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Stronger investment theory

Embracing complexity

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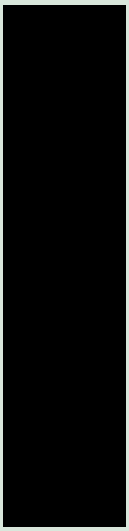

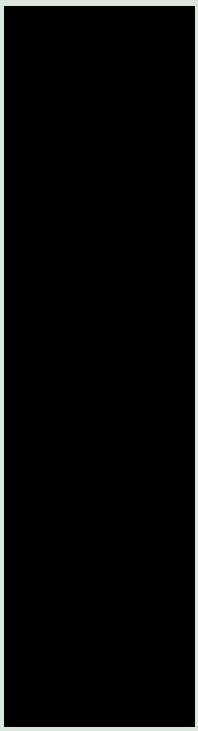

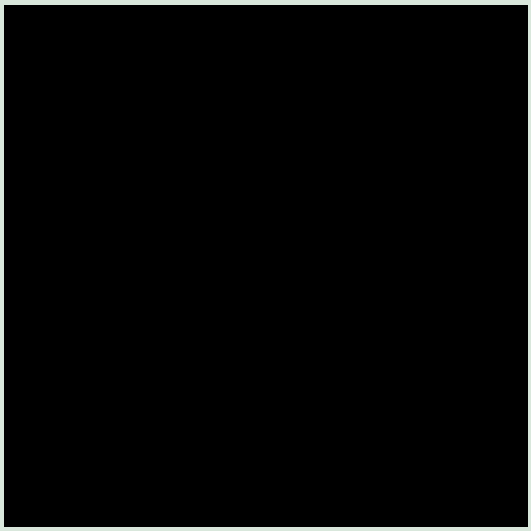

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Table of contents

Introduction

In 2007, global financial markets experienced the first signs of the Global Financial Crisis (GFC) in the US subprime lending market. The damage to economies and markets was so profound and prolonged that even today the healing process is far from complete in many parts of the world. An over-leveraged Main Street, a greedy and irresponsible Wall Street, and exploding complexity in financial markets matched by under-resourced and under-effective regulators all joined with devastating results.

Not only did capital markets fail, but mainstream/prevailing finance theory was seriously challenged in the GFC's wake. Jeremy Grantham used the subtitle, 'The story so far: greed + incompetence + a belief in market efficiency = disaster' in the first GMO quarterly letter for 2009 (Grantham, 2009). Martin Wolf, the chief economics commentator at the *Financial Times,* suggested that it was indeed the 'mistaken ideas' of market efficiency that 'helped to bring the economy down' (Wolf, 2009). However, prevailing finance theory did have defenders such as Professor Jeremy Siegel at Wharton, who blamed the US Federal Reserve for not cracking down on the housing bubble (Siegel, 2009).

The Royal Swedish Academy of Sciences fuelled the debate further when it announced the winners of the 2013 Nobel Memorial Prize in Economic Sciences: Lars Peter Hansen, known for his statistical breakthrough (the so-called 'generalised method of moments'), Eugene Fama and Robert Shiller. The interesting, yet puzzling, fact is that Fama is widely recognised as the father of the efficient market hypothesis (EMH), while Shiller once famously stated, "The efficient market hypothesis is one of the most egregious errors in the history of economic thought" (Wallace, 2010). Reacting to the news, Paul De Grauwe, professor at the London School of Economics, tweeted, 'Nobel Prize for Fama who led millions to believe financial markets are efficient and for Shiller who showed opposite. What a contradiction.'

We believe there is an intellectual clash on finance theory that requires attention. We also believe that the transmission of mainstream theory to mainstream practice needs attention. If theory guides practice, why do so many investment practitioners appear to disregard modern portfolio theory?

Our goal in writing this paper is, firstly, to gain clarity on this intellectual debate by providing a synopsis of mainstream finance theory and its challengers, including behavioural finance, adaptive market hypothesis, reflexivity, rational beliefs equilibrium and a model that attributes the source of market inefficiency to delegation. We then put forward our assertion that equilibrium economics is really a special case of non-equilibrium economics, as we believe economies and financial markets are complex adaptive systems. Rather than treating financial markets as mechanistic systems that are always operating close to or at equilibrium, we believe they are perpetually changing ecologies of beliefs, actions, strategies and cultures competing for survival.

The ‘mainstream’

We define mainstream or prevailing finance theory as the theory taught at major universities and business schools. It is part of the core Chartered Financial Analyst (CFA) curriculum and is what appears in major journals. Mainstream theory forms the foundation of the investment industry participants’ knowledge base. It is important to note that the beliefs of investment practitioners can vary significantly from these theories, and in that sense the ‘mainstream’ could alternatively be defined as ‘where the money is’. We refer to this as mainstream practice. We will explore both in this paper, but start with theory.

Laurence Siegel (Fabozzi et al., 2014) suggests that the basics of investment finance theory can be distilled down to the following eight ideas:

- Time value of money
- Discounted cash flow
- Bond mathematics
- The no-arbitrage condition
- Option pricing
- Portfolio efficiency and optimisation
- Market efficiency
- Asset pricing models (such as the capital asset pricing model – CAPM)

Our review of this theory will mainly focus on a very fundamental area – dynamic financial market behaviour, and the capture of information and aggregation of individual participants’ actions and interactions. This allows us to ignore the less controversial of Siegel’s ideas – the time value of money. Market efficiency falls right into our scope.

It is worth stating that a stationary market means that statistical properties such as mean and variance that are used to describe the movement in prices in that market are constant over time; it does not mean that prices themselves are constant over time.

Asset pricing models are a bit tricky. We cannot avoid them completely because market efficiency and asset pricing models are inseparable twins. EMH comprises two distinct hypotheses: (1) financial assets have fair prices that are determined by asset pricing theories, and (2) market prices coincide with these fair prices. However, while the discussion of various risk/return trade-offs (such as the size of the equity risk premium) is clearly very important, we will treat it as outside the scope of our current paper. What we will address within asset pricing models are the widely used but seriously challenged assumptions, which include (but are not limited to) the state of equilibrium and the representative agent with rational expectations. Portfolio optimisation/construction will also receive some coverage given its prominence in almost all investors’ processes.

The market at an equilibrium

In short, the market at an equilibrium is defined as the goods/services/assets clearing at a price (or set of prices) at which the quantity supplied equals the quantity demanded. When viewed in this way, markets are deemed stationary by nature and can only be disturbed by large, unpredictable and exogenous events. Even after these events occur, there is a strong gravitational force that pulls markets back to equilibrium. It is worth stating that a stationary market means that statistical properties such as mean and variance that are used to describe the movement in prices in that market are constant over time; it does not mean that prices themselves are constant over time. Traditionally, many financial economists have held the view that only the state of equilibrium is interesting and worth interrogation. Many believe that unstable systems do not generate many interesting observations, a viewpoint possibly encouraged by Paul Samuelson’s comment, “How many times has the reader seen an egg standing upon its end?” The mainstream finance theory is built on general equilibrium models (the latest variation being dynamic stochastic general equilibrium – DSGE) which support idealised mathematical models and analytical solutions, the so-called ‘physics envy’. In a stationary world, bubbles should not exist, and financial crises ought to be extremely rare (that is, only caused by unexpected external forces such as war).

Financial markets, however, might not be stationary at all. Financial crises are more commonplace than exceptional according to Romer (2013), who counts six distinct shocks in the US markets during the past 30 years. Possibly one of the most well-known criticisms of general equilibrium theory comes from John Maynard Keynes: "The long run is a misleading guide to current affairs. In the long run we are all dead. Economists set themselves too easy, too useless a task if in tempestuous seasons they can only tell us that when the storm is past the ocean is flat again."

Representative agent with rational expectations

Rational expectations require participants in the financial markets to have a perfect probabilistic knowledge of the future. Technically, that means the market or economy has only one equilibrium, and everyone in the market or economy forms expectations around this unique equilibrium. The individual deviations from this perfect foresight can only be random and offset each other in aggregate.

The representative agent assumption then follows as a result: because the expected value of that random forecast error is zero (that is what random means), from a modelling perspective all participants in the financial markets can be combined into a single representative agent. Because everyone has perfect knowledge about themselves, everyone else and the market environment, an optimal investment strategy based on deductive reasoning is possible.

Because the expected value of that random forecast error is zero (that is what random means), from a modelling perspective all participants in the financial markets can be combined into a single representative agent.

Needless to say, these assumptions face some serious challenges. For starters, Kenneth Arrow (2004) points out the representative agent assumption is incompatible with economic exchanges – why are there both buyers and sellers of the same asset at the same time if you and I are the same? A similar point was made by Keynes in his 1936 magnum opus, *The General Theory of Employment, Interest and Money,* when he suggested that if all agents had identical expectations, market prices would fluctuate between zero and infinity.

Efficient market hypothesis

EMH refers to the informational efficiency of financial markets. There are three forms of market efficiency. The weak form claims that prices of traded assets fully reflect the information implicit in the sequence of past prices, the semi-strong form asserts that prices reflect all relevant information that is publicly available, while the strong form claims that prices instantly reflect even private (insider) information.

Empirical evidence lends its support to EMH as interpreted by some academics. Fama (1970) conducted a survey of empirical work and concluded that the results are strongly in support of the weak form of market efficiency and the evidence that supports the semi-strong and strong forms is extensive, and contradictory evidence is limited. A more recent study by Dimson and Mussavian (2000) claims that there is strong support for the weak and semi-strong forms, and even the strong form if the focus is on the performance of professional investment managers.

It is important to note that EMH is simply a statement that security prices fully reflect available information and does not specify how markets are supposed to reflect all information. As a result, tests of market efficiency are always joint tests of market behaviour and models of asset prices (for example, CAPM), and rejection of such tests does not necessarily mean that the market is not efficient. In fact, the joint hypothesis problem suggests that it is never possible to disprove market efficiency.

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While some economists might view EMH as the foundation of finance theory, the increasing evidence of 'anomalies'[1] suggests that EMH needs to be viewed critically.

[1]The use of the term 'anomalies' might shed light on the development of finance theories. In the hard sciences (for instance, physics), the discrepancy between reported results and what theories would predict will almost always lead to a process of theory revision – for example, the development of relativistic mechanics (physics for super-fast travelling items) and quantum mechanics (physics for super small items). Results that do not fit theory in finance, however, are often ignored or simply coined 'anomalies', making theory even harder to change.

Grossman and Stiglitz (1980) argue that strong-form efficiency is impossible – it has to admit the possibility of minor market inefficiencies to provide an incentive for investors to acquire and act on information. Shiller (1981) shows that price fluctuations in stock markets are too large (5-13 times) relative to the variation in dividend payments, which could imply market inefficiency. However, this claim is not free of the joint hypothesis issue (that is, it is a joint test of market efficiency and validity of Shiller's dividend model). Mehra and Prescott's (1985) equity risk premium (ERP) puzzle also poses some serious challenges to EMH – theory-implied volatility (and therefore ERP) is much lower than observed (ERP of 0.35% versus 7%).

Paul Samuelson formulated the well-known hypothesis that: "...modern markets show considerable micro efficiency (for the reason that the minority who spot aberrations from micro efficiency can make money from those occurrences and, in doing so, tend to wipe out any persistent inefficiencies). In no contradiction to the previous sentence, I had hypothesized considerable macro inefficiency, in the sense of long waves in the time series of aggregate indexes of security prices below and above various definitions of fundamental values." Jung and Shiller (2005) provide empirical evidence to support this dictum.

High-profile practitioners have also joined the critical chorus. Warren Buffett (1984) famously argued that the preponderance of value investors among the world's best money managers rebuts the claim of EMH proponents that luck is the reason some investors appear more successful than others. EMH supporters also struggle to make sense of financial crises. Former Federal Reserve Chairman Paul Volcker claims it is "clear that among the causes of the recent financial crisis was an unjustified faith in rational expectations, market efficiencies and the techniques of modern finance."[2]

Richard Thaler (2009) elegantly summarises EMH as having two main messages: (1) no free lunches, and (2) the price is right. He argues that the GFC should raise our respect for the no-free-lunch supporters given that not many investment strategies have successfully outperformed the market on a risk-adjusted basis. At the same time, the GFC provides ample evidence that the price is not always right.

It is important to note that EMH has been refined over the past decades to reflect the realism of the marketplace, including costly information, transactions and financing costs. Ang et al. (2009) conduct an extensive review of the theoretical and empirical literature concerning EMH and point out that the most recent expressions of EMH allow a role for arbitrageurs in the market who may profit from their comparative advantages (for example, specialised knowledge, lower trading costs, low management fees and so forth). As a result, the choice between indexation and active management is driven by the beliefs about the existence and potential of manager skill, the scale of the opportunities, the time preferences and risk aversion of the investor, along with the expertise and incentive structure of the specific manager.

Modern portfolio theory

In 1952, Harry Markowitz published his paper 'Portfolio Selection' in the *Journal of Finance,* and that paper laid the foundation for one of the most influential investment theories of all time: modern portfolio theory (MPT). Markowitz himself, however, never liked the word 'modern' and prefers to classify it simply as 'portfolio theory' (Markowitz, 1991). In a nutshell, it is a framework to quantify risk and return and determine the trade-off between them. MPT is all about diversification. Key to the theory is the concept that any investment opportunity should be assessed by its contribution to the overall risk/return profile – or efficiency – of the whole portfolio instead of on its own merits. For example, MPT breaks the risk of individual stock returns into systematic and unsystematic components and proposes that the benefit of diversification can be achieved by increasing the number of (not perfectly correlated) stocks in the portfolio. The purpose is to reduce and potentially eliminate all unsystematic risks. Mean-variance optimisation (MVO) is the mathematical tool of selecting and choosing the proportions of various assets to be held in a portfolio (using their mean, variance and covariance) to achieve efficient diversification.

[2] http://www.nybooks.com/articles/archives/2011/nov/24/financial-reform-unfinished-business

James Montier (2012) argues for abandoning the pursuit of the optimal, given no one has the perfect foresight about the future: "Ex ante optimality is inherently fragile; it is only optimal for your best guess of the future." Instead, he calls for building a robust portfolio fit for a wide range of possible future outcomes.

Using data from 1978 to 2011, Andrew Ang (2014) shows that both risk-parity and equal-weight strategies perform better than the full mean-variance procedure during that period.

Ang uses the analogy of food and nutrients to encourage investors to look beyond asset class labels to underlying factor risks.

MPT and MVO do not escape criticism on their idealistic underlying assumptions: homogenous and rational investors, perfect information, normally distributed asset returns, constant correlations and many others. The consequences are some practical challenges in using the theory. For example, this approach can be highly sensitive to estimation errors (the so-called 'garbage in, garbage out' effect) and small changes in the inputs, particularly with regard to expected returns. In other words, it fails to recognise the difficulty (or impossibility) in accurately forecasting expected returns and covariances. James Montier (2012) argues for abandoning the pursuit of the optimal, given no one has the perfect foresight about the future: "Ex ante optimality is inherently fragile; it is only optimal for your best guess of the future." Instead, he calls for building a robust portfolio fit for a wide range of possible future outcomes.

To address the issue of inevitable estimation errors, alternative optimisation strategies have been proposed, and various asset management companies have launched products to employ these strategies. For example, variances are believed to be much more predictable than expected returns. High-frequency sampling, readily available with today's technology, can significantly enhance estimation accuracy for variance and correlation, although it does not help achieve a better estimation of expected returns. A strategy aiming to build the portfolio with the lowest overall variance bypasses the need to estimate the expected returns (by assuming that they are all the same).

The risk-parity approach takes it even further – the weight of each asset in the portfolio is inversely proportional to its own variance. Constructing a portfolio that way completely avoids the need to estimate expected returns or correlations. An equally weighted portfolio (1/N portfolio) is the ultimate 'naïve' strategy that requires estimation of nothing. When there is no need to estimate anything, nothing can go wrong, but in the meantime, the diversification effect can still be achieved by pooling together not-perfectly-correlated assets in the spirit of John Maynard Keynes' remark that "it is better to be roughly right than precisely wrong". In fact, using data from 1978 to 2011, Andrew Ang (2014) shows that both risk-parity and equal-weight strategies perform better than the full mean-variance procedure during that period.

Factor investing is one of the latest developments in building well-diversified portfolios. The focus on asset classes can be too narrow and miss the rationale of why assets earn returns and why seemingly uncorrelated assets moved side by side during the financial crisis. In his book, Ang (2014) proposes that factor investing is closely associated with the concept of 'bad times'. Investors each have their own definition of bad times, given their liabilities, income streams, constraints and beliefs. Investors' wealth will take a hit in these bad times, and as a result they demand a risk premium for compensation. Examples of factors which can be fundamental and economy-wide are the market (the beta in CAPM), inflation, economic growth or volatility. Factors can also be linked to tradable investment styles, such as value, growth or momentum. A single asset class can consist of multiple factors. Ang uses the analogy of food and nutrients to encourage investors to look beyond asset class labels to underlying factor risks.

From mainstream theory to practice – a critical appraisal

It is clear that mainstream investment theory has found its way into the mainstream of investment practice, for better or worse, despite some strong criticism of its assumptions and mathematics.

For example, EMH implies that one cannot consistently achieve (net-of-fee) returns in excess of average market returns on a risk-adjusted basis. In Fama's 1991 study, although some mutual funds achieved minor abnormal gross returns, pension funds underperformed passive benchmarks on a risk-adjusted basis, a result that is in line with Grossman and Stiglitz (1980). As a result, an investor should only expect to make a return equal to the market return and should thus focus on minimising costs. As such, an index fund would be the most appropriate investment vehicle, allowing the investor to achieve the market rate of return in a cost-effective manner. Willis Towers Watson's research shows that in 2013, of the assets managed by the world's largest 500 asset managers (US$77 trillion in total), over US$10 trillion aimed purely to mimic the movement of the market.[3]

The fact that active managers are the larger part of the investment universe should imply that mainstream theory has not affected practice, because managers believe that they can add value by exploiting market inefficiency. However, while not strictly in line with EMH, the measurement of professional managers has its origin in CAPM, as shown by the industry-wide use of terms such as 'alpha' and 'beta'.

Financial modelling is another example of the impact of mainstream theory on practice. While we believe the financial models being developed and used in leading financial institutions are somewhat more sophisticated than a completely stationary process with a representative 'super-intelligent' agent, there are nevertheless signs that modelling's roots in equilibrium thinking are too deep, and that they are struggling to live up to the speed of change in the real world, particularly in times of crisis. A good example is the comment from David Viniar, the then-CFO of Goldman Sachs, that "we were seeing things that were 25-standard deviation moves, several days in a row".[4] Given that the likelihood of one 25-standard deviation event[5] is comparable to the probability of winning the UK National Lottery 21 or 22 times in a row (Dowd et al., 2008), this is more likely a result of bad models rather than bad luck.

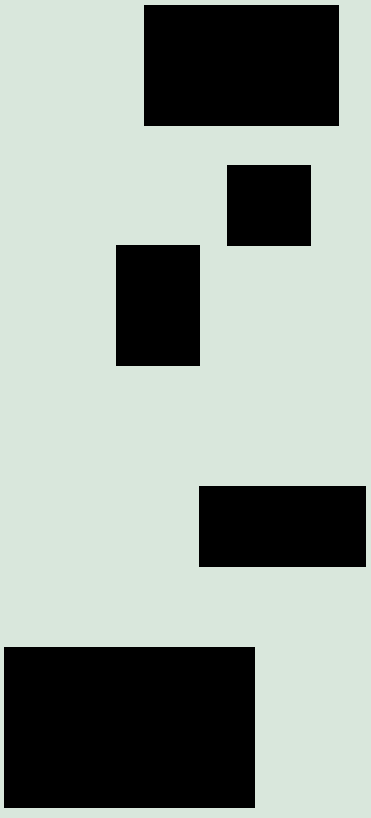
Mainstream investment theory also influences how the industry is regulated. Proponents of market efficiency believe that regulators should not try to interfere with markets. Robert Lucas, who received the Nobel Memorial Prize in Economic Sciences in 1995, notes that the main lesson from the EMH "for policymaking purposes is the futility of trying to deal with crises and recessions by finding central bankers and regulators who can identify and puncture bubbles. If these people exist, we will not be able to afford them" (Lucas, 2009). Adopters of this viewpoint are blamed by many for indirectly causing asset bubbles and their subsequent inevitable bursts.

"In theory there is no difference between theory and practice. In practice there is."

– Yogi Berra

"Practical men…are usually the slaves of some defunct economist."

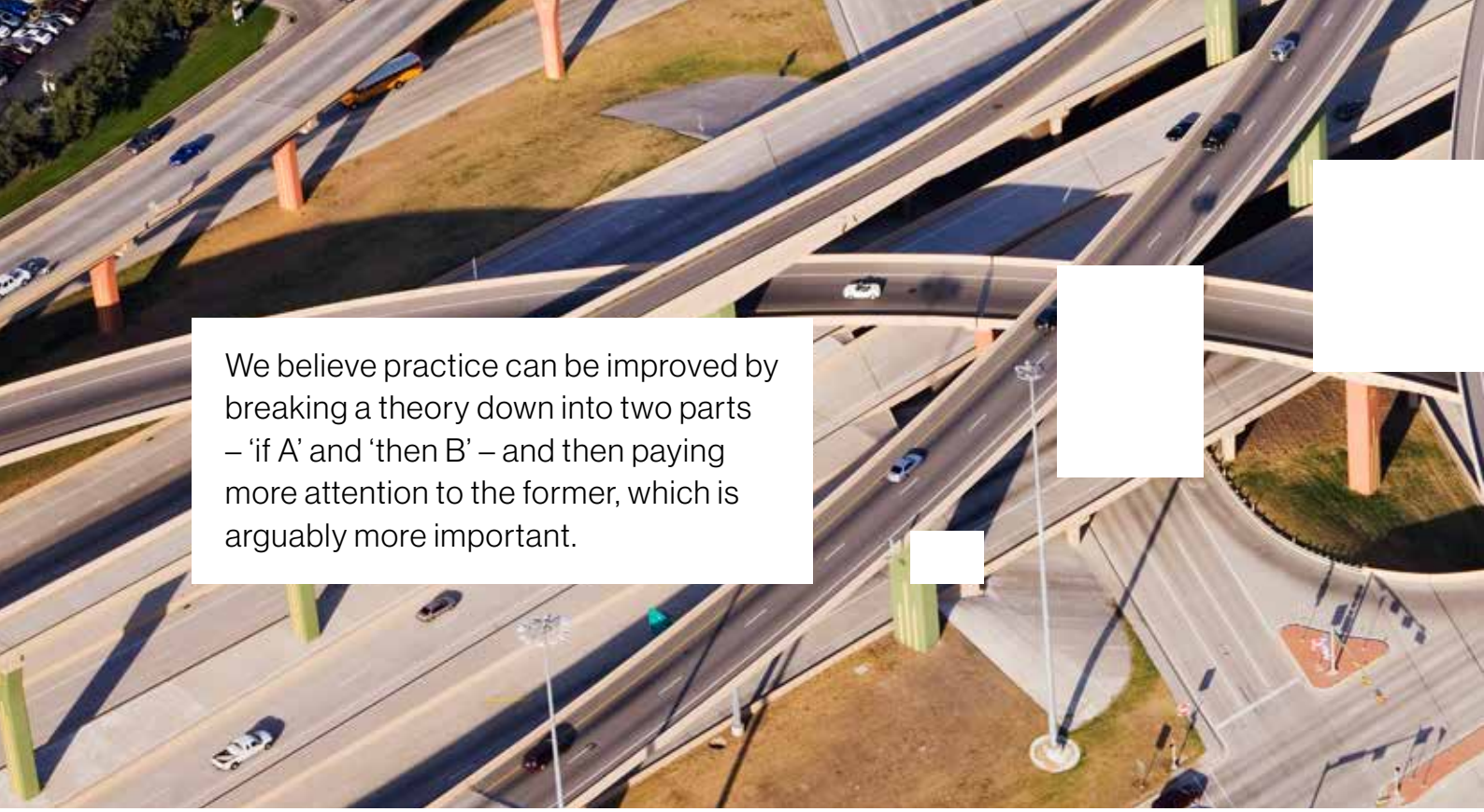
– John Maynard Keynes



[3] http://www.towerswatson.com/en-GB/Insights/IC-Types/Survey-Research-Results/2014/11/The-worlds-500-largest-asset-managers-year-end-2013

[4] http://www.ft.com/cms/s/0/d2121cb6-49cb-11dc-9ffe-0000779fd2ac.html#axzz3n9eNbskO

[5] One 25-standard deviation event is expected to occur every $1.309e^{135}$ years. For comparison, the entire history of the universe is around $1.2\text{-}1.4e^{12}$ years, and a mere 8-sigma event should occur less than once in that period.



We believe practice can be improved by breaking a theory down into two parts – 'if A' and 'then B' – and then paying more attention to the former, which is arguably more important.

At the same time, the significant limits of how mainstream investment theory is used in practice are evident. The UK's National Employment Savings Trust stated: "Investment theory and practice have evolved considerably over the last fifty years. Despite this, there is no generally agreed objective framework for investors that adequately describes how to view capital markets, or how to apply these insights for investment purposes."[6] We echo that by strongly suggesting that prevailing theory fails to represent and predict the world; it has proved to be of little practical use.

We do not think that too much emphasis should be placed on criticising assumptions that seem unrealistic. As Friedman (1953) wisely pointed out, the assumptions of any theory cannot be thoroughly realistic in the immediate descriptive sense. The distinction should be made between descriptive accuracy and analytical relevance. The formula for gravitational force assumes a vacuum, the pure form of which does not exist in the real world. And yet the formula is universally accepted and has far-reaching influences on everyday life. A meaningful theory always asserts that certain forces are more important than others in understanding a particular phenomenon. The key criterion to judge whether a particular departure from realism is acceptable or not should always be whether any empirically meaningful predictions can be produced with these unrealistic assumptions and whether there are any alternative theories delivering better predictions.

That, however, can be very challenging in the world of investing, where inferential power from empirical methods is very low due to its high level of noise (and due, in our opinion, to its non-stationary nature). In sharp contrast, financial economists and investors usually act as if the inferential power is high. In other words, there is not enough proper recognition of ambiguity in the system. The testability of any theory is low and the empirical discussion is often highly selective. If practitioners use these theories and models as if the testability is high, the consequences can be severe. One classic example is the role of mispriced structured products such as collateralised debt obligations (CDOs) and credit default swaps in propagating the GFC.

Even worse, as Blommestein (2009) suggests, academic economists can grow attached to their favourite theories and models and dogmatically bend reality to fit them. Einstein's mocking remark "If the facts don't fit the theory, change the facts" is taken too literally in some cases. While there is increased understanding of the limitations of current models, some academics dogmatically cling to past success. We believe practice can be improved by breaking a theory down into two parts – 'if A' and 'then B' – and then paying more attention to the former, which is arguably more important.

[6] https://www.nestpensions.org.uk/schemeweb/NestWeb/includes/public/docs/statement-of-investment-principles,PDF.pdf

Most theories completely ignore the influence of institutions or ethics. Institutions should matter, as group decision making can depart from rational economic assumptions. Institutional and governance interactions create even more dynamics that need to be captured, or accommodated, by theories. On the other hand, ethical standards are crucial facilitators for successful financial markets, and yet the entire set of investment theories is based on assumptions of ethically neutral behaviour. "Although these financial theorists have made important progress in analysing the consequences of important classes of incentive problems (adverse selection, moral hazard, and principal-agent complications), they do not address the full set of ex-ante and ex-post ethical transgressions: to lie, cheat, steal, mislead, obfuscate, distort and confuse" (Blommestein, 2009). Henderson and Ramanna (2013) further highlight the importance of ethics in market capitalism.

They suggest that in a 'thin' political process (in other words, self-interested corporate political activity influencing or even capturing politicians and regulators without the balancing force of well-represented and diverse views), it is both the ethical duty and in the self-interest of managers to preserve the legitimacy of market capitalism, even at the expense of financial profits. The thesis can be viewed as a challenger to Milton Friedman's shareholder value maximisation ethos.

To summarise, the relevance of mainstream academic theory to practitioners has declined over time. Because of the fault lines in mainstream theory, the theoretical foundations for practitioners have been very limited. We, as an industry, have inevitably developed norms of decision making that are essentially backward-looking and convention-based.

"In the absence of clear guidance from existing analytical frameworks, policy-makers had to place particular reliance on our experience. Judgment and experience inevitably played a key role."

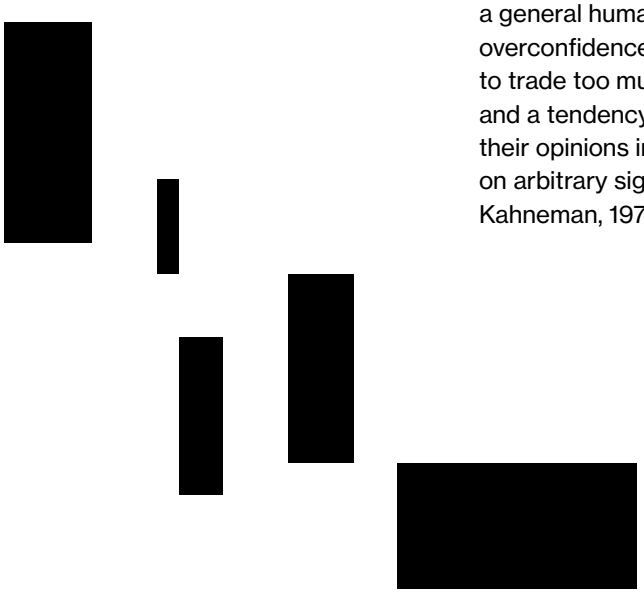
– Jean-Claude Trichet, former president of the European Central Bank

It is evident that not everyone agrees on all tenets of the mainstream investment theory we have reviewed so far. The paper will now consider a selection of alternative world views.

Behavioural finance

Behavioural economists do not believe markets are perfectly efficient, and attribute the imperfections in financial markets to a combination of cognitive biases (such as, overconfidence, overreaction, representative bias and information bias) and various other predictable human errors in understanding, reasoning and action. Robert Shiller, widely recognised as one of the founders of behavioural finance, seemed to be staging a direct attack on EMH by claiming it is a 'half-truth'.[7]

One can argue that Keynes' 'beauty contest' theory (1936) is highly behavioural in nature: "There are some, I believe, who practice the fourth, fifth and higher degrees." Investors in this framework are trying to buy into their predictions of the conventional valuation of assets in the near future, not the true value, and this describes how speculative markets function.



Prospect theory (Kahneman and Tversky, 1979) uses cognitive psychology to explain various divergences of economic decision making from neoclassical theory. Behaviour is vulnerable to the arbitrariness of psychological framing, and small changes in context can lead to profound differences in human behaviour (for example, people value gains and losses differently). Using prospect theory, one can explain the excess volatility of stock market returns by understanding that investors derive direct utility from fluctuations in the value of their wealth (Barberis, Huang and Santos, 2001).

Other contributions in the behavioural finance area include the 'house money effect' – the tendency for investors to take greater risks when investing with profits – which can help explain bubbles in asset prices (Thaler and Johnson, 1980). Investors' 'narrow framing' (Barberis, Huang and Thaler, 2006) – for example, mental accounting – can explain other evidence against efficient markets. There is also evidence of a general human tendency towards overconfidence that causes investors to trade too much (Odean, 2000) and a tendency for people to anchor their opinions in ambiguous situations on arbitrary signals (Tversky and Kahneman, 1974).

EMH supporters dismiss behavioural finance as an alternative theory to EMH – stating that 'people aren't rational' is not a theory, rather merely an empirical observation. An alternative theory would need to offer an explanation, including causal processes, underlying mechanisms and testable propositions. More importantly, behavioural finance keeps the analytical focus on individuals and falls short of specifying an aggregating mechanism – markets in aggregate can still stay error- and bias-free if individuals' errors and biases are random and offset each other. We will attempt to address this when we discuss complexity theory.

The implications of behavioural finance on investment practice are obvious. It provides legitimacy for investment strategies to exploit mispricing opportunities due to behavioural factors. These opportunities are not short term in nature, as behavioural economists would argue that investors are hardwired to make the same mistakes over and over again, and cannot be arbitraged away completely due to the limits to arbitrage. Richard Thaler, a well-known behavioural economist, set up his own investment management firm in 1998 to exploit these mispricing opportunities.

Over the past two decades, the number of fund managers that integrate behavioural concepts in their investment process has steadily increased. Wallace (2010) points out that according to one estimate, half of the 200 listed small-cap value funds in the US use some form of behavioural finance concepts in building their portfolios.

[7] http://www.nytimes.com/2013/10/20/business/robert-shiller-a-skeptic-and-a-nobel-winner.html?_r=0

Adaptive market hypothesis

Adaptive market hypothesis (AMH), proposed by Andrew Lo (2004 and 2011), is an attempt to reconcile EMH with behavioural economics by applying the principles of evolution to financial interactions: competition, adaptation and natural selection. Lo suggests that much of what behavioural finance refers to as irrationality – for example, loss aversion, overconfidence and mental accounting – is, in fact, consistent with an evolutionary model of individuals adapting to a changing environment via simple heuristics.

The concept of 'satisficing' (or bounded rationality) – first introduced by Simon (1955) – argues that individuals engage in making choices that are merely satisfactory rather than optimal, as humans are naturally limited in computational abilities. This concept is integral to AMH. The hypothesis suggests that when the environment changes and the heuristics of the old environment are no longer suited to the new, 'behavioural biases' are observed. Rather than labelling them 'irrational', these behaviours should be labelled as 'maladaptive' – "The flopping of a fish on dry land may seem strange and unproductive, but under water, the same motions are capable of propelling the fish away from its predators," Andrew Lo (2004 and 2011.)

That leads to the conclusion that market efficiency is highly context-dependent and dynamic. In a highly competitive market where multiple market players chase scarce opportunities, the market is likely to be highly efficient (for instance, the market for 10-year US Treasury notes). If a small number of market participants are competing for abundant opportunities in a given market, that market will be less efficient. Efficient and irrational markets are two extremes, neither of which fully captures the state of the market at any point in time.

"The flopping of a fish on dry land may seem strange and unproductive, but under water, the same motions are capable of propelling the fish away from its predators."

Lo suggests AMH has several investment implications, including:

- The relationship between risk and reward is unlikely to be stable over time.
- There are opportunities for arbitrage.
- Investment strategies will perform well in certain environments and poorly in others.
- The primary objective is survival; profit and utility maximisation are secondary.
- The key to survival is being adaptive.

Rational beliefs equilibrium

We now introduce a less well-known theory that argues financial markets are not as efficient as EMH supporters would suggest, for reasons that are not driven by behavioural factors.

Key to this theory is the concept of a stable process that defines market movement (Kurz, 1999), as opposed to a stationary process widely embedded in mainstream theories. A stationary process is defined as a system in which all the joint probabilities of variables remain constant over time. The statistical properties of such a process can be discovered completely through data crunching the past and as a result agreed by all participants in that system. For a stable process, empirical properties are also well defined, or in other words, statistical analysis can be successfully carried out just as for a stationary process. The key difference is that the true statistical properties of a stable process can never be learned, even when endowed with all possible empirical information about the process. A stable process can be characterised as a sequence of regimes and, in practice, no one knows exactly the parameters of the prevailing regime, or its start and end dates. Let us look at a simple example where investors are witnessing a price/earnings (P/E) ratio of 20 for a major equity index, while the all-time

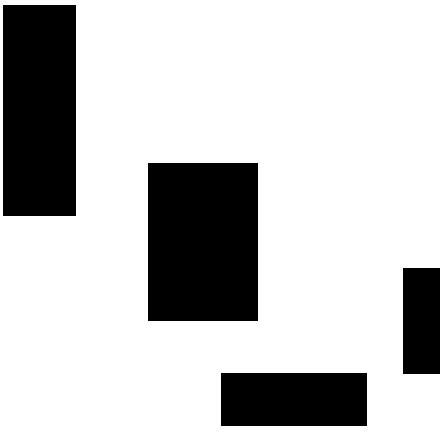
Key to this theory is the concept of a stable process that defines market movement (Kurz, 1999), as opposed to a stationary process widely embedded in mainstream theories.

average P/E ratio for that index is 15. Under a stationary process this would represent a sell signal, as the P/E ratio will necessarily fall or revert to the mean (albeit a short-term rise is possible). Under a stable process, there is no such sell signal: (1) this could be the start of an extended regime of higher-than-normal P/E ratio readings, and/or (2) there is no certainty that the observed historical average of 15 is the true average, as it could drift to a higher true average value.

The next term to explore is 'rational beliefs'. M. Kurz chose the term to contrast with the 'rational expectations' of mainstream theory. The complete information held by all investors, as discussed above, leaves only one (rational) probabilistic view of the future. In the rational beliefs framework, the assumption of complete information is relaxed so that different investors have different information (for example, individuals may have access to data of various lengths or frequencies and may interpret them differently). As investors know their information is incomplete, they must form beliefs to guide their decisions, and the only requirement of the theory is that these beliefs must be rational, in the sense that they do not contradict the past data on which they are based. However, it does not necessarily rule out a societal belief structure and the shift of that structure at the aggregate level. For example, the societal belief structure can be either optimistic or pessimistic and when one particular mood dominates the society, financial markets can indeed be stable, even exhibiting the characteristics of an equilibrium. Regime shifting manifests itself when the societal belief structure switches between the two.

In this framework, mistakes are allowed (mistakes here are defined as the acts or thoughts that are wrong on the ex-post basis but completely rational and unavoidable on an ex-ante basis according to their beliefs) and it is when these mistakes become highly correlated that we can observe excess market volatility or bubbles building up/bursting.

The theory also allows room for pricing model uncertainty (PMU), referring to the fact that there is a divergence of opinion on how to price a new event (for example, quantitative easing). In other words, market participants cannot agree on the 'map' from exogenous variables to prices. This represents another source of market volatility.



Another contribution of the theory is that it makes a distinction between exogenous market risk (risk due to news about fundamentals, as Shiller observed in his 1981 paper) and endogenous market risk (the arithmetic difference between total observed market volatility and volatility due to the news, a result of overshooting and difference in beliefs). A rough estimation suggested by Brock (2014) is that one-third of total volatility is exogenously determined, leaving two-thirds to endogenous risk.

In recognising that markets can be inefficient, Brock (2014) proposes two ways of legitimately outperforming markets:

- Use deductive logic to arrive at a deeper understanding of structural changes than other investors do for the long-term trend.
- Exploit short-term endogenous risk (excess volatility) by understanding correlated mistakes and PMU.

A rough estimation suggested by Brock (2014) is that one-third of total volatility is exogenously determined, leaving two-thirds to endogenous risk.

Reflexivity

We now focus on insights from investment practitioners and review two investment managers' philosophies. George Soros (2008), influenced by his tutor Karl Popper, has been an active promoter of the relevance of reflexivity to economics and financial markets.

To unpack the concept, it helps to introduce two different functions of one's thinking: (1) the cognitive function to understand the world, and (2) the manipulative function to change the situation to one's advantage. In the cognitive function, a market participant's views reflect the reality, while in the manipulative function they shape the reality. When both functions operate at the same time, they can interfere with each other, or at the very least cannot be disentangled objectively due to two cause-and-effect flows.

The complexity of the world can well exceed our capacity to comprehend it ('fallibility', to use Soros' term) and as a result, the participant's view of the world is always partial and distorted. Confronted with a reality of extreme complexity, we are obliged to resort to various methods of simplification – generalisations, dichotomies, metaphors, decision rules and moral precepts.

Reflexivity can then connect any two or more aspects of reality, setting up two-way feedback loops between them, which can be either negative or positive.

Consequently, while there is only one external reality, there will be many different subjective views. Reflexivity can then connect any two or more aspects of reality, setting up two-way feedback loops between them, which can be either negative or positive. Negative feedback is self-correcting while positive feedback is self-reinforcing (similar to correlated mistakes discussed earlier). Equilibrium is a possible end result for a self-correcting negative feedback process. On the other hand, positive feedback cannot go on forever because eventually Stein's law[8] will kick in when the gap between views and reality becomes unrealistically large. Such initially self-reinforcing but eventually self-defeating boom/bust processes are perfect explanations of financial crises.

The concept of reflexivity clearly presents some serious challenges to equilibrium theory. Equilibrium should be viewed as a special case of reality rather than the general truth. It is also very important to recognise that financial markets can affect the fundamentals they are supposed to reflect (especially when leverage is involved) – for example a market fall can create a negative wealth effect, reducing consumption and quoted company earnings. Soros believes this is the point that behavioural finance is missing.

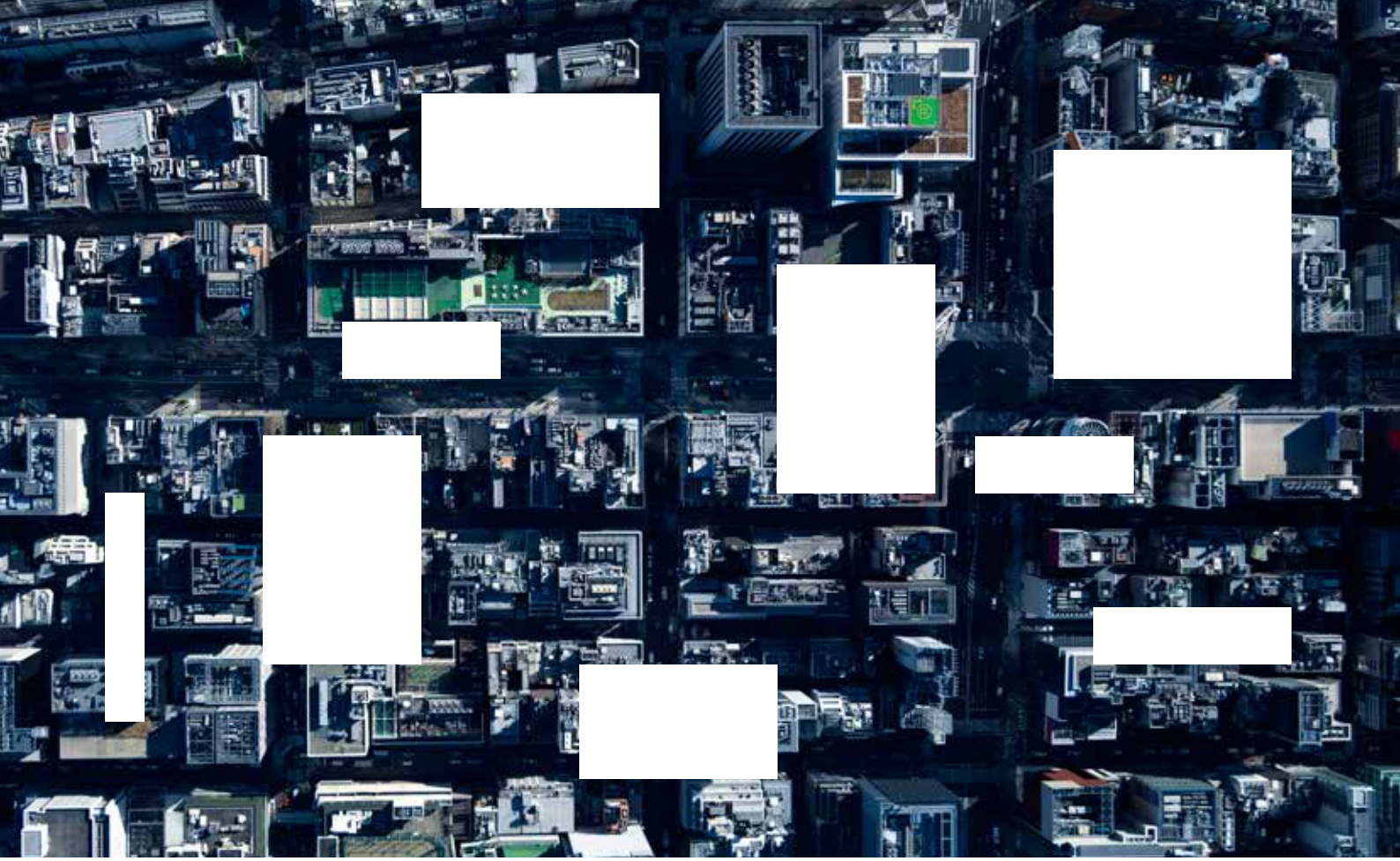
[8]"If something cannot go on forever, it will stop," Herbert Stein.

Delegation

The last theory we review has its origin in the work of Paul Woolley, another successful fund manager. The basic premise is relatively straightforward: financial markets are inefficient and exploitative, as investors do not invest directly in securities but through agents such as asset managers, creating a principal/agent problem. The act of delegation creates a series of issues: asymmetric information, misalignment of interests and asymmetric pay-off structures for asset managers.

Vayanos and Woolley (2008) argue that momentum, 'the premier unexplained anomaly', can be explained by this model. Trend-following strategies are a natural consequence of short-term incentives (for example, short-term performance fees) and once momentum becomes embedded in markets, it is in managers' interests to ride, and further reinforce, the trends. Asset owners contribute by firing underperforming managers and investing in outperforming managers. The end results are mispricing and market inefficiency, along with rent capture, that lead to misallocation of both financial and human capital.

The model suggests that the principal/agent problem is the biggest one, therefore the solution lies in having the principals recognise the nature and the extent of the problems, and then change the way they contract and deal with agents. Woolley (2010) has a long list of policies that he urges leading asset owners to adopt, some of which are rather radical, including capping portfolio turnover at 30% or staying away completely from alternative investing.



Investment industry as a complex adaptive system

Q: Some say that while the 20th century was the century of physics, we are now entering the century of biology. What do you think of this?

A: I think the next century will be the century of complexity.

– Stephen Hawking

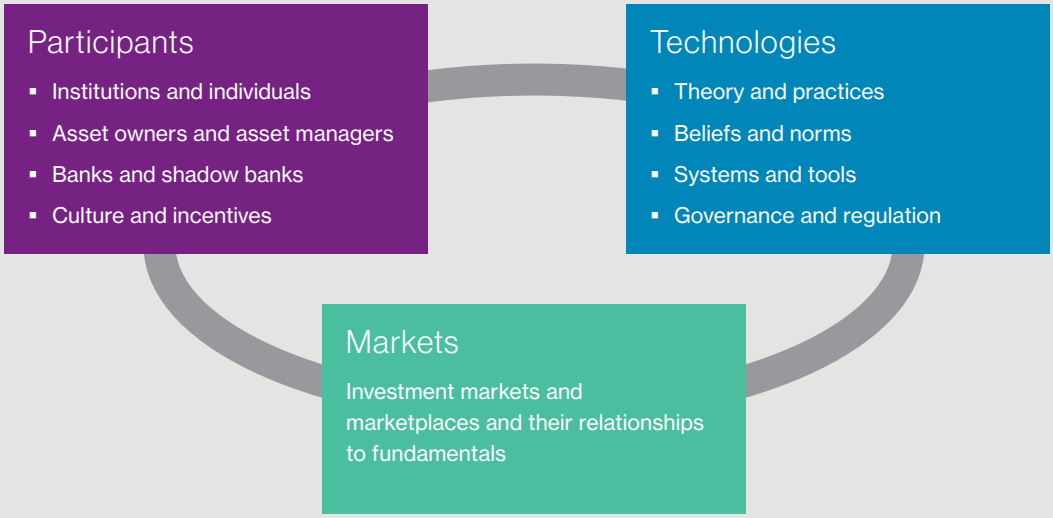
Having reviewed mainstream finance theory and five other theories/economic thoughts that challenge, supplement and, to some extent, replace the mainstream, we conclude that a coherent framework to understand and interpret the intellectual debate is needed. We believe that not only do we need to embrace a new mindset that the world is not machine-like, but investors also need a new set of tools to handle more realistic descriptions of the world.

We believe complexity science – an emerging discipline originating at the Santa Fe Institute[9] – offers a new way of thinking about finance. Complexity science is the study of complex adaptive systems. Rather than impose on the system our conception of how it works, we can instead study the components of the system and observe how the system-level behaviour emerges from the interactions between those components. A complex system is a system where the whole is greater than the sum of the parts. Complex systems exhibit emergent properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents.

We postulate that financial markets are fascinating examples of complex systems. There are many types of agents (investors, intermediaries and regulators) using existing technologies (the theory under discussion, governance and regulation) who meet in markets (exchanging securities) and marketplaces (for products and talent), as illustrated in *Figure 1* on page 16).

[9] http://www.santafe.edu

Figure 1. **Investment industry as a complex adaptive system**



Each major market has hundreds, if not thousands, of institutional investors, and multiple thousands of individual investors. The investors span multiple markets, resulting in interconnectedness of apparently separate systems. Despite complex aggregate behaviours, there is underlying simplicity – people buy and sell a security. Transactions cause a security's price to change, which triggers subsequent transactions and further price changes – typical of interaction. In addition, news flow can cause coupling when unrelated parties trade on the same story. Stock price charts over different lengths of time cannot be distinguished, meaning that stock price movement is scale-free with respect to time.[10] Unintended consequences are very common in financial markets, particularly in respect of changes in regulation. A Google search on 'unintended consequence' and 'financial markets' yielded 1,760,000 results.[11]

Despite complex aggregate behaviours, there is underlying simplicity – people buy and sell a security.

Financial markets are full of examples of emergent phenomena. For instance, bubbles and busts are not controlled by any single actor or group. Consequently, they can be considered a behaviour of financial markets that emerges from multiple individual interactions. Financial systems are also adaptive and evolving. If we compare financial markets today with any previous point in time, we will see remarkable changes, and yet seldom have these changes appeared material at the time. The underlying simplicity remains – the buying and selling of securities – but now the trades are in decimals, occur in fractions of a second, and may not happen on an exchange. The number and variety of securities available have also ballooned, particularly in derivatives. This complexity has created new asymmetries of knowledge and understanding for exploitation, as vividly illustrated by Michael Lewis in his latest book titled *Flash Boys.*

We believe that 'endogenously generated non-equilibrium' is the natural state of financial markets. This challenges the mainstream assumption of equilibrium, that the market can only be disturbed by exogenous shocks. There is no proof that can be offered to demonstrate conclusively that financial markets do not have an underlying equilibrium. Ultimately, it comes down to an individual's belief about how the market operates. However, the clear exhibition of the other characteristics suggests to us that financial markets do not exist in equilibrium. It may appear in many situations that financial markets as a whole correspond loosely to equilibrium, but beneath the surface we also see mechanisms that produce forces and as a result cumulative changes which at a certain point lead to a non-linear jump. In evolutionary biology, this is referred to as 'punctuated equilibrium'.[12]

[10]This is an alternative expression of Benoit Mandelbrot's idea (first formed in the 1960s) that stock market prices follow a fractal pattern. See for example http://www.scientificamerican.com/article/multifractals-explain-wall-street.

[11]As of 23 July 2015

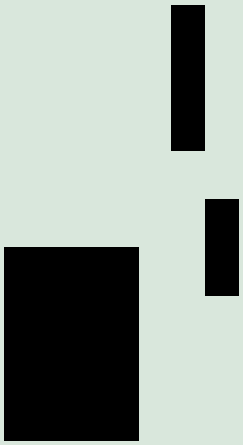
[12]http://en.wikipedia.org/wiki/Punctuated_equilibrium

Hyman Minsky's financial instability hypothesis is a good example of these forces in play – the financial system may look as though it is stable, or in equilibrium, but those are precisely the conditions that cause debt to increase, which creates future instability. Brian Arthur (2015) offers a compelling analogy with the sun. It appears to be a large ball in uniform spherical equilibrium when viewed from the earth. But underneath this 'equilibrium', there are extremely dynamic phenomena such as gigantic magnetic loops, X-ray bright spots, and mass plasma ejections moving at up to 2,000 kilometres per second. The sun is never at equilibrium. Neither are financial markets.

Complexity finance works with the assumption of heterogeneous agents that have imperfect information. In most cases, to some degree, participants in the financial markets do not have complete knowledge. This might be caused by insufficient resources to process all the information regarding an extremely complex product. If an investor has to read over one billion pages to understand the make-up of a CDO^2 contract fully,[13] it is safe to assume that these pages will not get read and investment decisions must be based on an incomplete understanding. Or consider counterparty risk. In a highly connected banking system, each bank has a large number of counterparties and each of those counterparties itself has a large number of counterparties. Knowing the ultimate counterparty's risk becomes, in the words of Andrew Haldane, chief economist at the Bank of England, akin to "solving a high-dimension sudoku puzzle. Counterparty risk is not just unknown; it is almost unknowable".[14]

Another potentially much more important force is well illustrated in the Keynesian beauty contest and Soros' principle of reflexivity: there is no optimal move, and investors have to confront a genuine lack of knowledge by applying subjective beliefs about subjective beliefs, and then apply third, fourth and higher degrees. Financial market participants who, via the manipulative function (to use Soros' words), cannot only shape other participants' subjective beliefs but also cause market fundamentals to change. Uncertainty becomes self-reinforcing. That leads to historically contingent and path-dependent financial markets. Because prices of the financial instruments can affect the fundamentals that they are supposed to reflect, the historical path of prices will influence its future trajectory.

Where does this leave an investor who has to make an investment decision? In a world of 'we simply don't know', the pure deductive logic of mainstream theory looks increasingly anomalous. This is where complexity finance reaches out to behavioural finance for help. Brian Arthur (2015) argues that human deductive rationality is bounded (limited) and when faced with ill-defined situations with irreducible uncertainty, people use inductive reasoning. They look for and match patterns (for instance, it is common to hear people saying "this financial crisis reminds me of the Great Depression"). It also means simplifying the problem by building temporary



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Knowing the ultimate counterparty's risk becomes, in the words of Andrew Haldane, chief economist at the Bank of England, akin to "solving a high-dimension sudoku puzzle. Counterparty risk is not just unknown; it is almost unknowable".

There is no optimal move, and investors have to confront a genuine lack of knowledge by applying subjective beliefs about subjective beliefs, and then apply third, fourth and higher degrees.

[13]This calculation is sourced from Andrew Haldane's April 2009 speech at the Financial Student Association (http://www.bis.org/review/r090505e.pdf). CDO^2 is used as a shorthand for CDO of CDOs (typically 125 of them), which are themselves bundles of normally 150 RMBs (residential mortgage-backed securities). There are around 200 pages in a typical RMB prospectus. That is 22,000 years of reading, assuming one can read 50,000 pages a year.

[14]ibid

hypotheses to work with. Deductive reasoning can still be applied based on current hypotheses/beliefs (for example, given that I believe equities are overvalued, I should underweight them in my portfolio), which are constantly shaped by feedback from the markets and environments. As a result, hypotheses can be discarded when they cease to perform, and they can be replaced with new ones. In this sense, financial markets act as an 'ongoing computation' or 'search engine' looking for the next profitable opportunity. Financial markets become algorithmic.

Arthur (2015) views the presence of both positive and negative feedback as a defining property of complex systems.

Another key concept is positive feedback, introduced and discussed earlier in both the rational beliefs equilibrium and reflexivity sections of this paper, particularly self-reinforcing asset price changes in financial markets. Arthur (2015) views the presence of both positive and negative feedback as a defining property of complex systems. Equilibrium theory is only compatible with negative feedback. However, if a system only contains positive feedback, the system will run away and show explosive behaviour. A 'live' financial market results from the interaction of both forces. When negative feedback becomes the dominating force, financial markets can converge to temporary equilibrium, and in that sense, the equilibrium-heavy mainstream finance theory is just a special case of complexity finance. Even so, bubbles and crashes are entirely possible when the positive feedback force is dominant.

The transition from a negative-feedback-dominated state (self-repairing) to a positive-feedback-dominated state (self-destructing) can be highly nonlinear and as a result financial markets can exhibit a 'robust yet fragile' property. Only three years prior to the GFC, Ben Bernanke celebrated over 20 years of 'the great moderation',[15] and yet since 2007 the global financial system and world economy has been embroiled in an acute period of instability. This is also called regime shifting or phase transition. The tipping point is a key concept when regimes shift. Haldane (2009) argues the shock that caused the tipping point in the GFC – the subprime crisis – was rather modest by global financial standards. Scientists and financial economists suggest it is important to watch out for some early warning signs, although it is difficult to predict when the tipping point will be reached. For further reading in this area, we suggest Kritzman and Li's work (2010) in financial turbulence.

Complexity introduces multiple disciplines

Complexity theory represents a novel scientific approach across traditional discipline boundaries and creates opportunities for research from multiple disciplines. It can be viewed as an overarching framework that describes the participants, technologies and markets, and their interaction. Network theory, a multidisciplinary academic field itself, is closely linked to complexity and its central concept of the 'interconnectedness of all things'.[16] The United States National Research Council defines network science as 'the study of network representations of physical, biological and social phenomena leading to predictive models of these phenomena'.[17] The world economy consists of highly interdependent commercial and financial networks, and as a result, network theory can be a good framework to improve our understanding in areas such as how organisations in the financial markets are connected or how markets are and could be structured.

With a better understanding of how agency and competition issues present themselves, game theory can then throw light on how solutions can be improved.

Management science, also known as operational research, explores what organisations do and how they work. With the help of mathematical analyses and sometimes computer simulations, insights can illuminate management issues and solve managerial problems that normally manifest themselves in an environment where co-operation and competition co-exist. As a consequence, game theory can be particularly helpful in understanding the landscape where strategic decision making needs to be conducted. A good, simple example of applying game theoretical thinking in financial markets is the zero-sum game nature of active investing. Gross of fees, active outperformance relative to the benchmark must exactly equal the underperformance of other active strategies. This is simply a mathematical fact. With a better understanding of how agency and competition issues present themselves, game theory can then enlighten how solutions can be improved. Over time, competition can and will evolve, and fitness landscapes will test organisational attributes of the market participants. That is the research subject under evolutionary theory. Within an evolutionary framework, participants, technologies and markets interact and evolve dynamically in accordance with the 'law' of selection. In that sense, sound investments need to be well adapted to the changing environment instead of just having the highest Sharpe or information ratios. Andrew Lo's adaptive market hypothesis mentioned above is a good example of establishing links between finance and evolutionary biology.

In this lengthening list of relevant disciplines, we also include anthropology – the study of humans and their behaviour, past and present. It builds on knowledge from the social and biological sciences as well as the humanities and physical sciences to understand human societies and cultures and their development. A central concern of anthropologists is the application of knowledge to the solution of human problems. In the context of investing, it means understanding the self and others in the group and individual contexts, and understanding cultural dynamics.

[15] http://www.federalreserve.gov/BOARDDOCS/SPEECHES/2004/20040220/default.htm

[16] A phrase the author Douglas Adams put into the mouth of his fictional detective in *Dirk Gently's Holistic Detective Agency,* UK, William Heinemann Ltd (1987)

[17] http://www.nap.edu/catalog/11516/network-science

Lastly, behavioural economics and neuroscience have a special focus on the cognitive process and how that process might produce certain biases. For example, a neuroscientist can trace the circuitry our brains use to make the kinds of decisions we rely on as investors. It sheds light on why investors choose to make certain investment decisions, in the context of emotions like greed or fear. Why do investors chronically buy high and sell low? Why is there more money chasing alpha than harvesting beta? More importantly, by understanding how the brain works, we hope to overcome certain biases to get better results.

A review of other theories through the lens of complexity

If by now we have successfully convinced you that financial markets are complex adaptive systems, how do we make sense of the 'mainstream' and 'non-mainstream' investment theories that we have previously reviewed? In this section, we try to do just that.

Unfortunately, but unsurprisingly, the mainstream theories are least compatible with the complexity worldview, indicating a sticky but, in our view, highly rewarding evolution of beliefs. The belief in a natural state of equilibrium only subject to large external shocks needs to be replaced by the concept of endogenously generated non-equilibrium with both negative and positive feedback forces in play. Investors cannot be equipped with complete information and make the optimal move all the time. They differ in requirements, ability and constraints. With imperfect information, they employ a combination of inductive and deductive reasoning. Markets are 'search engines' looking for the next profitable opportunity, and are not efficient all the time. The concept of market efficiency is not necessarily wrong, but it is incomplete. Financial models need to be built both from top down (DSGE) and bottom up (agent-based modelling, examined shortly).

Markets can be persistently inefficient due to human error and cognitive biases. In our opinion, what is missing is the aggregation mechanism that turns individual actions into market behaviours.

Behavioural finance provides great insight into how participants in the financial markets make individual decisions. Markets can be persistently inefficient due to human error and cognitive biases. In our opinion, what is missing is the aggregation mechanism that turns individual actions into market behaviours.

AMH has so many complexity elements in it that it seems reasonable to categorise it as one of the complexity models. Market players learn and adapt via simple heuristics. Competition drives adaptation and innovation, and natural selection shapes the market ecosystem. Evolution determines market dynamics. It is very in line with the complexity view that market efficiency is merely a special case of market behaviour that is a function of market ecology – a context-dependent and dynamic concept. AMH has addressed the issue of underweighting the influence of the institution in mainstream theories. It has picked up some elements from behavioural finance, but their integration remains a work in progress. Overall, it is certainly a plausible framework that works well in the complex adaptive system space.

Rational beliefs equilibrium theory produces a lot of sensible concepts – rational beliefs, endogenous market risk, pricing model uncertainty and correlated mistakes, among other ideas. In our view, these concepts tie in practitioners a lot more than the mainstream theory counterparts. It is, however, still an equilibrium theory with its implied aggregation mechanism. The assumption of time-invariant mean and variance (for the stable process) can be challenged.

Reflexivity is an insightful concept, but the theory is still being developed. As a result, most practitioners instinctively understand parts of the theory, but rarely in ways that can be used in practice. It is a very important concept that is closely related to interconnectedness and path dependency, and is possibly the most important force driving financial market dynamics.

The work on delegation also contributes significantly to our understanding of one of the less understood investment issues – how asymmetric information, misalignment of interests and asymmetric pay-off structures create market distortion, and how these issues can be managed. However, the work's narrow focus on a single factor leaves it unintegrated with other aspects of finance. Many practitioners support the thesis, but this driver's impact remains a question.

VUCA environment

Today's investors are operating in an extraordinarily volatile, uncertain, complex and ambiguous (VUCA) environment. In stark contrast, the theoretical foundation to guide investors' actions is unhelpfully weak, as we have detailed. So we urge investors, both asset owners and asset managers, to recognise and embrace the complexity in our system and move towards a complex adaptive system worldview where more realistic phenomena can emerge.

This worldview will inevitably call for a step up in practice across the whole spectrum of investment activities for all types of investors, as detailed in our companion research paper, *Going above and beyond: stronger investment theory and practice.*

We urge investors, both asset owners and asset managers, to recognise and embrace the complexity in our system and move towards a complex adaptive system worldview where more realistic phenomena can emerge.

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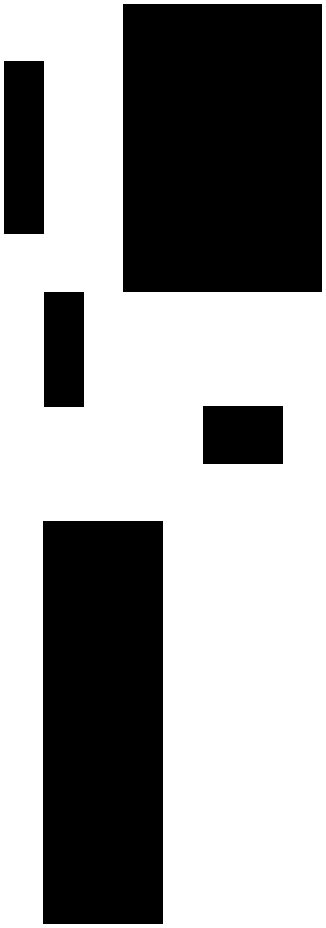

Limitations of reliance

Limitations of reliance – Thinking Ahead Group 2.0

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