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Mean reversion in investment markets: a survey

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Abstract

This paper surveys and discusses the economic and actuarial literature and finds theoretical and empirical evidence of mean reversion in all economic markets, but in a non-linear fashion, when the markets are priced at relatively extreme levels. There is a danger that capital rules that do not recognise this mean reversion will be procyclical, aggravating stresses in the market.

Keywords: Resilience Reserves; Investment; Efficient markets; Non-linear

Introduction

The paper is a follow up to the Resilience Reserve Taskforce (2005) of which the author was convenor. The Taskforce recommended that the formula for the investment market shocks should assume some mean reversion of the parameters concerned: dividend yields, real interest rates and anticipated inflation. The recommendation is currently still under consideration by the actuarial profession and the regulators. As a contribution to their deliberations, this paper is intended to provide an in-depth (although not exhaustive) review of the actuarial and economic literature on mean reversion.

There are four main sections. The first provides background and is intended for an actuarial audience. It looks at the subject of literature reviews of academic research; to some of the philosophical and statistical issues that relate to proof and understanding, a brief technical note as to some of the jargon in this field and a discussion of the relationship between market efficiency**Error! Bookmark not defined.** and mean reversion.

Academic economic research is covered in the next section. In most cases, this has tended to look separately at the different economic variables, and so the different subsections consider currency markets, interest rates, inflation and equity markets respectively. Considered in this order of increasing complexity, it becomes easier to build up a picture of the important issues.

The third section looks at the actuarial literature, which is mainly focussed on models that cover all of the variables of interest.

The final section discusses and summarises the results, raising some possibilities for ongoing research and development.

There is a brief index at the end which indicates where the more technical terms are first used and explained.

1 Background

This section provides some philosophical and practical background to the controversial issues being considered. It should become clear that final answers are not available, and that our understanding is necessarily tentative. Readers familiar with academic literature may want to skip subsections 1.1 and 1.2. Those familiar with the econometric literature on investment modelling can skip the rest of section 1.

1.1 Literature reviews

Reviewing the relevant academic literature is the first step of any serious research. There is no point in re-inventing the wheel, and every advantage in standing on the shoulders of those that have gone before.

Until perhaps 15 years ago, reviewing the literature on any single topic was a manageable activity. There were a limited number of academic journals and once one had found some relevant papers, one could follow the trail of references to find more important earlier papers. More recent publications could be found by using a printed citations index to discover papers that had subsequently referred to these papers, and other research related by keyword.

In the last decade, this has become more difficult if not impossible. Published academic research has exploded so that there are frequently too many papers to read – even on the most esoteric subjects. In addition to the formally published research, there are vast numbers of working papers and articles published by academic departments, research organizations and policy think tanks. The internet makes almost all of them immediately available. An internet search for "mean reversion" and "investment" produces almost 100,000 references. Limiting the search to Google Scholar reduces it to a still impossible 5,000. Trying again with the ISI Web of Knowledge, which only searches academic journals (and within those only that subset with an adequate number of cross references to the main body of the academic literature), produces only 28. This would be manageable on its own but many papers on this subject will not use the term. Even writing ten years ago, Campbell *et al* (1997) mentions the impossibility of covering all the papers that have investigated the efficiency of markets.

Academic research has its own limitations and it not always easy to sift what is important and reliable from the relatively trivial and speculative. It can be argued that even the best journals have become less open to critical debate over time[1] so making it more difficult to understand the areas of controversy. A particular problem arises when those in the same field appear to ignore each other. Of interest to this paper is the question of the efficiency of markets. Two prominent winners of the Nobel prize for economics, Joseph Stiglitz and Robert Merton, are able to write major papers about similar ways to understand market imperfections without referring to each other. Apparent market inefficiencies arising from the cost of information and those that arise from transaction costs and institutional structures are discussed in Stiglitz (2002) and Merton and Bodie (2005) respectively. In spite of the obvious overlap, there are no cross-references in these otherwise weighty papers.

Listing on the ISI Web of Knowledge or other academic databases such as EBSCOHost, which has been used extensively for this paper[2], is therefore no guarantee of value or even statistical legitimacy as, for instance, illustrated by Ferson *et al* (2003). While all the journals are peer reviewed, and many to an extremely high standard, the review process is not uniform. In most instances, it is performed voluntarily by other academics, and while their anonymity usually prevents conflicts of interest, it may be easier for them not to work through all the arguments and conclusions. Nevertheless, journals listed on the databases probably set a higher standard of refereeing than others. The others can be identified in this paper by the presence of a web address in their reference.

Another problem for actuaries is that the professional actuarial journals are not indexed on these indices. Peer review of actuarial papers may also be relatively uncritical, but this is less of an issue if a discussion of the paper is published. Readers should be aware that the discussion can play an important part role in understanding, particularly where there is controversy.

There are some shortcuts, such as referring to more recent papers, which will usually summarise at least one string of previous research. This method creates the risk that their importance is overemphasised, but it is often taken in this paper.

1.2 Understanding

If one cannot cover all the ground, the aim must be to attempt to produce a broad outline with a sample of the more prominent features. The object of a research paper is understanding, and not mere information. This means searching out insights, comparing and contrasting

alternative views and approaches, and attempting to synthesise a framework for thinking about the subject.

How this might be done is itself controversial. Pemberton (1999) and Huber and Verall (1999) provide some insights. Both emphasise the need for both theory and empirical testing in developing actuarial economic models, and the need for judgement in their application. They (and apparently most philosophers of science) therefore reject the empiricist view that only falsifiable theories can be considered valid. This is an important consideration when it comes to applying some of the insights gained from this paper.

They do, however, appear to accept the other positivist view that true knowledge ought to be dispassionate, if not disinterested. While superficially attractive, this view is unrealistic: a deep understanding is not likely to come to those for whom the subject has no interest – of a material or other kind. Polanyi (1962) "demonstrates that the scientist's personal participation in his knowledge, in both its discovery and its validation, is an indispensable part of science itself. Even in the exact sciences, 'knowing' is an art, of which the skill of the knower, guided by his personal commitment and his passionate sense of increasing contact with reality, is a logically necessary part."[3] Strong feelings about a subject are a good basis from which to launch the pursuit of understanding, although they become counterproductive if they blind us to credible alternatives or inconsistencies in our own views. The heated actuarial debate[4] on fair values has spilled over into questions of market efficiency and mean reversion at times. While it is preferable to reduce the heat, the participants in the debate are probably those from whom we can learn the most.

Emotional and self-interested argument is not an insuperable obstacle to understanding unless it goes unrecognised: both in ourselves, and in other participants in the discussion. As with many difficult questions, mean reversion is difficult to prove and we have to keep an open mind. We also have to make regulatory decisions on capital which require us to take a position.

1.3 The null hypothesis and significance

Even if it is not self-interested, prior belief plays a critical role in the question of mean reversion, as in many others. If one believes that markets follow random walks, this is a falsifiable hypothesis: it would be rejected (using the standard statistical conventions) in most papers if the probability of the observed data being from a random walk was less than 5%. On the other hand, if one thought that, theoretically, markets ought to revert to some mean over time, one would test a null hypothesis that incorporated mean reversion. Some of the papers referenced here come to different answers because they are testing different hypotheses.

A paucity of data may well mean that few tests are sufficiently significant, statistically, to reject either null hypothesis. In such cases, one can determine a balance of probability, or be guided by prior beliefs or judgement.

Most of the papers referenced do report the development of some model. As a warning, it is worth mentioning the common pitfalls in developing and testing a model. Some of the papers that are referenced may not be free of the pitfalls related, but are included for the insights that they do offer.

- Data mining (or data snooping) arises if a sufficiently large number of potential relationships are attempted before finding one with an acceptable fit. Given enough models and enough parameters it is possible to fit a mathematical formula to any finite set of data. Even where, as with the research reported in this paper, the models are fitted to much the same data, one or two rejections of a null hypothesis - out of a few hundred reported attempts - are to be expected on random grounds.

- Over-parameterization is another form of data mining caused sometimes by including variables that have been tested and rejected - in the final model. It is quite possible for some apparently significant variables to lose their significance if these "noise" variables are removed. This is aggravated if there is multi-collinearity - where the explanatory variables are correlated with each other. Such regressions will often produce coefficients of the wrong sign.

- Some of the authors can be accused of naivety in that they appear to ignore relationships that are obvious to those more experienced or widely read. A model that fails to utilise variables which have been proved to be significant in other research has limited meaning. Adding variables that have been shown to be significant will not only improve the fit to the data, but can also change the significance (and even the sign) of new variables.

- Outliers pose a problem to any regression, as they can completely transform the interpretation of the results. They should be removed if they are likely to be the result of measurement error, or arise from causes not being investigated by the model. They may however be critical to the result, as is the case when considering mean reversion, which often seems to depend on relatively extreme values.

- The distribution of the regression residuals (or error terms) is critical. If they are auto-correlated (with previous errors) or not normally distributed, then the standard tables used to determine significance are not meaningful. Tests to ensure their normality are not always performed.

In general, papers that fail to reject one or other null hypothesis have not been reported here.

1.4 Technical note

This is not a technical paper, but it may be helpful to note some of the terminology common to many of the papers mentioned. The major question is whether a particular time series reverts to a mean, or whether it is a random walk with the current value being the best estimate of the next value. These definitions can be interpreted mathematically:

$$\Delta x_t = x_t - x_{t-1} = (\alpha - 1)x_{t-1} + \varepsilon_t$$

If $\alpha = 1$, this equation is said to have a unit root, and the change in x is a random walk with the error term ε governing the distribution. If $\alpha < 1$, then the time series will be mean reverting (in this case to 0). If $\alpha > 1$, it will explode, and is not often of interest. Tests for unit root are therefore tests for the absence of mean reversion.

More complicated tests for mean reversion allow the series to be auto-correlated, and for the possibility of trends. This requires estimates of the trend, and for lags up to p periods with a formula of the form:

$$\Delta x_t = \mu_0 + \mu_1 t + (\alpha - 1)x_{t-1} + \sum_{j=2}^{p} \beta_j \Delta x_{t-j+1} + \varepsilon_t$$

Stationary series are those for which the mean and variance are expected to be the same regardless of the time period over which they are measured. Series with random walks, trends, or reversion to a mean are not stationary, although the first two can be converted into stationary series by differencing or detrending.

1.5 Arbitrage and mean reversion

It may be helpful at this stage to clear up a particular misunderstanding. Mean reversion does not necessarily mean that investment markets offer arbitrage opportunities. This point seems to have given rise to misunderstandings at times.

Arbitrage free can be used as a synonym for completely efficient markets. When used to describe a valuation or projection model, it means that arbitrage opportunities do not exist in the world described by the model. Well known actuarial examples of models that fail this test are:

Models that project the returns on risky assets at a higher rate than risk free rates and then discount them at the risk free rate – so implying that the equities are really worth more than their current market values.

Models that project changes to interest rates that are uniform for all durations, which imply that profits can be made from assets that have durations of a wider spread than the liabilities.

One of the mathematical conditions for models to be arbitrage free, discussed briefly for instance in Campbell *et al* (1997, 293ff), is the existence of state price deflators (also called stochastic discount factors or the pricing kernel) by which one can calculate the value of an asset using risk neutral expectations. The deflators can be interpreted as revealing the utility of investors. The underlying intuition is that arbitrage is only possible if there is no risk of losing money; as long as the risky asset can possibly earn less than the risk free asset there is no arbitrage available.

The greater return expected from share investments (the equity premium or equity risk premium) does not therefore necessarily represent an arbitrage possibility. Historical experience suggests however that the equity premium is too high to be explained by risk aversion, so creating the equity premium puzzle as discussed in Siegel and Thaler (1997). They also find mean reversion in real returns to equity investments over longer periods, and suggest that equities offer a lower risk than fixed interest investments over a twenty year span. This is not an arbitrage unless 20 year returns always exceed risk free returns, but cannot be theoretically explained without introducing additional variables. One alternative explored by them is to abandon the theory of the efficiency of markets and to introduce behavioural theories and myopic behaviour by investors. Plausible attempts have however been made to explain the equity premium without introducing investor myopia. Vissing-Jorgensen (2000) derives an estimate of the costs of obtaining information that explains US levels of stock market participation and suggests that the cost of obtaining appropriate information explains a large part of the puzzle. A model developed by Gourinchas (2000) suggests that the desire for significant precautionary savings also reduces participation in the stock market.

Campbell *et al* (1997) also report evidence that the level of the equity premium varies over time and discuss some of the literature that has attempted to explain both its size and variation. Such explanations include changes to expectations and risk aversion, the supply and demand for investment funds as well as the costs of investment. Their fluctuating equity premium is compatible with efficient markets.

They also discuss share market bubbles, which could be interpreted as occurring when equity investments were expected to yield less than risk free investments. If prices were expected to continue rising over a limited period, bubbles can be rational and consistent with efficient markets, but it appears impossible to reconcile bubbles with absence of arbitrage in the longer term in markets where all assets and derivatives can be traded. Bubbles are discussed further in section 2.4.2 below.

2 Economic research

This section looks at the results of academic research into the variables of interest.

2.1 Currency markets

Identical commodities should sell at identical prices in different markets – after allowing for costs of transport. Rogoff (1996), in a valuable literature review, outlines a puzzle that – in the short run at least - they do not. In that paper, he suggests that while economists all believe that purchasing power parity (PPP) should hold in some form or other, it had taken some 400 years of research to find persuasive data to demonstrate that prices do tend to revert to the expected mean. The pace of reversion, which he set at 15% pa, is however sufficiently slow to represent a puzzle – even if "one confines attention to relatively homogenous classes of highly traded goods".

There are obvious explanations that also apply to other markets. In the first place there are frictions: not just transport and other trading costs, but tariffs and other barriers to trade. There is also the likelihood that traders and arbitrageurs may not be able, or find it worthwhile, to respond to price differentials until they become relatively large. The idea can be expressed[5] as a "band of inaction" around PPP with mean reversion applying outside this band.

There are a variety of models that have been tried to fit this pattern. In one of the more elegant Taylor *et al* (2001), confirmed and adapted by Paya et al (2003), use an exponential smooth transition auto-regression (ESTAR) model. The model is of the form:

$$y_t = c' x_t + [\exp(-\alpha(y_{t-d} - c' x_{t-d})^2)][\Phi(L)(y_t - c' x_t)] + \varepsilon_t$$

where x_t is a set of deterministic or stochastic regressors, $\Phi(L)$ is a polynomial of the lag operator and ε_t represents an error term. The exponential weight is limited to the range [0,1] to prevent it from blowing out. The adjusted mean, $c'x_t$, allows for a secular trend and for a link to the relative change in productivity growth between the two countries, which theoretically would lead to a change in the relative strength of the currencies. The resultant fit for a range of European currencies and the US dollar over 22 years to May 2001 suggests faster mean reversion than reported by Rogoff, especially for the larger shocks away from PPP. For a 10% shock, half lives (representing the time taken to move half way to a long term equilibrium) vary from 13 to 41 months; for a 40% shock the half lives vary from 1 to 17 months. The authors explain the differences in the parameters of the formula for different countries by differences in the ease of arbitrage. This, in turn, depends on geography and institutional structures (including culture).

Amongst this literature, Taylor (2001) provides a useful analysis of two pitfalls in measuring mean reversion. The first is the problem of time averaging. He finds, for instance, that measuring currency rates or returns at monthly intervals will overstate the half life by some 50% if the true half-life is greater than a month, and by more if it is less. The second issue is that of non-linearity, which leads to increasing errors as the band of inaction widens. He uses what he calls the simplest, non-linear model that the reversion is linear outside the band of inaction. This is called threshold autoregression (TAR), and requires estimates of the thresholds as well as of the parameters of the reversion. An exponential approach might be preferred as it more parsimonious.

There is, intriguingly, another independent strand of research into mean reversion and PPP sparked off by O'Connell (1998) who argued that the long term linear mean reversion was "overvalued" because of cross-sectional dependence. High inflation had simultaneously affected most of the countries in the samples and thus created spurious relationships. This

strand ignores what would appear to be the superiority of the non-linear tests, but the non-linear researchers, in turn, appear to ignore these other influences that should be considered in the modelling process.

After referring to the non-linear developments, Taylor and Taylor (2004) say that "the idea of long-run PPP now enjoys perhaps its strongest support in more than thirty years, a distinct reversion in economic thought." It certainly appears to me that recent research has resolved the puzzle of PPP. Small deviations from PPP present little in the way of profitable arbitrage opportunities, and can remain for some time. Large deviations from the productivity weighted PPP do however produce a speedy and measurable mean reversion.

2.2 Interest rates

Unlike PPP for currencies, there is no natural level to which interest rates can be expected to revert. There are however good theoretical reasons to expect the real rate of interest to be within a band of some 0% to perhaps 10%. Below nominal rates of 0%, there will be opportunities for arbitrage as is it possible to hold cash if there is no inflation, or non-perishable goods if there is. If real interest rates were 10% in a developed economy (where the balance sheets of the banks exceed GDP and there are numerous other loans and rental on property to pay), total real interest and rent payments could account for 20% of GDP. If half the people in a country are lenders and renters and the other half rentiers (who receive interest and rent), the borrowers will be paying an average of 40% of their gross incomes in interest and rent. While perhaps not impossible, it is difficult to envisage such a situation being sustainable, or to find evidence that it had occurred in a modern economy.

In the vast literature on interest rate modelling (most of which covers nominal interest rates), two strands can be examined briefly. One, such as Mankiw and Miron (1986) finds that there is insufficient evidence to reject the hypothesis of a unit root. On the other hand, many interest rate models, such as Vasicek (1977) and Cox, Ingersol and Ross (1985), provided for a linear reversion to a mean. These models did not initially fit observed data well, but have been developed to fit more closely.

Some subsequent work has shown that the relationship is not linear. Jones (2003) however shows that any attempt to measure the parameters precisely is largely dependent on the hypothesis being tested. He provides an interesting illustration of how results can differ widely depending on alternative Bayesian prior distributions. The problem can be characterised as arising from a paucity of data at extremes. One can believe that each extreme event is likely to be unique in its causes and the way in which markets return to normality. If so, it provides no evidence of future mean reversion.

Kapetanios *et al* (2003) apply an ESTAR model to interest rates in the major OECD economies with success. Their model differs from the equation above in that they do not allow for a combination of lags. Interest rates too, therefore, appear to be mean reverting as they approach extreme values.

There is less research on the real interest rate as determined by deducting inflationary expectations from nominal rates, but Lai (2004) finds evidence of mean reversion in the US.

2.2.1 Term structure

Seo (2003) finds a non-linear mean reversion in the term structure of interest rates using a TAR approach. He ascribes these plausibly to transaction costs, which prevent investors from realizing arbitrage opportunities. His adjustment coefficients which describe the mean reversion are regime-dependent[6], which makes the model more complex.

Chan and Cheung (2005) produce a TAR model of Australian long and short term interest rates with three regimes based on thresholds of the difference between the two rates. The model may well be over-parameterized, but has mean reverting properties.

2.2.2 Credit risks

Jarrow and Turnbull (2000) bring together default and market risks to model credit risks. They refer to the need, arising from banking regulation, to capture the risks of default, downgrade and spread. The first two are clearly related and are clearly cyclical. Collin-Dufresne and Goldstein (2001) confirm that firms adjust their leverage over time to find an optimal level with the result that credit spreads are mean reverting. Prigent *et al* (2001) find evidence of non-linear mean reversion of the indices, as does Bhanot (2005), who confirms that survival bias does not change this result.

While there is a large literature on the modelling of credit risks, it may be more helpful to concentrate on pro-cyclicality. This is the problem that backward looking, risk-based regulatory capital will rise after defaults and spreads increase, and then be too high for the improvement to come. This is precisely the problem that the Resilience Reserve Taskforce was attempting to address with its recommendations. Allen and Saunders (2004) survey the literature and say that they see a consensus on the basic idea of addressing pro-cyclicality, but little agreement on model and policy specifics.

Borio *et al* (2001) is a working paper from the Bank for International Settlements (BIS), source of the Basel accords, and is the most cited reference on Google Scholar on pro-cyclicality. They also express no doubts as to the cyclicality of the risks, and the nature of the problem. “We argue that the worst excesses of these financial cycles could be mitigated by increased recognition of the build up of risk in economic booms and the recognition that the materialisation of bad loans in recessions need not imply an increase in risk.” They endorse forward looking risk models that identify variables at the extremes of their range: “exchange rate misalignments, credit booms and asset price booms seem particularly relevant.” They recommend a range of responses: including education, more appropriate provisioning and counter-cyclical adjustments to capital. They however favour supervisory discretion for the latter rather than fixed rules – on the basis that these will be difficult to develop. They do however mention the approach taken by the Spanish regulators, which is to allow banks to deduct their specific provisions for losses that have occurred from their general, statistical provisions for total expected losses.

This debate does appear to be relevant to insurance regulation. Capital requirements that do not recognise when markets are in extreme positions risk distorting the markets still further. Barker (1999) mentions incidents of the forced sale of equities, and purchases of fixed interest stocks, as a result of capital requirements.

2.3 Inflation

As with real interest rates, there is no obvious long term level for inflation, except perhaps the targets set from time to time by central banks. Given that explicit inflation targeting is relatively recent, there is not enough data to confidently test this possibility. There are reasons for believing that the inflation rate cannot fall much below zero – real interest rates would rise too high. There is however no obvious reason why the inflation rate should not explode, as has been observed too often.

As with the other time series investigated, there are many independent strands of research on inflation. Much of the earlier economic work does not consider mean reversion at all, and where it does, only considers linear characterizations, which from the earlier discussion, are unlikely to be significant. The few reported attempts that have tried non-linear models have been more successful. Baillie *et al* (1996) analyse monthly inflation for 10 different countries,

and find strong evidence of long memory with mean reverting behaviour for all countries except Japan. Arghyrou *et al* (2004) try a variety of linear and non-linear models on UK inflation rates over the last third of the previous century. That they have attempted a number of models suggests that there is data mining, and the large number of parameters that they use suggests some over-parameterization. In spite of this, their rejection the null hypothesis of a random walk for inflation appears plausible.

2.4 Equity markets

This brings us to the interesting question of whether there is a band of inaction for equity markets. Unlike interest rates and inflation, there are a number of ways of modelling the "true" value of a share, with prices deviating from this value to the extent that the assumptions in the particular model do not hold.

One can make the assumption that various markets are competitive and free of arbitrage opportunities. If the market for every company's products was perfectly efficient, the mean value of a share would be the book value of the tangible and intangible assets (adjusted appropriately for inflation). If the price were higher, an arbitrageur could raise capital for a new company of the same sort, buy the same assets and then sell the shares for a premium. If the price were lower, then the companies would not invest in replacement assets and would pay their entire cash flows back to their shareholders until the productive capacity in the market was sufficiently reduced.

One can relax the assumption that the underlying markets are efficient, and consider the position if only the investment markets are efficient, and can accurately forecast companies' earnings. Under these circumstances, every company would generate earnings at a risk premium to the risk free interest rate of suitable duration. The duration would depend on the period for which the earnings were predictable. If one makes the additional assumptions required for the capital asset pricing model[7], then the margin over the risk free rate can be determined and a fairly accurate estimate made of the value of the company.

If alternatively, we assume that retained earnings are used to increase dividends in real terms at some predictable rate, the fair value of shares can be determined by the dividend yield. One obvious problem is that optimal dividend policy changes with the tax regime, which provides a major obstacle to the assumption that the long term payout ratio will be constant.

2.4.1 Empirical relationships

Economists refer to the ratio of market price to book value as Tobin's q. There is clear evidence of mean reversion in price earnings ratios and Tobin's q as described, for instance, in Harney and Tower (2003). They used a value for Tobin's q that adjusted for inflation, and produced values of less than 1 for most of the previous century. Cavaglia and Moroz (2002) find that industry share prices tend to converge to long term dividend yield, interest rates and earnings levels. Cutler *et al* (1991) find significant reversions to the dividend yield in Australia, Canada, the UK and some US periods, but not in the other countries they model.

There is also evidence that shares in different countries, stocks and sectors revert to their average relative to the global market. Balvers *et al* (2000) find reversion from 18 countries to a portfolio representing the average value for the 18 countries when testing annual data. Stotz (2004) finds evidence of mean reversion in 50 large European shares using a combination of profits and book values.

Futures contracts are relatively easily priced using the spot price of the underlying asset and assumptions about interest rates and dividends, or storage costs. Even in this market however, there are costs to arbitrage, and Monoyios and Sarno (2002) find an ESTAR mean reversion

to the theoretical price that produces a superior fit to a linear mean reversion to underlying stock prices.

There is research, such as Narayan and Smyth (2005), that rejects mean reversion, but this might be accused of being naïve in that the authors only look for reversion to an absolute value, and test on daily data which may well hide longer term reversion.

Other recent work includes considerable analysis of models of behavioural biases, such as Brav and Heaton (2002). While these biases may well be one of the causes of market price anomalies, it is difficult to think of them as a reliable basis for setting capital rules, and so they are not described here in any detail.

The overall conclusion is that there appears to be mean reversion from the extreme of equity market values relative to interest rates, dividend yields and market: book ratios.

2.4.2 Bubbles

The corollary of mean reversion in the extremes is that prices occasionally demonstrate bubble-like behaviour.

Bubbles can be explained by herd behaviour as for instance in Hirshleifer (2001) and Hirshleifer and Teoh (2003). Herd behaviour may arise from irrational psychological biases, or from rational incentives not to take a contrarian view. The theory of rational bubbles is famously illustrated by Keynes, who described investment as a beauty contest where the prize goes to the person who best guesses the preference of the majority.

Allen and Gale (2000) take another view, and suggest that the bubbles in Japan and in Scandinavian countries during the eighties and nineties arose from excessively generous credit that exposed the banks to moral hazard by investment opportunists.

There are however other reasons why share prices may be at a level unjustifiable in terms of their intrinsic value. Some arise because some investors will not sell shares that they know to be overpriced. Owners who are involved in the management, or who have family and other ties to a company, may chose not to sell over-priced shares, while other investors will not sell for tax reasons. Passive investors may also be limited by prior decision to buy and hold shares in their index. Woolley and Bird (2003) criticise passive investors for buying shares that were clearly overpriced during the 2000 tech bubble. They cite evidence that share prices rise if they are included in a share index favoured by passive investors as evidence of market inefficency. They do not raise the problem that this effect is aggravated by share price indices that are based on capitalization rather than tradability, but this problem appears to have been addressed in the last few years.

Restraints on short selling can also explain bubbles. Short selling is particularly risky, as a "bear squeeze" can require a purchase at inflated prices when it comes to delivery. Perhaps the most colourful of these in recent years was the manipulation of the silver price in the late eighties. The Bunker Hunt brothers were the most famous participants in a consortium that drove the silver price up 650% in one year as short sellers attempted to cover themselves[8]. The gold price bubble of the same years may well have been an irrational parallel.

Gilchrist *et al* (2005) develop a model of bubbles, assuming restraints on short sales and the incentive of companies to issue more shares when prices are high, and to invest the money in expanding their operations. They investigate the 2000 tech bubble, and find that companies behaved as might be expected from their model. They did not find excessive and wasteful investments took place because companies restricted their share offerings in order to maintain the price. Woolley and Bird however suggest that European communication companies did make wasteful investments; a large part was overpaying governments for licences.

There is thus sufficient evidence to suggest that bubbles can and do occur in some investment markets.

2.4.3 Comparative performance

Malkiel (2004) looks at the success of technical and fundamental models to predict returns. He uses dividend yields, price earnings ratios and a model based on interest rates and Tobin's q, and finds evidence of out-performance. If markets do mean revert, such relationships should be exploitable.

Becker *et al* (1999) find, however, that mutual fund managers are unable to benefit from market timing. This confirms considerable other research and observation that active managers – as a whole - do not appear to beat the market. It is not however clear that this finding is of significance. The average investor must do as well as the market, and these findings merely show that mutual fund managers and active investors (as a whole) are no different from the average investor. If companies do raise more money when the market is high (as found by Gilchrist *et al* (2005) and others) then they clearly benefit at the expense of investors. Matching the market would therefore be an achievement.

The performance test for mean reversion would be to see whether those investors that attempt to read market levels do better than those that do not. The performance of asset allocation hedge funds could provide such a test. Capocci and Hubner (2004) confirm that earlier analyses appear to have overstated the success of hedge funds, but they do find that one quarter of US hedge funds managers appear to be successful in finding arbitrage opportunities. Amongst these are funds with a market timing strategy. Do *et al* (2005), in contrast, find no evidence of over-performance in Australian hedge fund managers. The evidence of there being opportunities to exploit market timing is therefore weak.

Occasional inefficiencies in markets are partly explained in a widely referenced article by Grossman and Stiglitz (1980) who prove the impossibility of completely efficient markets. There must be enough inefficiency in the market to make it worthwhile for traders and arbitrageurs to operate. Anomalies in relative value and bubbles can only occur if there are not enough active investors.

2.4.4 Beliefs

The consensus opinion of experts is also of interest. There is no definitive answer here, but Welch (2000) asked a sample of over 100 financial and economics professors whether they believed in the efficiency of markets or not. Over 90% believed that equity markets were efficient and followed random walks in the short run. Over a third however thought that markets showed negative auto-correlation over a three to five year horizon, and a few more thought that the value of the equity premium changed over time.

This was confirmed by a later survey. When the first survey took place in 1998, the arithmetic average long term risk premium estimated by the participants was 7%, reducing to 5.5% when the survey was repeated in 2000 – as reported in Welch (2001). One of the reasons may have been that Welch's original paper reported that the respondents believed that the consensus view within the economics profession was as high as 8%, and that this had "anchored" their views at a higher level.

The relatively low level of belief in a varying equity premium contrasts somewhat with the view of Campbell *et al* (1997, 286): "It used to be thought that expected asset returns were approximately constant and that movements in prices could be attributed to news about future cash payments to investors. Today the importance of time-variation in expected returns is widely recognized, and this has broad implications for both academics and professionals…"

As their text book is regarded as something of a classic by some, the slowness in the spread of this view about fluctuating risk premiums is disconcerting, but does illustrate the difficulty of developing an informed consensus of views.

2.5 Property

Most of the research in this area has been on US listed property trusts, which would be expected to display some equity type characteristics. Stevenson (2002) is the most cited article, and finds that statistics from some markets reject the unit root null hypothesis. He concludes that mean reversion is slow. He does not however refer to the paper of Okunev and Wilson (1997) that finds significant results for an exponential reversion to the mean and slow convergence of equity and listed property indices.

There does not appear to be any work on direct property that is relevant.

3 Actuarial literature

Central to the actuarial literature is the Wilkie model, of which Wilkie (1995) provides perhaps the best description. It provides estimates of the growth of prices, wages and dividends; short and long term interest rates (real and nominal for the latter), dividend yields (and thus share prices) and currency conversion rates. The extended model includes estimates for 16 countries for the share prices and currencies.[9]

Huber (1997) provides a thorough criticism of the Wilkie model. He is in particular concerned that there are elements of data mining in the model, and that the inflation and the long term interest rate residuals in the out-of-sample data, available since the calibration of the model, were inconsistent. He also felt that the inflation model should incorporate market information on inflationary expectations. His conclusion was that actuaries needed a complete re-evaluation of economic theory that included an incorporation of efficient market theory and rational expectations.

This criticism is of the same type as Exley *et al* (2002), who provide an analysis of mean reversion in equity markets focussing on the risks of finding spurious results in short term data, and showing how some markets do, and others do not, reflect mean reversion to dividend yields.

For fixed interest markets, Guthrie *et al* (2000) develop a model and give the conditions under which mean reversion can be consistent with arbitrage free models of the market. Cairns (2004) is published in the mainstream economic literature and brings together models that satisfy the needs of option pricing and longer term actuarial projections.

A number of other actuarial models are described in Lee and Wilkie (2000) and Chan (2002). Thomson (1996) and Sherris *et al* (1999) cover South Africa and Australia respectively, with the latter not finding evidence to reject the random walk. Whitten and Thomas (2000) adapt the Wilkie model by adding another regime to most of the variables. Booth and Marcato (2004) suggest further adaptations of the Wilkie model for direct property.

In most cases, it should be said that these authors seem to have taken greater pains to avoid the pitfalls of model fitting than is common in the academic literature. They do not however usually look very deeply into the alternative modelling approaches that can be found in the economic literature.

One example of a painstaking analysis of auto-correlation is Grenfell (2005). While there appears to be no theoretical justification - nor adequate data - for some of the longer term correlations reported in that paper, the shorter term cycles for share markets are more suggestive of some persistent relationships. In particular, the four year cycle for equities does

coincide with US presidential elections, which Nickles (2004) shows to have persisted in every cycle since the early fifties. This would also be consistent with other research, reported for instance in Cutler *et al* (1991), which shows that many markets overshoot in the short run and correct in the second (or perhaps fourth) year.

Also of interest are the remarks in the text book by Panjer *et al* (1998) on mean reversion, but they take no position on the issue, merely acknowledging different results from different studies.

4 Conclusion

There is probably full agreement that real world markets cannot be completely efficient. There must be some residual error in pricing from which traders and arbitrageurs can generate the profits to motivate them to continue to keep prices within reasonable limits. The deviations from fair or intrinsic value can sometimes be surprisingly high, as is convincingly demonstrated in the case of deviations from PPP. Fixed interest and equity markets are a different category to currency markets because of the presence of many players, low barriers to entry, and the low costs of transacting and obtaining information. There is also more difficulty in determining the fair value to which prices might revert.

The PPP idea of a "band of inaction", within which prices do not revert, has considerable theoretical appeal that is strongly supported by a great deal of empirical research. Within this range all investment markets appear to exhibit random walks. That there are limits to these ranges (except the upper bound to inflation) appears obvious from both theory and empirics. All of the series we have discussed therefore appear to display mean reversion in extremes.

This does not mean that there are arbitrage opportunities, but it does mean that the expected yields from different asset sectors and classes change over time, and that there might be profits to extract from re-balancing portfolios. There is some evidence that some hedge fund managers are able to extract these profits. Even extreme values can persist for some time however, and there can be no guarantee of profit: there is unlikely to be consensus at any time that a particular market value does represent an extreme or a turning point.

The banking literature on capital and pro-cyclicality is also in agreement that there is enough evidence for cycles and mean reversion. The main question is how this should be transformed into regulatory practice.

Further work on the resilience reserves can take such accepted facts into account. If mean reversion is to be used, the simple model proposed by the Resilience Reserve Taskforce may be adequate. Alternatively there may be a need to produce a more sophisticated regular model of Australian investment markets that delineates the thresholds beyond which random walks are less likely to apply. Such a model could conceivably be based on the macro model of the Reserve Bank of Australia (RBA) described by Stone *et al* (2005). It includes sub-models for the exchange rate, inflation and interest rates, and also takes changes in relevant foreign variables into account. It is used for the RBA's policy making purposes, but might have a wider usefulness.

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Index of the use of some more technical terms

[1] As: Coelho P R P, De Worken-Eley F & Mcclure J E (2005) Decline in Critical Commentary, 1963-2004 econjournalwatch.org/main/intermedia.php?filename=CoelhoetalEconomicsInPracticeAugust2005.pdf

[2] Courtesy of Macquarie University, where the author is a Visiting Fellow.

[3] From the description of the book at Amazon.com.

[4] The controversy has possibly been hottest in the UK, but can be illustrated by the title of the symposium sponsored by the Society of Actuaries in Vancouver, 2003: "The Great Controversy: Current Pension Actuarial Practice in Light of Financial Economics."

[5] Said by Taylor (2001) to go back to a 1916 paper by Eli Heckscher.

[6] The parameters of the model switch between different regimes (or states of the world) in a random fashion. Regime shifting models often fit the data well because of their fatter tails and ability to reflect clumps of increased volatility.

[7] These include a stable correlation structure for all shares and sufficient market participants who can invest or borrow at the risk free rate.

[8] They were later convicted of market manipulation. Legal aspects of the case are covered in Williams (1995), but a very brief account of the events is set out at http://web.pdx.edu/~jjackson/HuntSilver.html

[9] Wilkie (1995) is cited 75 times on Google scholar and 24 times on the ISI, although half of these appear to be errors with such titles as "Aromatherapy practice in nursing: literature review"!