[52] Richardson K, Cilliers P, Lissack M. 2001. Complexity Science: *A "Grey Science for the Stuff in Between"*. 9-12.

[53] For more detail on the implications of boundaries refer to : Richardson KA, Lissack M. 2001. *"On the Status of Boundaries, both Natural and Organisational: A Complex Systems Perspective"*. Emergence 3(4) 32-49.

[54] This argument highlights the severe limitations of financial models such as CAPM and Portfolio theory that are based on assumptions of perfectly rational and efficient markets. Perfect rationality is perhaps the most unrealistic assumption in Traditional Economics. It is built on two assumptions: First, is that people pursue their self interest in economic matters and second is that they pursue their self interest in very complex and calculating ways. Economists assume that we take into account inflation rates, GDP growth rates etc in our daily decision making. They also assume that we process all this information using equations and

Richardson develops this argument further by posing the following question - Assuming the notion of incompressibility to be correct what does this mean for analysis? Incompressibility essentially counteracts the possibility of the existence of a globally and permanently valid perspective or paradigm and following from this the use of a perspective or framework to describe any subsystem within a complex system.[55] He says we should note that how we define any 'sub-system' would be dependent upon our perceptions and the use of our description rather than a permanent feature of the real world. This observation begs the question whether sensemaking and modeling is of any use at all. What it means, however, is

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calculations. Some of the typical examples of the assumptions that economists make about the world we live in are :

All information needed to make decisions is completely and instantly available for free.

- There are no transaction costs i.e. fees, taxes and tolls.
- All products are pure commodities sold only on price i.e. there are brands or differences in product quality.
- Companies are always working as efficiently as possible.
- Decision makers only interact with each other through price and usually through an auction mechanism.

These kind of assumptions have led Axel Leijonhufund a macro economist to comment that Traditional economics models incredibly smart people in unbelievably simple situations while the real world is more accurately described as believably simple people coping with incredibly complex situations. Behavioural biologists have shown that people are intelligent but not in the traditional economic sense. They are poor at complex logical calculations but very good at recognising patterns, interpreting ambiguous information and learning. Beinhocker E. 2007. *The Origin of Wealth*. 51-54.

[55] Richardson includes in this argument the perspective of mathematics. A subject that he says by nature trivialises the existence of boundaries. Mathematics cannot wholly describe any subsystem within a complex system. Hayek F. *The Theory of Complex Phenomenon*. 1998. 59. writes that it is often thought that the use of statistical techniques would overcome the problem of working with large numbers of elements in complex structures. Statistics however deals with the problem of large numbers by eliminating complexity and deliberately treating the individual elements as if they were not systematically connected. It avoids the problem of complexity by substituting information on individual elements with information on the frequency with which their different properties occur in classes of such elements and it deliberately disregards the fact that the relative position of the different elements in a structure may matter. In other words it proceeds on the assumption that information on the numerical frequencies of the different elements of a collective is enough to explain the phenomenon and that no information is required on the manner in which the elements are related.

not that we should not attempt to make sense, but that we should be strongly aware of the conditional and temporary nature and limitations of any perspective that might be used in supporting an analysis of any problem. We must demonstrate considerable humility or we will continue to believe that our current understanding is true and defines all that is possible. Richardson's solution to the observation that no one perspective can capture the inherent intricacies of complex systems leads us when we analyse complex systems to consider a number of perspectives. The underlying basis for this is that by exploring a number of perspectives a fuller and more intense appreciation of the "state of affairs" or "problematic situation" of interest will be developed. Thus contributing to more informed and sounder decision-making.

I will now take a close look at the economy which forms the arena upon which investment decisions are made. We will argue that it is complex and thus encapsulates the characteristic of emergence and connectivity within it.

Chapter Two

The Economy as a Complex System

Characteristics and Emergent Phenomena

2.1 Characteristics of the Economy

Economic reality is characterised by; nonlinearity, discontinuity, and a variety of phenomena that are not so easily predicted or understood. At the same time the broad coherence of economic systems is more impressive than ever in the face of such phenomena. The order of the economy appears to emerge from the complex interactions that constitute the evolutionary process of the economy.[56]

The economy can be deemed a complex system as it exhibits characteristics of complexity. Characteristics such as dynamism, nonlinearity, adapatation, human behaviour and networks (connectivity).

2.1.1 Dynamic Endogenously Driven

Our first observation is that the economy is a dynamic system that is endogenously driven by the structure of the economy itself. Traditional Economics recognised that the economy changes but viewed changes in the economy as generated from exogenous sources such as technology changes, political events and changes in consumer tastes.[57] The economy can be

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[56] *Complexity Economics*. Edited by J. Barkley Rosser, Jr. [book forthcoming, Edward Elgar, 2003] www.cob.jmu.edu/rosserjb/COMPLEXITY%20IN%20ECONOMICS.doc

[57] Traditional economics is based is based on the concept of equilibrium and closed systems borrowed from physics, in particular the physics of motion and energy. Just as in physics a rolling ball will come to rest at some point the economy is seen as reaching an equilibrium point. External shocks such as technology changes, politics and consumer demand disturbs equilibrium and then the economy moves to a new equilibrium point. There are two problems with utilising the concept of equilibrium. First equilibrium is the end state in a closed system, the point at which the system has exhausted all its capacity for change and has reached a state of entropy. The economy is an open system and has the capacity for self renewal. Second, the mathematics of equilibrium required early economists to make a set of highly restrictive assumptions that have increasingly detached theoretical economics from the real world. These are assumptions such as perfect rationality and efficient markets. They begin with unrealistic assumptions that lead to unrealistic conclusions.

thought of as a collection of stocks and their related flows. The stocks can be tangible like money and people and intangible like consumer confidence, and these rise and fall over time.[58] The various stocks and flows are connected to each other in complex ways. For example if the stock of employment fell to a low level (high unemployment), then the reserve bank might cut interest rates in order to encourage borrowing, which would expand the stock of money available for investment, which would then be used by businesses to invest in new production capacity, creating more demand for employees, thus raising the stock of employment, which would finally feedback to effect future interest rate policy. Such chains of relationships between stocks and flows in a dynamic system are known as feedback loops. Positive feedback reinforces, accelerates or amplifies whatever is happening be it a virtuous cycle or a downward spiral. Systems with positive feedback can thus exhibit exponential growth, exponential collapse, or oscillations with increasing amplitude. Negative feedback is a dampening cycle – instead of reinforcing it works in the opposite direction. While positive feedback accelerates change, negative feedback dampens change, controls things and brings things back in line. Dynamic systems also have a third ingredient; time delays. Any change in stocks and flows takes time to impact upon the economy- a lagged effect.

Thus it is not difficult to see that dynamic systems can become quite complex if you have multiple stocks and flows interacting via both negative and positive feedback loops. The positive feedbacks drive the system, accelerating it, but at the same time the negative feedback are fighting back to dampen and control it. When time delays are thrown in, the driving and dampening can get out of balance and out of sync causing the system to oscillate in highly elaborate ways.

2.1.2 Nonlinear system

The second observation is that the economy is a nonlinear system. Nonlinear literally means not in a straight line. An important characteristic of nonlinear systems is that one can get widely varying behaviours simply from tweaking one variable. This is called sensitivity to initial conditions. A related characteristic is that nonlinear dynamic systems are path dependent or in other words history matters. These two characteristics, sensitivity to initial conditions and path dependence make nonlinear dynamic systems very difficult to work with and in many cases impossible to predict.[59]

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[58] Beinhocker E. 2007. *The Origin of Wealth*. 100.

[59] Beinhocker E. *The Origin of Wealth*. 106.

John Sterman, a professor at MIT's Sloan School of Management in his studies on nonlinearity and business cycles focussed on why many commodities go through complex boom and bust cycles. Industries as diverse as copper, aircraft, cattle and electricity have one thing in common; their cyclical swings in prices and industry capacity are much more volatile than the swings in underlying demand or in the economy overall. We thus have big effects without any obvious big causes, in other words a nonlinear relationship. Figure 2 below, depicts the commodity cycles of various industries. We can see that the data has a definite periodicity, but the cycles are not exactly regular nor are they quite random. These cycles could be seen as complex.[60]

The most important negative feedback loop in traditional economics is the role played by price in supply and demand. If demand goes up, prices will rise, causing supply to increase which then causes prices to fall until supply and demand are back into balance. Traditional economists usually assume all this happens at once, ignoring the role of time delays. Thus, while supply and demand balance in economic textbooks, the real world is full of inventories, excess production capacity and other stocks to buffer disequilibrium. Sterman postulated that the differences in adjustment speeds of these various buffer stocks might ultimately be what lay behind the dynamics of commodity cycles. Sterman decided to test his hypothesis by building a computer model of a simple commodity market to see if he could reproduce the statistical characteristics of the cycles.[61]

[60] Sterman J. 2000. *Business Dynamics*. 791-798

[61] Sterman J. 2000. *Business Dynamics*. 798-841

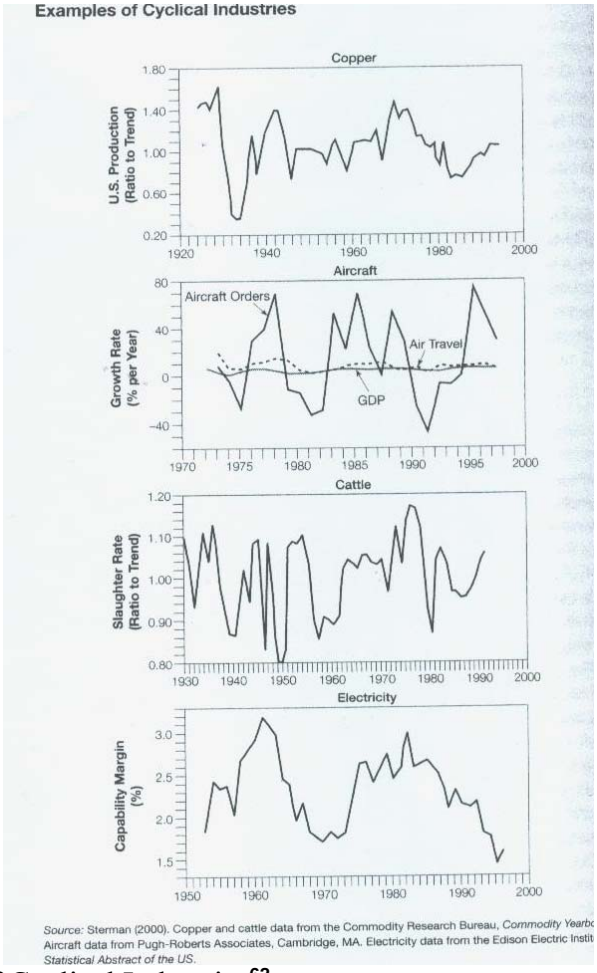

Figure 2: Examples of Cyclical Industries[62]

Unlike traditional models, his model (a systems dynamics solution) had explicit stocks for inventory and production capacity, positive and negative feedback loops, time delays and nonlinear relationships. He showed that a factory making a hypothetical product "widget" is faced with three critical buffer stocks against supply and demand mismatches – inventory of widgets, available productive capacity and long term productive capacity. Sterman's model has a structure of these feedback loops all running at different adjustment speeds. His model showed that when demand for widgets increase and the short term production capacity falls short of meeting demand, then customers frustrated at the backlog in orders, order more. The production manager will than increases production until he reaches full production capacity. This takes time due to hiring and training of workers, ordering raw material, getting authorisation for finances and so on. The company increase prices and due to huge demand the market accepts price and company profitability increases. Seeing that the business is

[62] Sterman J. 2000. *Business Dynamics*. 793.

hugely profitable, management make plans for building extra capacity by building another factory. Six months later demand tapers of due to increase in supply from competitor production lines, fashion changes or customers finding substitute products. Prices begin to fall, inventory piles up and now there is excess capacity in the industry as competitors had reacted to the initial demand exactly as this company did, by increasing their production capacities.

When Sterman ran this model, he found that it generated commodity cycles that were statistically similar in important ways to real world cycles.[63] The model shows that the combination of the different timescales in the feedback loops and human fallibility make such cycles almost inevitable. One of the implications of Sterman's model is that the only way to mitigate the cycle is to change the structure of the system itself. For example one could reduce the time delays in the system such as the time to add new capacity, one could make small investments in capacity such as building mini factories or outsourcing, one could improve information system by having access to customer inventories and sales, or one could increase transparency on how much capacity is actually in the industry and how much is under construction.[64]

One of the most interesting aspects of Sterman's work is that it highlights just how difficult it is for our mental models to grasp and develop an intuition for nonlinear dynamic systems. Our brains are just not wired to think this way. The combination of human behaviour and dynamic structure in the economy explain complex phenomena.

2.1.3 The adaptive economy

The economy and markets are open systems and also social systems that are made up of people as well as physical systems such as matter, energy and information. These are all subject to the laws of physics as any other phenomena.[65] The economy being an open system should therefore tap into properties of self organising or self renewing systems, which have the distinguishing feature of system resiliency.[66]

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[63] Sterman J. 2000. *Business Dynamics*. 824-828.

[64] Beinhocker E. 2007. *The Origin of Wealth*. 114.

[65] Beinhocker E. 2007. *The Origin of Wealth*. 71.

[66] Wheatley M. Leadership and The New Science. 88.

In these systems disequilibrium plays a very important role in the process of growth and adaptation. Researchers looking at the dynamics of these systems over time have found that they were capable of exchanging energy- taking in free energy to replace entropy that was produced. Thus deterioration of the system was not inevitable. Prigogine's work on the evolution of these systems led to the concept of dissipative structures, because they dissipate energy in order to recreate themselves into new forms of organisation. Faced with amplifying levels of disturbance, these systems posses innate properties to reconfigure themselves so that they can deal with new information.[67]

Another characteristic of self organising systems is their stability over time. Here there is a paradox as there is the presence of many fluctuations and instabilities occurring at a local level while the total system remains stable. This phenomenon is found in the economy as well with frequent and ongoing occurrences of oscillations and punctuated equilibriums while maintaining global stability. The system allows for and tolerates many levels of autonomy and for fluctuations all the while preserving stability and integrity with the environment.[68]

Darwins idea of adaptation and evolution in the biosphere has been borrowed to explain the growing order and complexity of the econosphere. Evolution by means of differentiation, selection and amplification or as Dennet puts it through "sorting, winnowing and building things."[69] The process of adaptation is through the power of an algorithm which is an all purpose formula for innovation through trial and error that creates new designs and solves difficult problems.[70] These new views of economic evolution however differ radically from that of Social Darwinism. For instance cooperation is seen as just as vital an ingredient in economic development as competition and that while both biological and economic systems

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[67] Wheatley M. Leadership and The New Science. 88.

[68] Wheatley M. Leadership and The New Science. 95.

[69] Dennet D.1990. *Darwins Dangerous Idea*. 51.

[70] Dennet D.C.1996. *Darwins Dangerous Idea*. 50-60. He writes that Darwin offered a theory for creating design out of chaos without the aid of the Mind. He had discovered the power of an algorithm. An algorithm is a certain sort of formal process that can be counted on logically to yield a certain sort of result whenever it is processed. It is composed of simple steps that can be executed with absolute reliability by a simple mechanism. No matter how impressive the product of an algorithm, the underlying process always consist of nothing but a set of individually mindless steps succeeding each other without the help of intelligent supervision.

share the core algorithm of evolution and thus have some similarities, their realisation of evolution are in fact very different and must be understood in their individual contexts.

Evolution is a method for searching enormous, almost infinitely large spaces of possible designs for the almost infinitesimally small fraction of designs that "fit" according to their particular purpose and environment.[71] As Dennet puts it, evolution is a search algorithm that "finds needles of good design in haystacks of possibility"[72] We experiment and try things keeping and building on what works and discarding what does not. This is part of the evolutionary process.

Evolution is a result of three interlinked processors, namely Physical Technology, Social Technology and Business Design. [73] A critical factor in economic growth is the evolution of technology as was experienced in the Industrial Revolution and more recently in the advances in digital computer phenomena. Technology can be broken down into Physical and Social technology.[74] Physical Technology is what we normally associate technology to be things like the steam engine, microchips, the computer network. Social Technology are ways of organising people to do things. Things like settled agriculture, the rule of law, the monetary system, the modern corporation, venture capital and the banking system. Businesses fuse Physical and Social Technologies together and express them into the environment in the form of products and services.

Businesses are themselves a form of design. The design of a business encompasses its strategy, organisational structure, management processes, culture etc. Business designs evolve through a process of differentiation, selection and amplification with the market determining the ability to survive. It is this three-way co evolution of Physical Technology,

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[71] Beinhocker E. 2007. *The Origin of Wealth*. 14.

[72] Dennet D. 1996. *Darwins Dangerous Idea*. 157.

[73] Beinhocker E. 2007. *The Origin of Wealth*. 14.

[74] Nelson R. 2003. *Physical and Social technologies and their Evolution.* Columbia University working paper. Nelson writes that Physical Technology advances are more easily assimilated than Social technology advances. The major advance in Social technology has been due to substituting Physical technology with social technology such as electronic communication and mass production. He also proposed that technologies that are proving the hardest to advance often have very large elements of social elements rather than physical.

Social Technology and Business Design that accounts for the patterns of change and growth which is evident in the economy.

2.1.4 Human behaviour – Role of Agents

A theory of human behaviour has to be at the core of any economic theory as it is the interaction of individuals and their decisions whether they act in their own capacity or collectively within businesses that impact on the economy.

There is a very important distinction that needs to be analysed between assumptions made by traditional economists and those from the complexity school regarding human behaviour and how we make decisions.

The assumption of perfect rationality in Traditional Economics assumes that we are one hundred percent deductive, that we always work on unambiguous, well defined problems. It also assumes that we don't learn; after all there is no need to learn if we are already have full information. Deduction only works on very well defined problems. There must be no information missing or ambiguity. It is a powerful method of reasoning but inherently fragile and inflexible. While induction is more error prone, it is also more flexible and better suited for the incomplete and ambiguous information that the world throws at us.

The cognitive view of science is the exact inverse. It portrays human minds as being information processing organs. The human mind is capable of incredible feats of information processing and learning that is very different from the picture portrayed by perfect rationality. We are good pattern recognisers and story tellers rather that maths calculators. Stories are vital to us because the primary way we process information is through induction. Induction is essential reasoning by pattern recognition. It is drawing conclusions from a preponderance of evidence.

John Holland a computer scientist and Brian Arthur an academic teamed up with other researchers at Santa Fe and built a computer model depicting the behaviour of the market using inductive based reasoning.[75] They found that running the model with one single rule – perfect rationality and a learning rate of zero led to results that were very much like that predicted by Traditional economics. The model quickly settled down to a price that was close to the theoretical equilibrium price, which corresponded to the fundamental value of the stock. There was relatively little trading volume or volatility and no one earned particularly higher returns then anybody else.

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[75] Arthur W. 1995. Complexity in Economic and Financial Markets. 9.

They then ran the inductive based computer model, with one hundred artificial investors each with sixty expectational models (competing rules in each agent's head), initialised the rules with a random scattering of strategies and raised the learning rate above zero.[76] Trading volume went up, volatility climbed and the stock price had a far more complex dynamic including bubbles and crashes. The market also developed patterns of quiet and calm periods interspersed with stormy intense periods. There were also large differences in the relative performance of agents.

What caused this change to a more dynamic and realistic market is as follows; if everyone starts with the same perfect rationality rules with little learning than the market moves along in a herd like manner with price roughly at equilibrium. As soon as heterogeneity and learning are introduced, things get much richer and more complex. Let's say for some reason, the price of a stock moves upward. Some agents have active rules that look for growth in the stock price and then buy. As the price rises more and more agents will buy which causes prices to rise higher and higher. Other players however might focus on fundamental value and at some point begin to sell because they think the stock are overvalued. If enough of them come in at once they could tip the stock back down triggering the entry of players who have rules to sell declining stocks, sending the share price plunging as the growth players sell their stock. There might also evolve new rules that specifically look for this up - down patterns and then try and exploit it. All this price movement is driven by the dynamic interaction of various rules in the population and has little or nothing to do with changes in the underlying value of stock. Nor are the complex patterns due merely to random noise. Instead, there is a complex battle of beliefs going on within the heads of agents and among the agents, which leads to volatility and complex patterns in the market.

In the complex adaptive system of the economy, understanding the micro - level behaviour of individuals is essential to understanding how the system as a whole behaves. The Traditional economic model of human behaviour is overly simplistic and fundamentally at odds with an enormous body of evidence, simply for the sake of mathematical compliance. Today the model has inputs from psychologists, computer scientists and cognitive scientists that portray

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[76] For a criticism on the use of the computational models used by Arthur and Holland see Gerald Silverbergs review in www.santafe.edu/~wbarthur/Papers/Pdf_files/Silverberg_web.pdf. He argues that the conclusions about expectations and non stationarity (in terms of market moods, herd effects, technical trading) in their studies are still only amenable to anecdotal verification. Serious thought has to be given as to how such models can be tied to reality and what statistical data have to be gathered to make their conclusions possible.

humans as inductively rational pattern recognisers who are able to make decisions in ambiguous and fast changing environments and to learn from them.

The Traditional model implicitly assumes that people only care about the outcome of economic decisions and not the process that people go through in making them. Things like bargaining, fairness and coercion do not enter the picture. In addition the model assumes that people only care about what they personal gain or lose and do not look at the effect on other people.[77] Experiments have shown that humans have strongly ingrained rules about fairness and reciprocity that override calculated "rationality". Herbert Gintis, the behavioural researcher and his colleagues observe that humans are "conditional co-operators" who will behave generously as long as others are doing so, and "altruistic punishers" who will strike back at those perceived to behave unfairly, even at the expense of their own immediate interests.[78]

In the traditional model people share no common errors or biases. Some of the common errors and biases that researchers have uncovered in normal people include; Framing biases, representativeness, availability biases, difficulty judging risk, superstitious reasoning, mental accounting.

To summarise the complexity view on economic agents and behaviour: Economic agents make choices based on current beliefs and hypotheses (predictions) about future prices, interest rates, competitors strategies and the state of the economy. These choices when aggregated in turn shape share prices, interest rates, market strategies and the state of the economy. Thus at one level the economy is a vast collection of beliefs and hypotheses, constantly being formulated, acted upon, changed and discarded, all interacting and competing and evolving and coevolving, forming an ocean of ever changing and predictive models of the world. At times these expectations and beliefs simplify into a simple homogenous equilibrium set but more often they produce complex ever changing patterns. This inductive ecology of expectation model is by definition an adaptive non linear

[77] Beinhocker E. 2007. *The Origin of Wealth*. 120.

[78] Gintis H, Bowles S, Boyd R and Fehr R. 2005. *Moral Sentiments and Material Interest*. 10.

network.[79] It displays complex, pattern forming, non stationery behaviour. One can conjecture that actual financial markets live within the complexity regime.[80]

2.1.5 Networks

Networks are essential in any complex adaptive system.[81] Without interactions between agents, there can be no complexity. To understand the power of networks and its role in the economy a quick examination of a Boolean network reveals its dynamism. A Boolean network is a network of nodes that can be in a state of 0 and 1. It seems very simple but it is the basis by which the World Wide Web has been built. There are three variables that guide the behaviour of such networks.[82] These are; the number of nodes in the network, the measure of how much everything is connected to everything else and the measure of "bias" in the rules guiding the behaviour of the nodes.

The first important fact about Boolean networks is that the number of states a network can in scales exponentially with the number of nodes. A network of 2 nodes can be in 4 states; a network of 3 can be in 8 states and so on. It would probably be impossible to visit all the possible states of a human brain for instance. The positive side of all this is that as the network grows in size, the amount of information it can capture or the things it can do also grows exponentially. This exponential growth in possible states creates a very powerful kind of economy of scale in any network of information processing entities. Traditional economists have usually thought of economies of scale as a function relating cost and volume. For example an increase in production of widgets will result in a decrease in cost of widget. The laws of Boolean networks force one to think of another kind of economy of

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[79] Holland J. 1988. The Global Economy as an Adaptive Process. 117-124

[80] Arthur W.B. 1995. Complexity in Economic and Financial Markets. 1.

81 Traditional economics tend to ignore networks, as they do not fit neatly into the equilibrium paradigm. These traditional models assume that agents only interact through auctions, or in some other price setting mechanism or in one on one negotiation. This assumption probably comes about because auctions and two person games can be portrayed as equilibrium systems, while larger groups of people involved in complex interactions are much more difficult to model mathematically. In a complex paradigm, researchers have shown that networks have a number of very general properties that are universally applicable- Beinhocker E. 2007. The Origin of Wealth. 141.

[82] Beinhocker E. 2007. *The Origin of Wealth*. 148

scale. As the size of the Boolean network grows, the potential for novelty increases exponentially. Thus a Boolean network with ten nodes can be in 2^{10} possible states and for one hundred nodes would be 2^{100} states. Thus if we think of human organisations like corporations as a kind of Boolean network then we can see that as an organisation grows in size, the space of innovations unfold exponentially.

There is however a constraint to this innovation and that is the diseconomies of scale driven by the second variable of Boolean Networks, which is the degree of connectedness. As the numbers of nodes grow the number of connections will scale exponentially and the number of interdependencies in the network grows faster than the network itself. Thus changes in one part of the network will impact on other parts and increases the probability exponentially with the number of nodes that a positive change in one part of the network will have a negative impact somewhere else. Stuart Kaufman, the mathematical biologist calls this interdependency "complexity catastrophe."[83] This means that densely connected networks become less adaptable as they grow as in large corporations that are slowed down by bureaucracy. We thus have two opposing forces at work here as an organisation grows the degrees of possibility grow exponentially while its degrees of freedom collapse exponentially. Network theory shows that organisations can take two actions. One is to reduce the density of connections, by use of hierarchies or spinning of companies into autonomous operating divisions and the other is to increase the predictability of decision making by instituting rules. Thus there are benefits of scale but diseconomies of complexity that increases the dynamism and complexity of the economy.

2.2 Complexity and Emergent Phenomena

Having seen the nature of the economy that is deemed to be dynamic and complex one needs to now examine what are some of the emergent phenomena that arise out of complex systems. Before this is done let's have a look at what Traditional Economics have to say about this:

Traditional economics offer two competing hypothesis to explain the oscillating patterns we see in the economy.[84] On the one side we have the microeconomics based real business cycle theory, which holds onto the rational equilibrium view and sees the economy as merely propagating external shocks. Under this theory the key causes of economic oscillations are

[83] Beinhocker E. 2009. *Strategy at the Edge of Chaos*. 118. Quotes Kaufmann.

[84] Beinhocker E. 2007. *The Origin of Wealth*. 166.

exogenous political events, changes in technology and other factors. But such models cannot tell us why the cycles have been so persistent throughout history, despite enormous changes in the exogenous factors that are thought to be the causes. On the other side we have the macroeconomics based new Keynesian view. This body of work has been less orthodox and has incorporated less than perfect rationality, dynamics and time delays in order to find endogenous explanations. In many ways the New Keynesianism is a step in the Complexity Economics direction, but the new Keynesians have not abandon the concept of equilibrium and as a result, the empirical success of the theory has thus far been limited.[85]

Complexity economics views economic patterns such as business cycles, growth and inflation as emergent phenomena arising endogenously out of the interactions in the system. Complex adaptive systems tend to have signature emergent patterns that are common across many types of systems. We will look at three such signature patterns: oscillations, punctuated equilibrium and power laws.

2.2.1 Oscillations

Oscillations are a common feature in complex adaptive systems. In most cases the ups and downs emerge from the structure of the system itself rather than from any outside source. So how might the structure of an economic system generate endogenous oscillations? In the 1950s Jay Forrester of MIT invented a game called the Beer Distribution Game - a game simulating the manufacture and distribution of a commodity, which demonstrates how a combination of human behaviour and dynamic structure can interact and produce oscillations in a simple economic system.[86]

In this game there are four agents; the brewer, the distributor, the wholesaler and the retailer. Orders flow up the supply chain from consumer to brewer and beer flows down in reverse. There is a time delay between ordering and receiving the beer and there is no communication allowed between players other than through orders. The orders start at four cases and then move to eight orders in the second round where it stays till the end of the game. This once of step up in orders sends a perturbation down the supply chain. According to Traditional economics, this exogenous shock in demand should simply cause the players to move to a new equilibrium after a few turns of adjustment, with everyone ordering eight cases and everyone's inventories staying constant once the new equilibrium has been reached.

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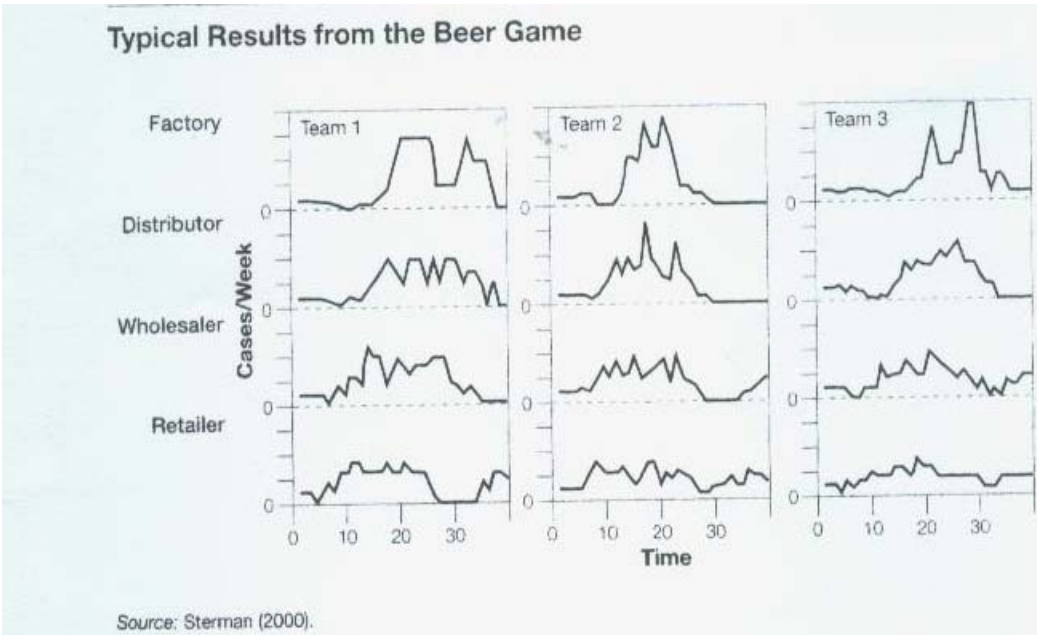
[85] Beinhocker E. 2007. *The Origin of Wealth*. 167.

[86] Senge P. The Fifth Discipline. 28-40.

In experiments with real people however the players inevitably over react to the jump in demand by over ordering as the inventory falls. As this wave of over ordering travels up the supply chain, it is amplified. The inevitable consequence of this is that large amounts of beer eventually start flowing back down the supply chain and everyone gets swamped with inventory. The overreaction cycle swings the other way and players drastically cut their orders some even to zero. This oscillating waves of over ordering and under ordering wash up and down the cycle chain and the industry incurs very costly cycles of boom and bust. See Figure 3 below.

Traditional economics say that if the players were perfectly rational and in the game they have information to be perfectly rational, the wild oscillations should not occur. The game should just step neatly from one equilibrium to another. If one calculates the cost generated in the experiment versus those in the perfectly rational case, the cost generated by real humans are on average ten times the perfectly rational costs.

Figure 3: Cycles of Boom and Bust[87]



Just what kind of behaviour leads to such wild oscillations in a relatively simple environment? Sterman has been able to statistically derive the decision rule used by the participants.[88] The rule is based on a behaviour known in psychology literature as anchor and adjust. Rather than deductively calculate their future beer needs by looking at all the inventory on the board (which they can see) and incorporating the effects of time delays, the

[87] Sterman J. 2000. *Business Dynamics*. 687.

[88] Sterman J. 2000. *Business Dynamics*. 684-698

participants simply looked at the past pattern of orders and inventory levels and inductively anchor on a pattern that seems normal. Their, IF THEN rule consequently try to steer them to maintain that normal pattern. Thus a player might anchor on four cases as the normal pattern of orders and then struggle to adjust when things are not normal, for example "My inventory is dropping order more!" In an environment with time delays, the anchor and adjust rule causes individuals to overshoot and undershoot which in turn leads to the emergent pattern of cyclical behaviour.

The game receives a single shock- the increase in orders from four to eight, and the system never returns to equilibrium. This is because the ultimate source of the oscillations is not the exogenous shock itself (it just gets things started), but the behaviour of the participants and the feedback structure of the system. The system is not propagating exogenous dynamics; it is endogenously creating them.

The lesson one can learn from the real economy is that the causes of cycles may ultimately lie in the way the inductive rules people use in their decision making interact with the dynamic structure of the economic system. One implication is that standard solutions of interest rate cuts and increase government spending do not address the root causes of the cycle; they merely address the symptoms. If government wants to influence cycles they would need to look at the structure of the economic system itself.

There is evidence that the dynamic structure of the economy is changing, even without explicit government intervention. There are two ways to dampen the cycle in the Beer Game; one is to reduce the time delays and the other is to give the participants more information. The information technology revolution has directly affected both factors. Data shows that the volatility of the US business cycle has experienced a sharp reduction in the 1980s with the widespread adoption of computers. Computers have enabled companies to speed order processing, adopt Just in Time (JIT) practices and electronically link produces and retailers with their supply chains. There is some debate about how much of volatility is attributable to these changes in technology and business practices versus other factors.[89]

2.2.2 Punctuated equilibrium

Stephen Jay Gould coined the term "punctuated equilibrium" to describe a pattern of alternating calm and storm.[90] He challenged Darwin's assumption that random mutation and

[89] Beinhocker E. 2007. *The Origin of Wealth*. 172.

[90] Beinhocker E. 2007. *The Origin of Wealth*. 173.

natural selection lead to gradual evolution. He argued instead that fossil evidence showed evolution was discontinuous. This natural endogenous feature of the evolutionary process occurs when times of relative calm and stability are interrupted by stormy restructuring periods or punctuation points.[91] Patterns of punctuated equilibrium show up in the crashes of stock markets. One of the conclusions reached by researchers is that an important contributor to this behaviour is the network structure of the interactions in the system. Many types of networks self organise in a structure that has a mixture of very dense connections and very sparse connections.[92] Karl Marx and Joseph Schumpeter have noted that technological innovation proceed in similar patterns of calm and storm. Two key observations can be made.[93] The first is that no technology is developed in isolation. These interrelationships are not just technological but economic. The economic web has grown around the car for example it includes industries ranging from steel making to oil, hotels and fast food. The second observation is that technologies are inherently modular. Modules are the assembled into architectures. Innovations in modules can enable new architectures, but it is innovation in architecture that tends to have the big catalysing ripple effects on innovation.

Traditionally fluctuations were seen as disturbing equilibrium. But order based on equilibrium is vulnerable to destruction (owing to the stagnation and absence of adaptation), whereas order based on disequilibrium has a higher probability of being maintained. When disruption occurs, our managerial or investor response is to impose order as quickly as possible as our mindset is programmed on the virtues of stability.[94] Organisations and institutions are structured to reduce ambiguity and other mechanisms are used to provide focus and coherence. The question must be asked – do organisations benefit from these measures? Analogies to the natural sciences cause us to consider that the most beneficial course of action to ensure long term survival might be to foster disequilibrium. Punctuated equilibrium suggests the utilisation of a different framework; that of a resilience view, with an emphasis on keeping ones options open. In an uncertain world for an entity to survive it must have a good fit with the environment and it must be ever vigilant (mindfulness) and adaptive.

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[91] Beinhocker E. 1997. Strategy at the Edge of Chaos. 114.

[92] Newman M. 2003. The Structure and Function of Complex Networks. 192.

[93] Beinhocker E. 2007. *The Origin of Wealth*. 175.

[94] Pascale R.1990. *Managing on The Edge*. 108-109.

2.2.3 Power laws

Power laws along with oscillations and punctuated equilibrium are another significant characteristic of complex adaptive systems. One prediction of Traditional Economics is that stock prices should follow a random walk. They tell us that stock prices will move when a piece of news hit the markets and that big price movements should correspond with big, unexpected news. Cutler, Porteba and Summers have tested this prediction by studying stock movements from 1941 to 1987 with corresponding news events. They found no correlation between news events and crashes.[95]

In the 1950s, two geophysicists Gutenberg and Richter studied earthquakes.[96] They plotted power of earthquakes (magnitude) with the number and were surprised to find that the graph did not look like the Gaussian distribution (bell curve). They graphed the data with logarithmic scale on both axis and found an almost dead straight line.

They found that for Earthquakes there is no typical size in the middle of the distribution, rather earthquakes occur across all size scales, but the bigger the earthquake the rarer it is - See Figure 4. Specifically with each doubling in magnitude, the probability of a quake of that size occurring drops by a factor of four. It is thus a slippery slope down the distribution from the smallest to the largest quakes. Physicists call this kind of relationship a power law because the distribution is described by an equation with an exponent or power.[97]

Figure 4: An Example of Power Law Distribution: Earthquake Magnitudes.[98]

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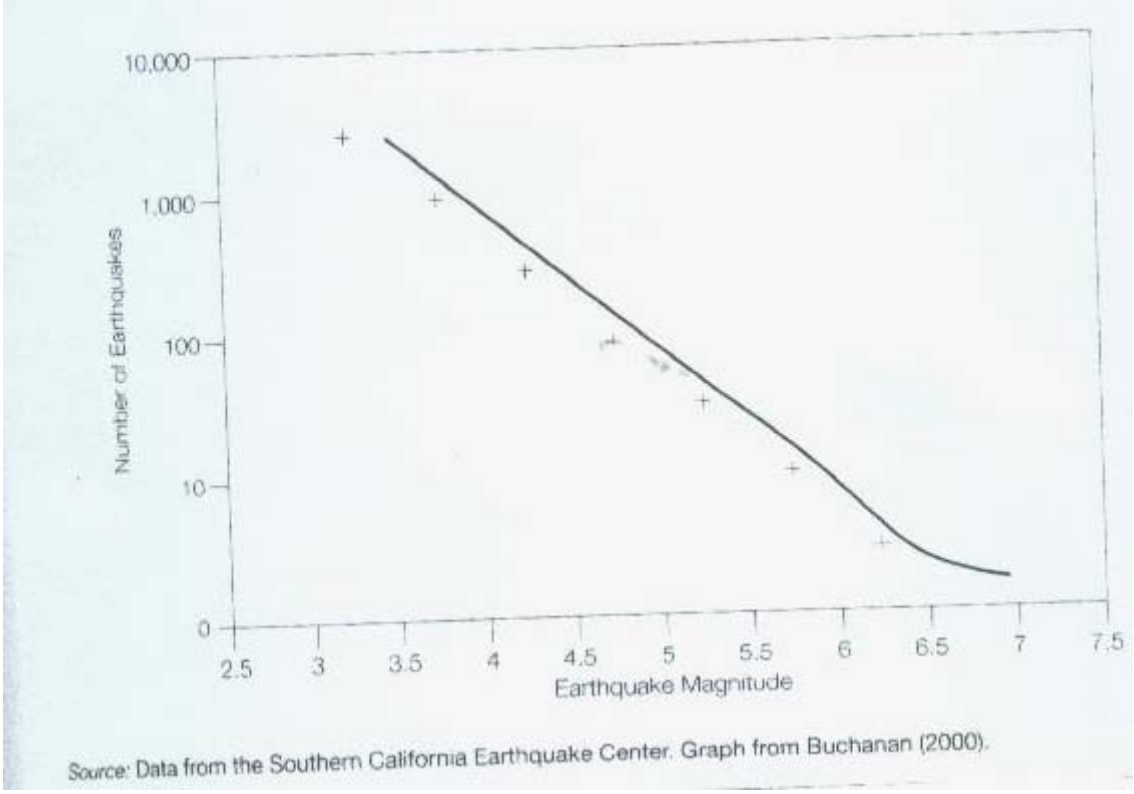
[95] Cutler D, Poterba J and Summers L. 1989. *What Moves Stock Prices?*. 7.

[96] Buchanan M. 2003. The Physics of the Trading Floor. 10.

[97] Buchanan M. 2003. The Physics of the Trading Floor. 11.

[98] Beinhocker E. 2007. *The Origin of Wealth*.179.



Source: Data from the Southern California Earthquake Center. Graph from Buchanan (2000).

Benoit Mandlebrot found the same power law when he studied cotton, gold and wheat prices. An econophysicist, Gene Stanley calculated that if stocks followed a random walk as Traditional Economics states than the probability of the 1987 Black Monday crash occurring was 10^{-148} percent.[99] Thus it is highly unlikely that the market could have just randomly walked its way into a crash of that magnitude. Gaussian random walks (Bell Curve) almost never have fluctuations greater than five standard deviations, yet in real economic data such as stock market crashes, five standard deviations and larger do occur.

Stanley then took thirty million records for six thousand US stocks over a thirty year period from 1962 to 1996 and found power laws. One of the consequences of this result is that financial markets are far more volatile than Traditional Economics would lead us to believe. If the markets follow a power law, than the probability of a Black Monday event is more like 10^{-5}, which means there is a good chance one will happen in any 100 year period. This clearly has major implications for how investors think about and manage risk.

Why are stock markets so much more volatile than Traditional theory predicts? And why does the volatility follow a power law? Doyne Farmer and his team believe that they have

[99] Beinhocker E. *The Origin of Wealth*. 180.

found the answer.[100] There are two types of trade one can make. The first is market order; in which a trader gives the order to buy or sell stock X right now for the best available price. The second is a limit order in which a trader gives the order to buy stock X if the price falls to R100 (or sells if the price rises to R100). For every stock in the market there is an electronic order book that keeps track of the limit orders. In effect the limit order book is an inventory for unfilled orders.

Let's see what happens when a new market order hits the book. Most stock exchanges have two rules to fulfil orders; these are price priority and time priority. Price priority means that we start with the best price in the book, fill the order as much as we can, then move to the next price. Time priority means that if there are two limit orders in the book at the same price, the earlier order gets filled first.

To illustrate let's take an example: You call your broker with a market order to buy 1000 shares of stock X at the best available price. The current best sell offer in the book is a limit order for R102 and there are 200 shares available at this price. The system fills 200 shares of your order at that price, leaving 800 shares to be filled. The system than looks further up the limit order book for the next best price which is say a limit sell order for 300 shares at R105. You buy those shares leaving 500 unfilled on your order. Marching further up the limit order book there is a limit sell order for 600 shares at R107. You take 500 of the 600 and your order is fulfilled. Average price you pay is R105.40 per share. The impact of your 1000 share order was to drive the asking price from R102 to R107. Thus we can see how a market order hits the order book and zaps out a bunch of limit orders, moving the price up or down.

Farmer and his team also wanted to know how this process of order fulfilment and the structure of the limit order book affect prices. In his study from data from the London Stock Exchange he found that the cause of large price fluctuations was the structure of the order book itself – large fluctuations occurred when there were large gaps between price levels in the book. They found that limit order books tend to be quite chunky and sparsely populated. Even the biggest most liquid stocks have thirty or so price levels populated with limit orders and lots of unpopulated prices and therefore gaps. Thus the patchiness of order books contributed to stock volatility and the smaller more thinly traded stocks were more volatile

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[100] Farmer J.D, Gillemot L, Lillo F, Sczabolcs M and Sen A. 2004. *What Really Causes Large Price Changes?* 383-397.

than large more liquid stock.[101] The power law pattern of price movements emerges from the structure itself.

Thus the lessons learnt from the Beer Game and Farmers model are the same: Complex emergent phenomena such as business cycles and stock price movements are likely to have three root causes:[102] The first is the behaviour of participants in the system. Human beings have real behavioural regularities such as anchor and adjust rules. Second the institutional structure of the system creates dynamics, which when combined with participant behaviour, led to oscillations in the Beer Game and power law volatility in Farmers stock market model. Third, we have exogenous inputs into the system that initiate and help drive the dynamics of the system. This was the increase in order in the Beer game and news in the case of the stock market. While exogenous factors play a role, traditional economics have over emphasised this variable at the expense of the others.

Complexity Economics does not have all the answers to the puzzle of economic patterns but it provides us with new tools to begin to understand how these various factors combine to result in the behaviours we observe. The ultimate accomplishment of Complexity Economics would be to develop a theory that takes us from theories of agents, networks and evolution all the way up to the macro patterns we see in real world economies. Such a comprehensive theory does not as yet exist but such a theory would view macro patterns as emergent phenomena; that is, characteristics of a system as a whole that arise endogenously out of interactions of agents and their environment.[103]

2.3 Complexity and Investment (Financial) Theory

2.3.1 Random Walk Theory

Finance is one of the few areas of economics in which theories and equations are applied in the real world. Finance theory is also unique in that it is the most empirically tested area of economics. Financial economists have at hand minute-by-minute data on the trading of tens of thousands of assets.[104]

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[101] Farmer J.D, Patelli P and Zovko I. 2005. The Predictive Power of Zero Intelligence In Financial Markets. 2254-2259.

[102] Beinhocker E. 2007. *The Origin of Wealth*. 185.

[103] Beinhocker E. 2007. *The Origin of Wealth*. 167.

[104] Beinhocker E. 2007. *The Origin of Wealth*. 382.

In 1990 Louis Bechelier, a young French graduate completed a dissertation called "The Theory of Speculation". In it he made the remarkable claim that stock prices moved according to a random walk. The radical implication of this claim was that there was no more useful information in the path of a stock price over time than there was in the wanderings of a drunk down the streets of Paris. Sixty years later this theory was used by the economist Paul Samuelson who made the random walk theory the corner stone for traditional finance theory. An extraordinary group of economists then developed upon this theory; economists such as Paul Cootner, Harry Markowitz, Jabes Tobin, Franco Modigliani, Merton Miller, Fisher Black, Myron Scholes, Eugene Fama, William Sharpe and Robert Merton.[105]

According to traditional financial theory, the way we should value a stock or any other financial instrument is to look at the future cash flows we will get from the stock over time.[106] In traditional finance, all investors are rational and they search out all available information on a particular stock, form a set of expectations of future cash flows from holding the investment, asses the risks to come up with a discount rate and then calculate what the stock is worth today. Thus at any given moment, the price of a stock reflects all the information available on the stock and everyone's expectation based on that information. So a stock that investors expect to grow in the future will have those expectations already built into the price today. Likewise any expectation that future dividends will decline would cause your valuation to drop. Similarly your perception of the investment risk will cause your discount rate to change, also changing the valuation of the stock.

Once you have digested all the available information and calculate the price you are willing to pay, in theory, the only reason you could change the price is if a new piece of information comes along that changes your future expectations. This is how individual investors make their decision, now consider what happens when we have a number of investors trading with each other. Not everyone interprets information the same way. Some are positive about the stock and some negative. Thus you have many people in the market and they have a spectrum of expectations and a spectrum of holdings in the market. The market acts as a system of auction whereby the pessimists will sell to the optimists. At some point all the investors will hold as much stock as they want and there is no incentive to trade anymore. We have reached

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[105] Beinhocker E. 2007. *The Origin of Wealth.* 382-383.

[106] Beinhocker E. 2007. *The Origin of Wealth.* 383.

equilibrium and the price set at this point is the market price. In effect the market price represents a consensus view of all the expectations and information in the market.

It is the efficiency of the market in digesting information that causes prices to move in a random walk. Thus, if everyone is absorbing the available information and doing the calculations correctly the only thing that will make the price move is a new piece of information. Since Traditional Economics assumes that the arrival of news is random, and no one knows if this news is good or bad, prices move randomly as they are influenced by the wind of news.

An important implication of the random walk model is that there is no useful information in past stock price movements. Whether a stock went up or down yesterday has no bearing on whether it will go up or down tomorrow – the only thing that is driving prices is news that is random. If there were any pattern in past prices, rational investors would spot them and use this information in their valuation. Their trading would then arbitrage the pattern out of the market, making it random again.

2.3.2 The Efficient Market Hypothesis

The combination of rational investors and arbitrage means that it is impossible to beat the market and generate higher returns than the market as a whole. This is known as the Efficient Market Hypothesis. The idea is that if everyone is using the same formula to calculate prices (perfect rationality) and has access to the same information than prices will reflect this. Since you cannot be smarter than perfect rationality, the only way to come up with price that better reflects the “true” value of the stock is to have information that other people do not have. And you cannot gain his advantage due to insider trading laws and the supposedly dissemination of information to everyone all at once via 24 hour, 7 day coverage of the news networks and the internet.

At this point one might say how do you explain successful investors such as Warren Buffet and George Soros? Aren’t there smart investors and dumb investors? A traditional finance theorist would say yes, but it is the smart investors who would set the market price. If you had only two types of investors the smart ones and the dumb ones than the smart ones will take advantage of the dumb ones ignorance and buy and sell until the market price equals the smart guys price. The smart investors will make money and over time their capital and share of the market will grow. In real world markets, the majority of the capital is under the control

of pension funds, mutual funds and other professional investors and it is these investors trading that generally set the price.[107]

What explanation would you have for mutual fund advertisements in the media showing a fund beating the market averages and its competitors over time? According the Traditional Financial economist there are two possible explanations: One is that the fund is taking on more risk than average. In an efficient market one can generate higher returns than the market average but there is no free lunch. The price one pays is higher risk and so on a risk adjusted basis one is still not beating the market. The second explanation is luck.

Traditional finance theory has developed into a rigorous and coherent theory that encompasses behaviour of individual investors up to the movements of global markets. Reality has however not been kind to the theory. Events such as the 1987 crash and the technology bubbles of the 1990s have presented challenges to traditional finance. More importantly a new generation of empirical work using highly advanced statistical tools has called into question the theories core tenets. Beikenhocker says, " at best the theory is a rough approximation that works under certain circumstances, at worst one can say it is plain and simply wrong"[108]

To conclude then, the following should be noted.[109]

- First, a substantial body of empirical and experimental evidence shows that real world investors look nothing like their theoretically perfect rational counterparts. Investors do not discount in the way Traditional theory assumes; they have various biases regarding risk, are subject to framing errors in processing information and use heuristics to make decisions. This does not mean that investors are irrational or make decisions purely on emotion. Rather they are 'boundedly' and inductively rational, instead of perfectly and deductively rational. Perfect rationality is a poor approximation of economic reality.
- Second, Bechelier was wrong. Markets do not follow a random walk. There is evidence that market data has considerable structure, which has the signature characteristics of an adaptive system.

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[107] Beinhocker E. 2007. *The Origin of Wealth*. 386.

[108] Beinhocker E. 2007. *The Origin of Wealth.* 387.

[109] Beinhocker E. 2007. *The Origin of Wealth.* 387.

- Third, financial markets are not efficient in the Traditional economics sense of the word, but they are highly effective in an evolutionary sense.

2.3.3 Mandlebrot and Power Laws

Benoit Mandlebrot an eccentric Polish born mathematician published in 1963 a paper titled "The variation of Certain Speculative Prices". In four arguments he disproved the Random Walk hypothesis.[110]

- The distribution of the data had much fatter tails than a bell shaped curve had. In other words there were extreme price swings than a random walk would predict.
- Those extreme events were in fact quite extreme; just a few price movements explained a large proportion of the total variance.
- There appeared to be some clustering of price movements in time; in other words, a pattern of punctuated equilibrium, and
- The statistics describing the data were not stationery as the Random walk predicted but changed over time.

Not only did Mandlebrot shoot down the Random Walk hypothesis but he also proposed and alternative. He suggested that the tails of the cotton price distribution followed a power law.[111] Mandlebrot's proposal neatly explained the fat tails and extreme volatility of the data – all features that the random walk hypothesis could not explain. In later work Mandlebrot would describe financial markets as having fractal geometry- not only was there structure to be found in financial data, but the structures appeared over multiple time scales from minutes to months. Mandlebrot confirmed his results with additional data from wheat prices, railroad stock, interest rates and exchange rates.

Andy Lo and Craig McKinley presented a paper that proved that the stock market does not follow a random walk. They took a slightly different tack. Instead of following tests that focused on the question of whether future stock prices could be predicted from past stock prices. The answer was no, but as Lo and McKinley pointed out, while the answer is consistent with Random Walk theory, it does not prove it. They asked a slightly different question – Do any patterns or regularities that exist in the data depart from a purely random pattern in a statistically significant way.[112] They found two patterns that provided powerful

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[110] Mandlebrot B. 1963. The Variation of Certain Speculative Prices. 394-419.

[111] Mandlebrot B and Hudson R. 2004. *The(Mis)behaviour of Markets*. 152-159.

[112] Lo A and Mackinley A. 1999. *A Non Random Walk Down Wall Street*. 4.

evidence against the Random Walk, both of which were consistent with Mandlebrot's findings. First, they found there was a correlation between prices and time, and second they discovered that the variance of the market prices did not behave as the Random Walk hypothesis said it should.[113]

In order to understand the importance of these power laws (Paretian) we need to compare them with Gaussian distributions. They differ radically. The main feature of the Gaussian distribution can be characterized by its mean and variance whereas a Paretian distribution does not show a well-behaved mean or variance. A power law, therefore, has no average that can be assumed to represent the typical features of the distribution and no finite standard deviations upon which to base confidence intervals.[114] Gaussian distributions tend to exist when events are completely independent of each other. When you introduce the assumption of interdependence across events, Paretian distributions tend to be relevant because positive feedback loops tend to amplify small initial events. For example, the fact that a website has a lot of links increases the likelihood that others will also link to this website.

McKelvey and Andriani suggest that Gaussian distributions can change into Paretian distributions under two conditions – when tension increases and when the cost of connections decreases.[115] In a competitive rapidly globalising economy, tension rises as competitive intensity increases and as business landscapes evolve faster than the capacity of most organisations to adapt. Simultaneously, costs of connections are rapidly decreasing as the world economy shifts towards freer movement of goods, money and ideas and the rapid improvements in the price-performance of information technology infrastructure. The effect of this is that Paretian distributions become even more prevalent.

In a world of Pareto distributions, extreme events become much more noticeable. Extreme events can take many forms. They can be sudden and severe disturbances like earthquakes or financial stock market collapses. These extreme events that are ignored in a Gaussian world are not only more common than expected but also of a vastly larger magnitude and more consequential.

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[113] Lo A and Mackinley A. 1999. *A Non Random Walk Down Wall Street*. 14.

[114] Hagel J. *The Power of Power Laws*. Edge Perspective

[115] McKelvey B and Andriani P. 2005. Why Gaussian Statistics are mostly wrong for Strategic Organisation. 219-228.

Our institutions are largely designed for a Gaussian world where averages and forecasts are meaningful. As a result, we have created a number of push programs that have delivered significant efficiency. In a world of sudden, severe and difficult to anticipate shifts, push programs become much less viable and one needs to become a lot more creative in terms of designing pull platforms.[116]

There are some extreme events that have a more positive outcome that the examples of earthquakes and financial collapses. These events play out on a longer time span than sudden dramatic events. Companies like Google and Microsoft have achieved enormous concentration of economic value creation that is not possible with the averages of the Gaussian world. These extreme events emerge first in the "fat tail", on the fringe of conventional business activity, driven by a different view of business opportunity, and then gather impetus until they eventually break into the head of the distribution and change the game for everyone else. The challenge for business managers is to differentiate the signal from the noise in the fat tail and to spot early on the emergent extreme events that could reshape the business landscape. The Gaussian focus on averages overlooks these events, treating them as meaningless □"outliers".

Another form of extreme event that is found in a Paretian world is the tendency for extreme forms of clustering in social networks. This takes the form of clustering in mega-cities in physical space or clustering of traffic on web sites in virtual space. Economic value inevitably follows these social clusters. This has powerful implications for business, ranging from where to locate operations in physical space to how to redesign institutional architectures to accommodate thousands of business partners.[117]

In a Pareto world focus is shifted to processing patterns rather than processing dots as we do in a Gaussian world. Processing dots means processing data, a low-level cognitive activity. By contrast, processing patterns (pattern recognition) is a high-level cognitive activity, one that involves selecting relevant patterns from among many possibilities. In a Paretian world, analysing events on face value can distract you from seeing the deep structures influencing these surface events. Surface events are extremely complex and rapidly evolving while the deep structures display more simplicity and stability. These deep structures are intensely

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[116] For more details on push and pull platforms see section 3.7.1

[117] See section 3.4 for examples of these business partners in the example of the company Li Fung.

historical in nature having evolved through positive feedback loops and path dependence. Quick deductions become misleading and understanding requires a dynamic view of the landscape.

The rewards for achieving a better understanding of the Paretian world are enormous in terms of investment. "Small moves, smartly made, can lead to exponential improvements in wealth creation provided they leverage the deep structures that define Paretian distributions. In contrast to the scaling strategies in the Gaussian world, different and even more powerful scaling strategies become feasible in the Paretian world, converting instability from a liability into an advantage."[118]

McKelvey describes the Gaussian perspective of the world as one favouring "stability over instability, structure over process, objects over fields, and being over becoming."[119] There is a natural and very human tendency to seek out the typical or the average and to search for more predictability. By implication, "a Paretian world requires a much more dynamic view of the world, one that looks for patterns in evolving relationships, rooted deeply in context, and that understands how these changing patterns reshape who we are as well as our opportunities for growth."[120]

2.3.4 Doyne Farmer's Model

In 1989 the Berlin Wall fell and that had great implications for financial theory. Physicists from the Eastern Bloc as well as from the US found themselves out of a job in the defence industry at the end of the Cold War. These mathematicians were hired by Wall Street to create computer models to help make money. They found huge anomalies between theory and reality. These physicists therefore turn to chaos theory, nonlinear dynamics and complexity theory for answers. This was the meeting point of financial theory and complexity theory. One such physicist was Doyne Farmer. He found that the equilibrium frameworks of Traditional finance made economist forget about time and that markets are dynamic systems. Farmer and his colleagues found they could detect statistically significant signals in market data. See Figure 5 below. These signals consisted of complex patterns and relationships

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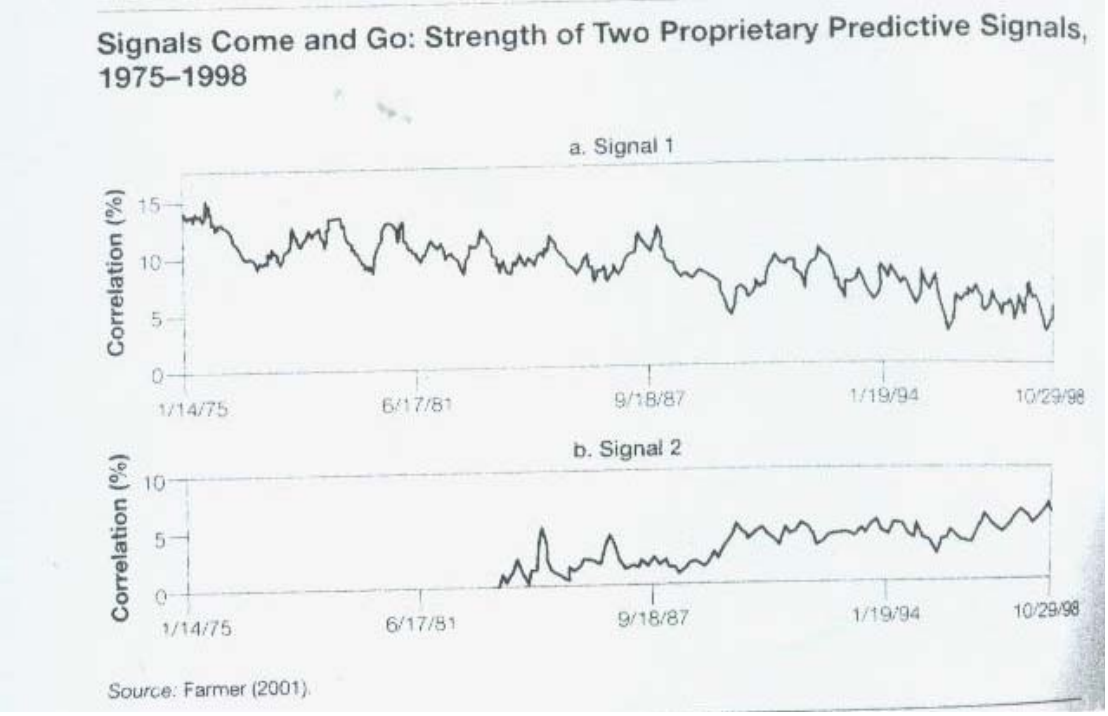
[118] Hagel J. *The Power of Power Laws*. Edge Perspective

[119] McKelvey B and Andriani P. 2005. Why Gaussian Statistics are mostly wrong for Strategic Organisation. 219-228.

[120] Hagel J. *The Power of Power Laws*. Edge Perspective.

between various factors that predicted future share prices for example, interest rates, trading volumes etc. As these signals were proprietary information they did not disclose exactly what they consisted of. Traditional theory says that any such signals, once discovered, could be arbitraged away immediately. But Farmer and his team found that signals would persist over time, often for days, months or even sometimes for as long as a decade. See Figure 5- Signal 1. Often they could see the signals weaken over time, as traders discovered and exploited them. But they also found that complex, nonlinear dynamics of the markets meant that new signals were constantly being created even as old signals faded due to arbitrage. See Figure 5- Signal 2.

Figure 5[121]



In fact Farmer found that the market formed a kind of evolving ecosystem. Heterogeneous traders and investors with a variety of mental models and strategies populate the markets. As those agents interact with each other over time, they constantly learn and adapt their strategies. They deductively experiment. The complex interactions of these agents, their changing strategies and new information from the environment cause patterns and trading opportunities to constantly appear and disappear over time. The Santa Fe Institute's Brian

[121] Beinhocker E. 2007. *The Origin of Wealth*. 392.

Arthur poetically once called markets "ecosystems of expectations"[122] to describe the interplay between agents and their strategies.

In the Santa Fe Model agents engaged in an evolutionary search for profitable strategies.[123] Which strategies were successful at a particular time depended on the strategies the other agents in the market were using. Agents could be grouped into the type of strategies they followed – value investors, technical traders, and liquidity traders. Thus a dynamic was created whereby particular combinations of strategies would create patterns or structures in the market, which in turn would change the behaviour of other agents, as they sought to exploit those strategies, which create further patterns causing other agents to react and so on. The results of the model did a good job of replicating the coming and going of patterns that Farmer had observed.[124]

As regards the relationship between price and value is was found that they roughly track each other, but not perfectly – time delay between action of trader and response of market. This market dynamic not taken into account in Traditional model that assumes everything happens at once. In Traditional finance, price and value can be different, but the difference is merely random short term noise as prices bounce around the true value and thus an average price equals value. As the departure from fundamental value are random and short term, no one can make money from them and thus the only sensible strategy is to be a fundamental investor.

Not only was Farmer's model consistent with his personal experience, it was also consistent with a large body of empirical evidence. First, he replicated the key qualitative statistical characteristics of real world data including the fat tails that Mandlebrot discovered. Second, despite the claims of Traditional theory, a number of studies show that some forms of technical trading can be profitable. Finally, several studies have shown that fundamental value can only explain a small proportion of overall stock price movements.[125]

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[122] Arthur W. 1995. Complexity in Economic and Financial Markets.

[123] The Santa Fe Model formulated by Arthur, Holland and others was described in section 2.1.4.

[124] Le Baron et al. 1999. Time Series Properties of an Artificial Stock Market. 1487-1516.

[125] See for discussion and references: Campbell J, Lo A and MacKinlay A. 1997. *The Econometrics of Financial Markets.* 253-287.

2.3.5 A new definition of market efficiency[126]

For Complexity economists, financial markets are evolving ecosystems of competing trading strategies. Markets react very quickly to new information and markets have been getting faster at processing information over time with developments in news channels such as Bloomberg and CNN, the internet and increasing computing power. Traditional theory predicts that with better information, prices should become less volatile relative to value, when in reality the opposite has been happening. As the power of information and technology has been increasing, it appears to have made markets more volatile, not less so. The evolutionary explanation is that as information technology improves, it opens up the design space of possible investment strategies and increases arbitrage and technical trading opportunities rather than decreasing them and thus we have seen a dramatic rise in the number of hedge funds.[127]

Markets are efficient at processing information. This informational efficiency is a cornerstone of the efficient market hypothesis. However the theory assumes that markets only use their great forecasting power on information related to a stocks fundamentals, while in the real world, traders also make bets on what other traders are doing and thinking. This more dynamic outlook puts the market in an infinite loop of forming expectations on the expectations of people forming expectations and so on. John Mayanard Keynes recognised this and said "we devote out intelligence to anticipate what average opinion expects average opinion to be"[128] These expectations of expectations feed the evolutionary dynamics of the markets, which means that while markets are powerful information processors, they are not efficient in the Traditional economic sense of the word. Markets are highly effective evolutionary systems. Markets are the best social technology yet devised for integrating the views of large numbers of people, to put prices on complex assets, and to allocate capital. Furthermore the competitive intensity of markets ensures that they are fast at processing information and that there is pressure on the participants to continuously innovate. Andrew Lo of MIT calls this evolutionary effectiveness of markets the 'Adaptive Market Hypothesis"

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[126] Beinhocker E. 2007. *The Origin of Wealth*. 399.

[127] Beinhocker E. 2007. *The Origin of Wealth*. 399.

[128] Keynes J.M. 1964. The General Theory of Employment Interest and Money. 156.

2.3.6 Summary

The complexity economics view of finance is still forming and many questions remain unanswered. For Wall Street, the City of London and other financial markets the implications of Complexity finance are only just beginning to be felt. A number of firms, both major banks and hedge funds, are employing the statistical and modelling techniques of Complexity economists in devising their investment strategies- and many of these firms either employ or are advised by various econophysicists and behavioural economists.[129]

The impact on individual investors is likely to be long term. Complexity economics does not change any of the broad guidelines given to individual investors such as the importance of diversifying ones portfolio or investing for the long term.[130]

[129] Beinhocker E. *The Origin of Wealth*. 403.

[130] Beinhocker E.2007. *The Origin of Wealth*. 403.

Chapter Three

The Implications of Viewing the Economy as Complex on Investment Decisions

3.1 Introduction

In Chapter Two an analysis of academic research on the nature and behaviour of the market was put forward. How does this compare with the viewpoint and actions of investors? These individuals who are actively trading and interacting with the markets on a daily basis can give us an insight that goes beyond the theory. We are fortunate to have the insights of Warren Buffet and George Soros both legendary investors who are very articulate and have very distinctive and strong viewpoints on the nature of the economy and the behaviour of stock markets. Buffet is unique in that he has practical experience of successful investments for over forty years and has developed a logical explanation for his success. Buffet disagrees with the assumptions of Efficient Markets as in the EMH sense and the assumption of perfect rationality. He sees the economy as being complex and he has utilised strategies that have been reactive rather than proactive to the market.[131] He understands that markets are changing continuously and he adapts to the nature of the investment problem as it really is.[132] An understanding of his viewpoints are crucial in understanding the implications of investing in complex adaptive systems.

3.2 Warren Buffet's Model

A simple summary of Warren Buffets model would be: Given the complex nature of the financial universe, predictions are impossible, thus it is better to invest on the notion of common sense. If a company is doing well and has a long history of superior performance, has long term competitive advantages, is managed by smart and stable people and the price is reasonable then you buy. Your cognitive makeup, mental models and your understanding of

[131] Hagstrom R. 1999. *The Warren Buffet Portfolio*. 85/83.

[132] Hagstrom R. 1999. The Warren Buffet Portfolio. 85.

human psychology influence the purchase decision. Each of these elements will be explored in the next section:

3.2.1 Cognitive

Buffet says that the way you actually view something, the way you are "wired" is important in making good investment decisions. The cognitive function in combination with mental models or a world view allows you to screen information. One of his mental models is not to work according to a strategic plan but to adapt decisions as opportunities arise. This is a very adaptable method that takes into account the dynamic and complex nature of the market as well the distinctive and unique features of each situation. According to Stephen Pinker we humans are wired to loath uncertainty and strive to eradicate it. Instinct moves us to map out areas, find the lay of the land, and familiarise ourselves with the surroundings in order to "remove the terror of a landscape lacking a frame of reference"[133] Buffet utilises this by staying within his circle of competence and once he understands the issues he favours a non intervention approach by not dictating how managers should reach their goals. He sidesteps the issue by hiring managers that are self motivated, capable and honest.

Buffet is reactive to the environment rather than proactive. He does not attempt to solve business problems but seeks to avoid them. As he says you do not charge through a herd of elephants but you go around them. He has no view of the future that dictates what business or industries he will enter. He prefers to focus on the economic characteristics of the business he wishes to own and the personal characteristics of managers with whom he wishes to associate with. He functions only to screen investment opportunities and to allocate capital. His scope is not limited by history, structure or concept. This hands of management style and an open mind gives him flexibility to make investments where he deems to get the best return. He has built very effective mental models that are continuously being refined by learning through action and reflection.

3.2.2 Mental Models

Mental Models are the second factor that will influence an investment decision.

Charlie Munger, Buffets colleague says that the first rule to learn is to carry multiple models in your mind. These need to be embraced from various disciplines, to create a multidisciplinary approach to thinking. This will include an understanding of behaviour models that come from psychology, mathematical models from probabilities to optimise your

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[133] O'Loughlin James. 2004. *The Real Warren Buffet*. 52.

portfolio, and an understanding of the model of complex adaptive systems to appreciate the folly of predicting markets.[134] Being an expert in these fields is not required but just an understanding of some of the important ideas and the combination of several of these models to give you an insight.[135]

In the following section some of these insights that have been derived from a multidiscipline approach are discussed.

3.2.2.1 Model of Risk

Buffet utilises a number of ways to reduce risk. They are taking a long term view on investment, incorporating a margin of safety and portfolio concentration when purchasing shares and finally working within your circle of competence. Below we analyse each of these:

3.2.2.1.1 Risk and long term investing.

Buffet places great emphasis in finding what the intrinsic, inherent value of the company is and understands that in time the inherent value will be reflected in the stock price. As Ben Graham said " in the short term the market is a voting machine, but in the long run it is a weighing machine."[136] The market is a voting machine as it represents the perceptions and expectations of investors and a weighing machine in that in the long term it represents the value of the share. He buys with a long term view, as he believes that risk is linked to an investors time horizon. If you buy a share today, to sell tomorrow than you have entered into a risky transaction. However if you extend this time horizon out to several years, the probability of it being a risky transaction declines meaningfully assuming of course that you have made a sensible purchase. This is due to three things: First, the fact that if the company is good, earnings will probably be good and value would have been added to the company during the intervening years. Second if you had purchased at a discount to inherent value than the market will eventually recognise value in the future and rerate the price of the share. Finally, a long term view will mean low transaction costs as you are not buying and selling frequently and you are not paying capital gains on the sale of these shares. The profit gain lie within the business in its retained income and is only actualised in the future when the market rerates the share.

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[134] Hagstrom R. The Warren Buffet Portfolio. 17

[135] Hagstrom R. The Warren Buffet Portfolio. 18.

[136] Graham B. 2003. The Intelligent Investor. 212.

Buffet cautions that the translation of earnings into share price is both "uneven" and "unpredictable". Although the relationship between earnings and price strengthens over time, it is not always predictable. "While market values track business values quite well over long periods, in any given year the relationship can gyrate capriciously"[137] He says that "the speed at which a business's success is recognised, furthermore, is not that important as long as the company's intrinsic value is increasing at a satisfactory rate." He says "In fact, delayed recognition, can be an advantage: It may give us the chance to buy more of a good thing at a bargain price"[138]

Just as an example of the kind of down to earth commonsense thinking and logic he utilises lets look at the saving on capital gains when holding a share for a long time. Buffet asks us to imagine what happens if you buy a $1 investment that doubles in price each year. If you sell the investment as the end of the first year. you would have a net gain of $0.66 assuming you are in the 34 percent tax bracket. In the second year you invest $1.66 and it doubles in value at year end. If the investment continues to double each year, and you continue to sell and pay the tax and reinvest the proceeds at the end of twenty years you would have a net gain of $25,200 after paying taxes of $13,000. If on the other hand, you purchased a $1 investment that doubled each year and was not sold until the end of twenty years, you would gain $692,000, after paying taxes of approximately $356,000. There is a vast difference in your return.

Investing for the long term therefore has a value connotation. If one purchases with the long term in mind these investments tend to be well thought out investments ensuring good management and solid business fundamentals are in place. Then one is purchasing a business rather than some short term speculation where profits for profits sake are the driver of ones decision.

3.2.2.1.2 Risk and portfolio concentration

Buffet follows a strategy of portfolio concentration rather than diversification going against the grain of modern financial theory of diversifying risks by increasing the number of shares in a portfolio. His argument is that buying fewer shares will mean that you are placing more money on these and you will increase your intensity of thinking about the business and you will only purchase once you are comfortable with the economic characteristics of the

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[137] Berkshire Hathaway Annual Report. 1981. 39.

[138] Berkshire Hathaway Annual Report. 1987. 15.

business. “Diversification serves as a protection against ignorance. It is poor decision making to think that to ensure nothing bad happens to you relative to the market that you should own everything.”[139] Buffet says that this is probably a good approach for someone who does not know how to analyse business. This protection comes at a price which is that you will earn average returns. Keynes had this to say about concentrating a portfolio; “ It is a mistake to think one limits one’s risk by spreading too much between enterprises about which one knows little and has no reason for special confidence. One's knowledge and experience are definitely limited and there are seldom more than two or three enterprises at any given time in which I personally feel myself to put full confidence.”[140]Thus the optimal portfolio is a focus portfolio that stresses big bets on high probability events, as opposed to equally weighted bets on a mixed bag of probabilities.[141]

This is a keen psychological insight that humans are scared to commit and lazy to focus and study. Under conditions of complexity as far as risk is concerned ‘less is more’ as fewer investments reduces risk and increases return assuming you know what you are doing, that is you have the right cognitive, mental and behavioural models.

It should be noted that following a strategy of portfolio concentration rather then diversification seems to be contrary to the strategy followed by complex adaptive systems. Complex systems require requisite variety in order to enhance chances of survival thus favouring a diversification strategy. Buffet does not adjust the discount rate for uncertainty rather he adjusts the price he will offer for the investment. This gives him a margin of safety should there be a downturn in the market. Buffet offsets risk by investing over the long term where value is recognised, within his circle of competence, and with a built in margin of safety in the price he pays.

3.2.2.1.3 Risk and Margin of safety

One can reduce risk by purchasing shares where the margin of safety (the discrepancy between intrinsic value and market price is high). Concentrating profits around a limited number of high probability events reduces risk and generates higher market returns. Buffet does not adjust the discount rate for uncertainty. If one investment looks riskier than another, he keeps the discount rate constant and instead adjusts the purchase price. He would in other

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[139] O Louglin James. 2004. *The Real Warren Buffet.* 65.

[140] Berkshire Hathaway Annual Report. 1991. 17.

[141] Hagstrom R. 1999. The Warren Buffet Portfolio. 34.

words obtain his margin of safety not by including a premium for equity risk as the CAPM requires, but by buying at a lower purchase price to begin with. "If you understand a business and if you can see its future perfectly, than you obviously need very little in the way of margin of safety."[142] Buffet thus focuses on value. If one purchases at a low price, one already have a margin of safety built in. This compensates for oscillations in the market.

3.2.2.1.4 Risk and knowledge (circle of competence)

Buffet's mental model limits decisions to investments he understands. He will not undertake investments in the h-technology industry as he feels he does not sufficiently understand the industry and therefore cannot calculate the stream of income. Charlie Munger says "The reason why we are not in high-tech businesses is that we have a special lack of aptitude in this area. The advantage of low-tech stuff is that we understand it fairly well. The other stuff we don't and we'd rather deal with what we understand. Why should we play a competitive game in a field where we have no advantage – maybe a disadvantage- instead of playing in a field where we have a clear advantage"[143] Buffet says that "there are people who can analyse technology but I can't"[144] As you can see from the above Buffet keeps focused on the knowable and the important. They work only within their circle of competence and thus reduce risk. Buffet maintains that risk comes from not knowing what you are doing. They only deal with investments that they know a great deal about and have identified the economic and behavioural "laws" that apply in this area. Buffet understands that it is important to recognise what you don't know. You cannot fool yourself. Understands his limitations. In order to invest in this industry one will require shifting ones mental model. A person will have to adopt new terminology, new definitions, a new way of looking at accounting systems and the nature of innovation. One will have to spend time to understand it. It's about focus and adapting and building and fortifying the mental models necessary to become successful.[145] Buffet understands that the human mind works efficiently when it is focussed on a few things. He focuses on investments in 'Franchise' businesses. These companies have strong financial resources, brand names, efficient and extensive distribution

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[142] Hagstrom R. 1999. The Warren Buffet Portfolio. 89.

[143] Hagstrom R. 1999. The Warren Buffet Portfolio. 105.

[144] Hagstrom R. 1999. The Warren Buffet Portfolio. 105.

[145] Hagstrom R. 1999. The Warren Buffet Portfolio. 108.

and logical networks that cannot be imitated easily. One such business is Coca Cola. These companies have a higher probability of survival in a complex adaptive world.

3.2.2.2 Model of prediction

Although the economy and the markets as a whole are too large and too complex to be predictable, there are patterns at the company level that one can recognise. "Inside each company, there are company patterns, management patterns, and financial patterns. If one studies these patterns, in most cases one can make a reasonable prediction about the future of that company. These are the patterns that Buffet focuses on, not the unpredictable behaviour patterns of millions of investors.[146] "I have always found it easier to evaluate weights dictated by fundamentals than votes dictated by psychology" he said.[147] We will continue to ignore political and economic forecasts, which are an expansive distraction for many investors and businessman. Once you understand that the market is a complex adaptive system, you freely put to rest any notion of predictability.[148] You also understand that the market will reach critical points of boom and bust. Buffet understands this and says that none of the blockbuster events such as Vietnam war, oil shocks, drop in the Dow made the slightest dent in Ben Grahams[149] principles, nor did they render unsound the negotiated purchase of fine businesses at a sensible price.[150]

3.2.2.3 Model of markets

The market is not always efficient and therefore investors willing to study and learn are given opportunities to beat the market. Buffett's problem with the efficient market theory rests on one central point: It makes no provision for investors who analyse all the available information and gain a competitive advantage by doing so. "Observing correctly that the

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[146] Hagstrom R. 1999. *The Warren Buffet Portfolio.* 183-184.

[147] Kilpatrick A. 1998. Of Permanent Value: The Story Of Warren Buffet. 794.

[148] Hagstrom R. 1999. The Warren Buffet Portfolio. 184.

[149] Ben Graham is an American investor and economist who is considered to be the first proponent of Value investing and investment approach he began teaching at Columbia Business school in 1928. He is the author of two very influential books on the subject; Security Analysis and The Intelligent Investor. Buffet credits Graham for providing him with a sound intellectual investment framework.

[150] Berkshire Hathaway Annual Report. 1994. 1.

market was frequently efficient, they went on to conclude incorrectly that it was always efficient. The difference between these propositions is night and day" [151]

3.2.2.4 Model of management behaviour

Buffet has built a mental model on the role of management behaviour. He says that in order for a business to be really successful the manager has to act as the owner of the enterprise. Many professional managers do not act as owners but in serving their own interests. Adam Smith said " The directors of companies, however being the managers rather of other people's money than of their own, it cannot be well expected, that they would watch over it with the same anxious vigilance… Negligence and profusion therefore, must always prevail, more or less, in the management of the affairs of such a company."[152]

For example management would like to retain profits and reinvest in the business they are running even though the return on investments are lower. This is because they want to increase the resources under their management thereby increasing their power base. Buffet calls this the institutional imperative and he describes the working as:[153]

- As if governed by Newton's First Law of Motion, an institution will resist any change in its current direction;
- Just as work expands to fill the available time, corporate projects or acquisitions will materialise to soak up additional funds;
- Any business craving of the leader, however foolish, will be quickly supported by detailed return and strategic studies prepared by his troops; and
- The behaviour of peer companies, whether they are expanding, acquiring, setting executive compensation or whatever, will be mindlessly imitated.

As you can see Buffet has welded together two cognitive and management behaviour conclusive realisations to make up a mental model. He realises that systemic factors greatly influence behaviour and the outcome of things re the Beer Game.[154] There are many companies structured with no commitment of ownership and the existence of cognitive dysfunction. The cognitive dysfunction takes the form of human beings adhering to inherent need to ensure self survival and self interest to the exclusion of allocating capital

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[151] Berkshire Hathaway Annual Report. 1988. 18.

[152] O'Loughlin James. 2004. *The Real Warren Buffet*. 27.

[153] Cunningham L. 2002. *The Essays of Warren Buffet*. 105.

[154] We have across this in our discussion on the nature of the economy and complex systems in section 2.1.

efficiently.[155] Within this "ancient logic" is contained the fear of being inconsistent with a prior commitment, the fear of departing from a prior definition of self and the fear of failure (heuristics). In this struggle to survive, behaving in this fashion of creating power bases kept you in the game with a chance for ultimate success via replication of your genes. This might be advantageous to the manager but hugely disadvantageous to an external investor.

Thus we have experienced, decent intelligent managers who are expected to make rational business decisions under conditions where the institutional imperative comes into play. Buffet to negate this 'weakness' will in his purchase decision choose very carefully the business he wishes to buy and prefers the owners of existing businesses to run the business with him. Any cash flow surpluses are channelled through to Buffet who will allocate capital. In instances where he cannot do this he chooses managers with a certain profile to run them. The characteristics are integrity, honesty, focus and dedication.

3.2.3 The Role of Psychology in the investment process

The third element that influences the investment decision is the role of human psychology and your understanding of it. Psychology, the twists and turns of human behaviour has no place in Efficient Market Theory or Modern Portfolio Theory. In an efficient market investors with the benefit of full information, instantly and rationally set prices. Hagstrom says that the more abstract the environment (and shares are an abstract concept to most people) the more forceful the intangible psychological factors become.[156]Much of what drives decisions in the stock market is explained by principles of human behaviour. We have seen this earlier in Keynes's comment on basing decisions on expectations of someone else who make decisions on the expectations of others and so on.

Benjamin Graham states that having an investors attitude is a matter of being prepared both financially and psychologically for the markets fluctuations – not merely knowing intellectually that a downturn will happen, but having the emotional ballast needed to react appropriately when it does.[157] In other words an investor must be able to handle psychologically the "bumps" in the market. Most investors are using price as a yardstick and are gripped by fear when they see prices falling. Their instinctive reaction is to sell. Buffet asks the question - if you go to a supermarket and prices have fallen do you buy more of the

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[155] O'Lauglin J. 2004. *The Real Warren Buffet.* 48.

[156] Hagstrom R. 1999. The Warren Buffet Portfolio. 142.

[157] Hagstrom R. 1999. The Warren Buffet Portfolio. 143.

item or less? You will tend to buy more, so it stands to reason that when prices of companies with good fundamentals fall there is more value to be gained by purchasing. Buffet has a keen insight into these kind of subtle anomalies which he uses to great effect in decision making.

In Graham's view an appropriate reaction to a downturn would be the same as a business owners response when offered an unattractive price; that is to ignore it. The true investor, says Graham scarcely is ever forced to sell his shares and at all other times is free to disregard the current price quotation His famous Mr Market story explains this well:[158] Graham created an allegorical figure called "Mr Market". Imagine you and Mr Market are partners in a private business. Each day without fail, Mr Market quotes a price that he is willing to pay for your share of the business or for you to sell your share to him. The business has stable economic characteristics but Mr Market's quotes are erratic, because he is emotionally unstable. Some days he is cheerful and optimistic and will quote a high price and some days he is pessimistic and quotes a low price. If Mr Market is in a foolish mood, you are free to ignore him or to take advantage of him, but it will be disastrous if you fall under his influence. This is the lesson that he preached: Do not be stampeded by other people's misjudgement and you need to protect yourself from the emotional whirlwind that the market unleashes. Investors will act irrationally. Fear and greed will permeate the marketplace leading to the occurrence of "foolish markets."

According to Munger, this psychology of misjudgement is due to our brain taking a short cut in analysis. We jump to easily to conclusions; we are easily misled and are prone to manipulation. He says he does a two track analysis.[159] First, what are the factors that really govern the interests involved, rationally considered? And second, what are the subconscious influences where the brain at a subconscious level is automatically doing these things – which by and large are useful, but which often malfunction. He uses this two step analysis in making investment decisions; first, consider rational expectations and probabilities, then carefully evaluate the psychological factors. Munger says that he and Buffet "entered the business world to find huge predictable patterns of extreme irrationality" when irrationality occurs it leads to predictable patterns of subsequent behaviour.[160]

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[158] Graham B. 2003. *The Intelligent Investor.* 204-205.

[159] Hagstrom R. 1999. The Warren Buffet Portfolio. 146.

[160] Kilpatrick A. 1998. Of Permanent Value: The Story of Warren Buffet. 683.

Investing is a social activity and human psychology plays an important role in the process. Pinker's statement that our brains are made for fitness, not for truth, summarises his ideas very well.[161] Thus Pinkers ideas of the role of emotion in decision making, and Tversrky's work on heuristics will have extreme relevance to investing. Warren Buffet says " When the price of a stock can be influenced by a "herd" on Wall Street with prices set at the margin by the most emotional person, or the greediest person, or the most depressed person, it is hard to argue that the market always prices rationally. In fact, market prices are frequently nonsensical"[162]

3.3 Conclusion- Buffet

The important point is that once one understands that the market is a complex system, one realises the baselessness of trying to predict. Thus Buffet focuses on what he calls the knowable and the important. The knowable is the fundamental evaluation of a company or what Buffet calls its franchise. That is choosing a financially strong company with sound management, a long track record and a good branded product. If this share is purchased at a reasonable price, you have reduced your risk if you hold over the long term. Markets will fluctuate wildly but over the long term acts as a weighing machine by recognising value. In effect you are ignoring the "noise" of the market - the emergent phenomenon of punctuated equilibriums that we have discussed earlier that is driven by the "irrational behaviour" of people in the market.

If we subscribe to a world view that sees the economy as a ever changing, dynamic and complex than our mental models have to be very different from any other paradigm be it the simple, linear, rationalistic thinking or any other. Professor Mauboussin of Columbia University says that ' the fundamental concepts haven't changed; it is still crucial to buy good financial businesses that are run by able managers and are available at sensible prices. But the economy and the world of business have evolved into quite different forms, and this has required investors to evolve their mental models to keep pace with the changing world"[163]

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[161] Taleb N. 2004. *Fooled By Randomness*. 182.

[162] Tier M. 2004. The Winning Investment Habits of Warren Buffet and George Soros. 78

[163] Hagstrom R. 1999. *The Warren Buffet Portfolio*. 109-110.

A successful investment system needs to be built on the foundation of an investment philosophy that's consonant with reality. An investment philosophy is a set of beliefs about:[164]

- The nature of investment reality: how markets work, why prices move;
- A theory of value, including how value can be identified, and what causes profit or losses; and
- The nature of a good investment.

3.4 George Soros' Model

George Soros was born in Hungary and had to make his escape when the Nazis took over Hungary. He enrolled at the London School of Economics where he met and was influenced by the philosopher Karl Popper. Popper provided Soros with the intellectual framework that, later, evolved into both Soros's investment philosophy and his investment method.[165] At the core of Poppers analysis lay his concept of falsification or 'fallibilism'. Ralf Dahrendorf wrote that Popper like other great men stood for one simple but infinitely powerful idea that in a world of uncertainty, we cannot know the truth, but can only guess. No amount of evidence can prove our guesses right, but often one fact suffices to prove them wrong.[166] This formed the basis for Soros's development of his model of fallibility. He came to the conclusion that all our views of the world are flawed or distorted and he concentrated on this distortion in shaping events.[167] He felt that every system was fallible and with critical thinking you could find the flaws in any system. He tested his theory by searching for developing market trends or sudden changes about to happen that nobody else had noticed or had noticed and underestimated the implications. For example he found one such trend in the banking industry.[168] Banks were highly regulated and were seen as serious, conservative and boring enterprises. Soros observed that the old style managers were retiring and being replaced with aggressive, young men with MBA's. This new management he felt would

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[164] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 189.

[165] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 56.

[166] Kaufman M. 2003. Soros-The Life and Times of a Messianic Billionaire. 70.

[167] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 56.

[168] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 57.

focus on the bottom line and shake up the industry. He advised to buy these shares and he was correct. In time the shares were rerated and he made a profit.

To Soros our distorted perceptions are a factor in shaping events. As he puts it, "what beliefs do is alter facts" in a process he calls reflexivity, which he outlines in his book "The Alchemy of Finance". In simple terms it is that people always act on the basis of imperfect knowledge or understanding, and that while they may seek the truth they never quite reach it because the very act of looking distorts the picture.[169] To give an example, as share prices rise, investors feel wealthier and spend more money. Company sales and profits rise as a result. Investors sensing better profits demand shares, which cause share prices to rise even further. Which then causes investors to spend more and so on. Economists call this the wealth effect. This is what he called a reflexive process- a feedback loop, where perceptions change the facts and facts then change perceptions.[170]

For Soros reflexivity is integral to understanding cycles of boom and bust and his explanation of Ben Graham's "Mr Markets" manic-depressive mood swings.

Soros watches very carefully for a disequilibrium situation in the market caused by some exogenous factor. This coupled with a study of the structural characteristics of the system that the disequilibrium is occurring in will lead to Soros developing a hypothesis as to what sort of trend this would cause. His hypothesis attempts to explain why the distortion between perception and reality exists. He calls this the "prevailing bias" and then uses his theory of reflexivity, to make investments. These perception changes are the psychology and the mood of investors, which finally plays out in the market. He is proactive in his thinking and might even test the market with small investments to test his hypothesis. He then measures the quality of his hypothesis and the progress of events.[171]The risk for him is in calling the timing of the investment right in the market.

Bill Rodgers, Soros's colleague has utilised this theory very successfully in commodity markets having spotted the change to freer more capitalistic markets by the Chinese governments. He built a hypothesis that China with its highly skilled, hardworking and cheap labour would become a very competitive producer to world markets. This would require huge increases in investment to build infrastructure to catch up with the developed nations and to

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[169] Kaufman M. 2003. Soros-The Life and Times of a Messianic Billionaire. 107.

[170] Tier M. The Winning Investments of Warren Buffet and George Soros. 58.

[171] Tier M.2004. The Winning Investments of Warren Buffet and George Soros. 66.

supply them with goods would lead to a huge demand for raw materials thereby driving the commodity boom. He was so ahead of the trend (1998) that he created an index- the Rogers International Commodities Index that quoted various commodities that were not quoted by any other fund.[172]

3.5 Warren Buffet and George Soros

Buffet's trademark is to buy good businesses with substantial franchises at good value and owning them for a long time. Soros is famous for making high leveraged trades in the currency and futures markets. Both have been among the most successful investors of the past three decades. They have some things in common:[173]

- Buffet and Soros share the same beliefs about the nature of the markets.
- Both have a phobia of losing money and are risk averse. Buffet because of experiences with the Great Depression and Soros because of the invasion of Nazis into Poland. As Soros says " If I had to sum up my practical skills, I would use one word: survival"[174] They would then invest in high probability events so that risk is small. They do not try and predict markets as they are complex and preservation of capital is very important to them and built into their investment models.
- Both do not favour diversification in their investments. They concentrate their financial resources on as few investments as possible.

Both Buffet and Soros are seeking to exploit gaps or distortions in people's perception and reality in markets. The both take advantage of perturberances, oscillations and punctuated equilibriums in the market to realise value. Buffet does this over the very long term, riding waves of fluctuations out until value can be recognised by the market. Soros uses this emerging phenomenon arising out of complex markets as the arena for his attention. Soros says, "I am fascinated by chaos. That's really how I make my money: understanding the revolutionary process in financial markets" In his view calm and order in the financial world can never be more than a temporary condition due to our incomplete view of the world. So there will be a never ending opportunity for the creation and testing of hypotheses to profit from chaos.[175]

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[172] Rodgers J. 2004. *Hot Commodities.* (xii) and (xvii).

[173] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 4.

[174] Soros G. 2003. The Alchemy of Finance.12.

[175] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 169.

Exploiting these anomalies in the market would not be possible in an efficient market with full information, rational behaviour and equilibrium. It can only occur in a complex world. Two examples to illustrate this:

First, Buffet In 1973 started buying shares in the Washington post at $27 a share. For Buffet this was a $400 million business that was as on sale for $80 million.[176] The market was in a recession and inflation was rising and the markets were disturbed by this anomaly of a downturn in the economy and rising inflation and were not in the mood for buying. Buffet was not looking at the market or the economy he saw a company that he understood, going at an 80% discount to its value that was well managed. He was able to purchase at a discount because of the irrationality of investors who panicked when the share price fell down misinterpreting, according to Buffet, the price of the share to be the value of the share.

The second example is of Soros who scans the environment for flaws in a system and for a situation of disequilibrium. These states of disequilibrium as we have discussed are set of normally by an exogenous factor. He finds this in exchange rate markets, which he says, are all fundamentally flawed. This is what happened to the British currency the sterling. In 1987 Britain became a member of the European Exchange Rate Mechanism (ERM) that was made up of a group of Common Market currencies that was anchored by the Deutschmark. Because of the link in sterling and Deutchmark, money poured into the sterling, as interest rates were higher in England. Then the Berlin Wall fell, the Soviet Union collapsed, Germany was reunified and the system says Soros "was thrown into a state of dynamic disequilibrium"[177]

The Deutchemark became the currency of both East and West Germany at an exchange rate that was bitterly contested by Chancellor Helmut Kohl the German premier who wanted to win an election and the Bundesbank who wanted to exchange the West German currency at a stronger rate that the East German one. Kohl won the dispute and the East German currency was exchanged at the overvalued rate of 1:1 for he first 4000 and 2:1 thereafter. This created a drag on the German economy for years and set the scene for the collapse of the ERM. The German economy beset by high inflationary pressures caused by capital injections into the East Germany led the Bundesbank to raise interest rates, at a time when Europe and Britain in particular was in recession. We now had a link to the ERM and specifically to the Mark that was constant and economic policies that were out of sync. Soros knew that it was just a

[176] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 35.

[177] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 68.

matter of time before the system broke down and the weaker currencies would be thrown out of the ERM. He therefore sold the pound short. On September 16, 1992 the Sterling collapsed from 2.95 to the mark to 2.5 to the mark and Soros made a fortune. He was able to do so due to the combination of three things: exogenous driven disequilibrium in conjunction with the structure of the ERM system that was flawed and the behaviour of investors. A similar scenario played out again when Thailand decided to allow the Baht to float freely. The exogenous factor was in place leading to disequilibrium, panic from investors and the greed of speculators allowing Soros to short the Baht and make a fortune.

As you can see from the above two examples Soros's method is to look for situations where Mr Market's perceptions diverge widely from the underlying reality. On those occasions when Soros can see a reflexive process taking hold of the market, he can be confident that the developing trend will continue longer, and prices will move far higher (or lower) that most people using a standard analytical framework expect. He applies his philosophy to a market trend in its early stages and positions himself before the rest of investors and speculators catch on. He realises that he could be wrong and is critical of his own thought processors, but takes a position on a trend occurring and critically evaluates his thinking and can reverse his position if he realises he is wrong.

They both have highly developed mental models or beliefs about:[178]

- The nature of investment reality, that is, how markets work, why prices move;
- A theory of value, including how value can be identified, and what causes profit or losses; and
- The nature of a good investment.

This philosophy as Von Tharp, a prominent investment Psychologist says is important because you don't trade the market, you trade the beliefs about the market.[179] Buffet and Soros have consciously thought through each investment belief they hold. They are fully aware of the "why" behind every investment they undertake. Buffet's investment philosophy is centred around the theory of value and when he talks about the nature of investment reality, he frames his remarks in terms of business value and how managers and investors often act on some erroneous concept of value.[180] He believes that an investment has a measurable

[178] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 45.

[179] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 45.

[180] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 46.

"intrinsic" worth. Soros investment philosophy is also on determining value in the sense that market prices are determined more by perceptions and misperceptions than by the facts.[181] Thus value is a continually moving target determined by the changing perceptions and actions of actors in the market place.[182]

They both view the same investment reality but draw totally different conclusions about how to deal with it. Buffet does not delve deeply into why the market is wrong, he observes what it is and takes advantage of it. Soros on the other hand has developed a theory of why the market is wrong which is central to his way of profiting from it. Both reject the Efficient Market Hypotheses and the Random walk theory and between them you have a good explanation how investment markets work.

Their mental models are more in tune with the nature and characteristics of markets namely complex systems that are moved by:

- Exogenous factors that cause disequilibrium
- Systemic structural factors within markets that inherently cause fluctuations, and
- Behavioural factors of emotions and ignorance.

Thus paradigms are crucial in decision making and the more closely tied and relevant the paradigm is to reality the better your understanding and insights of the nature of markets. This should improve your decision making, assuming you are wired correctly and have the correct mental models. At times not really being absolutely correct (in your models) is not really crucial, but just the fact that you have a framework of some sort in which to screen information, evaluate against rules and come to sort of conclusion can be enough. Weick states that having an accurate environmental map may be less important than having some map that brings order to the world and prompts action.[183] Weick relates the incident of a Hungarian military detachment that was lost in the Alps and found their way back to camp with the aid of a map that they thought was of the Alps but which happen to be of the Pyrenees. These frameworks have the effect of animating and orienting people; "once people begin to act (enactment), they generate tangible outcomes (cues) in some context (social), and

[181] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros. 53.

[182] Tier M. 2004. The Winning Investments of Warren Buffet and George Soros.189.

[183] Weick K. 1995. Sensemaking in Organizations. 57.

this helps them discover (retrospect) what is occurring (ongoing), what needs to be explained (plausibility), and what should be done next (identity enhancement).[184]

3.6 Soros, Buffet and Complex Systems

At this point in the thesis an analysis of the characteristics of complex systems as well as the investment models of Soros and Buffet has been completed. When one looks at the economy as being a complexly evolving system and analyse the investment decision making models of Soros and Buffet one can come to the following conclusions:

a) The economy can be deemed a social system and therefore a complex evolving system; the characteristics of complex evolving systems are self-organisation, emergence, connectivity, feedback, interdependence, far from equilibrium states etc.

b) The interconnectivity of elements in the system supported by feedback loops (both positive and negative), driven by human expectations and perceptions, within the context of an economic system far from equilibrium leads to emergence of cycles that create opportunities (enhance the space of possibilities).

c) Soros and Buffet within this context exhibit differing strategies.

Soros's theory is that all structures and regimes are flawed because they are created by fallible humans and do not spontaneously occur through emergence. These man made structures require high maintenance in order to maintain stability. Ever increasing connectivity implies a high degree of interdependence. The greater the interdependence between related systems the wider the impact of a perturbation on other elated entities. Many of the swings in prices of exchange rates, commodities and goods are due to interdependence in world markets. Countries specialize in certain goods, achieve economies of scale and build a comparative advantage to other countries. All it requires is an exogenous external variable to cause a disequilibrium leading to instability and then to chaos. Opportunities can be found in conditions such as this that could be exploited by the alert investor. In the Currency example cited in 3.5, the flaw is the creation of the European Exchange Rate Mechanism that is anchored by the Deutschmark. European countries with differing economic and social conditions are expected to maintain standard consistent exchange rates with regards to the Deutschmark. All it required was the exogenous input of the fall of the Berlin Wall and human perception to create a new

[184] Weick K. 1995. Sensemaking in Organisations. 55.

order. This can be explained in terms of complexity; when an entity is faced with a constraint it finds new ways of operating. In this case the decoupling from the Mark is the new way of operating.

Buffet in contrast has a different perspective. Buffet understands that markets are not always efficient and predictable, his views more in keeping with the complexity viewpoint. He is of the opinion that the majorities of investors are stuck in the linear paradigm and therefore make poor decisions. If one understands connectivity and feedback mechanisms driven by expectations and perceptions than economic cycles are very real and frequent and are no cause for panic. They are like the patterns that Edward Lorenz found in his plotting of weather. The points stay within certain bounds, never repeating themselves and revealing a new kind of order; that is disorder within a large order. It is the overreaction of the majority of investors that create extreme price distortions (the greed of the herd driving prices up at times and the extreme despondency and depression of the herd driving prices unrealistically below intrinsic value). He understands the futility of predicting specific events and would rather be reactive and act after the event. Buffet tends to steer away from emergence driven through technology, as he does not understand which pathway new technologies would follow. Buffet is not interested in volatile, hi-tech, innovative and break the mold type companies. He focuses on companies that are very efficient in distributing real products and services and that are required daily by consumers for example American Express and Coca Cola. American express for their credit card that is required daily by consumers to purchase goods and services and Coca Cola that is consumed by consumers on a daily basis and has a strong brand loyalty that would be hard to replicate. These companies are financially and managerially very strong and have the resources to explore the space of possibilities and to adapt and thrive.

d) Below are two examples of interpreting Soros and Buffets strategy in terms of complexity language. This is interesting as it highlights how a framework can be created from which we can evaluate and make sense of concepts:

(i)The distinguishing characteristic of a complex adaptive system is that it is able to adapt and evolve and thus create new order and coherence. The fittest survive and replicate and any other objective leads to extinction.

-Buffet has survived the vagaries of the investment landscape and has accumulated substantial resources to make very large investments that are within reach of only a very few selected people. Buffet has the ability to purchase large companies (for example a 34 billion dollar railroad company) and increase his staggering resources. Buffet is fit in an evolutionary sense in that he has the necessary mental, psychological and financial capacity to accumulate and grow resources and he does this by investing in companies that are fit in an evolutionary sense.

-Buffet invests in companies that have shown the ability to survive in a complex adaptive system. He looks at the economic characteristics (finance, product, brand, logistics, management etc.) of the business and its history of earnings. These companies with substantial resources and an embedded history of success with high barriers to entry are able to leverage their competitive advantage to adapt and evolve faster that the competition and to emerge at the top of the order in the particular industry or market.

In evolutionary terms, profitability is not an objective in itself, rather it is a fundamental constraint that must be met if a business is to achieve the objective of survival and replication (or enduring and growing) Regarding the notion of profitability we find another set of constraints. To successfully execute a business plan, a management team must create an ecosystem of cooperation in an around an organisation. First, capital must be attracted to the enterprise and the providers of capital must see a potential return that is better than the alternative investment opportunities. Second, employees must be attracted and given incentives to work productively. Third, suppliers must see a profitable relationship with the business and fourth, the business must provide goods and services that people want. Management must also ensure that the business meets its legal obligations, pays its taxes, licenses etc. profitability is in fact a multi dimensional problem in pleasing lots of people. In evolutionary terms, this is the economic fitness function; fit companies do a better job in meeting this multidimensional constraint than unfit ones do.

A company in the traditional economic sense has maximization of shareholder value as the objective and complexity has survival and growth as an objective. In order to survive and grow the company has to be profitable, because unprofitable companies do not endure, and it has to give its capital providers a competitive return, as growth requires capital.

The critical difference lies in how management applies these concepts. The objective of

maximizing shareholder wealth has led to an obsession with managing the short-term stock price. A survey of four hundred chief financial officers found that they would forgo value creating long term investments if it meant missing analyst earnings estimates and more than three quarters said they would sacrifice economic value for a smooth earnings record.[185] A management team focused on enduring and growing would likely take a more balanced view. They would focus on the levers of value creation rather than the share price, and allocate resources to achieve a healthy relationship with stakeholders. The focus on endurance would encourage a long term perspective on investment and greater attention to building the foundations of longevity through factors such as strong organisational culture. Meanwhile a focus on growth would keep the pressure on performance high providing a source of challenge and spur innovation. It also leads to better relationships with other constituencies via corporate social responsibility and public relations initiatives.

The objective of enduring and growing echo the imperatives of executing and adapting where management's job is to devise and execute plans. Both stem from the same evolutionary logic. The fact that companies are typically better at executing than adapting reflects its short-term focus on earnings. Following the dual objectives of endurance and growth forces management to fully confront the inherent tension in executing and adapting and creates pressure to strike a balance between the two. In a competitive evolutionary environment 'endure and grow' is the what and 'adapt and execute is the how. Enduring and growing are the fundamental pressures placed on designs in an evolutionary system.

(ii)According to laws of dissipative structures, it is possible to have more than one equilibrium point. The specific paths that a system may follow depend on its past history. Past history affects future development and there are several possible paths/patterns that a system may follow. This explains why the precise behaviour of a complex system may be very difficult to predict.

Soros utilized Poppers intellectual framework that in a world of uncertainty we cannot know the truth, but can only guess. No amount of evidence can prove our guesses right, but often one fact suffices to prove them wrong. Soros came to the conclusion that every system was fallible and with critical thinking one could find flaws in the system. He

[185] Beinhocker E. *The Origin of Wealth*. 412.

therefore searches for these inherent flaws where there are gaps in reality and the truth. Soros is not sure what specific paths a likely scenario would take, as having a large number of interactions is no guarantee of emerging behaviour resulting. Many of the interactions may be negligible or irrelevant and may cancel each other out. In a large number of cases a large number of interactions can work against the emergence of interesting behaviour by creating a lot of "noise" that drowns out an emerging signal. The emerging behaviour may need to be temporarily protected and isolated from other interactions so that it can reach critical mass to be self-supporting. Soros cannot predict which path an interaction might take, but he formulates hypothesis as to the likely outcome. Soros is aware of the "Bifurcation point"; the zone between determinism and free choice where the system has various options. He then conducts experiments, testing these hypothesis by investing limited funds and watches the reaction of the markets. Soros has been known to change direction completely from his initial hypothesis if the market signals prove otherwise. There are many occasions where emergence is cancelled out, as there are too few connections or the way these connections are organised and configured. Soros's strategy is in tune with the strategy that is likely to be followed by complex adaptive systems where the proactive strategy of requisite variety and keeping options open can lead to successful choices being made. Rather than thinking of strategy as a single plan built on predictions of the future, strategy should be thought of as a portfolio of experiments, a population of competing business plans that evolve over time and that mirrors the evolutionary competition going on outside the marketplace.[186] Strategy as a portfolio of competing experiments requires one to:[187]

-Think of strategy analysis as having a different purpose- not to get an answer but to create prepared minds.

-An evolutionary approach to strategy emphasizes creating choices, keeping options open and keeping as many a number of possibilities alive as possible at any point in time. The objective is to make lots of small bets and to make big bets on the successful experiments where uncertainty is lower.

- Emphasise learning and adapting over a predicting and planning mindset.

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[186] Beinhocker E. *The Origin of Wealth*. 334.

[187] Beinhocker E. *The Origin of Wealth*. 337

3.7 Strategies to Cope within a Complex Adaptive Economy

Thinking in terms of complexity suggests that companies and investors need to be prepared to survive the upheavals, shakeouts and technology shifts that punctuate the markets. To prosper over the long run a company must adapt as easily and quickly as the market does or even faster. More specifically it must be a strong competitor in the current regime and a smart evolver, able to innovate ahead of the market or to adapt with it.[188] An examination of strategies suggested by academics to cope with complexity in various fields follows :

3.7.1 Push versus Pull models[189]

Seely and Hagel examine the way companies fulfil the needs of the consumer and define them as either utilising push or pull models. Traditional business in general pursue a push strategy i.e. they pursue efficiency- executing operations better than the competition does. Highly automated factories or service platforms supported by rigid and standardised processors deliver resources to the right places at the right time. This is the push system and the core assumption is that demand can be anticipated and resources mobilised in the most efficient and reliable way to meet it. This is a rigid system as it requires top-down control where you have to specify, monitor and enforce detailed activities and tasks. This rigidity restricts the number and the diversity of the participants thus limiting the innovation and learning that can take place in them. The highly specified, centralised and restrictive nature of push systems prevents companies from experimenting, improvising and learning as quickly as they should. They not only inhibit product innovators but make it much harder to implement incremental process innovation rapidly. They hinder companies form participating in the distributed resource networks that lead to competitive advantage. In a dynamically complex globalised environment with tightly coupled connections companies run the risk of inaccurately forecasting leading to excess inventories and costly restructuring efforts to keep up with market shifts. Managers try and compensate for uncertainty by using options, derivatives and other forms of hedging. But these are patches on a more fundamental problem and that of forecasting demand.

Pull models are emerging as a response to growing uncertainty. Instead of dealing with uncertainty through tighter control, pull models do the opposite. The next frontier of

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[188] Seely F and Hagel III J. 2005. *The Next Frontier of Innovation.*

[189] Seely F and Hagel III J. 2005. *The Next Frontier of Innovation.*

innovation will require adoption of pull capabilities as well as reliance on traditional push systems. Pull systems have theoretical beginnings in lean manufacturing where Toyota utilised outsourcing to pull inventory as required. The same has happen to media via the internet where customers pull what they require when they require it. The difference between push and pull systems are:

Push Systems	Pull Systems
Demand can be anticipated	Demand is highly uncertain
1) Top down Design	Emergent Design
Centralised control	Decentralised Control
Procedural	Modular
Tightly coupled	Loosely coupled
Resource Centric	People centric
Participation restricted	Participation open
Few Participants	Many diverse participants
Efficiency Focus	Innovation Focus

Figure 6: Push vs Pull Models[190]

An example of a company utilising the pull model is Li Fung the clothing apparel company that supplies clothing to the major clothing chains in the world. Li Fung has 7500 business partners in 37 countries. They own no factories of their own and have developed a network of trust based relationships that they can tap into. The advantage of this is flexibility; they can move orders to specialised units anywhere in the world that can provide the skills and the competitive advantage and at the instance of political instability in one region orders can be moved quickly to other areas. Pull platforms are enhanced much more frequently than push programs and enhancements can occur at multiple levels. Modules can be recombined in innovative ways to serve new needs.

We see from this example how via pull strategies we can overcome structural constraints within a system. Just as we saw in the simplified model of the Beer Game how structure combined with human behviour can lead to over or under forcasting of demand. Here we

[190] Seely F and Hagel III J. 2005. *The Next Frontier of Innovation*

have an innovative example of how structural constraints can be overcome leading to efficient utilising of resources to create value. We can see form the table above showing the differences between the push and pull model that the pull model more closely tracks the characteristics of complexity; demand is uncertain, emergent design, diversity and innovation. The language is the same as that of complexity. We must note that in terms of resilience, we need to build more resilience into our systems through decoupling – striking a balance between self sufficiency and interdependence. Too much interdependence leads to too close coupling that can have devastating impacts should one part of the system fail. There is a tight rope that needs to be walked here that finely balances self sufficiency and interdependence.

3.7.2 Resilience - Ecosystems

In 1973, C.S Holling introduced the word resilience into the ecological literature as a way of helping to understand the non- linear dynamics observed in ecosystems. Ecological resilience was defined as the amount of disturbance that an ecosystem could withstand without changing self organised processors and strategies.[191] This is defined as alternative stable states. Other authors consider resilience as a return time to a stable state following a perturbation. The term adaptive capacity is used to describe the processors that modify ecological resilience or system robustness to changes in resilience.

In socio ecological systems diversity leads to resilience. Biodiversity plays a crucial role by providing functional redundancy. For example, in a grassland ecosystem, several different species will commonly perform nitrogen fixation, but each species may respond differently to climatic events, thus ensuring that even though some species may be lost, the process of nitrogen fixation within the grassland ecosystem will continue. Similarly, when the management of a resource is shared by a diverse group of stakeholders (e.g., local resource users, research scientists, community members with traditional knowledge, government representatives, etc.), decision-making is better informed and more options exist for testing policies. Active adaptive management whereby management actions are designed as experiments encourages learning and novelty, thus increasing resilience in social-ecological systems.[192]

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[191] Gunderson L. 2000. Ecological Resilience – In Theory and Application. 425-439.

[192] Walker B, Carpenter S et al. 2002. Resilience Management in Socio-ecological Systems.

The role of diversity is just as important in ecosystems as in economic systems. The market is made up of a diverse number of investors following various strategies that differ with respect to time horizons, levels of risk and categories of investment. The interactions of this diversity lead to maintenance of structure and function. Such diversity provides robustness to system functionality and resilience to the systems behaviour. The solution to maintaining ecosystems is Adaptive Management. The word adaptive is used so to acknowledge that natural resources being managed will always change, so humans must adjust and conform as situation changes. Active learning is required and adaptive management view policies as hypotheses – policies are questions masquerading as answers. When you view policies as hypothesis or questions than management actions become experiments. (Soros investment style uses this to great effect making small bets or experiments to test the state of the market). The process of Active management includes highlighting uncertainties, developing and evaluating hypothesis around a set of desired outcomes and structuring actions to evaluate or test. Adaptive Management is structured to make learning more efficient. Trial and error is the default model of learning that leads to experience. Both Soros and Buffet utilise a similar model of Adaptive Management in their models. Soros formulated hypothesis based around some flaw in the structure of the system or in human behaviour. He then tests the market to see if his hypothesis is valid. He learns as he goes and is flexible enough to adjust his strategy correcting his hypothesis. Buffet is more reactive and spends his time locating companies that are resilient - that have the managerial, financial and innovative capacity to withstand emerging economic phenomenon be it economic cycles or competition. He constantly analyses these companies to find the ones that can adapt and innovate.

3.7.3 Managing the Unexpected- The Role of Expectations

Karl Weick and Kathleen Sutcliff have written a book that examines the issue of how organisations deal with unexpected events or crisis.[193] This is linked to complexity and the issue of emergence and how to respond to it. The ability to deal with a crisis situation is largely dependent on the structures that have been developed before chaos arrives. The event can in some ways be considered a "brutal audit" where every weakness shows itself and anything left unprepared becomes a complex problem.[194] An audit also uncovers weakness in

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[193] Weick K and Sutcliffe K. 2007. *Managing the Unexpected*.

[194] Weick K and Sutcliffe K. 2007. Managing the Unexpected. 3, quotes Legadec P. Preventing Chaos in a crisis: Strategies for Prevention, Control and Damage Limitation. 54.

resilience that is defined as the capability to recover. Resilient action that enables recovery from a setback is built out of a broad repertoire of action and experience, the ability to recombine fragments of past experience into novel responses, emotional control, skill at respectful interaction and knowledge of how the system functions.[195] Weick talks about high reliability organisations. They know that they have not experienced all of the ways that a system can fail. They know that they have not deduced all possible failure modes and they have a deep appreciation of overconfidence. This appreciation takes the form of ongoing mindfulness embedded in practices that enact alertness, broaden attention, reduce distractions and forestall misleading simplifications.

Buffet and Soros represent these mindful characteristics that Weick and Sutcliffe mention above.[196] Buffet is highly focused and only acts within his circle of competence. He refused to invest in technology and missed the boom as he felt he was not competent in this field. He and Soros continue to make sense of their mental models and continually test them for validity. They both learn from past mistakes and are humble in their attitude. They make mistakes but the mistakes do not cause a complete collapse of their financial structure. Buffet counteracts such an event occurring by limiting risk by investing for the long term, setting a margin of safety, working within his circle of competence and narrowing his investment focus to a few large investments. Buffet sets a margin of safety by purchasing when prices show value covering himself from exposures of uncertainty and collapse. Soros utilizes

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[195] Weick K. 1993. The Collapse of Sensemaking in Organisations: The Mann Gulch Disaster. 628-652.

[196] Weick K and Sutcliffe K. 2007. *Managing the Unexpected.* 32-35, define mindfulness as "rich awareness of discriminatory detail". By that they mean that when people act, they are aware of context, of ways in which details differ and of deviations from their expectations. Mindful people have the big picture of the moment, a kind of situational awareness but more than this in the sense that it involves the ongoing scrutiny of existing expectations, continuous refinement and differentiation of expectations based on newer experiences, willingness and capability to invent new expectations that makes sense of unprecedented events, a more nuanced appreciation of context and ways to deal with it, and identification of new dimensions of context that improves foresight and current functioning. Mindfulness is focused on clear and detailed comprehension of emerging threats and on factors that interfere with such comprehension. Small failures have to be noticed (the preoccupation with failure), and their distinctiveness must be retained rather than lost in a category (reluctance to simplify). People need to remain aware of ongoing operations if they want to notice nuances that could be symptoms of failure (sensitivity to operations). Attention is also crucial for locating pathways to recovery (commitment to resilience) and the knowledge of how to implement these pathways (deference to expertise).

hedging to counteract his risk. Both have been wired to expect the worst reflecting their experiences in the Great depression and German occupation of Hungary and are preoccupied by the thought of failure. They have both been very resilient over a long investment lifespan and this because they have kept errors small and improvised when crisis has occurred allowing their investment system to keep functioning. This resilience demand deep knowledge of the system and oneself. They understand the way their mental models are setup and the biases that make up human decision making. What matters is their practices or actions. These practices produce reliable, mindful, flexible functioning because they convert concerns about failure, simplicity, operations, resilience and expertise into routines that reduce and mitigate misspecification, misestimation and misunderstanding.[197]

Weick states that if you want to manage the unexpected you have to understand how expectations work and how to engage them mindfully. Expectations are built into organisational roles, routines and strategies. These expectations create the orderliness and predictability that we rely on when organising. Expectation can create blind spots which take the form of belated recognition of unexpected threatening events. These blind spots sometimes get larger because we do a biased search for evidence that confirms our intial expectations and avoid evidence that disconfirms them. To counteract these blind spots, organisations and individuals try to develop a greater awareness of discriminatory detail. This mindfulness uncovers early that expectations are inadequate, that unexpected events are unfolding and that recovery needs to be implemented. The unexpected can take three different forms; sometimes expected events do not materialise, sometimes expected events materialise and sometimes the shockingly unimaginable occurs. In each of these three cases the surprise starts with an expectation. If you hold an expectation you look for evidence that confirms them rather than evidence that disconfirms them. If you find confirming evidence that "proves" that your instincts about the world are correct and that you are in control. The continuing search for confirming evidence pospones your realisation that your model has limits. If you are slow to realise that things are not the way you expected, the problem worsens and becomes harder to solve and gets complicated with other problems. When it finally becomes clear that your expectation is wrong, there may be few options left to resolve the problem. In the meantime efficiency and effectiveness has declined, the system is vulnerable to further collapse and profitability is in jeopardy.

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[197] Weick K and Sutcliffe K. 2007. *Managing the Unexpected. 19.*

In the case of the unimagined expectation occurring. High reliability organisations steer people to mindful practises that encourage imagination. Practices that encourage imagination, foster enriched expectations, raise doubts about all expectations, increase the ability to make novel sense of small interruptions in expectations, and facilitate learning that intensifies and deepens alertness.[198]

3.7.4 Summary

There are many lessons to be learnt from other fields of study especially in the way they deal with a complex adaptive world. Three very different fields of study have been examined; organisational push and pull, ecosystem resilience and high reliability organisations management of crisis.

- Pull strategies move away from the problem of predicting demand and distribute risk through the use of networks. This creative use of tweaking leverage points in the structure of the system and a change in mindset leads to creation of value.
- Ecosystem resilience shows us the power of diversity in promoting resilience in an ecosystem. It confirms the strategy of pull systems in which diversity is used in distributed networks; eg. Li Fung. Ecosystem Resilience also promotes the use of Adaptive management and active learning models where everything is treated as hypotheses to be critically assessed as to their validity. This is very similar to Soros's method of evaluating flaws in a system and developing a hypotheses as to what pattern would emerge that he could take advantage of.
- In managing the unexpected Weik and Sutcliffe highlight the role of expectations and the use of mindfulness to manage unexpected situations. Soros and Buffet both share this mindset of mindfullness and this can be seen in their extreme awareness of situations, their checking and rechecking of expectations and the critical evaluation of the validity of their hypotheses and worldviews. This is driven by their fear of failure. As Munger said "it's the way you are wired" that determines your success.

[198] Weick K and Sutcliffe K. 2007. *Managing the Unexpected. 29.*

Conclusion

The focus of this dissertation has been to explore and make sense of the economy and to evaluate the complexity worldview and its implications for investment and management decision making. We did this by examining the characteristics of the economy and found circumstantial evidence and some support from economists such as Kenneth Arrow and Brian Arthur that the economy exhibits characteristics of a complex adaptive system. Such a system shares the following characteristics: First, the economy is an open dynamic system as energy and mass constantly flow keeping it in dynamic disequilibrium. Second , these systems are made up of interacting agents. What each one does affects the other creating complexity and making outcomes difficult to predict. The interaction of agents in a complex system are guided by rules: laws of physics, codes of conduct or economic imperatives such as 'cut margins to maintain market share'. If the collection of rules is fixed, the result is a complex system. If the rules are evolving such as strategies pursued by investors in the market, the result is a complex adaptive system. Third, complex adaptive systems exhibit emergence and self organisation. The effect of decisions of a few investors has marginal impact but aggregate the decisions of many and a dynamic market emerges. What emerges is the result of bottom-up dynamic interactions of investors rather than a top down master plan. When this happens the market is said to be self organised. The emergent structure is independent of specific agents and will persist despite individual investors entering and leaving the market.

Scientists have found that complex adaptive systems are governed by deep common laws. For example one characteristic of complex systems is punctuated equilibrium. This natural endogenous feature of the evolutionary process occurs when times of relative calm and stability are interrupted by turbulent retraction periods or punctuation points. Punctuated equilibrium makes it difficult for participants to survive as their strategy and skills tend to be optimised for the stable periods and then suddenly become obsolete when the inevitable restructuring takes place. Buffet seems to have an intuitive understanding of this law. He quotes Benjamin Grahams story of Mr Market that fluctuates up and down depending upon the collective mood of investors in the market. When they are positive than companies are valued highly and the shares are sought after and when negativity sets in markets lose value. He purchases shares at the appropriate punctuation points. Furthermore Buffet sticks to basic

industries and companies with an entrenched market position and large barriers to entry. These companies can withstand punctuation shocks due to their financial and competitive positioning muscle. An example of this is Coca Cola that have brand and widespread distribution advantages that cannot be replicated by competitors easily.

Soros believes that our systems and our thinking is flawed. The problems inherent in our flawed approach to investment extends to many of the problems we face today especially that of the self reinforcing nature of our economic systems, that is oriented to achieving unending material growth. The implications of this are gross unequal incomes disparity and ecological exploitation. We need to change our ways of seeing and acting that acknowledge that the world is a chaotic and deeply interdependent place that will not yield to to attempts to over power it. We must come to understand the nature of complexity, chaos and interconnectedness and to train ourselves in ways of acting that embrace this unmistakable reality. It must meet three criteria.[199] It must simultaneously be systematic, participative and emergent.

We have to change how we view the world and that will cause us to change how we act. We need to reorient ourselves to a systemic method of viewing things. This is difficult as we still focus on the parts rather than the whole system. We still believe that what holds a system together are point to point connections that we must painstakingly weave together. Complexity only adds to our task by adding more connections, increasing our information load and as things increase in quantity and in detail, we find the span of control widens until we are unable to manage anymore. Increasing complexity requires increasing level of energy to manage and high maintenance. The way out of this complexity is to step back and refocus our attention to the whole. The use of appropriate mental models allows us to observe the movement of the total system and develop new approaches and responses to manage a complex system. Peter Senge in his work on systems theory developed nonlinear models that portray the dynamics of organisations. This approach requires very different expectations and analytic processors. Rather than creating a model to predict the future of the system, we are encouraged to experiment with different variables to see what happens to the systems critical points. It is not about controlling anymore but to learn and to increase your intuitions about how the system works so that you can interact with it more harmoniously. This is about thoughtful understanding and a humble deep respect for the web of activity and relationships

[199] Homer-Dixon T. 2002. The Upside of Down: Catastrophe, Creativity and The Renewal of Civilisation.

that comprise the system. The idea is not to intervene and try and change the system but to work around it and give form to what is unfolding. Buffet cleverly sidesteps this problem by being reactive and not charging through the herd of elephants but finding subtle ways around them. You can only do this once you understand the dynamics of the system.

The economy and markets are sensitive systems but very resilient as well. Peter Schwartz says that if we went back to 1987 and looked at what the problems or threats to financial markets were, there were basically two -the huge looming problems of the US deficit and Latin American debt crisis. At the time conventional economic thinking admitted only two scenarios. Either the economic system would crash into a prolonged depression, or we would magically defeat the problems created by these huge international financial imbalances permanently and break forth into stable prosperity. These scenarios did not make sense and with the benefit of hindsight has not occurred. Ariyoshi Okimura, the chief financial economist and director of the Industrial Bank of Japan says that he does not think these balances will go away, but he did not think that they would destroy the system. He felt that we would have managed imbalances and the question will not be how to eliminate them, but how to live with them. Okimura was correct. The economy has been volatile with many crashes and rises, with many individual winners and losers, but it has also been resilient. As new problems come up, investors and countries learn to adapt. We may see events that bring us to the brink, but the system itself won't fail. Instead it will evolve further with each new challenge and response.[200]

[200] Schwartz P. 1991. *The Art of the Long View*. 151.

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