Essays in Nonlinear Economic Dynamics
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Chapter 1

Introduction

This chapter describes the motivation for the dissertation, the problems it tries to solve and discusses the methods and solutions that have been developed. Chapters (2) to (6) follow the order in which the various issues were investigated. However, for expository reasons we first introduce the motivating evidence and then examine the methods of analysis. We also explain the links among the different chapters.

1.1 Evidence from Financial Practice

The late 90s have been a hard time for investors. The principles that guided the investment decisions for decades seemed to work poorly. A common approach consists to value stocks based on ratios, such as the Price-to-Dividends (PD) or Price-to-Earnings (PE) ratio. If the ratio is low (with respect to some level or its historical mean) it indicates that the stock is undervalued and the price does not fully incorporate the profitability measured by the dividends or earnings. A frequently used strategy is value investing, which consists of buying stocks that have low ratios (in other words, that are undervalued) and sells those that have high ratios (that are overvalued). This principle can also be used for the valuation of an aggregate stock index, such as the S&P500 index. Figure (1.1) shows the PD and PE ratio for this index from 1871 until 2001. It is clear that since 1995 the PD ratio indicated overvaluation of the aggregate stock market (compared to the historical peaks) and in 1996 also the PE ratio gave the same signal. What was the sentiment of investors at that time? The following quote from an article in Business Week in 1997 (when the PD ratio was approximately 50 and the PE ratio 25) illustrates the uncertainty on the direction of the stock market:

Bears have long warned of a sharp decline because stock prices - when measured by standard yardsticks of earnings, dividends, or book value - were as high or higher than ever been. No matter. The bull charged ahead. The bears who
Figure 1.1: Stock Price and Fundamental Value: 1880-2001

(left panels) Real stock price and fundamental value determined by dividends and the Price-to-Dividends (PD); (right panels) Stock price and fundamental value determined by earnings and Price-to-Earnings (PE) Ratio for the S&P500 index from 1871 until 2001. The data are described in Shiller (1989) and in Chapter (5).

bailed out a year ago missed some juicy profits: a 51% jump in the Dow Jones industrials and a 49% rise in the S&P500 index. ... The remarkable state of the U.S. economy is providing all the ingredients for more stock market gains. Growth remains strong, incomes are rising, productivity is improving, earnings are expanding, the budget deficit is shrinking, and inflation is tepid. ... Given these conditions, even many analysts whose models indicate overvaluation aren’t alarmed.


The first paragraph summarizes the sentiment of investors in 1997: the high ratios reached in 1996 suggested that the market was overvalued and that sound investment principles prescribed to sell stocks. However, the investors that sold stocks at the beginning of 1996 lost “juicy” profits of 50% in their holdings. The article indicates also that investors had different opinions about the future prospects of the stock market. Some expected the stock price to decrease in the coming years, the “Bears”, and others that the stock market would continue to grow, the “Bulls”. The second paragraph describes the arguments of “Bulls” to support a further increase in stock prices. The outlook of the fundamental variables
was positive: economic growth was strong, earnings were increasing and inflation was under control. In other words, there was an exceptional period of strong economic growth and stable (or even decreasing) price levels. An exceptionally favourable economic situation that required extraordinary stock valuations.

It is typical in financial news to report the opinions of so-called gurus, most of the time investment strategists of famous investment banks. In the 90s one of the most cited gurus was Abby Joseph Cohen of Goldman Sachs. An article in the New York Times at the end of 1999 describes her opinion about the valuation of the stock market:

As Abby Joseph Cohen puts it, she has been “jumping up and down” since the early 1990s, telling clients across America, that the stock market had plenty of room to grow, even when other strategists said the opposite was true. Using conservative and well-researched earnings estimates and factoring in the economy’s low-inflation environment, Ms. Cohen, the diva of this bull market, has argued in her measured way that the stock market’s undervaluation was a reason to expect good returns from equities. ... 

Ms. Cohen argued for years that the stock market could live with higher price-to-earnings ratios when inflation was low. Lower inflation, she has said, increases investors confidence in the growth of profits and makes them willing to pay more for a given level of earnings. But now, she noted, inflation is beginning to rise modestly. That means “inflation is no longer going down and it is no longer something that gives us a significant margin for improvement in valuations”, she said. That, she explained, is a reason for believing that the market will stay fairly valued.


Ms. Cohen, “the diva of the bull market”, bases her valuation of the stock market on fundamental analysis. She explained the undervaluation of the stock market during the 90s by a regime of low (expected) inflation that allowed investors to require a smaller rate of return on stocks. This implies that stock prices could be higher than were before. At the end of 1999, the undervaluation was corrected and she expected for 2000 no further increases. Ex-post, we know that in 2000 the stock market declined more than 20%. Also this article suggests that investors’ opinions are heterogeneous: she expected from the beginning of the 90s the stock market to be undervalued while “other strategists said the opposite was true”. However, Ms. Cohen became the “diva of the bull market” because her forecasts for many years proved to be correct.

Fundamental analysis explains the level of stock prices by earnings (or dividends), their expected growth rate and the required rate of return (that may depend on interest rates,
inflation and the risk premium, for example). However, there is evidence that some investors pay less attention to these factors and rely on indicators extracted from the price series itself. This type of analysis is known as technical analysis. Also in this case the financial press provides us with a guru: Ralph Acampora, Chief Technical Analyst at Prudential Securities.

A technical analyst, Acampora believes that a key barometer for how the market will fare is the June low of 8628. If the market falls below this number, explains Acampora, things could be OK. “But if we stay above that number, it’s possible that we could have a downside of 15% to 20%.” That would take the Dow down to the 7400 to 7900 range.


It is clear that Mr. Acampora predicts the level of the stock market without any consideration for fundamental factors (earnings, productivity growth and inflation). In his view, the only variable that plays a role is the price.

The existence of gurus and disagreement among them emerge also in the following quote:

In dramatic juxtaposition to moves by another influential market guru, Prudential Securities’ Ralph Acampora Friday advised investors to stay aggressive in stocks, saying that the market is riding a once-in-a-lifetime bull trend. ... Acampora’s comments came one day after another market guru, Abby Joseph Cohen of Goldman Sachs, cut her recommended stock position.


The article suggests that gurus predict the market (“stay aggressive in stocks”) based on different types of analysis. Ms. Cohen relies on fundamental factors while Mr. Acampora on non-fundamental factors. At the beginning of 1999 fundamental analysis indicated the stock market was fairly valued. However, technical analysis guru Acampora was still “bullish” advising to stay aggressively in stocks to benefit from a “once-in-a-lifetime bull trend”. The discussion indicates that investors use different tools of analysis (fundamental or technical) to form expectations about the future. They also pay more attention to the advise of a guru if in the previous years he turned out to be right.

Is it possible that smart investors arbitrage away profit opportunities? This type of investors are usually associated with hedge funds, that take leveraged positions to profit from mispricing situations. An example of these type of investors is Julian Robertson, founder of the Tiger hedge fund. The article reported below, discusses his investment philosophy and the view of a “bubble” which had occurred in stock prices:

Julian Robertson, one of the founding fathers of the modern hedge fund industry, is near to announcing the closure of his Tiger Management hedge fund
group. The move follows two years of poor investment performance at Tiger, during which time the size of the funds he manages has fallen from $22bn to $6bn. ... With his equity investments, he looked to buy shares that were relatively cheap on the basis of price-to-earnings ratios and other fundamental measures - known as value investing. ... Mr. Robertson said the current craze among investors for technology and internet stocks "is unwittingly creating a Ponzi pyramid destined to collapse". He added that his value-focused strategy of "buying the best stocks and shorting the worst" only worked in a rational market. Today market conditions are irrational, "where earnings and price considerations take a back seat to mouse clicks and momentum".

From: Financial Times, "Robertson berates US markets" and "Tiger hedge fund to close", June 26, 2000

The investment strategy of Mr. Robertson is to profit from investment opportunities of the fundamental type, that is under/over valuation of stocks ("buying the best stocks and shorting the worst"). This strategy assumes that in a rational market the price of a stock should revert back to its fundamental value. In the mid 90s Mr. Robertson judged the stock market was overvalued and took short positions to profit from the imminent correction of the mispricing. However, the stock prices drifted even further away from the fundamental value and his strategy lost money. Another important element is that investors decreased their holdings in Tiger funds: the decrease in managed funds from 22$bn to 6$bn is mainly due to withdrawals from clients. Investors were unsatisfied with the poor performances of the funds compared, for example, with an index fund that gave from 30% to 50% return a year. This confirms the previous evidence that investors compare the performances of the fund managers (or the guru they followed) and move their holdings to the managers (or gurus) that recently performed best.

1.2 Economic Models

The evidence in the previous Section can be summarized by the following stylized facts:

1. Investors form their expectations based on different sets of the available information: some believe that fundamental variables are relevant factors in the evolution of stock prices while others consider only the information contained in past prices.

2. Investors that form expectations based on the same information sets might interpret it differently.
3. The market follows the advice of gurus (fundamental or technical) and their popularity depends on the recent relative performance.

4. Rational arbitrage might fail to stabilize prices when irrational expectations dominate the market.

The asset pricing literature incorporated some of these stylized facts in so-called behavioural models. We will describe some of the models proposed in the literature. We do not aim to give a full account of the literature. Recent surveys of behavioural asset pricing models are Shleifer (2000), Hirshleifer (2001) and Barberis and Thaler (2002).

1.2.1 Heterogeneous Beliefs about Fundamentals Factors

As discussed above, analysts using fundamental analysis disagree about the interpretation of current information. Some strategists expect there is under/over valuation to be corrected while others believe that all fundamental information has been already incorporated in prices. There is robust empirical evidence of underreaction and overreaction to earnings announcements. When there is news about the profitability of a company, investors "underreact", that is, they incorporate slowly the new information into prices. "Overreaction" refers to the fact that investors drive prices at high levels when they experience a record of positive news. Hence, they are subject to two biases: at an early stage, they tend to undervalue the effect of news on prices and incorporate it only slowly; however, if the positive news persists they perceive a change in the profitability pattern of the firm and overvalue the stock.

A model that tries to explain the under/overreaction phenomena has been proposed by Barberis et al. (1998). They assume that a representative agent switches between two expectational earnings regimes. In one they expect earnings to mean revert while in the other to have a trend. In both cases their expectations are wrong because the true earnings process is a random walk. The probability of being in one or the other regime is updated such that they slowly incorporate the positive news (and the mean reverting regime implies that underreaction affects stock prices). When they switch, a trending regime creates persistence in their expectations and in stock prices. Investors behaviour can also be related to the experimental evidence of Tversky and Kahneman (1974). They found that individuals are subject to psychological biases such as Conservatism and Representativeness. Conservatism means that agents update their models only slowly. They need persistent information that the model they use is wrong to update it. This is clearly associated to the underreaction in stock prices: when earnings announcements do not support the existing valuations, they tend to incorporate only slowly the new evidence. Instead, representativeness is related to the tendency to classify events in some specific classes that ignore the true probability process.
This relates to the overreaction to news, that is, persistent evidence of positive news implies that they extrapolate that a trend is occurring.

In the discussion of the previous section, we focused on the expectations of investors about the aggregate stock market in contrast to individual stocks as in the over/underreaction literature. However, the same biases appear to characterize investors. During the 90s, Ms. Cohen justified higher stock valuations by the positive news of increased corporate profitability and low (and stable) inflation. On the other hand, other strategists interpreted the positive news differently and judged them as temporary fluctuations. Their expectations are consistent with the underreaction explanation described earlier. These analysts expectations were in the mean reverting regime of Barberis et al. (1998) and believed that the news would die out quickly. In the late 90s, the overreaction to the positive news started to display its effects: stock prices were much higher than warranted by fundamental valuations.

The interpretation of stock prices in terms of a time varying sentiment about the prospects of the economy is certainly supported by empirical and psychological evidence and by the descriptive discussion of the previous section. However, it does not account for other phenomena observed, such as the role of technical analysis, the existence of rational arbitrageurs and the performance evaluation of strategists.

1.2.2 Heterogeneous Beliefs about Non-Fundamental Factors

A realistic behavioural model should also account for the fact that investors use different types of analysis to form their expectations. There is evidence that some investors use technical analysis to forecast the market. The previous example of Mr. Acampora clearly supports this assumption. More convincing evidence is given by the survey studies of Frankel and Froot (1987) and Allen and Taylor (1992). They conducted surveys of forex traders to investigate the information and type of analysis they use in forming their expectations at different time horizons. They showed that at short horizons (up to 1 month) traders extract information from prices and make extensive use of technical analysis. However, at longer horizons they pay more attention at fundamental factors and expect the exchange rate to adjust toward the long-run equilibrium. This evidence suggests that there is a horizon dependence in the use of the different types of analysis: at short horizons, the traders perceive the news about the fundamentals as uninformative and extrapolate past prices. Instead, at longer horizons fundamentals are important in the determination of the exchange rate while technical tools are much less valuable. Shiller (1989) gives evidence of extrapolative expectations also in stock markets.

This evidence suggests that modelling the expectations of technical analysts might contribute to explain the large deviations from fundamental values. Some models have been
proposed by Frankel and Froot (1990), DeLong et al. (1990a) and Brock and Hommes (1998). We will briefly discuss the last two articles.

DeLong et al. (1990a)\(^1\) assume that some investors (noise traders) follow technical rules to form expectations while other investors (arbitrageurs) are aware of the irrational mispricing occurring in stock prices. However, arbitrageurs may not be able to correct the mispricing and drive the price back to the fundamental value because of "limits to arbitrage". One reason that limits arbitraging activity is the short investment horizon of arbitrageurs compared to noise traders. If the irrational traders become optimistic and drive the stock price persistently up, the arbitrageurs might be forced to liquidate their positions against the mispricing and realize the losses. DeLong et al. (1990a) introduced the concept of noise traders risk to indicate the risk created by deviations of stock prices from fundamentals due to the irrational expectations of traders. An explanation for the horizon limitation of arbitrageurs is that they are evaluated by investors at typically short horizons. If the mispricing is persistent and corrects at longer horizons compared to the evaluation period, investors might realize losses and move money away from the arbitrageurs. A key assumption of the model is the irrationality of noise traders that drive the stock price away from the fundamentals. The second key element is the limits to the arbitrageurs activity in taking large positions to correct the mispricing. The case of Julian Robertson discussed in the previous section illustrates this situation: his strategy of investing in stocks that were mispriced generated losses and the hedge fund experienced consistent withdrawals from unsatisfied investors.

Another model along these lines has been proposed by Brock and Hommes (1998). They assume that investors have heterogeneous beliefs about the persistence of the deviations of stock prices from the fundamental value. Some investors expect the stock price to adjust back to the fundamentals while others expect a persistent trend in prices. Investors are assumed to switch between the beliefs strategies based on their relative performance: if a belief performs relatively better than the alternative strategies, the fraction of investors with this belief will increase and have a higher influence in the determination of the stock price. The switching among beliefs that occurs in this model is deterministic and depends on the past relative performance of the beliefs type. The fraction of investors captures the performance-based evaluation of different strategies: those with better relative performances get a higher weight. Chapter (6) of this thesis is devoted to the estimation of this model to the yearly stock price data in Figure (1.1).

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\(^1\)See also Shleifer (2000) for an overview of the noise traders approach to model financial markets.
1.2.3 Heterogeneous Beliefs and Short-Sale Constraints

The recent stock prices run-up revived interest for an explanation suggested byLintner (1969) and Miller (1977). They assume that short-sale constraints prevent rational investors to short stocks in periods in which irrational investors are driving the price away from the fundamentals. Overconfident investors might push the price at higher levels and the arbitraging activity of pessimistic investors might be constrained by the short-sale. This approach offers another explanations for the “limits to arbitrage”: rational investors that use fundamental analysis might not be short the stocks in the desired amount. Recent empirical evidence supporting this approach is given in Ofek and Richardson (2002) and Diether et al. (2002) among others. Recent theoretical work is Scheinkman and Xiong (2002).

1.3 Time Series Analysis

In the previous section, we discussed various models that try to explain the empirical behaviour of stock prices and its deviations from the fundamentals. Two ingredients are common to all these models. One is the assumption that investors have heterogeneous expectations. The second key assumption is some form of constraint on the arbitraging activity of rational (fundamental) investors. Hence, when a group of investors have irrational expectations and the other investors are limited in their arbitraging activity, we can experience large deviations from fundamental valuations.

The empirical evidence suggests that stock prices deviate persistently from various notions of fundamental value but at long-horizons they are pushed back toward the equilibrium. This phenomenon is called in the literature mean reversion. Mean reversion indicates that asset prices contain a temporary (stationary) component that characterizes swings away from a permanent (non-stationary) component, typically associated with the asset fundamental value. Hence, asset prices have a tendency to revert back to the mean, or their fundamental value, but given the persistence of the deviations it occurs only at long-horizons. Mean reversion has been documented for many financial assets such as stock prices, exchange rates and also for commodity prices. An early reference for stock prices is Poterba and Summers (1988). It has been investigated mainly using two methods: variance ratios and long-horizon regressions. Variance ratios compare the variances of one-period and multi-period returns. The typical finding is that the variance ratios are larger than one at short-horizons and become significantly negative at longer horizons. This suggests that in the short term stock returns are positively autocorrelated but in the long term they typically have negative autocorrelations. This supports the hypothesis of mean reversion because it shows the tendency of returns to revert in the long-run. Another tool frequently used to investigate mean reversion is
the long-horizon regression. In this case, multi-period returns are regressed on a measure of deviation from the fundamentals, such as the PD or PE ratios. The results suggest that today's deviation have significant explanatory power for future multi-period returns when the holding period is long. In particular, a positive (negative) deviation from the fundamentals predicts a negative (positive) long-horizon return. Hence, if the stock price is above the fundamental (positive deviation) it will decrease toward the fundamental value in the long-term. Therefore, at long-horizons the relative change in stock prices will be negative.

This evidence suggests that stock prices have a tendency to diverge from fundamentals but to revert back in the long run. Recently, there has also been interest in testing for nonlinear time variation in the speed of mean reversion. The typical finding of these studies is that mean reversion is weak when the asset price is close to the fundamental value but the speed increases when the deviations become large. This can be interpreted as evidence that fundamental investors become active to correct the mispricing when it grows too large. This view is supported by the discussion in Section (1.1) of the investment strategy of Julian Robertson. His strategy describes well the action of fundamental investors in correcting the mispricing and generating mean reversion in prices. He was buying (shorting) undervalued (overvalued) stocks, that is, stocks that had a price lower (higher) than their fundamental valuation. It was a successful strategy for many years and made Mr. Robertson one of the most famous hedge fund managers. However, the closure of the Tiger fund in 2000 suggests that the stock price behaviour of the late 90s may have been different than previously. In the late 90s, the “stabilizing” action of rational investors did not succeed in counteracting the “destabilizing” demand for stocks of chartists. In addition, they realized large losses that decreased the amount of capital (because of investors withdrawals) available for their arbitraging activity.

In Chapter (5) we investigate the issue of mean reversion in stock prices. Similar work on the stock market has been done by Gallagher and Taylor (2001) and for exchange rates by Taylor and Peel (2000) and Kilian and Taylor (2003). In particular, Kilian and Taylor (2003) give an interpretation of their time series findings in terms of the existence of three types of traders. Two groups are fundamentalists that are heterogeneous in their valuations of the exchange rate. A third group is represented by chartists that are characterized by extrapolative expectations. This type of models are able to generate large and persistent deviations from the fundamentals similar to the overvaluation that occurred to the US dollar at the beginning of the 80s. We already mentioned the survey studies of Frankel and Froot (1987) and Allen and Taylor (1992). In Chapter (4) we propose a model similar to the chartist-fundamentalist models. We assume nonlinear time variation in the rate of extrapolation of the chartists and find support in the data.

Mean reversion implies that asset returns are predictable at long horizons. On the other
hand, returns at short horizons are difficult to predict. In the exchange rate literature, there are numerous studies comparing the ability of structural and time series models to beat the simple random walk in out-of-sample prediction. Meese and Rogoff (1983) tested the predictive ability of different exchange rate determination models. They found that structural models did not outperform the random walk predictor. This showed that, at short horizons, fundamental factors contain little information about the dynamics of the exchange rate. However, Hsieh (1989) strongly rejects the null hypothesis of independence for exchange rates returns using the BDS test of Brock et al. (1996). In addition, this finding is confirmed when the dependence in the conditional variance is taken into account. Therefore, there is dependence in the conditional mean but we are not able to exploit it for out-of-sample prediction. In a time series framework, Diebold and Nason (1990) used nonparametric techniques to test for the out-of-sample predictability of exchange rates. They found that these methods do not improve significantly in out-of-sample prediction. They suggested that the unpredictability could be explained in three ways: weak nonlinear dependence in the data, dependence that occurs in even rather than odd moments or as the effect of outliers and structural shifts. In Chapter (4) we try to shed some light on this puzzle.

The use of nonparametric methods is usually justified by the aim of detecting dependence structure in the data without relying on restrictive parametric assumptions. The usual motto used by proponents of these methods is “Let the data speak for themselves”. A parametric approach requires to specify a functional form for the relationship among the economic variables. Instead, nonparametric techniques allow the data to determine the shape of the relation. Another advantage is that they capture both linear and nonlinear types of dependence in the data. However, the flexibility of these techniques come at the price that they require large samples to give reliable results. Hence, it is then important to investigate the properties of nonparametric methods in finite (and typically small) samples. Nonparametric regression for time series requires the selection of two parameters: the lag order and the bandwidth. The bandwidth is the parameter that regulates the amount of smoothing applied to the series. A small (large) bandwidth is equivalent to use a large (small) number of parameters. The choice of the order in linear autoregressive models is done using selection criteria that balance the trade-off between the goodness-of-fit and the complexity of the model. The selection approach can be extended to the nonparametric case in which also the bandwidth has to be selected. In Chapter (3) we extend previous work on selection criteria proposed for linear models to a nonparametric setting. We find that some criteria have very misleading properties in finite samples. In addition, we propose a test for linearity based on the comparison of the goodness-of-fit of the parametric and nonparametric regression. The application to economic time series shows that there is evidence for the presence of nonlinear structure.
The use of nonparametric methods received increasing attention due to the emergence of the theory of deterministic dynamical systems, also known as chaos theory. A striking result of this theory was that purely deterministic nonlinear systems could generate time series that appear random to linear analysis, such as the autocorrelation function. It proved that linear time series analysis is inappropriate when the underlying data generating process is nonlinear. This encouraged the developments of new tools of analysis with power to identify the presence of nonlinear structure in the data. The new methods proposed for this purpose are all of nonparametric nature. Among the most used is the correlation integral, that measures the frequency at which paths repeat over time. In other words, it captures the predictability in the data and it is useful in tests of the null hypothesis of independence. Previously, we mentioned the BDS test for independence proposed by Brock et al. (1996). The statistic is based on the correlation integral and the fact that, under the null of i.i.d., it factorizes. An alternative interpretation of the BDS statistic comes from information theory. In Chapter (2) we discuss the different interpretations of the statistic. We also propose an alternative test statistic that is useful in determining the lag order of the nonlinear data generating process. Both the BDS and the statistic proposed here have the advantage of being functionals of the density function such that they are able to detect dependence that occurs also in higher moments.

1.4 Outline of the Thesis

The outline of the dissertation is as follows. Chapter (2) proposes to test for independence and linearity using a quantity similar to the BDS statistic. We use correlation integrals proposed in chaos theory to estimate the statistic. It captures dependence in the distribution as the BDS statistic. However, it has the additional advantage that it reveals the information contained in the $m$th lag when we account for the information already included in the previous $m - 1$ lags. It can be interpreted as a generalization of the partial autocorrelation function used for linear time series. The size and power of the tests are investigated by simulating deterministic and stochastic nonlinear models. An empirical application to the growth rate of post-war US GNP data shows that there is evidence of nonlinearity in the data. The Chapter is based on Diks and Manzan (2002). Chapter (3) investigates the finite sample properties of the selection criteria for local linear regression. We also propose a test for linearity based on the comparison of the goodness-of-fit of the parametric and nonparametric regression. Application to economic time series shows there is evidence of nonlinear structure for some of them. Chapter (4) proposes a simple model of exchange rate determination based

\footnotesize{In this context, path should be interpreted as a vector of lagged values of the variable.}
on investors heterogeneous beliefs and a time varying extrapolation rate of chartists. We replicate the forecasting exercise of Diebold and Nason (1990) and apply it to time series simulated from the chartist-fundamentalist model discussed above. It turns out that the test rejects the null hypothesis (of no improvement compared to the no-change forecast) in a very small percentage of the simulation. This suggests that the failure to beat the random walk could be the result of the interaction of small samples and slight nonlinearity in the underlying generating process.

In Chapter (5), we compare different notions of fundamental value allowing for time variation in the fundamental factors. Relaxing the assumptions of a constant required rate of return and growth rate of dividends does not help in explaining the deviations of the stock price from the Gordon fundamental value. We apply a nonlinear time series model to the PD ratio shown in Figure (1.1). The results suggest that before the 90s there is significant evidence of nonlinearity in the adjustment process toward equilibrium. Including the 90s, the dynamics of large deviations becomes more persistent and weakens the evidence for mean reversion.

Finally, Chapter (6) estimates an asset pricing model with heterogeneous expectations. The estimation results show that there is evidence for two groups of investors expecting mean reversion at different speeds. Before the 90s they both expect mean reversion but including also the 90s one group expects a bubble to occur in stock prices. The model also shows that they became dominant in the market and drove the stock price away from the fundamental.