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# Abstract

Tests for unit roots in log dividend yields, which are consistent with 'rational bubbles' in stock prices, are conducted for the S&P500 and Finnish stock market indexes. In addition to the traditional unit root tests, we split the data into 10-year segments and use frequency domain analysis to test for the presence of unit roots in the dividend yield data. The results strongly suggest the existence of bubbles in both the US and Finnish markets. Finally we develop a novel dividend yield-based method to track periods when stock prices divert their fundamental levels. This indicator produces promising results, as it seems to have some forecasting ability concerning booms and busts in the stock markets.

Key words: equity price, bubble, rolling ADF

# Tiivistelmä

Tutkimuksessa tarkastellaan rationaalisten kuplien olemassaoloa Yhdysvaltain ja Suomen osakemarkkinoilla erilaisin yksikköjuuriperusteisin testein. Perinteisen osinkohintasuhteen logaritmin yksikköjuurta testaavan menetelmän lisäksi tutkimuksessa käytetään spektrianalyysiä, koska analyysi mahdollistaa ajallisesti lyhyempien periodien tarkastelun. Molempien testien tulokset ovat samat: rationaalisia kuplia on esiintynyt sekä kotimaan että Yhdysvaltain osakemarkkinoilla.

Edellisten testien lisäksi tutkimuksessa kehitetään ja sovelletaan uudenlaista lähestymistapaa, joka hyödyntää viimeisimpiä aikasarjaekonometrisia tuloksia ja perustuu rullaavien osingon ja hinnan suhdetta koskevien informaatioikkunoiden käyttöön yksikköjuuritestauksessa. Tämän menetelmän selkeä etu aiempiin nähden on se, että se pystyy indikoimaan kuukausitasolla, ovatko markkina-arvostukset karkaamassa perusteiden oikeuttamilta tasoiltaan. Ensimmäisten tulosten valossa menetelmän tulokset vaikuttavat varsin lupaavilta.

Asiasanat: osakehinta, kupla, rullaava ADF

# Foreword

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Helsinki, August 2006
Katja Taipalus

# Contents

# 1 Introduction

Recent decades have witnessed a surge of interest in stock market developments. In the academic literature, bubbles – ie deviations of stock prices from fundamentals – have become a topic of particular interest. This is hardly surprising, since distorted prices may have severe repercussions for the functioning of the financial system and even for the economy as whole.

So far, the main concern has been that the authorities have lacked the ability to forecast bubbles with an acceptable degree of accuracy. The main purpose of this study is to offer a provisional solution to the problem by developing a new indicator for tracking the pressures associated with stock market bubbles. The primary advantage of the approach is that it is based on readily available information and so can be easily extended to cover a wide range of markets.

Before describing the indicator in detail, we will briefly review the earlier bubble-testing literature as well as the testing methods used and results obtained. After a quick evaluation of the methods, we use one of them – the basic unit root test – to test for the presence of bubbles in the Finnish and US stock markets. The results, which suggest that bubbles have been present in both the Finnish and US markets, are corroborated by a frequency domain analysis of dividend yield series.

The study is organised as follows. This chapter briefly discusses the basic definition of a bubble and its relation to the efficient market hypothesis (EMH); presents the classic examples of bubbles in the literature; lists several types of bubbles that have been identified; cites the most commonly offered reasons for the earlier equity market bubbles; and gives some reasons why tracking bubbles is important. Chapter 2 reviews the earlier bubble tests and their methodologies. Chapter 3 reports on testing for unit roots in US and Finnish stock market data and examines the frequency domain analysis. In Chapter 4 we develop the bubble indicator based on dividend yield data and test its forecasting power. Section 5 concludes the study.

## 1.1 Basic definition of an asset price bubble

In order to study asset price bubbles, one should start with a clear definition of an asset price bubble. This can be done either descriptively or in terms of empirical characteristics.

Dictionaries define a bubble, in a general sense, as something that lacks firmness and is fragile and insubstantial. Kindleberger (1987) nicely defines a bubble in Palgrave New Dictionary of Economics as 'a sharp rise in the price of an asset or a range of assets in a continuous process, with the initial rise generating expectations of further rises and attracting new buyers – generally speculators interested in profits from trading the asset rather than its use or earning capacity. The rise is usually followed by a reversal of expectations and a sharp decline in the price, often resulting in a financial crisis. A boom is a more extended and gentler rise in prices, production and profits than bubble.' In his book Manias, Panics and Crashes, Kindleberger (2000) adds that 'In the technical language of some economists, a bubble is any deviation from "fundamentals" '.

Concerning asset prices, the bubble concept is closely related to the basic pricing formula, which is used to represent the correct price of an asset: a price that is based on the values of fundamentals, fundamentals being those economic factors and variables that determine the prices of assets.

In its most common form, the pricing formula says that the price of an asset reflects all available information on the discounted future random payoffs associated with the asset. This is also the crux of the efficient market hypothesis (EMH), which says that asset prices in financial markets should always reflect all available information and hence that market prices should always be consistent with the 'fundamentals'. Validity of EMH would therefore rule out the possibility of bubbles in asset prices.

Because in this study we focus on various bubble-testing methods, the adopted view is that the strong-version EMH cannot hold at all times. As EMH has assumed such an important role in the asset-pricing literature, its theoretical background and the criticisms raised against it are treated in more depth in Appendix 1.[1]

[1] Copeland and Weston (1992) say in their book that 'the purpose of capital markets is to transfer funds between lenders (savers) and borrowers (producers) efficiently'. Thus market efficiency can be defined in terms of either allocative efficiency or operational efficiency. The classic definition of market efficiency is that of Fama (1970), who says that 'a market in which prices always fully reflect available information is called efficient'.

## 1.2 Literature on asset price bubbles – classic examples

Taking as our starting point that the strong-form EMH does not always hold, we assume that bubbles can occur from time to time in asset markets. In the literature, as eg in Charles Kindleberger's (2000) book, Peter Garber's (1990) article, and Didier Sornette's (2003) book, at least two of the three fascinating chains of stock market events are always mentioned under the heading 'stock market bubbles'. These three historical events are Tulipmania, Mississippi bubble and South Sea Bubble. The importance of these events is that they have been used to form a basis for the classical concept of a stock market bubble.

These three episodes entail some common features that have been linked closely to the bubble concept, the most important being extreme price appreciation. The three periods have been cited as good examples of pure speculative price appreciation without any reasonable economic foundation. On the other hand, Garber (1990) comes to the conclusion that two of them, the Mississippi and South Sea bubbles, were primarily market disorders caused by public sector malfunctioning and hence should not be classified as bubbles, and that they can be explained in terms of economics.

The period of Tulipmania in the Netherlands was one of great prosperity in which the tulips became, most importantly, a 'must' for wealthy people to own. The prices of tulip bulbs rose over a long period, at a fairly steady pace. As Garber (1990) notes, the actual peak phase for bulb prices was fairly short, beginning after speculators ('tavern regulars mimicking more serious traders', in Garber's words), entered into the tulip bulb market in 1636, having been lured by soaring prices. In connection with this episode, Sornette (2003) cites market players' increasing overconfidence as the basic reason for the speculation: 'people became too confident that this 'sure thing' would always make them money and, at the period's peak, the participants mortgaged their houses and businesses to trade tulips'. As mentioned, the actual peak period of speculation was short. In fact, already by early 1637 bulb prices were on the decline.

The other two classic cases, the Mississippi and South Sea bubbles, were strikingly similar in terms of the financial dynamics. As Garber (1990) mentions, 'each involved a company that sought a rapid expansion of its balance sheet through corporate takeovers or acquisitions of government debt, financed by successive issues of shares. The new waves of shares marketed were offered at successively higher prices. The purchasers of the last wave of shares took the greatest losses when stock prices fell, while the initial buyers generally gained.'

In both the South Sea and Mississippi bubbles, the actual period of price speculation was fairly brief. For example, in the South Sea bubble, it lasted only a couple of months, in the summer of 1720. Continuation of the pronounced price rise was called into question when it became obvious that the values of the companies were not at all justified by the values of their tangible or intangible assets. In both cases, it was assumed that the value of the intangible assets, ie the growing potential of the business, would justify the values seen in the markets. But investors' confidence faded before the anticipated growth was ever realised.

As mentioned earlier, the common feature of all three periods was extreme price appreciation, which fed on the ever-widening involvement of investors. But what triggered the price appreciation was not the same in each case. For the South Sea bubble – as well as for the Mississippi bubble – it was political corruption and sales growth, whereas for the Tulipmania it was an emerging new trend in consumption.

The problem of determining which events to classify as bubbles relates to the concept of economic fundamentals. How can one separate a bubble, having no economic justification, from a price rise due to perceived potential for business expansion? One cannot observe what investors are thinking when they engage in trading. We simply do not know whether someone decides to buy a stock because of an expectation of growth of a company's business or because of a speculative expectation that the stock will appreciate further, even without economic justification. The only thing we can observe is that investors participating in the markets expect share prices to appreciate further after they buy, for whatever reason. This is why the concept of a rational bubble has been so widely used in the bubble testing literature. This concept also covers the latter situation, in which investors are presumed to be aware that the price contains a bubble component.

In the following section, we present a brief review of the types of asset price bubbles mentioned in the earlier literature and give a more precise definition of a rational bubble.

## 1.3 Types of asset price bubbles

Several types of asset price bubbles have been specified in the academic literature, based primarily on how bubbles are thought to originate and develop. The first type is the ***speculative bubble***.[2] In this case, the asset is purchased under the belief that the price will appreciate further, but the belief is not based on objective changes in fundamentals. As Shiller (2000) says in his book on irrational exuberance, 'Initial price increases … lead to more price increases as the effects of the initial price increases feed back into yet higher prices through increased investor demand. This second round of price increases feeds back again into a third round, and then into a fourth, and so on.'

The underlying question in these feedback theories is what actually sets off the feedback process? One explanation relies on adaptive expectations, which means that past increases generate expectations of further price increases in the future. The second explanation emphasises increased investor confidence, which increases as the price increases. But the real crux of a speculative bubble is the estimated probability of a price rise. The bubble can continue only as long as investors think the price will rise again in the next period. Another consideration is that investors' demand for a stock cannot increase forever because there are always resource limitations, and when the demand stops increasing the price rise comes to a halt. This can be seen as the reason for the bursting of the bubble in speculative bubble theories. But how sudden or sharp will the burst will be is not at all agreed among bubble theorists.

There is a great deal of literature relating to speculative bubbles. A few works that might be cited are Hamilton (1986), which deals with testing for self-fulfilling speculative price bubbles; Siegel (2003), which offers an operational definition of a bubble; Raines and Leathers (2000), which is a book on speculative theories of stock market fluctuations that examines eg the theories of Keynes and Galbraith.

***Rational bubbles*** are often distinguished in the literature, one of the earliest mentions being in Blanchard and Watson (1982), which shows that there can be rational deviations from fundamental values in the asset markets. Rational bubbles are thought to be essentially much like speculative bubbles but with a small difference. As Evans (2003) says, 'According to the rational bubble theory, as prices overshoot

[2] Sometimes called a traditional or nonrational bubble.

their fundamental values there is an increase in the probability the bubble will burst. In turn, the possibility of financial loss increases the risk associated with the ownership of bubbling stock, thereby justifying the acceleration of its price.' Rationality here refers to the idea that investors are supposed to know that there is a bubble component in prices. But there is still an open question: Why would a rational investor be willing to pay for a bubble in a first place? The answer lies in investors' beliefs that they will be able to leave the market before the bubble bursts and that they regard the increases in a share's market price as sufficient compensation for the increased level of uncertainty.

In the rational bubble models, the price comprises two components: the fundamental price $P_t^f$ and the bubble component $B_t$. The bubble component solves the homogeneous expectational equation[3]

$P_t = P_t^f + B_t$, where the bubble component $B_t = E_t\left[\frac{B_{t+1}}{1+R_{t+1}}\right]$[4] (1.1)

Thus, in rational bubble models, agents' current decisions depend on both the current market price and their expectations concerning the future price and value of the bubble: Agents who are buying must firmly believe that they will be able to exit before the bubble bursts, and they assume that the bubble will be present in the next period.

There is a large amount of literature on rational bubbles. Meltzer (2003) covers rational and nonrational bubbles; Adam and Szafarz (1992) studies speculative (actually rational expectations) bubbles and financial markets; Flood and Hodrick (1990) and Dezhbakhsh and Demirguc-Kunt (1990) focus on testing for speculative (again actually rational) bubbles, the latter being concerned with the presence of speculative bubbles in stock prices. Wu (1995) studies the existence of rational bubbles in the foreign exchange market, and Wu (1997) deals with rational bubbles in the US stock market. Diba and Grossman (1987a, b) attempt to determine the inception of a rational bubble and (Diba and Grossman 1988) studies explosive rational bubbles in stock

[3] Tirole (1982) showed that rational bubbles cannot arise in a model in which there is a fixed number of representative agents. This is due to the transversality condition. In another article (1985), Tirole also showed that, in nonstochastic overlapping-generation models, bubbles are ruled out in the case where the interest rate is greater than the growth rate.

[4] As mentioned by Evans (1991), rational bubbles can take the form of deterministic time trends, explosive AR(1) processes, or more complex stochastic processes.

prices as does Craine (1993). Santos and Woodford (1997) studies the general economic conditions under which rational asset pricing bubbles can form in an intertemporal competitive equilibrium framework.

In addition to speculative and rational bubbles, two other bubble types are also mentioned in the literature, ***churning bubbles*** and ***intrinsic bubbles***. The ***churning bubble***, which was mentioned in Allen and Gorton (1993), involves asymmetric information between investors and portfolio managers. This information asymmetry gives portfolio managers an incentive to churn; their trades are then motivated by the profits they earn at the expense of the investors who hire them, and as a result assets may trade at prices that do not reflect the fundamentals.

***Intrinsic bubbles*** were first mentioned in an article by Froot and Obstfeld (1991). These could be treated as a special type of rational bubble that depends exclusively on aggregate dividends and so derives all of its variability from exogenous economic fundamentals instead of extraneous factors. The striking feature of this type of bubble is that, when the fundamentals are stable and highly persistent, any over- or undervaluation in price can also be stable and persistent. Moreover, these bubbles can cause asset prices to overreact to changes in fundamentals.

So far we have been concerned only with positive bubbles, in which prices are constantly rising. But there are also ***negative asset price bubbles***, which occur when market prices are undervalued compared to the fundamentals. As Shiller (2000) says, negative speculative bubbles may occur 'as initial price declines discourage some investors, causing further price declines and so on … price continues to decline until further price decreases begin to seem unlikely, at which point there is no reason for people to want to stay away from the stock'. Thus the basic mechanism in the negative bubble is the same as in the positive speculative bubble.

The focus of this study will later turn to testing for the presence of rational bubbles in equity markets. The three classic examples – Tulipmania, Mississippi bubble and South Sea bubble – all fall within the scope of this definition. During the speculative periods in these cases, investors believed that they would be able to cash out before prices began to descend. This idea is the cornerstone of the rational bubble.

## 1.4 Reasons given for the earlier equity price bubbles

Researchers, by no means unanimous as to the existence of bubbles in asset prices, have often voiced their doubts about it. One well-known critic is Jean Tirole (1982, 1985), who has argued that in a discrete-time finite-horizon setting stock prices cannot deviate from fundamentals unless traders are irrational or myopic. As Allen and Gorton (1993) mention, Tirole makes three important arguments for excluding the possibility of finite bubbles: 'First, with a discrete and finite number of points in time a bubble would never get started because it would 'unravel' … an agent would not buy the asset at a price above the discounted value of its payoff … because he would incur a loss if he did so … by back-ward induction it follows that a bubble cannot exist at any point in time. Secondly, if the probability of being able to sell the asset tends to zero as the horizon approaches then traders can only be induced to hold the stock by a price path that goes to infinity. Because there is finite wealth, there must be a date at which the (real) price path necessary to support the bubble would exceed the total available wealth in the economy … Finally, without insurance motives for trading not all of the finite number of traders can rationally expect to benefit since they know that the bubble is a zero-sum game. If traders are risk averse, some must be strictly worse off since they bear risk and not everybody can have a positive expected return.'

Tirole's critique is sufficiently weighty to make it difficult to construct a theory on the usual assumptions that is also consistent with the existence of bubbles. This has led some authors to abandon the traditional neoclassical assumptions of rational behaviour, as Allen and Gorton (1993) point out. They cite as examples Shiller (1984) and DeLong Shleifer, Summers and Waldmann (1990). On the other hand, remaining within the world of rational behaviour but allowing for an infinite number of time periods, one can side-step Tirole's first argument. The second and the third arguments are more problematic. Still assuming rational behaviour, one can take into account such things as shifts in growth opportunities (eg 'new era' productivity), which are difficult to evaluate and hence raise difficulties for valuing the amount of wealth to be allocated in the markets, as well as shifts in the degree of risk averseness. These topics have been covered in many recent books and articles (eg Evans 2003 and Campbell and Cochrane 1999).

Despite the criticisms of Tirole and others, we proceed here on the assumption that bubbles do exist. The main reason for this is that recent studies have been able to identify bubble features in stock prices in laboratory market experiments. A recent example is that of Caginalp, Porter and Smith (2001), who found in a laboratory experiment that market bubbles are reduced when the following conditions prevail: 1) a low level of initial liquidity (less cash than total shares), 2) deferred dividends, and 3) a bid-ask book open to traders. A large bubble occurred whenever the opposite conditions prevailed.

It might be useful to take a brief look at the reasons cited for why bubbles may originate in the first place. The following have been identified in the literature as driving forces for bubbles:

**1) Breaks or major changes in regulatory environment**

History provides several examples of major changes in regulatory environment or easing of regulation that leads to rises in asset prices (Sornette 2003 and Herrera with Perry 2003). The main reason for this is that it is difficult to adjust to the new situation and correctly value all the underlying potential and effects of the changes. In such situations, asset prices are highly prone to overreaction and misjudgement. We might mention the following examples: the breakdown of the Bretton Woods system, after which the speculative peak in prices was identified as occurring in 1973; and the deregulation and its effects on the markets in Mexico in 1994–1995 and in Thailand, Indonesia, Malaysia and Korea in 1997–1998.

**2) Growth prospects**

Growth prospects and potential, within a sector or country, can be difficult to evaluate, especially when the pace of growth was previously slower and has subsequently accelerated sharply. This might easily lead to overestimation of potential and thus to overvaluation of asset prices. One good example of this is the technology bubble of the late 1990s. But history provides us with other similar examples. Rapid growth of industrial production led to the great bull markets of the 1920s and 1980s, both of which ended in stock market crashes (for 'new era' cases, see Shiller 2000 or Pastor and Veronesi 2004).

**3) Policy changes**

Changes in policies, concerning taxation, monetary operations, pensions, etc can have far-reaching effects on asset prices (see eg Shiller 2000). First, the monetary policies and other operations of central banks that are aimed at maintaining a stable environment and sound financial system, play key roles in restoring and maintaining confidence in the financial infrastructure. Overly lax lending policies, ie a surging credit expansion, can easily lead to soaring asset prices (see eg Kindleberger 2000). Tax laws that shelter contributions to assets can readily affect their demand and thus impact their prices. Concerning pension systems, an example is the 401(k) in the United States and its possible effects on developments in the US stock markets in the 1980s and 1990s.

In this connection, Allen and Gale (2000) found several common features of the asset (stock and housing) price bubbles in Japan in the late 1980s, the Nordic countries in the late 1980s and early 1990s, and the emerging markets in the 1990s – to mention just a few of the latest incidents. Based on these observations, the authors identified three phases of asset price bubbles. In the first phase, financial liberalisation or a specific decision by the central bank enables a pronounced increase in lending, which leads to a rapid expansion of credit. This expansion is then accompanied by an extended rise in asset prices. In the second phase the bubble bursts, and in the third phase some firms and agents that had borrowed to buy assets at inflated prices go under. As a conclusion of their study, Allen and Gale identified the basic reason for the formation of a bubble in these cases as the abundance (or expected abundance) of available credit in the financial system.

**4) Market infrastructure**

In the early 1920s stock market practices were still fairly undeveloped. There was a lack of financial information about public corporations, no regulation against extensive market manipulation, etc. Since the crash of 1929, the US have gotten the Securities Acts of 1933 and 1934, and finally that of 1964, which focused on qualifications of investment advisers.

Infrastructural matters were integral to the stock market crash of 19 October 1987 (Black Monday). The official explanation provided by the Brady Commission identified the cause of the crash as the inability of market systems to handle the vast amounts of selling orders that were placed in the computerized trading system. The huge volume of orders to sell was connected with dynamic hedging strategies.

The crash of 1987 became a watershed for research on stock markets. Following the crash, more attention was paid to theories that explain investor behaviour and the possible price repercussions (eg Raines and Leathers 2000).

**5) Overtrading**

Kindleberger (2000) contains an excellent summary of recent financial crises, including stock market crises. The summary enables one to obtain information on the latest stock market booms and crashes and the factors deemed to be behind them. The speculation in each case has focused on specific countries, companies, or sectors such as trading companies, railroad companies, or technology stocks. Interestingly, one of the factors that is cited in Kindleberger (2000) as being common to all of these crises is a period of overtrading. He says that 'As firms or households see others making profits from speculative purchases and resales, they tend to follow … When the number of firms and households indulging in these practices grows large, bringing in segments of the population that are normally aloof from such ventures, speculation for profit leads away from normal, rational behaviour to what has been described as manias or 'bubbles'.'

Related to Kindleberger's ideas are those of Heaton and Lucas (2000), who list some likely reasons for the latest run-up in stock prices in the latter part of the 1990s. Among the reasons: baby boomers' savings for retirement were peaking at the time; productivity growth escalated because of technological improvements and political change; stock market participation rates and public awareness of the benefits of stock market investment increased; and, as mutual funds expanded, the transaction costs declined, which enabled greater portfolio diversification. All of these factors helped to boost trading volumes. Another factor was the 'irrational exuberance' that fuelled the price rise by inculcating inexperienced investors with expectations of double-digit returns over an indefinite horizon or at least long enough to enable one to reap huge benefits and exit. This subject is more thoroughly discussed in Shiller's (2000) book.

The above-cited reasons have been identified in the literature as the primary forces driving the bubbles in asset (stock) prices. But why do we care about stock price bubbles? Are there some monetary, regulatory or broad economic reasons for seeking to identify those periods when stock prices have bubbled? The answer to this question is central to the motivation for the present study, whose primary task is to test for bubbles in different stock markets. The next section focuses on the importance of tracking bubbles.

## 1.5 Why is bubble identification important?

The main question for this study is: why should we try to determine whether asset prices are bubbling or not? Why should we care about it? The answer is critical for the motivation and foundation of our project.

The importance of tracking bubbles in asset prices is due to the relationship between asset prices and overall functionality of the financial system and performance of the economy. These documented relationships have also aroused much debate on how monetary policy should take into account the behaviour of asset prices. As commonly agreed, central banks have two primary tasks: to promote a healthy economy and price stability, and to promote the stability of the financial system. These two tasks also indicate why regulators should be interested in asset price developments and possible formation of bubbles.

We start with the first primary task of the central bank, the promotion of price stability and a healthy economy. Concerning the relationship between asset price bubbles and economic growth, it has been shown that asset price bubbles can have long-lasting effects on the financial sector and thus also on overall economic growth. As regards stock market prices, their impact on the economy comes via four different channels: 1) stock market effects on investment, 2) firms' balance-sheet effects, 3) household wealth effects, and 4) household liquidity effects.

Regarding the causal relationship between stock market prices and investment, Mishkin (2001) and Herrera and Perry (2003)[5] explain it using Tobin's q-theory. When the value of q is high, firms' market values are high compared to the replacement cost of capital, and new plant and equipment is cheap relative to firms' market values.

Firms' balance-sheet effects, as noted in Mishkin (2001), are based on easier access to credit. When the price of a firm's stock rises, its net worth also increases, which simultaneously mitigates the adverse selection and moral hazard problems, which in turn leads to increased lending to finance the investment spending.

[5] Herrera and Perry (2003), which focuses on asset price crises in the Latin America during period 1980–2001, finds a strong positive association between stock prices and investment. A similar result was obtained by Goodhart (2003): 'In this normal cyclical pattern there is a crucial inter-relationship between fluctuations in asset prices and in the economy more widely'. According to him, this applies especially to property prices, but eg equity prices 'have been relatively more important in the US than elsewhere'.

The crux of the matter as regards household wealth and liquidity effects is in the fact that agents' decisions depend on wealth, which is affected by movements in stock prices. Rapidly rising stock prices may be interpreted as a signal of brighter growth prospects, which will lead to higher levels of expected employment and labour income and thus to a higher level of private consumption. This can lead to an increase in consumption and even to overconsumption if the stock market run-up is robust, as mentioned in Dupor and Conley (2004). Brighter prospects in certain sectors of the economy also attract investment flows, as the growth potential raises investors' hopes of better returns on capital.

The liquidity effect relates not only to households but also to firms, as mentioned. Herrera and Perry (2003) and Bean (2004) describe the effect as follows: appreciating asset values raise the value of collateral, which facilitates the accumulation of debt. Especially during an upswing balance sheets will look healthy, as asset-value appreciation becomes widely apparent.

As seen above, there are several links between asset prices and economic activity. These apparently affect the allocation of the capital, investment and demand. Because bubbles are based on misplaced expectations of the growth potential of certain sectors of the economy, they may cause inefficiencies in the allocation of resources in the economy. Financial resources may be used for capital investments in sectors where growth prospects are highly overstated. Indeed, Gilchrist, Himmelberg and Huberman (2004) show how stock market bubbles influence corporate investment by inducing firms to issue more shares and thus to raise new funding for investment. On a large scale, such a process would surely prove to be highly important, as the particular directions in which these new financial resources flow can affect the economy's future growth aspects and even the level of employment. It is clear that this is the sort of chain of events that occurred, at least on some scale, in the latter part of the 1990s. As Lansing (2003b) mentions, 'Firms vastly overspent in acquiring new technology and in building new productive capacity'. Another serious effect was that these booming sectors recruited lots of people who then lost their jobs in the course of the bust. Lansing (2003b) shows that the decline in business investment during the 2001 recession was much more pronounced than the average for the US economy, which is viewed as the result of the oversized investment boom in the late 1990s. In this respect, misallocation of capital can have long-run effects on economic growth.

In light of the above discussion, one might well ask whether a central bank should engage to pre-emptive policy actions in order to prevent possible misallocations? Two different types of such preemptive policy action have been discussed. Bernanke (2002) refers to these as 'leaning against the bubble' and 'aggressive bubble popping'. The first of these means that the central bank should take account of, and respond to, the effects of asset price changes on its macroeconomic target variables and should try to steer the asset prices away from the presumed bubble path. Aggressive bubble popping is even stricter: the central bank should sharply boost interest rates whenever it observes a potential bubble in asset prices. There are several problems connected with these proactive approaches. First, they require identification of bubbles in real time, or preferably even earlier. The big problem here is that we have no means of reliably forecasting the timing of a bubble. As Alan Greenspan[6] put it, 'There is a fundamental problem with market intervention to prick a bubble. It presumes that you know more than the market.' Another problem, mentioned in Bernanke (2002), is that besides deciding whether or not a bubble exists, the central bank should also measure the part of the price increase that is justified by fundamentals and the part that is not (see also Bean 2004). Finally, we would mention the problem of timing the policy action. Even if the problems related to bubble and fundamental value are solved, the fact is that the instruments of monetary policy are very blunt. As Bean (2004) puts it, 'Once a bubble is large enough to be reliably identified, the presence of lags in the monetary transmission mechanism complicate the calibration of an appropriate policy. Raising official interest rates will be counterproductive if the bubble subsequently bursts, so that the economy is subject to the twin deflationary impulses of the asset price collapse and the effect of the policy tightening.' Cogley (1999) raises the same point: 'deliberate attempts to puncture asset price bubbles may well turn out to be destabilizing … inability to identify speculative bubbles makes it difficult to take timely and well-measured countervailing actions.'

Another important link between asset prices and monetary policy is that of inflation. Academic discussion on this field has focused on a couple of core issues. The first relates to the ability of asset prices to signal future changes in inflation and the second one relates to the actual measurement of inflation. Regarding the first issue, it has been suggested that a rise in stock prices could be interpreted as a signal of improving economic conditions. This could lead to a rise in consumption and investment, which in turn would lead to a further

[6] Alan Greenspan, New York Times, 15 November 1998.

advance in inflation via growing demand pressures in the economy. Based on this argumentation, asset prices rise can be viewed as a leading indicator of inflation.

If the relationship were as straightforward as this, things would be relatively simple. But as Bernanke and Gertler (1999)[7] put it, 'Changes in asset prices should affect monetary policy only to the extent that they affect the central bank's forecast of inflation'. The same message is repeated in Bernanke and Gertler (2001): 'an aggressive inflation targeting rule stabilizes output and inflation when asset prices are volatile, whether the volatility is due to the bubbles or to technological shocks; and that, given an aggressive response to inflation, there is no significant additional benefit to responding to asset prices.[8]' In this respect, it would not matter whether or not there was a price bubble, as monetary policy should be tightened if inflation was projected to accelerate. Bernanke and Gertler in fact anchor their argument on the idea that, as regards rises in stock prices, the central bank is unable to distinguish between those driven by bubbles and those driven by fundamentals. Moreover, since both types of shock ultimately affect real output and inflation, the central bank might just as well respond directly only to fluctuations in these variables – and not to fluctuations in asset prices (see eg Lansing 2003a).

A somewhat different line of reasoning regarding the optimal policy response is found in a discussion paper by Kent and Lowe (1997), which argues that the negative impact of an asset price bubble could increase if it is deflated in time. The asset price bubble could burst in either the near or more-distant future. The further the bubble proceeds, the stronger the eventual impact it is likely to have on inflation and output. Therefore it would seem appropriate for the central bank to take action at an early stage by tightening monetary policy and thus rendering less likely the more extreme outcomes for inflation and output that might result from a prolonged bubble, even if such early action would drive inflation below target in the near future.

Cecchetti, Genberg, Lipsky and Wadhwani (2000) come to a similar conclusion: they propose that central banks raise short-term nominal interest rates in response to bubbles so as to improve overall macroeconomic performance. Cecchetti, Genberg and Wadhwani (2003) confirm that conclusion: 'Monetary policy that pursues an inflation-targeting strategy should attempt to identify and respond to asset price misalignments'.

[7] See also Bernanke and Mishkin (1997).
[8] See also Goodfriend (2003).

As we have seen, regarding inflation and output stability, there are two perspectives. On one hand, it is felt that since the central bank cannot distinguish between bubbles and fundamental shocks it is better to react only to observed developments in inflation and output. The other view asserts that economic performance would be improved if the central bank were to respond to bubble shocks. Regarding the two perspectives, two issues would seem essential. First, the central bank needs to know the extent to which asset prices contribute to overall inflation and, secondly, whether asset prices reflect the existence of a bubble. This knowledge would help the central bank perform its most demanding task, that of optimising the manner and timing of monetary policy actions.

Of course the measurement of expected inflation is central to monetary policy analysis, but even the measurement of actual inflation has come under serious debate. In academia, the debate has focused on two questions: What specific price index should a central bank target and should that index include prices of assets as well as prices of goods and services? Goodhart (1993) recommends that central banks replace the conventional inflation measures based on prices of goods and services with broader measures that include prices of housing and shares. This recommendation is clearly based on several historical events, including those in Japan in the late 1980s and early 1990s, the United Kingdom in the late 1980s and early 1990s, and the United States in the late 1990s. In the United Kingdom, as in Japan, the problem was that inflation remained low and stable for a long time even while the asset prices appreciated rapidly. As Mussa (2003) puts it, the problem in Japan was that 'the general inflation remained very low in 1988–1989, and it was difficult for the Bank of Japan to find a reason to begin to tighten monetary policy based on general inflationary pressures'. Prices of assets (land, buildings and shares), and hence their value as collateral, soared. The monetary tightening in Japan came too late. When consumer price inflation finally began to accelerate (peaking in 1991 at 4%), monetary policy was tightened. But this drove asset prices down, which in turn sharply reduced the value of collateral on banks' balance sheets and forced abundant write-offs (see eg Yamaguchi 2003). The United Kingdom experienced a strong rise in asset prices in 1985–1987, but again inflation accelerated with a lag, starting in 1988, which then induced the central bank to tighten monetary policy. As Filardo (2000) mentions, inflation had already climbed to 6% pa by the end of 1989, and in 1990 it was still higher. As to the most recent asset price upheaval in the United States, around the end of the 1990s, it is noteworthy that once again the CPI remained subdued for a long time, giving only muted signals of a pickup during the years 1999–2000. The overheating of the market was not reflected in the rate of the inflation (eg Mussa 2003).

If a central bank were to literally observe Goodhart's recommendations in its use of a broader measure of inflation, this would, as mentioned by Filardo (2000), mean that an increase in asset price inflation could prompt tighter monetary policy even if conventionally-measured inflation remained low and stable. In the examples of the United Kingdom and Japan, this would have led to monetary policy tightening much earlier then happened in fact, and the subsequent inflationary pressures would have been mitigated.

Concerning the question of a broader measurement of inflation, there are several interesting findings. Bryan, Cecchetti and O'Sullivan (2002), an interesting study on whether asset prices should be incorporated into the aggregate price statistic, finds that 'the failure to include asset prices in the aggregate price statistics has introduced a downward bias in the US Consumer Price Index on the order of magnitude of roughly ¼ percentage point annually'. This result implies that measured inflation lags behind actual inflation, which was higher than inflation as measured by the CPI. But as Filardo (2003) points out, 'If the increase in asset prices was due to higher expected goods prices, then the Bryan, Cecchetti, and O'Sullivan method would lead the monetary authority to tighten monetary policy and reduce the inflationary pressures. If, however, the increase in asset prices was due to an asset price bubble, then the Bryan, Cecchetti, and O'Sullivan method would generate an upward bias in their cost of life inflation measure and cause monetary authority to pursue an unnecessarily tighter monetary policy.' The key issue here is the extent to which an asset price rise passes through to inflation. The overall usefulness of including housing or stock prices directly in the inflation measure, as proposed by Goodhart, is not supported by Filardo (2000). His empirical analysis questions whether Goodhart's recommendation would lead to better economic outcomes. According to his results, housing price inflation does have some power in predicting future inflation, whereas share price inflation exhibits no power at all to predict future consumer price inflation.

Besides inflation and health of the overall economy, the other primary task of the central bank is to promote the overall stability of the financial markets. This brings us directly to the question of how a central bank should react to bubbles so as to promote financial stability. Concerning monetary policy actions and bubbles, there is no unanimous agreement on how to act. In responding to asset price bubbles, a central bank should be either reactive or proactive, as mentioned eg in Bean (2004). Reactive monetary policy should remain focused on achieving macroeconomic goals and should therefore deal only with the fallout from the unwinding of an asset bubble, whereas according to the proactive approach it is better to take pre-emptive actions against a bubble during an upswing in order to limit the potential cost of a collapse of the bubble. The main argument for proactiveness is that monetary policy should prick the bubble before it gets too large, since a long and steep fall in asset prices could have pronounced adverse effects on overall financial stability (eg Kent and Lowe 1997). As Bean (2004) also mentions, asset price bubbles are of concern to regulators because of the potential detrimental effects of bubble bursting in terms of financial instability and output contraction. In fact many (but not all) so-called bubble-periods and their collapses have been followed by financial system crises (see eg Kindleberger 2000).

It is well documented that the link between asset price bubbles and financial stability can lead to highly adverse outcomes. Kent and Lowe (1997) mention that 'A major fall in equity prices can create problems in the payment systems, with potentially large adverse consequences, … borrowers may find themselves unable to repay their loans'. One might well recall the major problems that emerged in the Japanese banking sector when collateral values suddenly plummeted. As Mishkin and White (2003) point out, the most important consequence for a policy-maker facing a stock market crash to consider is not the crash itself but rather the financial instability that may follow. The financial aftermath of a stock market crash is highly dependent on the strength of the balance sheets of financial and nonfinancial corporations.[9] If balance sheets are in good condition, the crash will not necessarily lead to a large-scale bout of financial instability but will operate through the usual wealth and cost-of-capital channels to impact the level of aggregate demand.

Considering the connection between bubbles and crashes and financial stability, it would seem appropriate to use two sets of indicators, one to indicate whether market prices are starting to bubble and another to indicate the condition of the balance sheets of financial and nonfinancial corporations. The extreme cases of financial

[9] Especially related to the financial sector distress, von Goetz (2004) researched the links between asset prices and banking distress in a monetary macroeconomic model. He's main idea was to look how falling asset prices affected the banking system via widespread borrower defaults. He came into the conclusion that the effect of falling asset prices is indirect, non-linear, and involves feedback from the banking system in the form of a credit contraction.

instability apparently emerge when asset price bubbles are combined with unhealthy balance sheets, as mentioned in Mishkin and White (2003). The combined information garnered from these two sets of indicators could markedly improve the ability of policy-makers to respond to situations in which financial stability is jeopardised.

To sum up what has been said above concerning optimal policy actions and developments in the asset prices, we focus on the following three core areas:

I. Asset prices and price stability. This concerns inflation and in two related issues. First, can developments in asset prices signal future acceleration of inflation and, secondly, should asset prices be included in the inflation measure? The second of these points has arisen because of historical experiences in which inflation has accelerated only with a significant lag but then so rapidly that the monetary policy actions needed to tame it have been robust enough to abet the downfall of asset prices. Optimal policy responses in these cases would thus occur at an early stage, at the onset of the asset price boom. It should be noted that the wisdom of acting in this manner depends more on the magnitude of the price surge and not so much on whether a bubble is present.

On the other hand, if one feels that asset price appreciation signals a future increase in inflation, the optimal policy action is either to tighten monetary policy immediately when the effects become apparent in either inflation or output, or already when asset prices begin to soar. Concerning reactions to an asset price rise without observing a rise in the rate of inflation, there are two viewpoints. According to one viewpoint, monetary policy should be tightened also in those cases where prices are bubbling. The other viewpoint says that tightening in such cases should be extremely cautious, since a bubble left alone might burst in its own time and leave the future inflation rate lower than had been expected. An optimal policy response thus depends on the chosen manner of acting. If it is decided to react already to a surge in the price level, it might be important to know first whether there is a bubble, instead of reacting directly to the price increase.

II. Asset prices and overall economic performance. Positive developments in asset prices increase wealth, companies' net worth, collateral values, etc. The latter developments boost investment and consumption. Positive developments in prices also indicate expectations of future growth and these expectations can affect investment. In such cases, if there is a market bubble developing, it may induce overly optimistic expectations, which can lead to overconsumption, overinvestment and misallocations of investment. Concerning the optimal policy response in these cases, it is recommendable to act when prices begin to bubble.

III. Asset prices and overall financial stability. Positive developments in asset prices increase collateral values and strengthen companies' balance sheets, which makes it easier to borrow. Therefore, on should not overestimate the values of companies or the collateral. If such valuations are overly optimistic, this may lead to sudden plunges in collateral values and, if financial institutions are not in good condition, to serious problems for overall financial stability. The optimal policy response would be to develop indicators of the condition of financial institutions and of bubble pressures, in order to be able to tame the bubble pressures in time.

As noted above, in many cases it would be recommendable to react only if there is a strong surge in the price level, whereas in some cases it would be crucial to know whether a bubble is forming or price rises are being driven by improved fundamentals. These points serve to motivate and provide the basis for our analysis. They imply that regulators would greatly benefit from information on the formulation of bubbles and bubble-pressures in asset prices, even though the following actions and appropriate policy response could differ from case to case. In the following chapters the main focus will be on developing and testing a facile method of identifying bubbles from asset price data using the unit root approach.

# 2 Identification of asset price bubbles – methods of testing for existence

In light of the problems in measuring bubbles, it is no wonder that a great number of econometric tests have been developed to detect asset price bubbles. Most of these tests have so far focused on detecting 'rational' bubbles.

As Gurkaynak (2005) mentions, the first econometric tests of rational bubbles were based on variance bounds (eg Shiller 1981, LeRoy and Porter 1981). The underlying idea is that it is possible to define bounds on the variance in asset price series under the assumption that prices are formed as the present value of dividends. When the variance bound is violated, this means that equity prices are not constructed as sums of expected discounted dividend flows. However, as Gurkaynak (2005) also pointed out, the underlying problem in all variance bound tests is that they are tests of present value models, and rejection can be due to a bubble or any other cause. Violations cannot be attributed solely to the presence of bubbles. A clear step forward in this sense came with the test developed by West (1987), the main contribution of which was to test separately for the presence of bubbles and model misspecification. His main innovation was to observe in two different ways (Euler equation and AR representation) how dividends impacted on equity prices and, after model specification tests, to argue that the price estimates produced by these two methods should be the same unless there is a bubble present in the prices. Flood, Hodrick and Kaplan (1987) regarded West's test as a significant advance in bubble testing, but found some evidence of model misspecification. Dezbakhsh and Demirguc-Kunt (1990) also used a procedure similar to this procedure, but modified it because of what they saw as size distortions in small samples.

An approach slightly different from that of West was used by Diba and Grossman (1987, 1988). In their analysis, the basis is still the present value formula, but they focus on the cointegration of dividends and stockprices since, in the absence of bubbles, the stationarity of dividends should account for the stationarity of prices no matter how many differences are taken in the dataseries. In their 1987 article they came to the conclusion that rational bubbles cannot start if they do not already exist. This meant that if a bubble was found in a stock's price, it must have been present at the initial sale.

Consistent with this, they showed that if an existing rational bubble bursts a new independent rational bubble cannot start. Campbell and Shiller (1987) also tested the cointegration in stock prices and dividends and extended their approach (1988, 1989) to allow for a stochastic discount factor and log linear approximation of the dividend/price ratio.

Evans (1991) strongly criticised Diba's and Grossman's argument, according to which bubbles cannot pop and restart. Evans showed by using Monte Carlo simulations that an important class of rational bubbles, so-called periodically collapsible bubbles (bubbles that erupt and start over again after collapsing close to zero value ), could not be identified by using standard tests for unit roots and cointegration, even when such bubbles were present by construction. He demonstrated that it was possible to construct a situation where prices were more explosive than dividends, but which appeared to be stationary when unit-root tests were applied. The problem was that periodic collapses in series made the processes look like stationary processes.

Evans' critique affected the bubble-testing literature. The subsequent literature focused on finding a way to test for bubbles in processes where the bubbles could erupt and start over again. One of the favourite methods was to treat bubble expansion and contraction as results of two different regimes, which could be tested via regime switch models. Related studies include Van Norden and Vigfusson (1996), Van Norden and Schaller (1997) as well as Hall and Sola (1993). Wu (1997) applied a slightly different approach in which he treated a bubble as an unobservable state vector and estimated it with a Kalman filter. His result was that estimated bubble components accounted for a substantial proportion of US stock prices. Bohl and Siklos (2004) used a momentum threshold autoregressive technique designed to detect asymmetric short run adjustments to the long run equilibrium and Wu and Xiao (2004) focused on testing periodically collapsible bubbles by introducing an alternative test that focused on the order of magnitude of fluctuations in the partial sum process of residuals from regressing asset prices on fundamentals. In something of a return to the roots, Koustas and Serletis (2005) analysed long US data series using traditional unit-root tests as well as performing tests for fractional integration in the log dividend yields. A summary of bubble- tests can be found in Table A2.1 of Appendix 2.

It is troublesome that the results from these articles still do not give us a definite answer as to the existence of bubbles. As a consequence of this uncertainty, there is a growing branch of literature that seeks to determine whether the modelling of fundamentals in price formation should be different from the plain present value model. Among these works are Ackert and Hunter (1999), Pastor and Veronesi (2004), Balke and Wohar (2001) and Heaton and Lucas (2000).

Our approach to the problem is more traditional. We use the traditional present value model as the foundation and our methodology comes from Campbell and Shiller (1988a and 1988b), Campbell, Lo and McKinlay (1997) as well as Koustas and Serletis (2005). However, our answer to Evans' critique is based on methods introduced in recent time-series analysis. The time-series analysis literature has advanced arguments according to which a process that changes between stationary and unit-root process during the sample, can be tested by using a unit-root test based on changing sub-samples of the data (Banerjee et al (1992)). Consistent with this, Taylor (2005) showed recently that when the change in the stationarity of the process is either I(1)-I(0)-I(1) or I(0)-I(1)-I(0), the rolling augmented Dickey-Fuller test is relatively robust for unit-root testing. As we assume that bubbles can change between expansive and contradictory phases, the stationarity of the process could change in either direction. Therefore we decided to use rolling augmented Dickey-Fuller tests. A further advantage is that in using rolling sub-samples we are able to get frequent assessments of the validity of market pricing. Data we are operating with consist of monthly observations of price indexes and dividends from the United States and Finland[10]. Frequent observations are not available for testing with annual data, which have previously been most often used in such tests.

[10] The United States stock market data was picked out due to it's long availability and the market data from Finland was included due to it's uniqueness. The Finnish data has some extremely interesting features: it is very volatile, there is extremely severe depression in the early 1990's and very strong technology-related boom in the stock prices in the end of 1990's and early 2000.

# 3 Testing for bubbles in the Finnish and US stock markets

## 3.1 Why dividend yield data?

The bubble test that we use is based on dividend yield data. Why did we choose to use such data? In addition to factors related to the methodology used, which were discussed above, a decisive reason for using dividend yield data was that dividend yields are among the commonly used summary statistics for valuations in the equity markets. Of course, dividend yield has its limitations, as shown eg by Vila-Wetherilt and Weeken (2002), but there are also some studies that show that dividend yields can actually predict market returns. We would mention a recent study by Lewellen (2002) and another by Campbell, Lo and MacKinlay (1997). Lewellen was able to show that dividend yields predicted market returns for the period 1946–2000 (NYSE data) as well as for several subsamples. Campbell, Lo and MacKinlay (1997), on the other hand, found that 'In US data the (dividend yield) is the most successful forecasting variable for long-horizon returns and on a short-term nominal interest-rate variable'. Based on these observations, we decided that testing on the basis of dividend yield data would be worthwhile.

## 3.2 The data

The raw data for Finland consist of dividend yields for the Finnish stock market, the total return index, and the HEX all-share index covering the period 31 December 1990 to 30 September 2004. Indices below are used in the construction of the dividend yield series in Section 3.3. The modifications discussed there allow us to extend the basic bubble testing to countries where testing has previously been hindered by a lack of suitable data.

The dividend yield (DY) series, which we use in the Chapter 4 in constructing a bubble indicator, were obtained from several commercial sources:

1) HEX all-share dividend yields provided by Bloomberg. The DY data are from monthly observations, and DY is calculated as the sum of the amount of gross dividend per share that has gone ex-dividend

over the prior 12 months divided by the current stock price. For the HEX index, the DY data are available from Bloomberg for the period 30 September 1993 – September 2004.

2) Global Financial Data DYs for Helsinki Stock Exchange. These monthly data cover the longest period, 31 January 1962 – September 2004. Global Financial Data DYs are the most important data inputs that we use, because of the length of the period available.

3) MSCI (Morgan Stanley Capital International) DYs constructed from MSCI Local (Finland) total return and price indices. DYs are constructed using the modification method presented in Chapter 3. In the MSCI local index for Finland, the number of stocks included is less than in the HEX all-share index. For this reason, the level of DYs differs somewhat. The DYs based on MSCI indices, cover the period 31 December 1988 – September 2004.

The raw data for the US stock market consist of dividend yields and total return and price index data for the S&P500[11]. The index data used here in connection with the modification method cover the period 31 December 1987 – 29 October 2004 and were provided by Bloomberg.

1) Bloomberg's DY data consist of monthly observations, and DY is calculated as the sum of gross dividends per share that have gone ex-dividend over the prior 12 months divided by the current stock price. For the S&P500, DYs are available from Bloomberg for the period December 1987 – 31 October 2004.

The dividend yield series that we use in Chapter 4, where we construct a bubble indicator, were obtained from the Global Financial Data:

2) Global Financial Data DYs for S&P500. These monthly data cover the longest period, 28 February 1871 – 29 October 2004.

Before presenting the modification method for testing for unit roots in the dividend yield series, it might be worthwhile to look at the overall development of dividend yields over the period under observation in

[11] Standard and Poor's 500 Index is a capitalization-weighted index of 500 stocks. It measures performance of the broad US economy via changes in the aggregate market value of 500 stocks representing all major industries. For more information, see www.standardandpoors.com / S&P Indices Methodology-guides.

the United States and Finland. One striking characteristic in both DY series (as seen in Figures 3.1 and 3.2) is the clearly observable downward trend.

This observation of course raises the question of whether companies' dividend distribution policies have changed significantly. In this connection, a number of interesting findings have emerged, which could affect the price-dividends relationship. One striking finding on dividends is presented in Fama and French (2001), which shows that the number of dividend payers decreased during the period 1978–1998. However, this does not mean that dividends are disappearing. DeAngelo et al (2004) were able to show that dividend payouts have become concentrated among the top earners. Brav, Graham, Harvey and Michaely (2003) found that firm managers seem to be reluctant to reduce dividends and that dividends are fairly steady over time. Dividend increases are tied to long run sustainable earnings but much less so nowadays than in the past. Stock repurchases are definitely viewed as an alternative to dividend distributions.

Considering the central role played by dividends in the present value pricing model, any dramatic change in payout policy could be problematic for the traditional present value pricing model. But as long as there are no dramatic changes or the emergence of a superior model, there is no reason to alter the approach to modelling stock prices. For this reason we stick with the basic present value pricing model as the foundation for the analysis that follows.

Figure 3.1 **Dividend yields, Finnish D/Y's, 1971–2004**

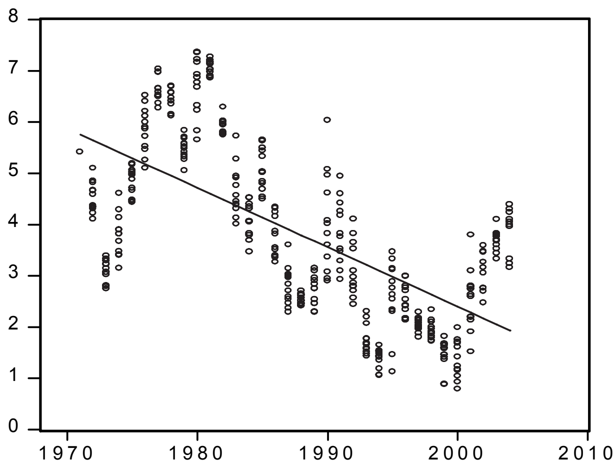
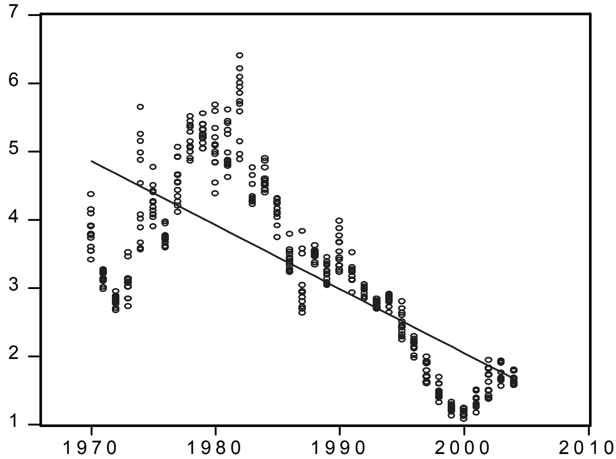


Figure 3.2 **Dividend yields, S&P500, 1970–2004**




## 3.3 Basic market data and modifications

In order to test for stationarity of the log of first difference of dividends, $\Delta d_t$, and log of stock returns, $r_t$, and for unit roots in the log dividend yield series[12], we need to have the appropriate data. This data must contain information on dividends, stock returns and dividend yields over a fairly long period of time.

In many of the earlier tests and studies of bubbles, the data frequency has been annual, which is quite sparse considering the nature of the phenomenon in question. Asset market bubbles usually peak quickly, and so annual series are likely to produce only very weak indications of bubbles. This is the main reason why we chose to use monthly data in this study. This is somewhat problematic because some of the data, eg the dividend series, are recorded only on a yearly basis (especially for Finland). In order to produce a monthly series, we had to do some modifications, which generally proved to work fairly well. In these data modifications[13] we used the information from total return indices and stock price indices to create a monthly dividend yield series.[14]

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[12] Justification for this testing procedure will be given in the Chapter 3.
[13] Similar data modifications have been used eg in Kajanoja (2004).
[14] In the Global Financial Data DYs no modifications were necessary as the data was monthly.

The crux of the modification is related to the fact that we had only daily observations on a total return index (TRI), and so we used the following approximation method, where $P_t$ is the value of the stock price index in period (t) and $D_t$ the amount of dividends associated with the index stocks in period (t):

$$\frac{TRI_t}{TRI_{t-1}} \equiv \frac{P_t + D_t}{P_{t-1}} \tag{3.1}$$

Thus the present dividend-price ratio (dividend yield) can be written as

$$\frac{D_t}{P_{t-1}} = \frac{TRI_t}{TRI_{t-1}} - \frac{P_t}{P_{t-1}} \tag{3.2}$$

In order to approximate the amount of dividends, we multiplied the resulting dividend yield $\frac{D_t}{P_{t-1}}$ from equation (3.2) by the sum of market values of companies included in the stock price index.

From the daily observations, it was easy to sum up a period to be scrutinised. We used the monthly (30-day) period and the following approximations for the variables $R_t$ (stock return in period t) and $D_t$:

$R_t$ is approximated by $\frac{TRI_t}{TRI_{t-1}}$ [15] (3.3)

$D_t$ is approximated by $P_{t-1} \cdot \left[ \frac{TRI_t}{TRI_{t-1}} - \frac{P_t}{P_{t-1}} \right]$ [16] (3.4)

Dividend Yield, $DY_t$, is approximated each month by $\frac{\sum_{t}^{t-364} D_t}{P_t}$ [17] (3.5)

The modified data loses some accuracy due to approximations used, but the advantages of using it clearly outweigh the drawbacks. The

[15] For a 30-day period (month), this is the sum of rolling 30-day returns.
[16] Again the monthly observation is the sum of rolling 30-day dividends.
[17] This includes the previous year's dividends and is rolling for each month, because dividends usually accrue over a one-year period.

most important advantage is that this enabled us to search for bubbles in more frequent (monthly) data and across many different countries and industry sectors, since the index data required for constructing the testable DY data (total return and price index) is nearly always available from the stock exchanges.

In order to be convinced that this modification produces a robust dividend yield level, we can compare the constructed dividend yields with dividend yield series obtained from commercial sources. This enables us to see how closely our dividend yield levels accord with actual data observations.

Comparisons (Figures 3.3 and 3.4) of constructed DYs reveal fairly close agreement with actual DY data. The fit seems to be better for S&P500 data than for the Finnish data. This may be partly due to the way in which the dividends were paid on the stocks.

Figure 3.3 **Dividend yields, Finland**

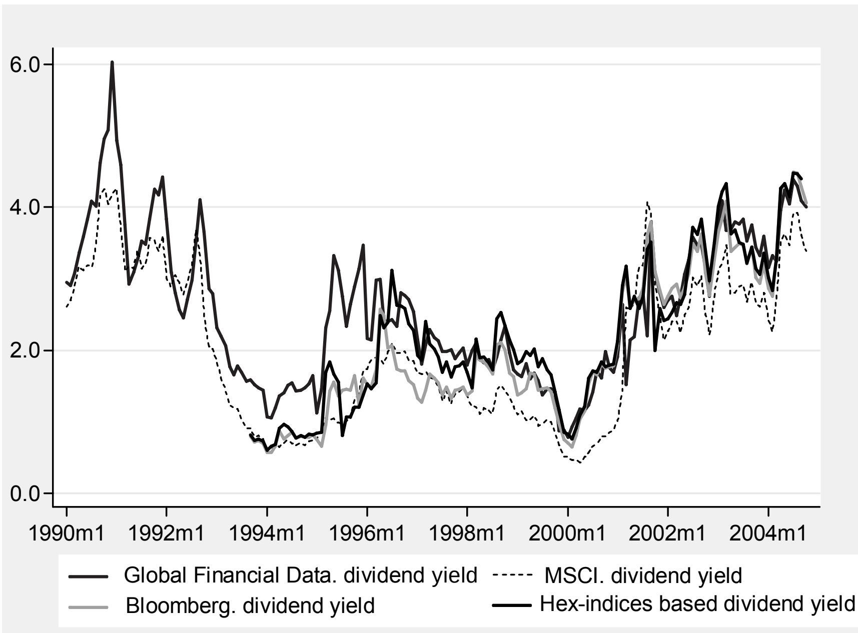
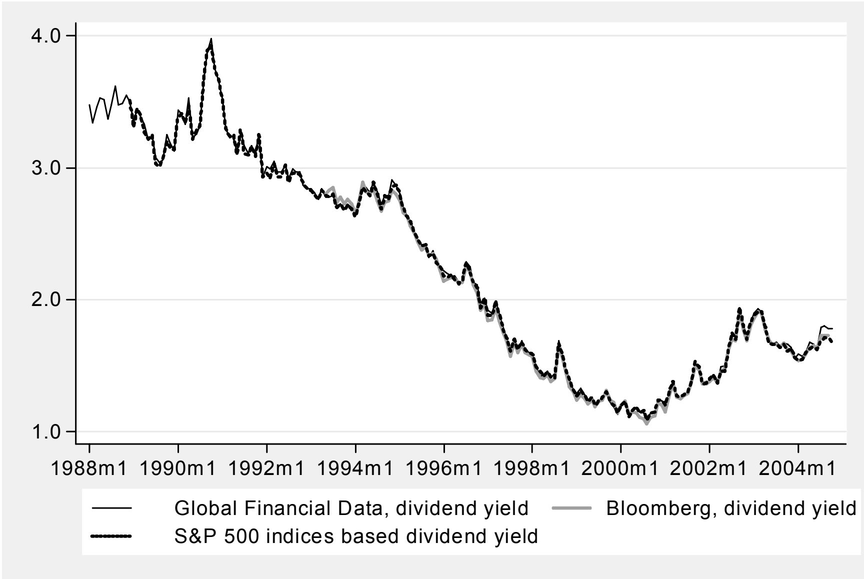


Figure 3.4 **Dividend yields, S&P500**




## 3.4 Testing for rational bubbles – unit root model

In this section we present the basic model used in constructing the test for rational bubbles in stock prices. We rely heavily on four sources: Campbell, Lo and McKinlay (1997), Campbell and Shiller (1988a and b) and Koustas and Serletis (2005).

Let us begin by defining the net simple return of a stock as

$$R_{t+1} = \frac{P_{t+1} - P_t + D_{t+1}}{P_t} = \frac{P_{t+1} + D_{t+1}}{P_t} - 1 \tag{3.6}$$

where $R_{t+1}$ denotes the return on stock held from time t to t+1, P the price of the stock and D the dividend. The return is not known until period t+1. Taking the expectation of identity (3.6), which is based on information at period t and rearranging, we obtain

$$P_t = E_t\left[\frac{P_{t+1} + D_{t+1}}{1 + R_{t+1}}\right] \tag{3.7}$$

Extending the expression for k periods, yields (note that i=k)

$$P_t = E_t\left[\sum_{i=1}^{k}\left(\frac{1}{1+R_{t+i}}\right)^i D_{t+i}\right] + E_t\left[\left(\frac{1}{1+R_{t+k}}\right)^k P_{t+k}\right] \qquad (3.8)$$

The last term in equation (3.8) is the expected discounted value of the stock price k periods ahead. As the horizon lengthens, this term is assumed to converge to zero. This assumption is satisfied unless the stock price is expected to grow forever at rate $R_{t+k}$ or faster. Under the convergence assumption, equation (3.8) can be solved forward by expressing the fundamental value of the stock, $F_t$, as the expected present value of future dividends

$$F_t = E_t\left[\sum_{i=1}^{\infty}\left(\frac{1}{1+R_{t+i}}\right)^i D_{t+i}\right] \qquad (3.9)$$

Abandoning the convergence assumption leads to an infinite number of solutions, all of which can be written in the general form

$$P_t = F_t + B_t \quad \text{as} \quad B_t = E_t\left[\frac{B_{t+1}}{1+R_{t+1}}\right] \qquad (3.10)$$

ie the price comprises the fundamental value plus the component $B_t$, which denotes a rational bubble.

So far, expected stock returns were assumed to be constant. Though this assumption is convenient, it contradicts reality, as expected stock returns are time-varying, which makes the relationship between prices and returns nonlinear. To overcome the problems of nonlinearity, Campbell and Shiller (1988a) suggest a loglinear approximation given by

$$r_{t+1} \approx k + \rho p_{t+1} + (1-\rho) d_{t+1} - p_t \qquad (3.11)$$ [18]

Approximation (3.11) holds exactly when the log dividend-price ratio is constant, as $d_{t+1}$ and $p_{t+1}$ then move together in step. Equation

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18 Here $k \equiv -\log(\rho) - (1-\rho)\log(\frac{1}{\rho - 1})$ and $\rho \equiv \frac{1}{[1+\exp\overline{(d-p)}]}$

(3.11), which is a linear difference equation for the log stock price, is analogous to the linear difference equation for the level of stock price with constant expected returns. In similar way as before, we can impose the no-rational-bubble terminal condition. Solving equation (3.11) forward and imposing the no-rational-bubble terminal condition, we obtain

$$p_t = \frac{k}{1-\rho} + \sum_{j=0}^{\infty} \rho^j \left[(1-\rho)d_{t+1+j} - r_{t+1+j}\right] \tag{3.12}$$

Equation (3.12) shows that if the stock price is currently at a high level, there must be some combination of high dividends and low stock returns in the future. This holds ex post, but also ex ante. For the ex ante version, we take expectations of (3.12) and take into account that $E_t[p_t] = p_t$ to obtain

$$p_t = \frac{k}{1-\rho} + E_t\left[\sum_{j=0}^{\infty} \rho^j \left[(1-\rho)d_{t+1+j} - r_{t+1+j}\right]\right]. \tag{3.13}$$

Equation (3.13) is a dynamic generalisation of the Gordon formula[19]. The main difference is that in the dynamic formula the effect on the stock price depends on how long the dividend growth rate is expected to be high or the discount rate low. We rewrite equation (3.13) so that instead of using the log stock price we use the log dividend-price ratio

$$d_t - p_t = -\frac{k}{1-\rho} + E_t\left[\sum_{j=0}^{\infty} \rho^j \left[-\Delta d_{t+1+j} + r_{t+1+j}\right]\right] \tag{3.14}$$

We focus now on equation (3.14). Recalling that Craine (1993) pointed out that if $\Delta d_t$ and $r_t$ are stationary stochastic processes, then the log dividend yield, $d_t – p_t$, is a stationary stochastic process under the no-rational-bubble restriction. Therefore, if we can find a unit root in the log dividend yield, this is consistent with the existence of rational bubbles in stock prices when $\Delta d_t$ and $r_t$ are stationary and stochastic processes.

[19] With the expectation of constant required returns and constant dividend growth.

## 3.5 Test results from the unit root model

The bubble-testing method described above can be summarised as follows:

1) Test whether $\Delta d_t$ and $r_t$ can be considered stationary series

2) If this is the case, test whether the log dividend yield $d_t - p_t$ is a stationary stochastic process, as it should be under the no-rational-bubble restriction. Finding a unit root in the log dividend yield is consistent with the existence of rational bubbles in stock prices during the testing period.

Our next step was to perform the above tests on the Finnish and US data series. The results are reported below in Tables 3.1 and 3.2. For the Finnish stock market data, both $\Delta d_t$ and $r_t$ proved to be stationary processes. All the tests using various time periods indicated the existence of a unit root in the series $d_t - p_t$. This is strong evidence for the existence of asset price bubble(s) in the Finnish stock market during the testing periods.

In order to further increase our confidence in the results, we applied both the augmented Dickey-Fuller and Phillips-Perron unit root tests[20] and also tested a variety of lags[21]. One could further confirm the results, especially if level shifts are spotted, by applying the modified testing procedures suggested by Lanne, Lütkepohl and Saikkonen (2002). However, for this study, the decision was made to stick with the basic unit root tests. These tests indicate the presence of a bubble(s) in the Finnish stock markets during the period 31 December 1971 – 30 September 2004.

[20] The augmented Dickey-Fuller and Phillips-Perron tests were chosen because they use different methods to control for higher-order serial correlation.

[21] Number of lags was either preset or chosen via the following tests: AIC (Akaike information Criteria) in ADF or Newey-West in PP.

Table 3.1 **Tests for order of integration, Finland**

1) Tests based on index data from HEX, 31 Jan 1991 – 30 Sep 2004

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $r_t$ | Monthly (eom) | -5.157 (PP)[22] | bandw.: 6[23] | -2.886 (C)[24] | unit root is rejected, $r_t$ is I (0)[25] |
| $r_t$ | Monthly (eom) | -7.225 (PP) | bandw.: 7 | -3.449 (C+T)[26] | unit root is rejected, $r_t$ is I (0) |
| $\Delta d_t$ | Monthly (eom) | -9.866 (ADF) | 0, based on AIC | -2.882 (C) | unit root is rejected, $\Delta d_t$ is I (0) |
| $\Delta d_t$ | Monthly (eom) | -10.280 (PP) | bandw.: 6 | -2.882 (C) | unit root is rejected, $\Delta d_t$ is I (0) |
| $d_t - p_t$ | Monthly (eom) | -1.770 (ADF) | 0, based on AIC | -2.880 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly (eom) | -1.405 (ADF) | 12, fixed | -2.882 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly (eom) | -1.754 (PP) | bandw.: 6 | -2.880 (C) | $H_0$ valid, unit root in $d_t - p_t$ |

2) Tests based on Helsinki stock exchange dividend yield data from Global Financial Data, 31 Jan 1971 – 30 Sep 2004

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $d_t - p_t$ | Monthly | -2.243 (ADF) | 14, based on AIC | -2.868 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -2.568 (ADF) | 12, fixed | -2.868 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -2.080 (PP) | bandw.: 4 | -2.868 (C) | $H_0$ valid, unit root in $d_t - p_t$ |

3) Tests based on Finnish stock market data from MSCI, 31 Dec 1988 – 30 Sep 2004

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $d_t - p_t$ | Monthly | -2.587 (ADF) | 10, based on AIC | -2.877 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -2.714 (ADF) | 12, fixed | -2.877 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -1.668 (PP) | bandw.: 6 | -2.876 (C) | $H_0$ valid, unit root in $d_t - p_t$ |

4) Tests based on HEX equity-index dividend yields from Bloomberg, 30 Sep 1993 – 30 Sep 2004

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $d_t - p_t$ | Monthly | -1.818 (ADF) | 1, based on AIC | -2.883 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -1.829 (ADF) | 12, fixed | -2.885 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -1.401 (PP) | bandw.: 6 | -2.883 (C) | $H_0$ valid, unit root in $d_t - p_t$ |

The test results for the United States differ somewhat from those for Finland. First, according to the test results, $r_t$ is a stationary process also for the United States, but the results regarding $\Delta d_t$ are somewhat contradictory. According to the augmented Dickey-Fuller unit root test, the hypothesis of existence of a unit root in $\Delta d_t$ cannot be

[22] PP in tests refers to Phillips-Perron unit root test and ADF to Augmented Dickey-Fuller unit root test.
[23] In Phillips-Perron unit root tests, bandwidth is chosen via Newey-West using Bartlett kernel.
[24] (C) indicates inclusion of a constant in the test. Use of constant is based on the time-series structure.
[25] In unit root tests, $H_0$ hypothesis is that the process has a unit root.
[26] (C+T) indicates inclusion of a constant as well as trend in the test.

rejected, but according to the Phillips-Perron unit root test the hypothesis can be rejected. We are inclined to favour PP in this case. Second, the results concerning the existence of a unit root in $d_t - p_t$ are twofold: for the longest possible period, 28 February 1871 – 29 October 2004, $H_0$ is always valid, indicating that there actually is a unit root in the $d_t - p_t$ process. This result is similar to that reported in Koustas and Serletis (2005) who, however, pointed out that, given the high probability of a structural break in the latter half of the 1990s, unit root tests based on the full sample should be viewed with caution. When Koustas and Serletis used 1996 as the break point, they were able to reject the null of structural stability at the 5% significance level. We split the data a bit differently. The first period covers the years 1871 to 1969 and the later period the years 1970 to 2004 (Bloomberg's data also covers a shorter period: December 1987 – October 2004). This split yields interesting results for unit root testing. According to both ADF and PP unit root tests, we are able to reject the existence of a unit root in $d_t - p_t$ during the period 1871–1969 but not in 1970–2004. This implies that there would be a bubble(s) in S&P500 asset prices during the later period but not in the first period.

## Table 3.2 **Tests for order of integration, United States**

1) Tests based on index data from Bloomberg, Dec 1987 – Oct 2004

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $r_t$ | Monthly (eom) | -5.507 (PP)[27] | bandw.: 2[28] | -2.907 (C)[29] | unit root is rejected, $r_t$ is I (0)[30] |
| $r_t$ | Monthly (eom) | -7.177 (PP) | bandw.: 0 | -3.481 (C+T)[31] | unit root is rejected, $r_t$ is I (0) |
| $r_t$ | Monthly (eom) | -5.521 (ADF) | 0, based on SIC[32] | -2.907 (C) | unit root is rejected, $r_t$ is I (0) |
| $r_t$ | Monthly (eom) | -5.521 (ADF) | 0, based on AIC | -2.907 (C) | unit root is rejected, $r_t$ is I (0) |
| $\Delta d_t$ | Monthly (eom) | -3.165 (ADF) | 6, based on AIC | -3.212 (C)[33] | $H_0$ valid, unit root can't be rejected |
| $\Delta d_t$ | Monthly (eom) | -8.322 (PP) | bandw.: 2 | -2.918 (C) | unit root is rejected, $\Delta d_t$ is I (0) |
| $d_t - p_t$ | Monthly (eom) | -1.369 (ADF) | 0, based on SIC/AIC | -2.876 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly (eom) | -1.253 (ADF) | 12, fixed | -2.877 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly (eom) | -1.055 (ADF) | 0, based on AIC | -3.433 (C+T)[34] | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly (eom) | -1.352 (PP) | bandw.: 7 | -2.876 (C) | $H_0$ valid, unit root in $d_t - p_t$ |

2) Tests based on S&P500 dividend yield data from Global Financial Data, 28 Feb 1871 – 29 Oct 2004

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $d_t - p_t$ | Monthly | -2.763 (ADF) | 1, based on AIC/SIC | -2.863 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -2.750 (ADF) | 12, fixed | -2.863 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -2.656 (PP) | bandw.: 8 | -2.863 (C) | $H_0$ valid, unit root in $d_t - p_t$ |

3) Tests based on S&P500 dividend yield data from Global Financial Data, 28 Feb 1871 – 31 Dec 1969

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $d_t - p_t$ | Monthly | -4.067 (ADF) | 1, based on SIC | -2.863 (C) | $H_0$ rejected, no unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -4.077 (ADF) | 12, fixed | -2.863 (C) | $H_0$ rejected, no unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -3.719 (ADF) | 3, based on SIC | -2.863 (C) | $H_0$ rejected, no unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -3.899 (PP) | bandw.: 7 | -2.863 (C) | $H_0$ rejected, no unit root in $d_t - p_t$ |

[27] PP refers to a Phillips-Perron unit root test and ADF to Augmented Dickey-Fuller unit root test.
[28] In Phillips-Perron unit root tests, the bandwidth is chosen via Newey-West using Bartlett kernel.
[29] (C) indicates inclusion of a constant in the test. The decision to use constant is based on the time-series structure.
[30] In unit root tests, $H_0$ hypothesis is that the process has a unit root.
[31] (C+T) indicates inclusion of a constant as well as trend in the test.
[32] SIC refers to Schwartz Information Criteria.
[33] It should be noted that the lag length in ADF is the absolute maximum for this amount of data, and rejection of the hypothesis is marginal.
[34] Trend included in this test because the period Dec 1987 – Oct 2004 includes a steep decline.

4) Tests based on S&P500 dividend yield data from Global Financial Data, 30 Jan 1970 – 29 Oct 2004

| Variable | Data | t-value | Lags | 5% Critical value | Result |
|---|---|---|---|---|---|
| $d_t - p_t$ | Monthly | -0.793 (ADF) | 0, based on AIC/SIC | -2.868 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -1.904 (ADF) | 0, based on SIC | -3.420 (C+T)[35] | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -0.887 (ADF) | 12, fixed | -2.868 (C) | $H_0$ valid, unit root in $d_t - p_t$ |
| $d_t - p_t$ | Monthly | -0.809 (PP) | bandw.: 6 | -2.868 (C) | $H_0$ valid, unit root in $d_t - p_t$ |

## 3.6 Frequency domain analysis

The time domain and frequency domain approaches are theoretically equivalent. In this study the motivation for using frequency domain analysis is that it enables us to use shorter time periods and so to get more precise indications of periods when possible bubbles have existed. The problem with the above unit root tests is that they only determine whether bubbles are present during the periods tested but do not enable more precise timing of bubbles.

The basic idea in frequency domain analysis is that any stationary time series can, according to Granger and Newbold (1986)[36], be treated as 'the sum of (possibly) a noncountably infinite number of uncorrelated components, each related to particular frequency, and the importance of any group of components with frequencies falling into some narrow band is measured by their composite variance. This variance when plotted against frequency is the power spectral function'. The main idea in frequency analysis is thus to split the variance of a series, var $X_t$, into components, var $X_t(w)$, where each component is associated with a certain frequency w in the range (w, w, w + dw).

There are three core functions by which the all the spectra can be formulated[37]. The first is the spectral representation of a stationary series, which can be written as

$$X_t = \int_{-\pi}^{\pi} e^{itw} dz(w) \tag{3.15}$$

where $E\{dz(w)\overline{dz(\lambda)}\} = 0,\ w \neq \lambda$ and $E\{dz(w)\overline{dz(\lambda)}\} = \lambda_0,\ w = \lambda$

[35] A downward trend is quite apparent in the time-series restricted to 1970–2004.

[36] More about spectral analysis can be found eg in Granger and Hatanaka (1964) and Jenkins (1965).

[37] For a more thorough presentation, see Granger and Newbold (1986).

where λ represents the autocovariance function.

The second function is that of the general linear cyclical process, of which two further generalisations are possible. The first allows the number of components to approach infinity and the second enables inclusion of a countably infinite number of components instead of just an uncountably infinite number of components. With these modifications, we can write the spectral representation of the stationary series in the form

$$X_t = \int_0^{\pi} \cos wt du(w) - \int_0^{\pi} \sin wt du(w) \tag{3.16}$$

where du(w) and dv(w) are random variables such that

$$\begin{aligned} &E[du(w)du(\lambda)] = 0 && w \neq \lambda \\ &E[du(w)dv(\lambda)] = 0 && \text{all } w, \lambda \\ &E[dv(w)dv(\lambda)] = 0 && w \neq \lambda \end{aligned}$$

Considering the integral sign – the elongated S – as denoting a sum, $X_t$ becomes the 'sum' of an uncountable number of uncorrelated components, each of the form

$$X_t(w) = \cos tw du(w) - \sin tw dv(w) \tag{3.17}$$

as mentioned in Granger and Newbold (1986). Here, we see that each component $X_t(w)$ is associated with a certain frequency, w. This equation can also be used in breaking the total variance into frequency pieces, so that each piece of variance can be written as

$$\text{var}(X_t(w)) = (\cos tw)^2 \text{var}(du(w)) + (\sin tw)^2 \text{var}(dv(w)) \tag{3.18}$$

After some further manipulation, as shown in Granger and Newbold (1986), the third equation can finally be identified. According to the third equation[38], we can write the covariance sequence $\lambda_\tau$ ($\text{cov}(X_t, X_{t-\tau})$ as

[38] Where the information from equations (3.15) and (3.18) are taken into account.

$$\lambda_\tau = \int_{-\pi}^{\pi} e^{i\tau w} s(w)dw \qquad (3.19)$$

where s(w)dw can be interpreted as the contribution of the component $X_t(w)$ to the total variance of $X_t$.

In frequency domain analysis the focus of interest is on the shape of the graph of the spectrum s(w). Any peaks or high values in the graph would suggest that the variances from those frequencies provide a large contribution to the overall var $X_t$. To get a feeling for the most common shapes of the spectra, we present a few examples. Recall that the simplest case is zero-mean white noise, where the white noise is made up of components each contributing equally to the series variance. The graph for this case would be constant over the whole frequency range. Graphs of series that contain cyclical components would have tall, narrow peaks at those frequencies. A series with important trend components would have a strong peak at the very low frequencies, while an AR(1) process with a positive coefficient would have dominating long-period components and its graph would be rising to the left. The closer the coefficient value in AR(1) is to unity, the higher the graph rises to the left. If the coefficient is unity (a unit root process), the peak in the graph becomes infinitely high on the left.

These features are our main concern as regards frequency domain analysis of dividend yield. But we are also interested in how the shape of the graph changes around the origin (0,0). If a unit root is observed in the process, the graph (periodogram) should curve more sharply towards the origin and rise towards the left, so as to become more L-shaped. This is the critical point for the bubble analysis of a dividend yield series. The dividend yield data are split into 10-year periods (each comprising 120 observations)[39]. Periodograms are constructed for all the periods. If signs of unit roots are found from the dividend yield data in any of the 10-year periods, the periodograms of these periods should curve more towards the origin and rise higher to the left, ie become more L-shaped than the periodograms without unit roots. Signs of unit roots could be interpreted as signs of bubbles – as in the unit root tests. This means that if we are looking for markets that are recovering from bubbles, the periodograms should shift back

[39] Granger and Hatanaka (1964) recommended a minimum of 100 observations, although some spectras have been estimated with as few as 80 observations. The number of lags should be less than (number of observations) / 3; for small samples, less than (number of obs.) / 5.

after a bubble period (ie further away from 0 and lower on the left side).

## 3.7 Frequency domain analysis of unit root using US and Finnish dividend yield data

Generally a data series that is to be analysed via spectrum analysis will first be detrended if it appears that strong trends are present. If this is not done, the periodogram and density spectra may be 'overwhelmed' by very large values of the cosine coefficient.

As seen from Figures 3.1 and 3.2, there is a clear downtrend in dividend yields for the sample periods. We decided not to detrend the samples, even though they are not strictly stationary. There were several reasons for this. First, we thought it would be impossible to fit a clear deterministic downtrend to the dividend yield data, mainly because if there were such a continuous downtrend in dividend yields we would expect to see zero dividends at some point in the future, which does not seem likely, even though payout policies in many companies have changed somewhat. Another factor is that we split the dividend yield data into 10-year segments, to enable a more effective search for changes in spectra during bubble periods. This means that we would need to detrend each 10-year segment, which could be problematic, as it has been shown that inappropriate detrending of time series can create periodicity when it is not a property of the underlying system (see eg Nelson and Kang 1981).

There is another point concerning these shorter time segments. In light of the main focus of our analysis, we are most interested in the positioning of spectra vis-à-vis the origin and each other. Any possible higher values of the coefficient of the cosine function due to such a trend would be present in each of the functions and so would not affect their relative positions vis-à-vis the other spectres, ie vis-à-vis their 'peer group'.

Moreover, the spectra here may be time-varying, which could complicate the analysis. One might question whether the spectra can be reliably estimated using the same process that is used for stationary series? Regarding time-changing spectres, Granger and Hatanaka (1964) said that 'for non-stationary series with time-changing spectra, we are able to estimate the average spectrum and also to find relationships between pairs of such series perfectly satisfactorily, using the methods devised for stationary series, always providing that the spectrum does not change too fast within time.' On this basis, we decided to use the methods of stationary series in the spectral estimation.

The estimation results were interesting. First, as seen the periodograms from the overall dividend yield samples[40] for the United States and Finland (Figures 3.5 and 3.6), there clearly are L-shaped periodograms for both countries. We thus have strong evidence of unit roots in these processes.

Because the period-lengths were the same as those in the unit root tests in the previous section, the shapes of the spectra strongly suggest that there is a unit root in the US dividend yield series for 1871–2004 and in the Finnish series for 1971–2004. It should however be noted that in the frequency domain analysis we used levels data rather than logarithms, as were used in the previous section. The decision to use levels instead of logarithms stemmed from the fact that, according to the spectral analysis literature, it is recommended that the data used in the analysis be in raw form, so as not to lose any of the salient features.

The interpretation of unit roots is essentially the same whether they are found in either the log dividend yield or pure dividend yield data, according to Granger and Hallman (1991). A unit root in either case will imply the presence of a bubble in the process.

[40] In both of these tests, and in the subsequent spectral analysis, we use dividend yield data from Global Financial Data for both countries. For Finland, this covers the period 31 Dec 1971 – 30 Sep 2004 and, for the US, 28 Feb 1871 – 29 Oct 2004.

Figure 3.5 **Periodogram of dividend yields from S&P500, 1871–2004, lag = 20**

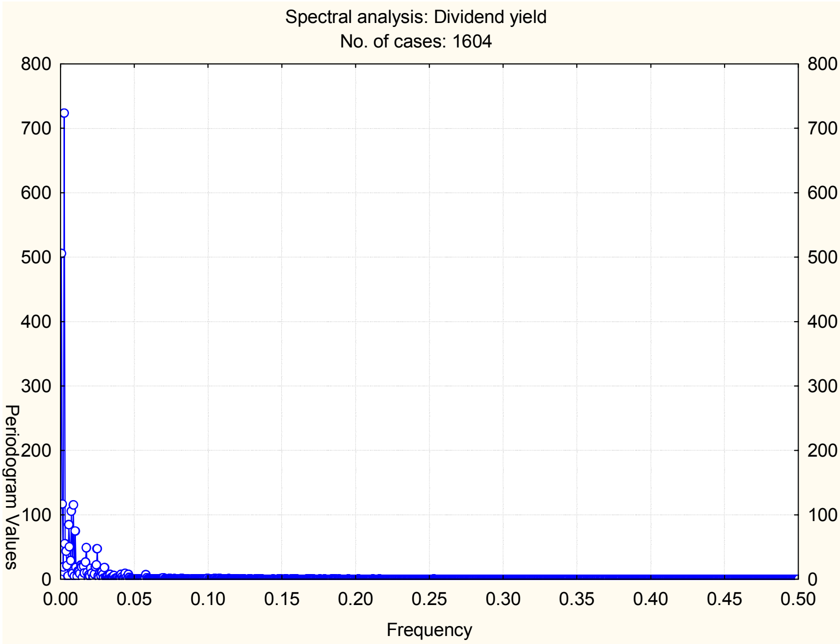
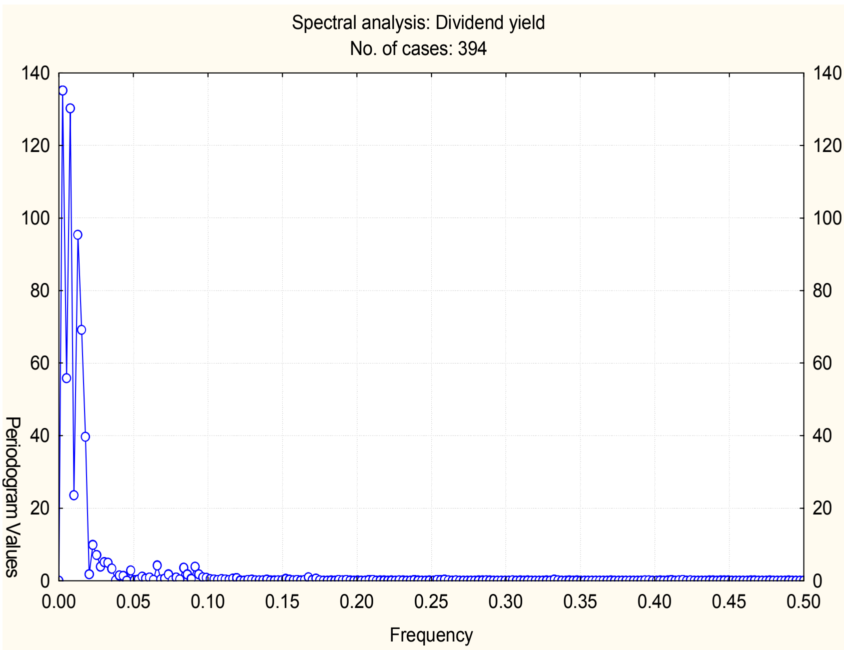



Figure 3.6 **Periodogram of dividend yields from Finland 1971–2004, lag = 20**



The next step is to split the dividend yield dataset into 10-year segments and see if the curvature is different for the corresponding periodograms. With a unit root in the process during a 10-year period, the graph (periodogram) should curve more strongly towards the origin and rise to the left, to become more L-shaped. The periodograms from different periods are presented in Figures 3.7 and 3.8.

Figure 3.7 **Periodogram of dividend yields, S&P500, lag = 19**

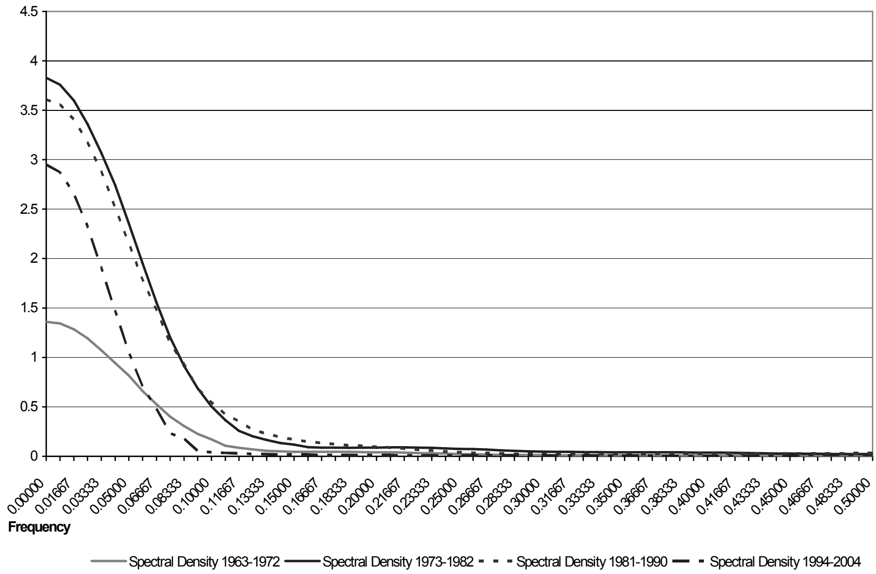
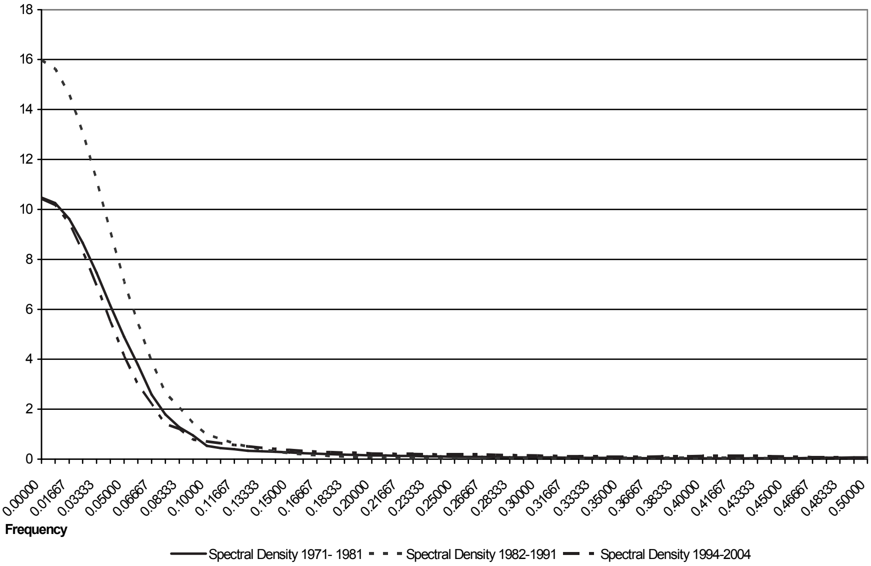


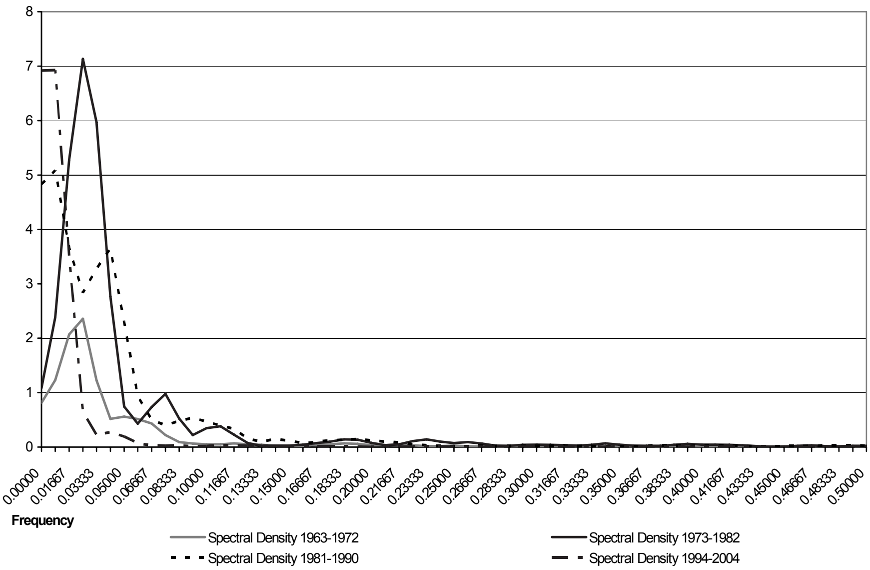
Figure 3.8 **Periodogram of dividend yields, Finland, lag = 19**




As seen from the periodograms, there are clear differences in the shapes for the different periods. Especially for the United States, the differences as between the 1963–1972 and 1981–1990 and 1994–2004 periodograms are clear. As regards Finland, one problem is the brevity of the time series. It is almost impossible to divide the data into 10-year samples so that popularly regarded ‘bubble-periods’ can be compared with other periods. The Finnish data clearly reveal a difference between spectral densities for 1971–1981 and 1982–1991. From these figures we can indeed find some evidence of L-shaped periodograms. In the first graphs, the lags are relatively long, compared to the length of the overall series. Therefore a shorter lag was also used. For a shorter lag (5)[41], the L-shaping of the curves during bubble periods is more obvious than for longer lags. The separation between unit root and other periods can be seen from Figures 3.9 and 3.10 below.

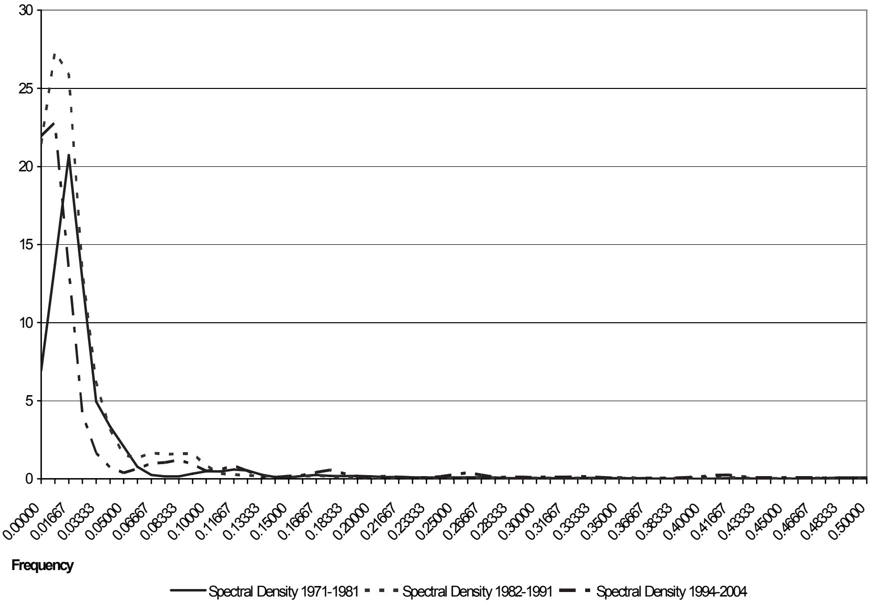
[41] As Granger and Hatanaka (1964) pointed out, the longer the lag, the greater the variance of the estimate at each point. The smaller the lag, the better the estimate.

Figure 3.9 **Periodogram of dividend yields, S&P500, lag = 5**




The US periodograms for 1981–1990 (incl. 1987 market boom) and 1994–2004 (incl. 1999–2000 market boom) rise very high on the left with no other jumps, in contrast to the curves for 1963–1972 and 1973–1982. It should be noted that each of these periods included at least some notable market incidents (1966 boom, 1973–1974 bust etc). Perhaps the two strongest were the boom before 1987 and the boom before 2000. During the latter period, the curve of 1994–2004 clearly squeezes towards the origin. In the series 1981–1990 we can distinguish two peaks in frequencies: 0.00833 and from 0.0333 to 0.04167. These shapes in 1981–1990 and 1994–2004 clearly indicate unit roots in dividend yields during these periods.

Figure 3.10 **Periodogram of dividend yields, Finland, lag = 5**




For Finland the spectral densities for the periods 1994–2004 and 1982–1991 clearly exceed that of 1971–1981 in their height to the left, and the periodogram for 1994–2004 actually bends much closer to the origin. Once again graph shapes clearly indicate the presence of unit roots in the dividend yield series for 1994–2004 and 1982–1991.

Overall, the features observed in the periodograms and their relative movements indicate that unit roots are present in the dividend yield series, a result that confirms the presence of rational bubbles in the stock market data. Comparison of the results from the frequency domain analysis with those from the unit root-based bubble tests of the previous section appear to corroborate the hypothesis that rational bubbles are present in the stock prices. As regards the spectral analysis, the indications of unit roots came from the periodograms covering the periods 1971–2004 for Finland and 1871–2004 for the United States. These results support the results obtained from the unit root tests of the previous section.

But even after this analysis, which enables us able to identify the existence of bubbles, we still lack some important information, namely the precise timing of bubbles. In the analysis above, we were able to split the dividend yield data into 10-year periods and to spot unit roots (bubbles) in some of the periods. But we were still unable to precisely date the bubble periods, ie periods when stock prices began to split from their fundamentally justified levels. As mentioned in Section 1.5, there is certainly a need for this kind of information, but at the moment there is still no means to obtain it. In the Chapter 4 our aim will be to develop a dividend yield information-based indicator that might be able to fulfil this function. In the following sections, we will also test this indicator and its bubble signals against stock market information from Finland and the United States.

# 4 A dividend yield-based method for precise dating of an asset price bubble

As shown in Chapter 3, using traditional unit root tests and frequency domain analysis we could not reject the possibility of bubbles in asset prices in either the United States or Finland. A drawback of both types of tests is that they only address the question of whether bubbles are present in asset price data over a certain, fairly long, time horizon; they are not capable of precise dating. We will attempt to date the bubbles more exactly on the basis of dividend yield time series data. To tackle this problem, we develop a new indicator method based on the ordinary augmented Dickey-Fuller method. Using a rolling data window for estimation enables us to pick up monthly signals, which is a clear advantage over the earlier methods.

Our interest in constructing a dividend yield-based indicator took root when we noticed that the rolling correlations in $\Delta DY_t$ seemed to move up at those times that were commonly referred to in the literature as bubble periods. We experimented with various lag-structures and, based on the correlations, came to the conclusion that the longer lags worked even better[42] in the sense that the periods became more concentrated around the bubbles. It was then natural to attempt to better control the higher order correlation in the time series by adding lagged differences of the dependent variable to the regression. For this task, the augmented Dickey-Fuller method (ADF) seemed a natural tool to use.

To choose an appropriate lag-structure, we carried out several estimations. The results from the diagnostic analysis suggested that the basic ADF(1) with a constant would be the best form of regression equation, and so we decided to concentrate on the equation

$$\Delta(d-p)_t = \mu + \gamma(d-p)_{t-1} + \delta_1 \Delta(d-p)_{t-1} \qquad (4.1)$$

Our primary concern here is the value of the coefficient $\gamma$, as it will emit signals of possible bubble periods. This augmented specification

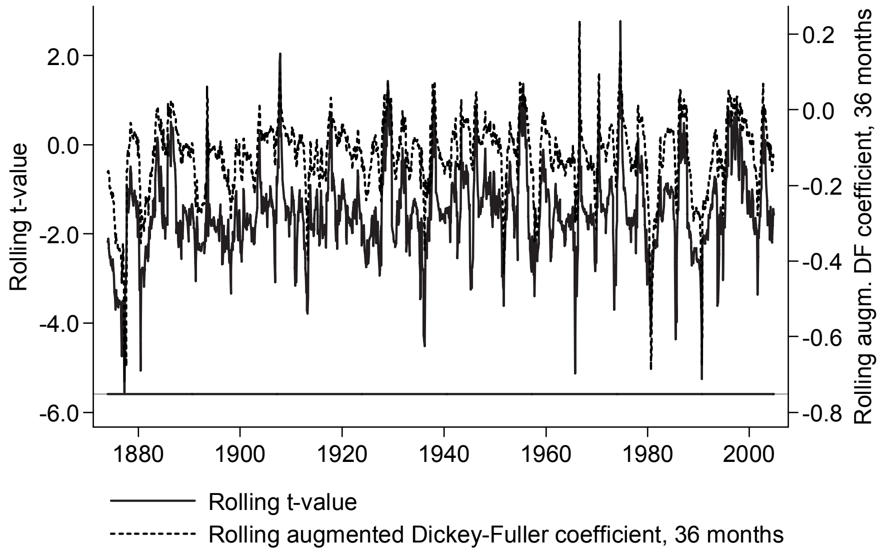
[42] For example, the 12-month rolling correlation in $\Delta DY_t$ is the correlation between the $\Delta DY_{t-12}^{t}$ and $\Delta DY_{t-13}^{t-1}$.

is generally used to test whether $H_0$: $\gamma = 0$ holds ($H_0$ accepted) versus the alternative hypothesis $H_1$: $\gamma < 0$ in the regular unit root testing environment. According to common belief, bubbles do emerge and then burst. This would mean that also the $d_t - p_t$ series would display changes between I(0) and I(1) processes over long data samples. Leybourne et al (2003) as well as Busetti and Taylor (2004) have shown that the conventional augmented Dickey-Fuller unit root statistic, when applied to a series which displays I(1) behaviour for some fixed fraction of the sample and I(0) behaviour for the remainder of the sample, will not diverge with the sample size, and hence the associated ADF test will be not consistent against such alternatives. Actually, Banerjee et al (1992) were the first to consider the use of recursive and rolling tests on the unit root null hypothesis against the alternative that the process displays stationary behaviour in part of the sample. Related to this, Taylor (2005) analysed these recursive and rolling tests further and found several crucial things concerning the contents of this article. First, he reported that the unit root test least dependent on the direction of change in an environment where the process changes between I(1)-I(0)-I(1) or I(0)-I(1)-I(0) is the rolling sub-sample augmented Dickey-Fuller test. Secondly, tests based on sub-sample sequences of ADF will only be consistent if at least one of the statistics in the sequence is calculated using purely I(0) data. And finally, the choice of window width in the case of rolling sub-sample proves to be crucial for the consistency of the test.

Based on these results, we chose to search for the existence of a unit-root in the $d_t - p_t$ series by using a rolling sub-sample ADF. We counted rolling t-values by using different window lengths. Figure 4.1 shows the rolling t-values for the 36 window-periods[43]. The problem in using rolling t-values is related to the specification of critical values. As window width and sample length affect the level of the critical t-values, as does the residual distribution, the critical t-values should be simulated with these features taken into account. But this is beyond the scope of this study.

[43] Meaning that the t-value is always calculated by using the previous 36 observations.

Figure 4.1 **Rolling t-values and critical t-value (large sample) for rolling ADF-test, USA**




Instead we are interested only in values of the coefficient γ since these can provide us with means for easier bubble indicating-applications.

If the residuals were normally distributed, a value of coefficient γ greater than zero would indicate a period where dividend flows do not match asset price level ie explosive series. In another words, such values would indicate the presence of bubbles in asset prices. One serious drawback is that the distribution of residuals from the regression is not likely to be normally distributed, so that the true critical value for a bubble signal may not be exactly zero (albeit somewhere in the vicinity of zero). The exact critical value would be extremely difficult to estimate, and we will not attempt it here. Instead, we opt for zero itself as our estimate of the true critical value.

What was said above about the value of the coefficient γ can be proved by considering more exactly the assumptions behind the Dickey-Fuller test. The basis for the Dickey-Fuller test is the ordinary AR(1) process, which can be written as

$$(d-p)_t = \mu + \rho(d-p)_{t-1} + e_t \qquad (4.2)$$

where $\mu$ and $\rho$ are parameters and $e_t$ is white noise. In order for $(d-p)_t$ to be a stationary process, it must be the case that $-1 < \rho < 1$. When $\rho$ equals one, $(d-p)_t$ contains a unit root and is a nonstationary process. When $\rho$ is greater than one, the process is explosive, which is what we are looking for. In most contexts, explosive series do not make much economic sense, so that in the Dickey-Fuller test the null hypothesis ($H_0$: $\rho = 1$) is tested against the one-sided alternative $H_1$: $\rho < 1$. But in our testing procedure, explosive cases are interesting because they indicate a breakdown in the relationship between dividends and prices.

In carrying out a traditional Dickey-Fuller test, one would subtract $(d - p)_{t-1}$ from both sides of equation (4.2) to obtain

$$\Delta(d - p)_t = \mu + \gamma(d - p)_{t-1} + e_t \qquad (4.3)$$

In equation (4.3), $\gamma = \rho - 1$, and hence the null and alternative hypotheses would be written $H_0$: $\gamma = 0$ and $H_1$: $\gamma < 0$, and a conclusion that $\gamma > 0$ could be viewed as an indication of an explosive series (assuming normally distributed residuals) and hence as a sign of a bubble[44]. This means that our definition of a bubble is based solely on the cointegrating relationship between dividends and prices. Whenever the series $d - p$ is explosive, this means that the cointegration has broken down and a bubble is indicated.

## 4.1 Recursive tests of ADF regression

In order to ensure that the regression form of our ADF function is stabile and useable, we performed some recursive tests. The results are reported in Tables 4.1 and 4.2.

[44] The fact that the augmented Dickey-Fuller works essentially in the same way means that we can also interpret the results similarly.

Table 4.1 **Recursive test of regression, Finnish D/Y-data, 1971–2004**

| Test | Purpose of the test | Result |
|---|---|---|
| Recursive estimates for γ | To determine if the coefficient is unstable. | The coefficient is very stable, does not breach the +/- 2 SE limits |
| CUSUM test | To find out if there is parameter instability. Possible instability could give a sign of possible regime shifts. | Does not cross the 5% significance line → no coefficient instability. Notable downward trend in test-values between 1990 and 2000. |
| CUSUM of squares | To find out if there is parameter or variance instability. | Strong, observable movement outside 5% critical lines; strongly suggestive of parameter or variance instability. |
| Stability test: Show's breakpoint test | The test is used to determine if the regression parameters change when the regression is estimated with different data subsamples; significant differences indicate structural changes in the relationship.<br><br>It was also in our interest to use as breakpoints the periods identified as bubble periods by the ADF coefficient γ given in the next section. If Chow's test indicates that there is indeed a structural change in the relation between these periods, this does reinforce the bubble-indication.<br><br>Note that for these breakpoints the underlying assumption is that the residuals are normally distributed, as the tested breakpoint periods are chosen so that γ >0. | Breakpoints:<br><br>1971.12 – 1986.04<br>1986.05 – 1987.09<br>1987.10 – 1998.12<br>1999.01 – 2000.02<br>2000.03 – 2004.10<br><br>The results indicate a structural change. Due to the fact that the periods get quite short for the estimations with the above breakpoints, I also tested the following breakpoints:<br><br>1971.12 – 1985.12<br>1986.01 – 1997.12<br>1998.01 – 2004.10<br><br>The results were unchanged, so that there appears to be a structural change in the relationship. |
| Theoretical Quantile-Quantile | Distribution of log DY values compared to normal distribution. | Left tale of distribution seems to be thicker than in normal distribution, right tale thinner. |
| BDS test | Test for time-based dependence in a series. | Number of observations is small (under 500), but at 5% significance level we cannot reject the independence hypothesis.<br>We also tried to split the data into even shorter time periods, to match the periods of the frequency domain analysis, but there were no change in the results. At 5% significance level we still could not reject the independence hypothesis. Due to the dearth of data, these results must be interpreted with caution. |

Table 4.2 **Recursive test of regression, S&P500 D/Y's, 1871–2004**

| Test | Purpose of the test | Result |
|---|---|---|
| Recursive estimates for γ | To determine if the coefficient is unstable (breach of +/- 2 SE). | Recursive coefficient is again very stable, does not breach the +/- 2 SE limits. |
| CUSUM test | To determine if parameter is unstable. Instability could indicate possible regime shifts. | Does not breach 5% critical line, and thus signals coefficient stability. Note that that after 1960 there is a strong downward trend and the values nearly reach the critical line. |
| CUSUM of Squares | To determine if parameter or variance is unstable. | Breach of 5% critical line, signs of coefficient or variance instability. |
| Stability test: Chow's breakpoint test | To determine whether regression parameters change when regression is estimated with different data subsamples. Significant differences indicate a structural change in the relationship.<br><br>It is in our interest to use as breakpoints those periods that will be identified as bubble periods by the ADF coefficient γ in the next section. If the test does indicate a structural change in the relation between these periods, this reinforces the bubble indications.<br><br>Note that for the breakpoints the underlying assumption is normally distributed residuals, as the tested breakpoint periods are chosen so that γ >0. | Breakpoints:<br><br>1871.02–1982.12<br>1983.01–1984.12<br>1985.01–1986.12<br>1987.01–1987.12<br>1988.01–1990.12<br>1991.01–1992.12<br>1993.01–1995.12<br>1996.01–2000.02<br>2000.03–2004.10<br><br>Results are somewhat conflicting. According to F-stat. we cannot reject the $H_0$ (no structural break), but according to log likelihood ratio we reject the $H_0$. Of course, with the data splitting, some periods are very short, so I tested another data split with breakpoint as follows:<br><br>1871.04–1995.12<br>1996.01–2004.10<br><br>Then we could reject $H_0$ of no structural break according to F-stat. and log likelihood ratio. This result implies a structural change in the relationship. |
| Theoretical Quantile-Quantile | Distribution of log DY values compared to normal distribution. | Left tale of distribution seems to be thicker than in normal distribution, right tale thinner. |
| BDS test | Test for time-based dependence in a series. | At 5% significance level, we cannot reject the independence hypothesis. |

Overall, the test results are somewhat conflicting. There are indications – albeit not strong ones – of possible coefficient instability, at least for the United States (less so for Finland).

The most interesting results are produced by the breakpoint tests for Finland and the United States. It indeed seems that there are structural changes in the relationships. Of course one can question the results from a breakpoint test with many splits in the data and regressions based on fairly small samples. But we obtained stronger results with the US data split into just two subsamples. For example, using S&P500 data and a breakpoint at 1996, we found strong evidence of a structural change in the relationship. This result is quite similar to that of Koustas and Serletis (2005). They tested for structural instability using a methodology suitable for small samples. The tests, which were developed by Andrews (2003), are able to handle situations where the number of observations in the period studied is very small. Employing the Andrews test, Koustas and Serletis (2005) were able to reject the null of structural stability at the 5% level of significance, with 1996 as the breakpoint.

The resulting structural break could be due to several factors. The usual explanation as regards the end of the 1990s is that there was an upward shift in productivity at the time, which boosted stock prices. This could be considered a regime shift. But a similar result could derive eg from a shift to more positive expectations, without any regime shift in productivity. This idea is certainly worthy of consideration, especially as the period after the break, at the end of the 1990s, is quite short and marked by extreme volatility. This was the reason we decided to use the same ADF regression model for the whole period and to ignore the possibility of shifts or breaks.

Concerning the interpretation of values of the coefficient $\gamma$ from the ADF regression, the most important thing is to consider is how the distribution of residuals from the regression compares with the normal distribution. This is critical in that if the residual distribution differs sharply from the normal distribution, the zero-level will not serve well as a critical level. The true critical level is in the vicinity of zero – above or below, depending on how the residual distribution differs from the normal distribution.

Looking at the theoretical quantile-quantile Figures 4.2 and 4.3 for Finland and the United States, as well as density Figures 4.4 and 4.5, we notice that there are some differences between the residual distributions and the normal distribution. Both of the residual distributions show significant kurtosis compared to the normal distribution. But because we did not have a better estimate of the precise critical value, we decided on zero and so we interpret values equal to or greater than zero as indicative of an explosive series and hence as a bubble signal.

Figure 4.2 **Theoretical quantile-quantile for residuals, Finland**

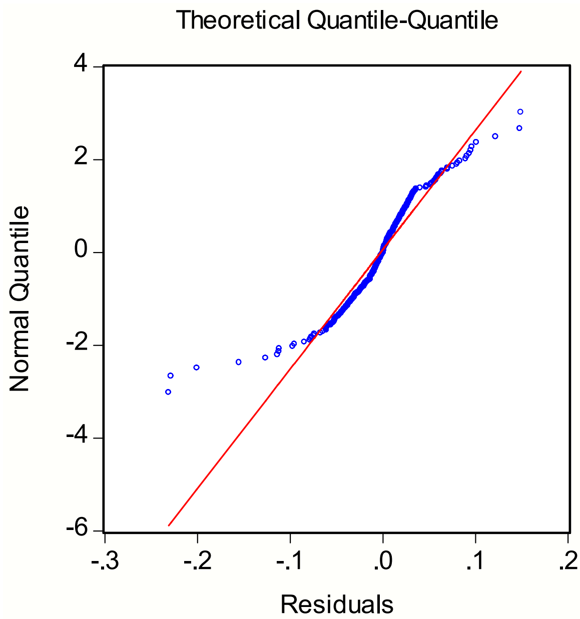



Figure 4.3 **Theoretical quantile-quantile for residuals, United States**

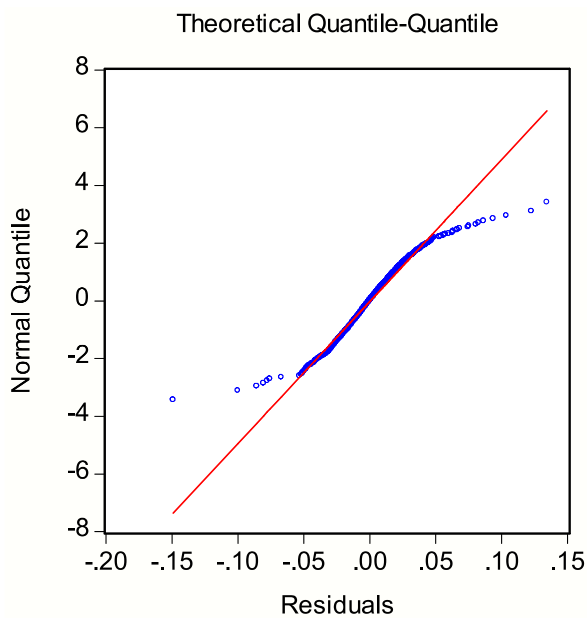


Figure 4.4 **Kernel density for residuals, Finland**

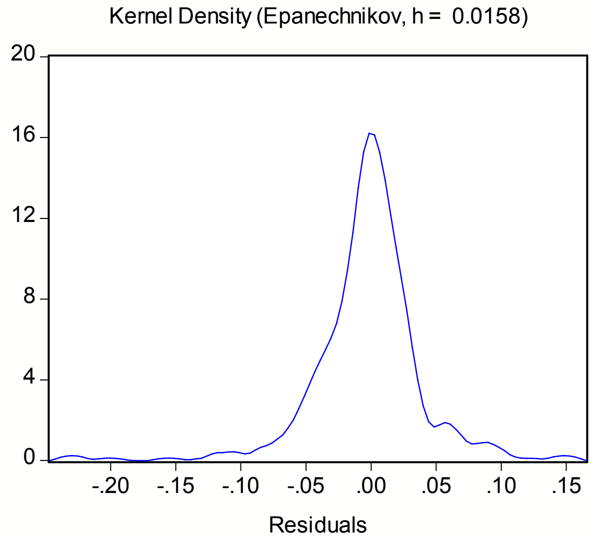
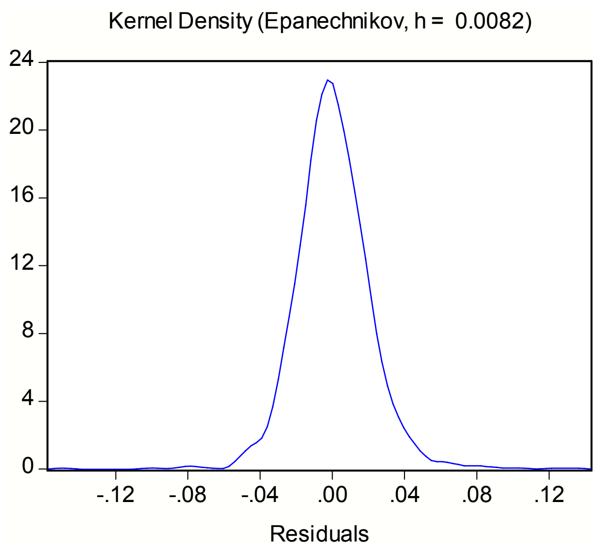



Figure 4.5 **Kernel density for residuals, United States**



## 4.2 Bubble signals from DY-based method

In order to have monthly updating of the indicator value (coefficient $\gamma$ in the ADF regression), we need a rolling window of data observations for estimating the regression (4.1). The 'window length' is the size of each sample of dividend yields used to estimate the sequence of ADF(1) regressions. The dividend yield data used here are Finnish stock market data and S&P500 data provided by Global Financial Data, which were introduced in Section 3.2.

Concerning time series properties, we had to take into account that, in order to get robust results, the window length should be as long as possible[45]. To choose the window length, we tested several possibilities: 12, 18, 36, 60 and 100 months of historical data. Statistical analysis indicated that the 36-month rolling window performed best. Indications derived from shorter windows hovered around those produced by the 36-month rolling period, and the longer periods mostly pointed to precisely the same periods as the 36-months window (see table A3.1 in Appendix 3).

It is important to keep in mind that the coefficient $\gamma$ will emit bubble signals not only when prices are rising faster than justified by the dividend flow (as with rational bubbles) but also when prices are falling faster than justified by the dividend flow. This is due to the fact that the theory's underlying model is the present-value pricing formula, according to which prices and dividends should be cointegrated. They are not cointegrated at those times when the price-dividend ratio is explosive or implosive, ie when $\gamma > 0$. In this sense, this indicator should be able to react to either large over- or undervaluations in market price compared to fundamentals[46].

Next we take a closer look at bubble signals emitted by the ADF(1)-based indicator. The periods identified as bubbles by the 36-month rolling window indicator for the Finnish and US stock markets, based on the normality assumption, are presented in Table 4.3. Because of the questionability of the normality assumption, these

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[45] Using this method, the values of the parameter $\gamma$ are always tied to the last month in the data window.

[46] Two important points: This model lacks information on the future level of expected dividends, which are included in the market prices. This is a serious drawback, common to all bubble tests based on the present value pricing model, but there is not currently enough data on (historical) expectations for incorporation into these pricing models. The other point is that this model assumes that the present value model performs well and produces the correct stock prices. This latter point has recently been subjected to some criticism (see eg Campbell 2000 or Zhong et al 2003).

periods should be interpreted with caution. It might be most useful to present the results graphically. The graphs showing bubble signals and price-index data are in Figures 4.6, 4.7, 4.8 and 4.9. The price-index data are cumulative percentage changes in price indices for the Finnish stock market and in the S&P500 during the 36-month periods (RHS). This price-index data for the Finnish stock market is from the Bank of Finland database[47] and for the United States from Shiller's data (the longest price-series available). Figures 20 and 21 show the ADF coefficient values and confidence intervals (+/- 2 stand dev). These intervals are again based on the normality assumption and are thus only close estimates of the confidence intervals, not the exact ones. From these estimates, we see that the coefficient intervals move quite smoothly even when the values of the coefficients are changing, which suggests steadiness of the statistical environment. However, our confidence in this result is again tempered by the normality assumption.

Table 4.3 **Bubble periods identified by $\gamma > 0$ since 1972, rolling 36-month window**

| | |
|---|---|
| Finland | 31.3.**1983**, 31.5.**1983** – 31.3.**1984**, 30.4.**1987** and 30.6.**1987** – 31.10.**1987**, 31.7.**1990** – 31.1.**1991**, 31.1.**2000** – 29.2.**2000**. |
| USA S&P500 | 30.4.**1974** – 31.1.**1975**, 28.2. – 31.3.**1978**, 31.3.**1986** – 30.9.**1987** (not including 31.7.1986, 30.9. – 31.12.1986, 29.5. – 31.7.1987), 29.9.**1995** and 30.11.**1995** – 28.6.**1996**, 29.11.**1996** – 28.2.**1997**, 30.5.**1997** – 30.9.**1997**, 31.3. – 30.4. as well as 30.6.**1998**, 30.9. – 31.10.**2002**, 31.1. – 28.2.**2003**. |

[47] Covering not only the HEX index, but its predecessors as well.

Figure 4.6 **Bubbles identified in Finnish stock market, 1983–1993**

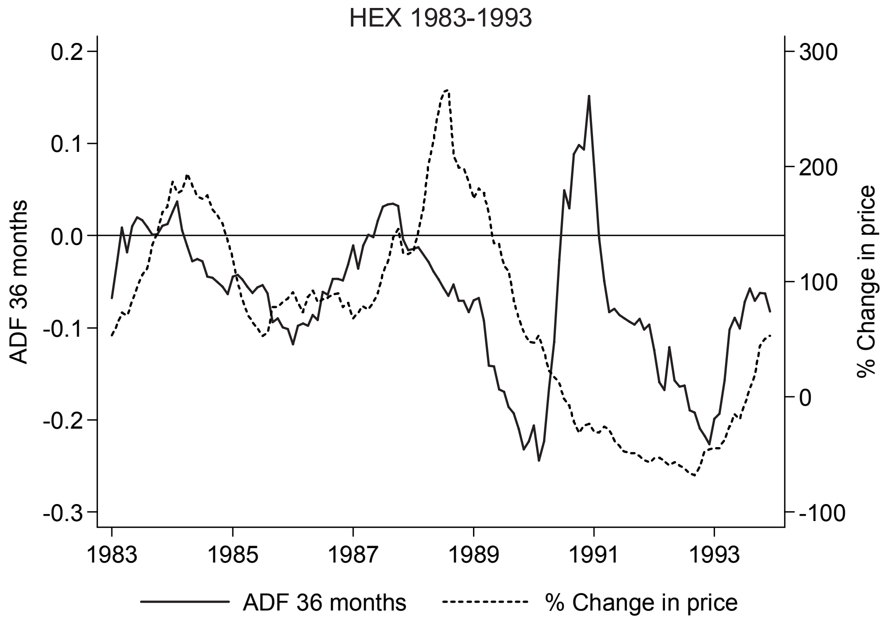



Figure 4.7 **Bubbles identified in the Finnish stock market, 1994–2004**

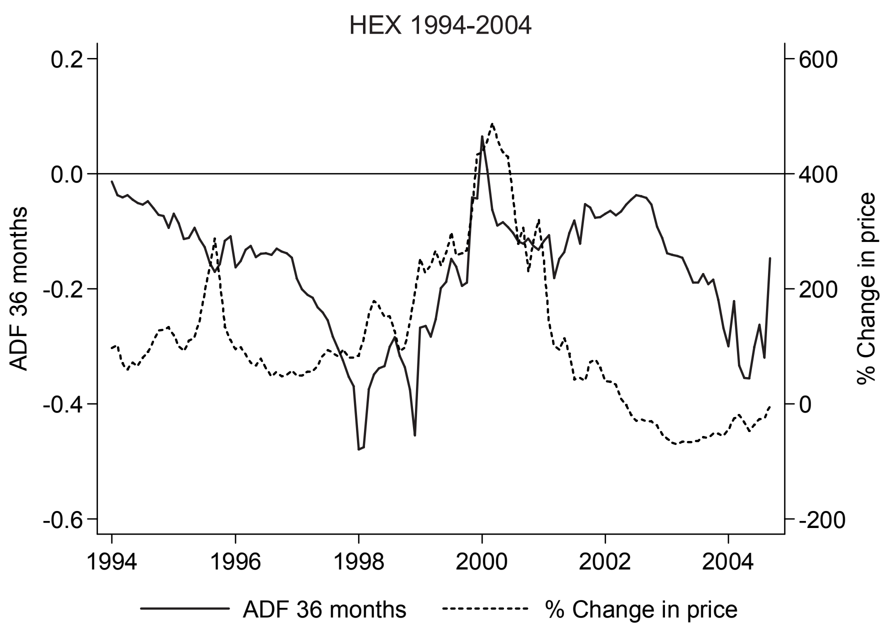


Figure 4.8 **Bubbles identified in US stock market, 1983–1993**

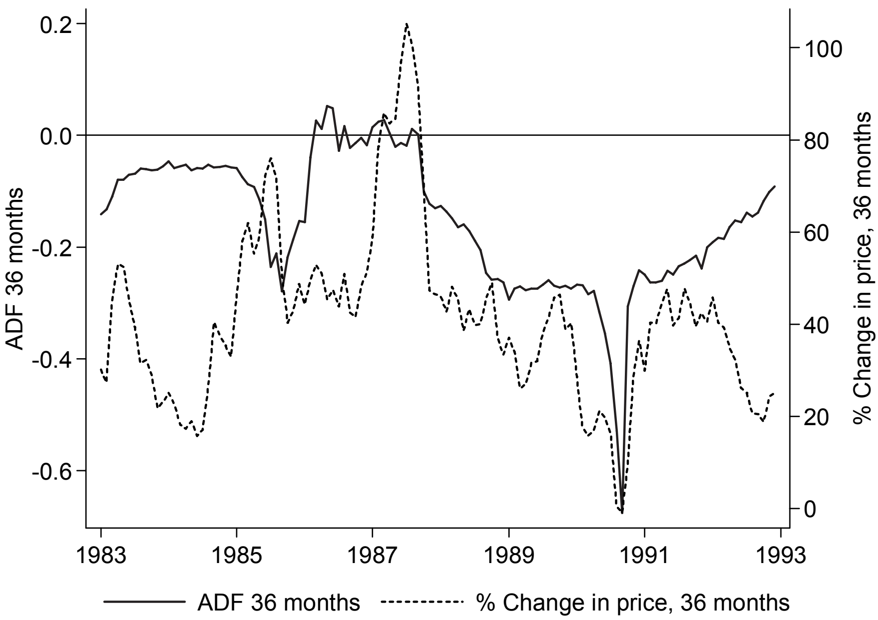



Figure 4.9 **Bubbles identified in US stock market, 1994–2004**

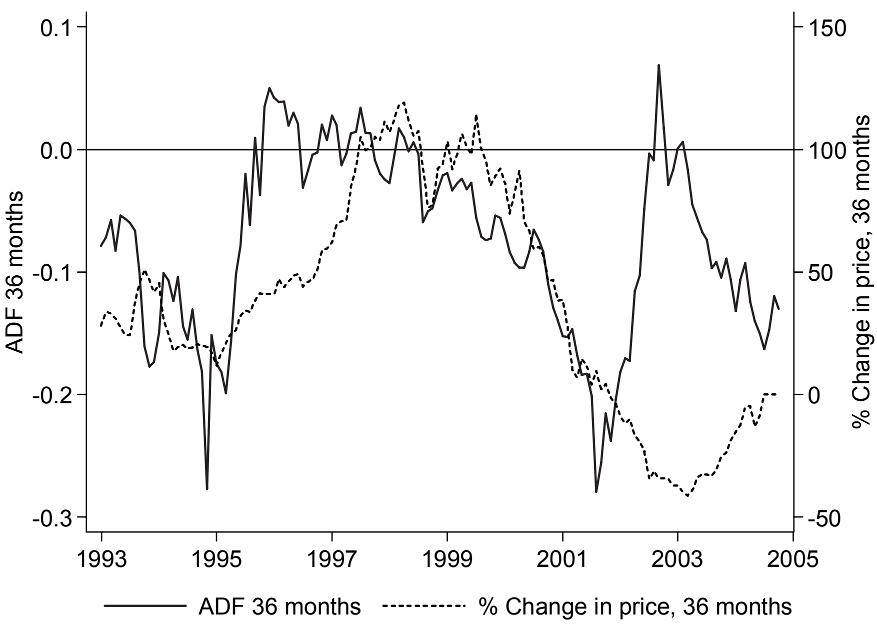


Figure 4.10 **Confidence intervals for ADF coefficient, HEX, 1983–2004**[48]

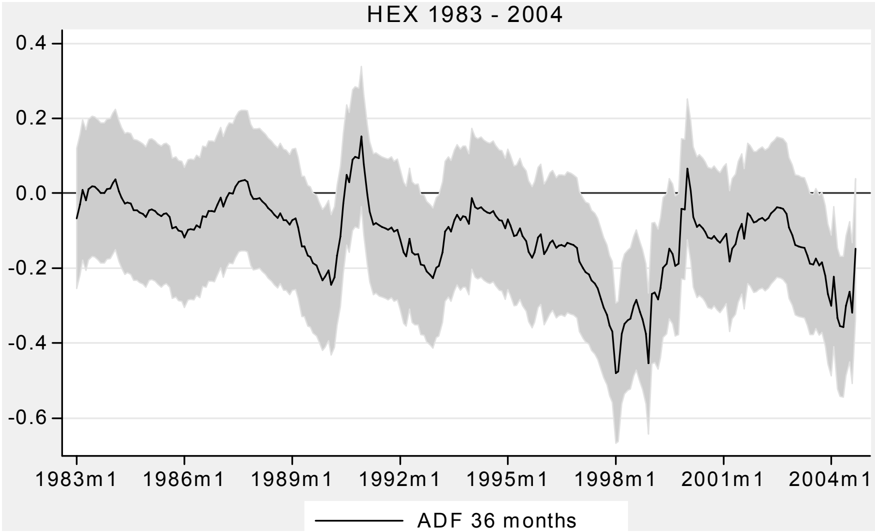
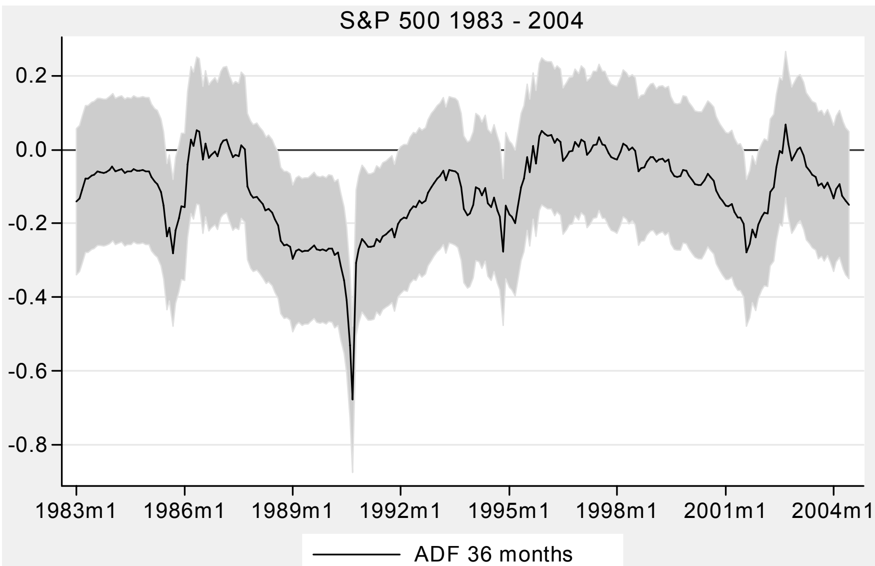



Figure 4.11 **Confidence intervals for ADF coefficient, S&P500, 1983–2004**




48 Confidence intervals for Finland and USA: approximations due to assumption of normally distributed residuals.

Looking at Figures 4.8 and 4.9, which depict developments in the United States, a couple of interesting things stand out. First, bubble signals indeed seem to be correlated with strongly bearish/bullish market prices. Thus it would appear that the indicator is able to identify bubbles in both under- and overvaluation situations.

On the other hand, the reactions of the ADF coefficient to market prices are a bit puzzling. It seems to be highly sensitive to changes in market prices. Moreover, it signals a technology bubble in the late 1990s and early part of 2000 in the United States. Bubble signals begin to appear as early as 1996, which would indicate that the boom in S&P500 prices was not justified by the level of dividends. The timing here closely accords with the fact that expectations of long-term earnings growth for S&P500 companies began to rise steadily after 1995. As Yardeni (2003) reports, these earnings expectations had risen to 14.9% by the end of 1998, from an average level of 11.4% during 1985–1995[49]. But it is indeed strange that the bubble signals ended already in 1998, long before market prices peaked in early 2000. Of course, this could be partly explained by the possibility that the true critical value is not exactly zero.

Besides considering the signals given by the ADF coefficient, it might be useful to examine overall stock market developments. As regards the late 1980s and early 1990s, Raines and Leathers (2000) note that the early-1980s' bull market in US stocks continued all the way up to the crash of 19 October 1987. The impact of the crash was brief. Already in 1989 US stock prices were rallying again, and they reached a new high in October. Iraq's invasion of Kuwait fomented fears about rising oil prices and had a restraining effect on the stock market. However, by 1991 the market was again strongly bullish. In 1991 the DJIA breached the 3000 mark and posted a 20% gain for the year. Because of a continuous upsurge, first warnings of a new speculative boom in the stock market were publicly uttered in the summer of 1992.

Considering in this light the signals emitted by our bubble indicator, a number of important similarities appear. Throughout the early part of the 1980s, starting in 1983, the indicator remains at a fairly high level. The earliest bubble signals are emitted already at the onset of 1986. They neatly end at the time of the market correction in October. The ADF indicator also seems to reflect the bearish market

[49] Earnings expectations peaked in August 2000, at 18.7%. S&P500 dividend payout ratios, on the other hand, had been declining since 1993, an indication that companies' earnings growth had outpaced dividend growth.

conditions in the summer of 1990, before stock prices again went on the rise in 1991. The long upward march of the early 1990s is also reflected in the ADF indicator, which clearly displays a positive trend.

Moving ahead in time, 1995 can be labelled a real boom year for the US stock market.[50] As Raines and Leathers (2000) note, 'Financial markets commentators were again asserting that the conventional stock market indicators were warning of an overvalued market'. Things continued much the same in 1996, with even more commentary to the effect that the market was overvalued. By the summer of 1996, the newspapers were full of such commentary.

An interesting adjunct here was the role assumed by individual investors in the commentary starting in 1996. Investing in stocks had became a 'national hobby', and there were also reports of huge inflows of new money into mutual funds. In November 1996 Fed officials were reported to be concerned about the possibility that the market was overvalued. At this time, moreover, stock markets around the world were reportedly in the midst of a boom fuelled by central banks' generous provision of liquidity (Raines and Leathers 2000).

As we now know, this was only the onset of an upsurge in stock prices that went on for another four years. For this period, the ADF indicator seems to react very sensitively to rising stock prices already from the start of 1995 and its first bubble signal is emitted in the autumn of 1995. Thereafter, bubble signals are emitted almost continuously until summer of 1998, when the indices underwent a downward correction (Russian default and LTCM crisis in 1998 absorbed market liquidity). Strangely, the ADF bubble indicator moves into a downward trend before it manages to signal a bubble around the turn of 1999–2000. The next bubble indications do not appear until the end of 2002, after a downtrend in prices had continued for some time. One might explain this by noting that by the end of 2002 stock prices had dropped so low compared to the dividend flow that stocks were notably undervalued. This interpretation receives support from the fact that the ADF indicator turns down and drops below the zero-line just as stock prices start to move up again.

Regarding movements in the indicator, it is noteworthy that the dividend flow changes constantly and, consequently, so does the price level that is it justifies. This is why the price level need not be the same as it was before the bubble signals began in order for the signals to come to a halt. It is reasonable to assume that during a recession firms are willing to pay smaller dividends, which means that during a

[50] DJIA, for example, increased 33%.

very bearish period smaller price jumps would more strongly affect the ADF-based bubble indicator.

Here we are only analysing relatively short periods for the US market. The longest run of S&P500 prices (the whole period for which dividend yield data are available) and bubble signals emitted by the ADF indicator are discussed more thoroughly in Section 4.3. There, we compare the timing of bubble signals emitted by the ADF indicator for periods regarded as stock market bubbles and the worst crashes discussed in the literature by Kindleberger (2000), Raines and Leathers (2000), Mishkin and White (2003), and Shiller (2000). Before that, we examine bubble signals emitted by the ADF indicator for the Finnish stock market.

In Figures 4.6 and 4.7, which depict the Finnish stock market during 1983–2004, one can locate several bubble signals. The first occurs at the start of the 1980s, and the next one starts in the spring of 1987 and runs into the autumn, which neatly accords with the 1987 US stock market bubble and its bursting in October 1987.

For Finland there are some indications that the asset price boom of the late 1980s was fuelled by abundant lending. In addition to a stock price boom, Finland experienced a upsurge in housing prices. The 1990–1991 bubble signals for Finland suggest excessive undervaluation, which might mean that the correction in stock prices at that time was excessive in light of the level of dividends. In the early 1990s Finland was on the brink of a banking crisis and recession, and companies clearly modified their dividend payout policies.

The strong recovery in Finnish stock prices from summer of 1992 to the end of 1993 is clearly reflected in the ADF indicator. The indicator rises sharply during the period but remains clearly below the zero-line. The next bubble signals do not appear until the end of the 1990s, in connection with the technology bubble. It is interesting to notice how sensitively the bubble indicator reacts to the sharp jump in the price index during the period starting in late 1998. Finally the indicator (the coefficient $\gamma$) breaks through the zero-line at the start of 2000.

Note that for Finland there was no real warning of a negative bubble after the boom in 2002 (the value of $\gamma$ increases throughout), even though prices descended sharply, as was the case for the United States. One possible explanation for this is that the bubble in Finland was actually based on technology companies, many of which had only recently or during the bubble been listed on the exchange. Moreover, many of these companies had been founded only a little earlier. It is noteworthy that during the few next years only a couple of these newly listed companies actually paid dividends, so that, even though the prices of technology company stocks plummeted, the modest reactions of the coefficient $\gamma$ are not completely lacking a basis, as the dividend flows for the bubbling stocks were very sparse. The situation as regards the US market was different because of differences in the construction of the S&P500 index.

As we saw from previous analysis, the bubble signals produced by the ADF coefficient were quite accurate for the Finnish and US stock markets, as concerns periods of both boom and bust. Overall, it would appear that the ADF indicator was fairly good at identifying periods commonly regarded as bubbles in the stock markets. It is also noteworthy that the signals always related to periods when overall economic prospects seemed to brighten up or expectations of future economic growth were highly elevated, or prospects were especially opaque. The previous figures have included the 36-month cumulative price change in price index and, as can be seen, the ADF signals accorded quite closely with this information. For the purposes of comparison, we used actual price index values instead of percentage changes, but this did not work as well with the ADF indicator, and moreover the level of the price index is not very informative (Figures 4.12, 4.13, 4.14 and 4.15).

As a final concern in this study we look at bubble signals for the S&P500 over a longer period of time, 1871–2004. We compare the ADF coefficient signals for this period against stock market bubbles and busts identified in the earlier literature as well as against the stock price index data. This will be taken up in Section 4.3.

Figure 4.12 **Bubbles identified in Finnish stock market, 1983–1993 (price index level on LHS)**

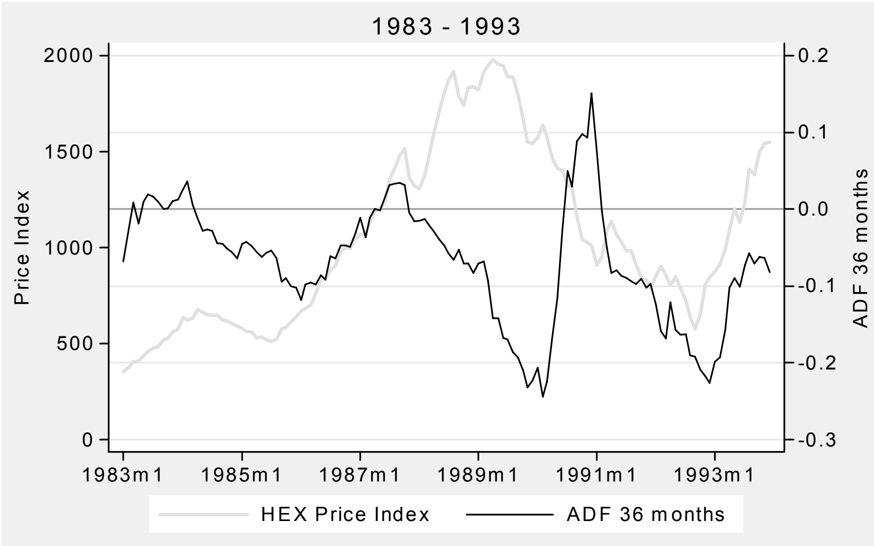



Figure 4.13 **Bubbles identified in Finnish stock market, 1994–2004**

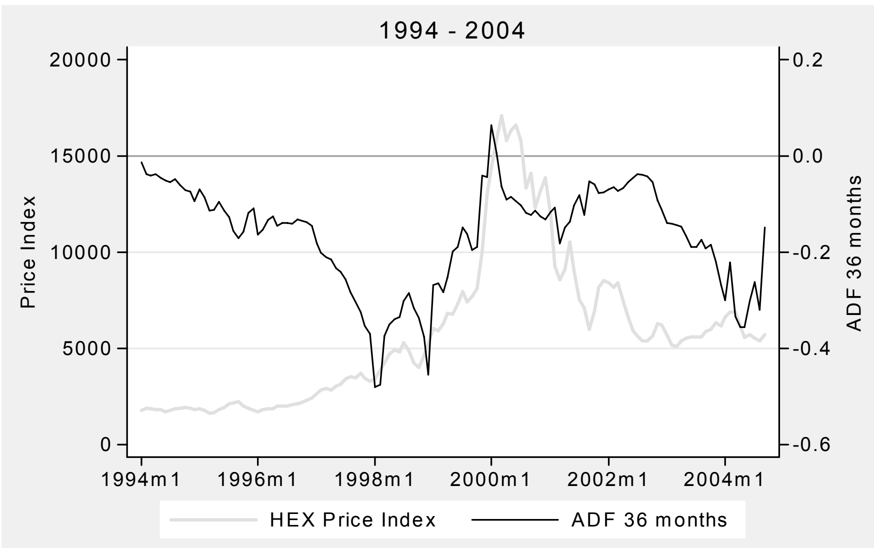


Figure 4.14 **Bubbles identified in US stock market, 1983–1993**

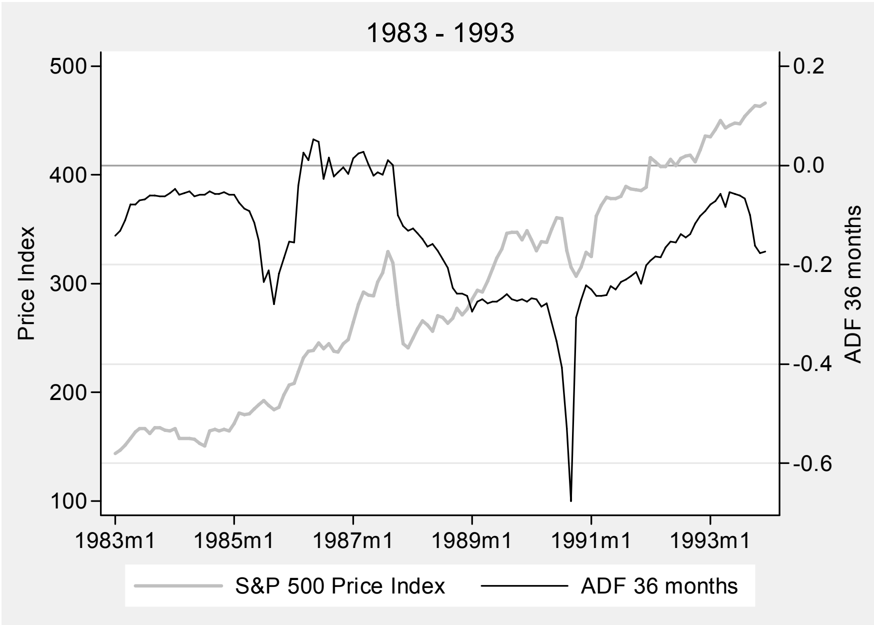
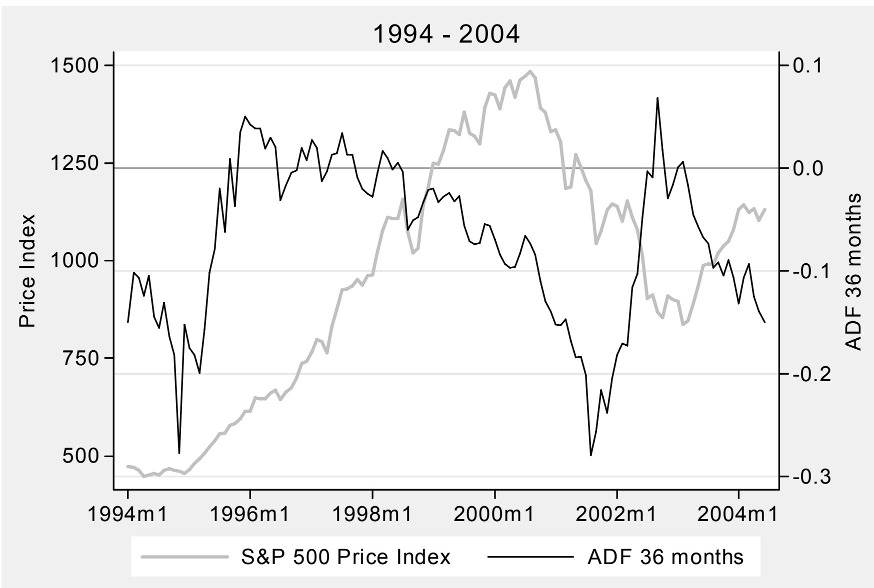



Figure 4.15 **Bubbles identified in US stock market, 1994–2004**



## 4.3 Bubble signals for the United States: the history

In this section we study market developments and the indicator's bubble signals on the basis of the long data series for the US stock market. The purpose here is to compare bubble signals emitted by the coefficient with periods that have been identified as bubble periods in the earlier literature on booms and busts in the US stock market.

We focus on identified stock market bubbles since 1850. For the early years, Raines and Leathers (2000) and Kindleberger (2000) identified several booms and busts in the US stock market during the period 1850–1900. Raines and Leathers (2000) labelled as crisis years 1837, 1857, 1869, 1873, 1884 and 1893 and Kindleberger (2000) cited 1873 as a year with a relatively short speculative peak (from spring to autumn) and the early 1890s (with a speculative peak in December 1892).

The final years of the nineteenth century, as well as the early years of the twentieth, could be described as years of a sharply rising market. The first few years of the twentieth century have been frequently cited in the literature as including several periods of boom and bust. The first mentioned boom of the century was that of 1901, which peaked in the first half of the year. The second commonly recognised boom was the bull market of 1903, which was followed by a bust in the autumn of 1903. This bust is usually labelled the 'rich man's panic', as those hit hardest were market insiders. The small investors managed to exit before the panic began. Mishkin and White (2003) located the core reason for the 1903 bust in the banks' policy of calling in loans to underwriting syndicates that had been sponsoring new issues during the previous two years. Recovery from the 1903 panic was fairly quick. There were signs of a new sustained market boom already in 1904. This new boom period ended with the crash of 1907, which had a pronounced impact on the stock market, even though some writers have labelled it a 'banking panic' (see eg Sobel 1965).

During World War I, the US stock market was quite bearish, and there was a prolonged downtrend during 1914–1918. This period was followed by a robust ascent, particularly after 1926. This boom lasted all the way up until the famous crash of October 1929. As Shiller (2000) writes, the bull market of 1920s was a time of widespread public enthusiasm concerning the stock market. The era was also one of rapid economic growth, as well as important technological innovations (eg in automobiles and electrification), which undoubtedly spurred some of the ‘new era’ thinking and growing optimism regarding economic growth. That optimism was an major factor in the rapid increase in leveraging for stock purchases that marked the late 1920s. The rise in prices of exchange-traded stocks was especially pronounced during the period from spring of 1928 to autumn of 1929. It is perhaps because of factors already cited (widespread participation in the stock market, leveraging etc) that the crash of October 1929 had such devastating economic consequences. The long slide in stock prices finally came to a halt in 1932.

The 1930s started out in a bearish mood. Stock prices did not peak until 1937, after which they resumed the slide. The next period of expansion did not come until the beginning of the 1940s, with the peak occurring in the summer of 1946 (related to the production needs of World War II). The next market peak came in the mid-1950s, when the market suddenly expanded from autumn 1953 to the end of 1955.

Optimism about the prospects for economic growth began to gain momentum when John Kennedy was elected president. By early 1966, the P/E ratio had climbed to a lofty level and the stock market peaked. In January the DJIA breached the historic 1000 level, a level not attained again until 1972, on the eve of a stock market crash. This was followed by a sharp decline in the market during the years 1973–1974; in fact, the downtrend continued until January of 1975, when a new ascent began.

The next speculative peak is dated 1979. The period 1982–1987 was marked by a strong upsurge in stock prices, which finally ended on ‘Black Monday’, 19 October 1987. The subsequent period, running up to the present, was discussed above in Section 4.2 and so will not be covered here. Instead, we present a table that includes a list of US stock market booms and crashes as identified in the following sources: Kindleberger (2000), Shiller (2000), Raines and Leathers (2000), Mishkin and White (2003), and the Investment Company Institute report authored by Rea and Marcis (1996). The same table presents signals emitted by our stock market bubble indicator and the periods for which the indicator value starts to rise at a clearly accelerated pace. This latter information is important because it could serve as an indication that bubble-building pressure is present in the stock market, ie that stock prices have begun to change faster than the underlying fundamentals.

As seen from Table 4.4, comparison of the bubble indicator’s behaviour against dates cited in the literature as stock market bubbles or crashes shows that on average our bubble indicator is able to date most of the bubbles. There seems to be somewhat of a problem concerning the length of the historical data series used in constructing the indicator. In some cases, the indicator misses the peak by several months, which could be related to the (non)normality problem. Therefore it might be useful to look also at movements in the indicator, especially in its rate of increase. In the last column of Table 4.4 we have thus identified the periods in which definite shifts have occurred in the indicator's rate of increase. We see that these shifts do indeed anticipate peaks in stock prices, usually with leads of several months or even longer.

This forecasting ability could provide regulators with important information on increasing price pressures in stock markets, pressures that could separate stock prices from economically justified levels. Of course, one cannot rely solely on this information. It should always be reviewed in the context of overall economic conditions and other indicators. The bubble indicator should be seen primarily as one additional means of filling in the gaps in regulators' tools and thus as an aid in focusing more sharply on unstable situations regarding asset prices – a need that was more extensively covered in Section 1.5.

Besides comparing our indicator against other studies, we could also compare the continuous bubble signals emitted by our indicator with the 36-month cumulative percentage changes in the price index, as was done in Section 4.2. The following figures present US stock price data from Shiller's website. The index data is updated from that used in his book 'Irrational Exuberance' (2000).

The first of the figures (4.16) covers the period 1874–1897. The first large rise in the price index took place during the first years of the 1880s and was accompanied by a substantial decrease in prices in 1883. There is a sharp rise in the level of the coefficient $\gamma$ towards the critical 0-level during the strong index rise, but not enough to breach the critical line. The coefficient first emits bubble signals for the period of strong downward correction starting at the end of 1883. The next bubble signals in 1886 match with the strongly rising stock prices and the last signals in this figure, in summer 1893, appear to be coincident with the crises that followed the speculative peak in December 1892. This period is also mentioned by Raines and Leathers (2000) as well as by Kindleberger (2000).

Table 4.4 **Bubbles in US stock market, 1850–2004**

| RAINES-LEATHERS | KINDLEBERGER | SHILLER | MISHKIN-WHITE | ICI | INDICATOR'S bubble signals | Time when indicator-value starts rising steeply |
|---|---|---|---|---|---|---|
| Bubbles and crashes:<br>1837<br>1857<br>1869<br>1873<br>1884 | Speculative peaks and crises:<br>1873 speculative peak in Mar 1873, crash in Sep 1873 | | | | Oct 1883 – Nov 1883<br>Nov 1885<br>Feb 1886<br>Jun 1886 – Nov 1886 | |
| 1893 | 1890: speculative peak in Dec 1892, crash in May 1893 | | | | Jul 1893 – Aug 1893 | Apr 1893 |
| Strong bull markets 1897–1906, incl. two panics (1901, 1903 rich man's panic) | | Bull market: Jan – Jun 1901; P/E 25.2 | Rich-man's panic 1903, crash in Oct, panic began earlier in Jul | | Oct 1903 – Nov 1903 | Nov 1902 |
| 1907 Oct crash | 1907: speculative peak in early 1907, crash in Oct 1907 | | Sustained boom in stock market 1904–1906, crash began Mar 1907 | | Aug 1907 – Feb 1908 | Nov 1906 |

| **RAINES-LEATHERS** | **KINDLEBERGER** | **SHILLER** | **MISHKIN-WHITE** | **ICI** | **INDICATOR'S bubble signals** | **Time when indicator-value starts rising steeply** |
|---|---|---|---|---|---|---|
| 1914–1918 bull market | | | World War 1<br><br>Market reaches new high in Oct 1916, bottoms in Dec 1917 | | Sep 1917 – Dec 1917 | Nov 1916 |
| Boom 1921–1929; prices soared in spring 1928 – autumn 1929<br><br>1929 Oct crash; bottom in 1932<br><br>28 Oct 1929, -12.8%<br><br>29 Oct 1929, -11.7%<br><br>6 Nov 1929, -10%<br><br>24 Sep 1931, -7.1% | 1920–1921: speculative peak in summer 1920, crash in spring 1921<br><br>1929: speculative peak in Sep 1929, crash in Oct 1929 | Stock market recession in 1920–1921<br><br>Strong real earning in 1921–1926<br><br>Sep 1929 P/E ratio 32.6<br><br>Crash in Oct 1929 | Market peaks in Sep 1929; stock market bearish until bottom in Jul 1932 | | Sep 1928<br>Nov 1928 – Sep 1929 | Oct 1927 |
| 12 Aug 1932, -8.4%<br><br>5 Oct 1932, -7.2%<br><br>31 Jul 1933, -7.9%<br><br>18 Oct 1937, -7.8% | | | 1930–1933 and 1937 prices peaked Oct 1937, indices decline till bottom in May 1938 | | Oct 1937 – Jan 1938<br>Mar 1938 – May 1938 | Apr 1936 |

| **RAINES-LEATHERS** | **KINDLEBERGER** | **SHILLER** | **MISHKIN-WHITE** | **ICI** | **INDICATOR'S bubble signals** | **Time when indicator-value starts rising steeply** |
|---|---|---|---|---|---|---|
| May 1946 – Oct 1946, -23.2% | | | 1940: declining market May–June 1940<br><br>Prices peak in Jul 1946, after rising from Sep 1945 | Expansion[1]: Apr 1942 – May 1946, +138.5% in S&P500<br>Contraction:<br>May 1946 – Jun 1949<br><br>Expansion: Jun 1949 – Jan 1953, +87.4%<br>Contraction: Jan 1953 – Sep 1953 | May 1943<br>Mar 1946 – Jun 1946 | Sep 1945 |
| Early 1950s – mid-1960s boom, up 400% | | Strong market rise: Sep 1953 – Dec 1955 | | Expansion: Sep 1953 – Jul 1956, +109,6%<br>Contraction: Jul 1956 – Dec 1957<br><br>Expansion: Dec 1957 – Jul 1959, +48,1%<br>Contraction: Jul 1959 – Oct 1960 | Nov 1954 – Dec 1955 | Oct 1951 and<br>Jun 1954<br>Jun 1958 |

| RAINES-LEATHERS | KINDLEBERGER | SHILLER | MISHKIN-WHITE | ICI | INDICATOR'S bubble signals | Time when indicator-value starts rising steeply |
|---|---|---|---|---|---|---|
| Dec 1961 – Jun 1962, -27.1%<br>Sep 1966 – Oct 1966, -25.2%<br><br>Dec 1968 – May 1970, -35.9% | | Kennedy-Johnson peak, P/E 24.1 in Jan 1966, prices had surged since May 1960 | 1962: prices peak in 1962, crash in Apr 1962 | Expansion: Oct 1960 – Dec 1961, +33.5%<br>Contraction: Dec 1961 – Jun 1962<br><br>Expansion: Jun 1962 – Jan 1966, +67.8%<br>Contraction: Jan 1966 – Oct 1966<br><br>Expansion: Oct 1966 – Dec 1968, +38.1%<br>Contraction: Dec 1968 – Jun 1970 | Aug 1966 – Sep 1966<br><br>May 1970 - Jun 1970 | Mar 1966<br><br>Dec 1969 |
| 1970s roller coaster<br><br>Aug 1973 – Nov 1974, -44.4%<br><br>Sep 1976 – Feb 1977, -26.9% | 1970s: speculative peak in 1973, crash in 1974–1975 | 1966 – early 1992 time of low returns | 'Penn-Central 1969–1970: market peak in Nov 1968, quick decline begins in May 1970<br><br>Sharp market decline from Nov 1973 to Oct 1974, prices start to rise again in Jan 1975 | Expansion: Jun 1970 – Apr 1971, +36.3%<br>Contraction: Apr 1971 – Nov 1971<br><br>Expansion: Nov 1971 – Jan 1973, +27.6%<br>Contraction: Jan 1973 – Dec 1974<br><br>Expansion: Dec 1974 – Sep 1976, +57.2%<br>Contraction: Sep 1976 – Mar 1978 | Apr 1974 – Jan 1975<br><br>Feb 1978 – Mar 1978 | Oct 1973 |

| **RAINES-LEATHERS** | **KINDLEBERGER** | **SHILLER** | **MISHKIN-WHITE** | **ICI** | **INDICATOR'S bubble signals** | **Time when indicator-value starts rising steeply** |
|---|---|---|---|---|---|---|
| Strong rise in index early 1980s – 1987<br><br>Apr 1981 – Aug 1982, -24.1%<br><br>Aug 1987 – Nov 1987, 30.5%<br><br>19 Oct 1987, -22.6%<br>26 Oct 1987, -8.0%<br>13 Oct 1989, -6.9% | Speculative peak in 1979, crash in 1979–1982<br><br>Speculative peak in 1985–1987, crash in Oct 1987 | Crash in Oct 1987<br><br>Crash in Oct 1989 | Sharp rise in stock prices from 1984, crash in Oct 1987 | Expansion: Mar 1978 – Nov 1980, +52%<br>Contraction: Nov 1980 – Jul 1982<br><br>Expansion: Jul 1982 – Oct 1983, +53.3%<br>Contraction: Oct 1983 – July 1984<br><br>Expansion: Jul 1984 – Aug 1987, +118.0%<br>Contraction: Aug 1987 – Dec 1987<br><br>Expansion: Dec 1987 – Jun 1990, +49.6%<br>Contraction: Jun 1990 – Oct 1990 | Mar 1986 – Sep 1987 | Sep 1985 |
| Sharp rise from mid-1990 till 2000<br><br>27 Oct 1997, -7.2% | | Period of strong growth, crash of 2000 ended boom of mid-1990–2000 | 1990: decline starts in Juy-Aug 1990, lasts till Oct 1990<br><br>Soviet Union breaks up in 1991<br><br>Brief slump in 1998, LTCM and Russian default<br><br>2000: decline from Aug 2000 | | Sep 1995<br>Nov 1995 – Jun 1996<br>Nov 1996 – Feb 1997<br>May 1997 – Sep 1997<br>Mar/Apr – Jun 1998<br><br>Sep – Oct 2002<br>Jan – Feb 2003 | Mar 1995<br><br>Nov 2001 |

[1]ICI expansions is from trough to peak (in the middle) and contraction is from peak to through.

The next figure (4.17) covers the period from 1898 to1928. In the bubble-related literature there are several stock price booms and declines identified during this period. The most well known are the bull-market periods of summer 1901, the 1903 'Rich-man's panic', the boom in 1904–1906, which ended in a sharp slide in October 1907 (Sobel (1965) called it a 'banking panic'), and finally the booming stock markets of 1921–1928, which accelerated particularly after 1926. The ADF-coefficient emits bubble-signals which match quite well the 1903 incident (coefficient rises sharply after December 1902, bubble indication at the end of 1903), the 1907 crash, the crash of 1917 and the boom of 1928. At the end of 1920s, the value of the coefficient starts to rise sharply already in October 1927. The continuous bubble-signal starts in November 1928 and continues until September 1929. In the literature, the rise in prices of exchange-traded stocks has been especially pronounced during the period from spring of 1928 to autumn of 1929 (the crash took place in October 1929). See figure 4.18 (1929–1949).

The next bubble signals are very close to the long slide in stock prices of the early 1930s. During this slide, the coefficient value surges towards the 0-line. Between December 1931 and July 1932, when the US stock markets had a very negative tone, the coefficient moves very close to 0 but does not break the 0-line.The next clear bubble signals were emitted in October 1937-January 1938 as well as in March 1938 – May 1938. These periods are related to strong negative corrections in stock prices. The correction of 1937 was also cited by Raines and Leathers (2000) as of one of the strongest corrections ever in the stock market.

The next period of expansion did not come until the beginning of the 1940s. Expansion in the stock markets began in spring 1942 and ended in the spring-summer 1946. This period was clearly related to the production needs of World War II. The first bubble signal in the ADF-coefficient was emitted already in May 1943, which is coincident with the strong run-up in the index value. The next signal appears in January 1946 and persists until June 1946. The period from May to October 1946 was one of sharply declining markets.

Figure 4.19 presents the time-period from 1950 to 1970. During this period the coefficient values signal three bubble periods: November 1954 – December 1955, March 1956 (the levels stays close to 0 throughout the period from January to March 1956), from August 1966 to September 1966, and finally from May 1970 to June 1970. When these indications are compared to developments in the markets, the first of these periods can be connected with the rising stock market from September 1953 to July 1956. During this period the S&P500

index rose by 109.6% according to ICI. In the summer-autumn of 1959 the indicator once again gets close to 0-limit, as the next index top is reached in July 1959, but strangely the coefficient value sinks as prices rise further. The 1966 period, on the other hand, can be related to the sharp market decline during September and October of 1966 when the markets corrected by 25%. The last period in spring 1970 relates to the strong negative correction in May 1970 (see eg Mishkin and White, 2000).

For 1971–1982 (Figure 4.20) we can extract two bubble-warnings, for the periods April 1974 to January 1975 and February to March 1978. The first of these periods is related to the contraction of January 1973 – December 1974, which is one of the largest contractions in the history of the S&P500 index. During this period the index sunk by 43.4%. The next, and very short, indication coincides with the index decline which bottomed out in March 1978.

The last two figures on the USA (4.21 and 4.22), show the last two periods of the years 1983–1992 and 1993–2004. These were discussed in section 4.2.

Figure 4.16 **Bubbles identified in the US stock market, 1874–1897**

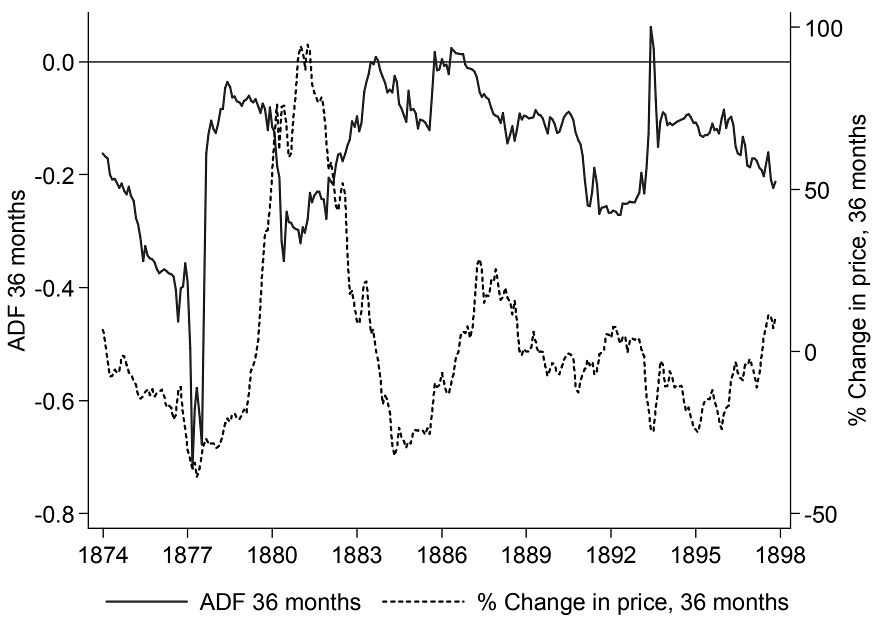


Figure 4.17 **Bubbles identified in the US stock market, 1898–1928**

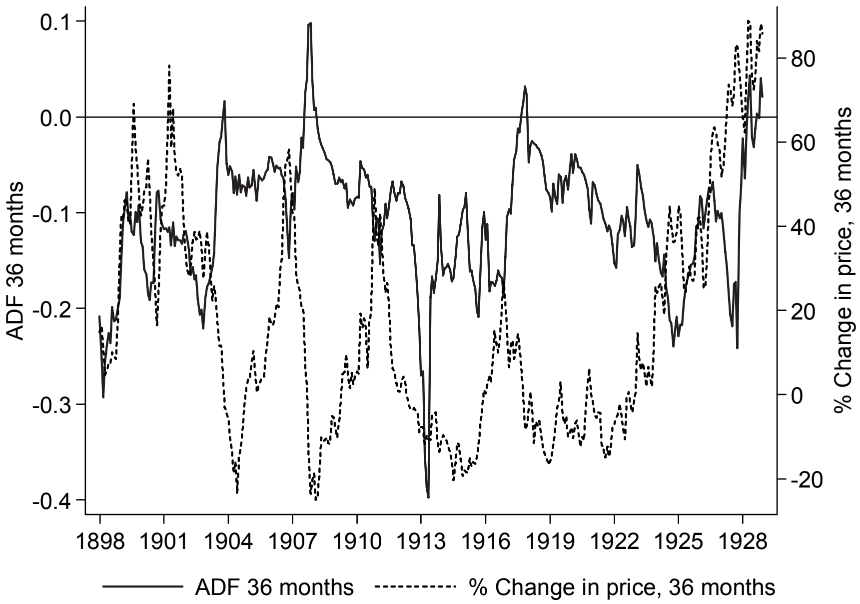



Figure 4.18 **Bubbles identified in the US stock market, 1929–1949**

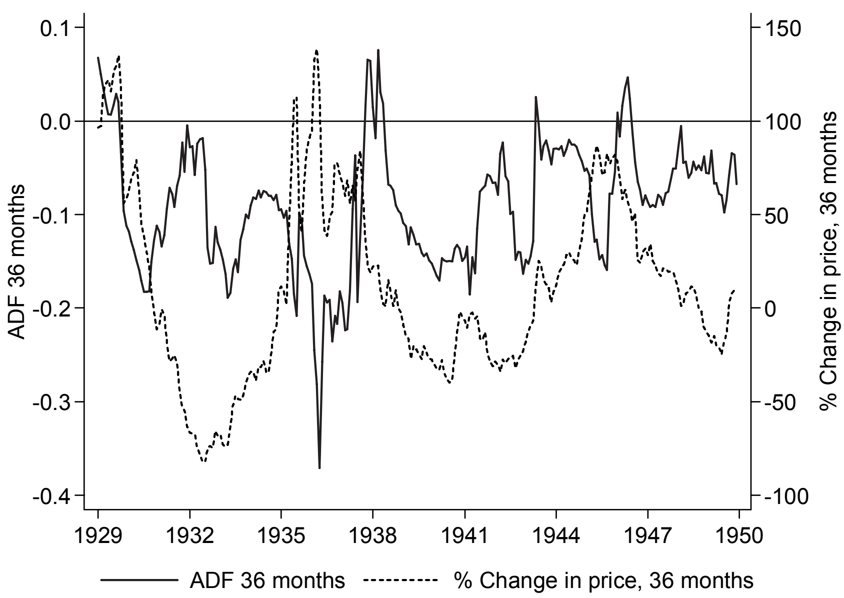


Figure 4.19 **Bubbles identified in the US stock market, 1950–1970**

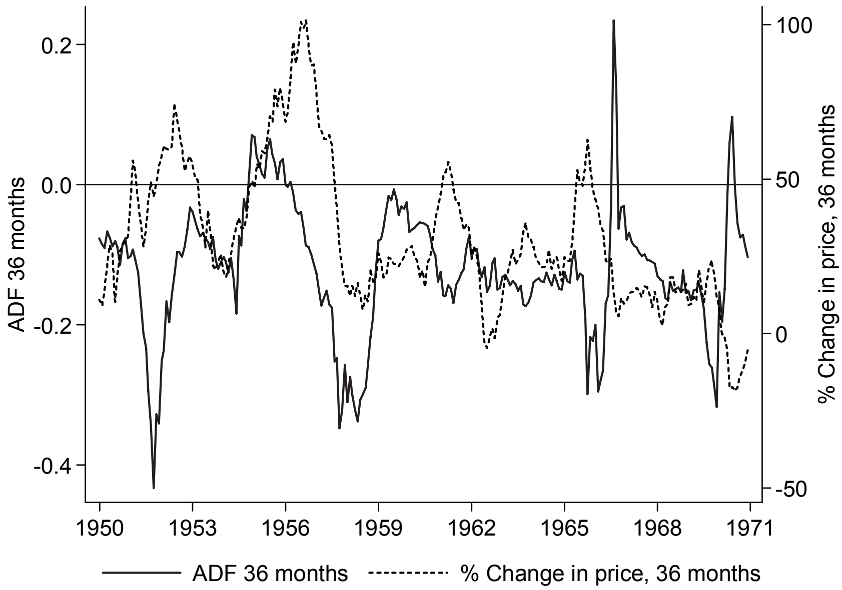



Figure 4.20 **Bubbles identified in the US stock market, 1971–1982**

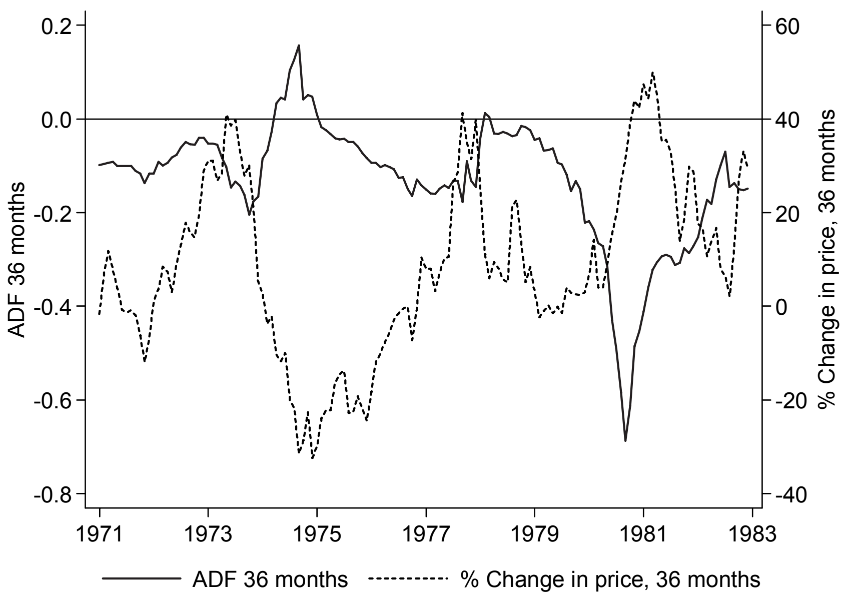


Figure 4.21 **Bubbles identified in the US stock market, 1983–1993**

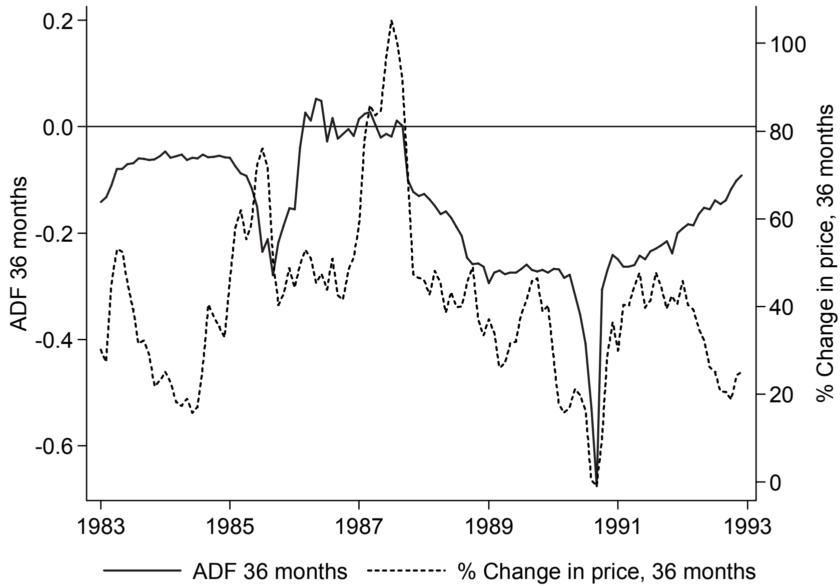
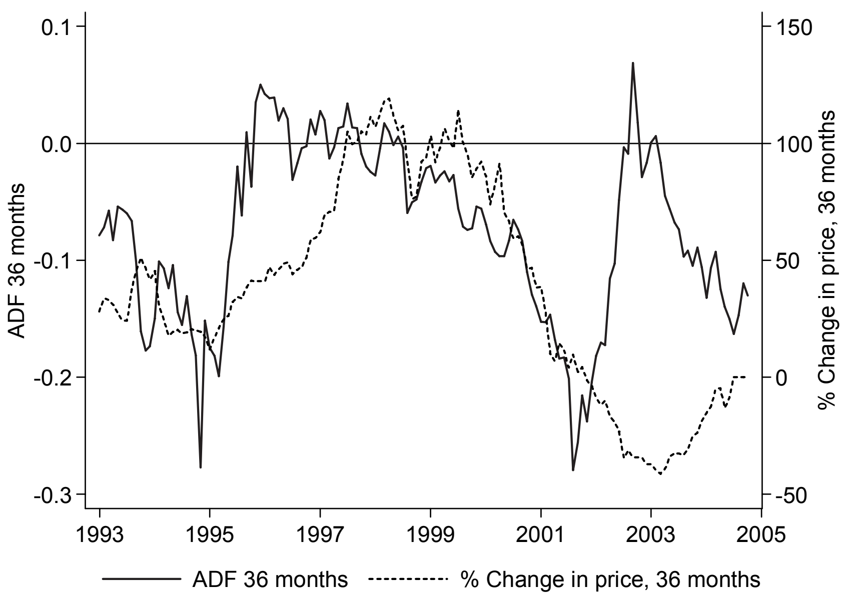



Figure 4.22 **Bubbles identified in the US stock market, 1994–2004**



# 5 Conclusions

The importance of recognising situations where asset prices are not in line with fundamentals becomes clear when one considers the various linkages between developments in asset prices and in the macroeconomy. First, if we assume that asset price developments can reflect the expected rate of inflation, policy-makers should react to sharply rising asset prices. Second, policy-makers and regulators should act especially when a price bubble is starting to develop, if they intend to promote the overall stability of the financial system, because bubble bursting can have severe destabilising effects on the financial system, especially via the (likely) meltdown of collateral values. Here, one might well recall the real-world case of Japan. Third, policy-makers and regulators should pay attention to price bubbles because such bubbles and the underlying expectations can seriously misdirect the economy's resources and thus impair the economy's growth prospects.

The main problem as regards reacting to asset price developments has been the difficulty of knowing whether or not a given price level is justified by the fundamentals. In this study, we have presented a method of evaluating developments in stock-price discovery, a method based on the fundamental relationship between dividends and asset prices and which is thus easy to apply to other markets (eg housing markets) as well.

Regarding the existence of bubbles, we used three different kinds of tests in order to determine whether bubbles have been present in the US and Finnish stock markets. All of our test results were consistent in the sense that each was able to date bubbles on the basis of the data analysed. We used these three different kinds of tests because they were able to deal with different periods. In this way, we were able to conduct more sharply focused estimations for periods in which there were bubbles.

Despite the advantages, the method has some shortcomings which should be taken into account when interpreting the results. The first to mention is that the method relies heavily on the present value pricing formula and on assumption that all firms distribute profits by paying dividends rather than by eg repurchasing stock. If buybacks were to gain in popularity, the relationship between dividends and prices could weaken or even break down. This could have an effect on the valuation of stocks. One must also consider, whether sub-samples of three, five and eight years period are long enough to tell whether prices and dividends are moving in the same direction. The answer is not necessarily, but the caveat applicable to all current methods is that they are not able to discount the expectations, since we do not know how long a period of expected future dividends and revenues is actually reflected in the prices.

In any case, this study offers an answer to the main question we have confronted here, as to the existence of bubbles in the stock market. Let us conclude by noting that, according to our tests, there have occurred bubbles in both the US and Finnish stock markets. Based on the results for the ADF coefficient, it nonetheless seems clear that further work is warranted.

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# Appendix 1

## Efficient market hypothesis

### I Theoretical background of the efficient market hypothesis

There is a close relationship between EMH, according to which prices reflect fundamental values, and the basic pricing formula. As mentioned in Shleifer (2000), the theoretical foundations of EMH depend heavily on following three considerations:

- First, investors are assumed to be rational and to value securities rationally. This implies that all news concerning fundamentals is immediately evaluated and passed through to market prices. Therefore asset prices always fully reflect all available information. But people differ on the meaning of 'all available information', and the different interpretations have led to three different forms of EMH[51]: weak form, semi-strong form, and strong form.

- Second, trades carried out by nonrational investors are assumed to be random and hence likely to have mutually offsetting effects. For this reason, these trades should have no net effect on market prices. The crucial aspect of this assumption is that such trades are not correlated with each other.

- Even for the case of correlated trades there is a rationale for EMH. To the extent that there are nonrational investors, there must also be rational arbitrageurs who act to eliminate the price effects of

[51] Fama (1970) describes the differences in information that is incorporated in prices in the three forms of EMH. In the weak form, the information incorporated in prices is simply historical prices. Thus it is impossible to earn superior risk-adjusted profits based on knowledge of past prices, since all such information is already incorporated into prices. In the semi-strong form, the information incorporated in prices is all publicly available information on fundamentals, ie information that affects a company's ability to generate profits and dividend flows. Under this form of EMH it is impossible to earn superior risk-adjusted profits based on knowledge of any publicly available information such as announcements of annual earnings, since all such information is already incorporated into prices. In the strong form, the information set contains all information available, even insider information. This is an extremely strong assumption, as it means that it would even be impossible to earn superior risk-adjusted profits based on insider information, as all of it is already incorporated into prices.

nonrational traders and their correlated trades (Shleifer 2000 and Raines and Leathers 2000).

There is a great deal of literature on anomalies and how they relate to the above three considerations and to the three forms of EMH mentioned in the footnote. These observed and documented anomalies call into question the reality of efficient markets. A key issue is whether these documented anomalies are sufficiently strong to prove that there are indeed inefficiencies in the markets or are they merely mildly inconsistent with efficient market theory.

## II Inconsistencies in EMH

The main documented anomalies in connection with the assumptions of the EMH include the following:

### II.I EMH assumption concerning investor rationality: Can investors be considered rational and do they value securities rationally?

Overall rationality of capital markets: According to Mishkin (1981), 'The theory of rational expectations, introduced by John Muth, asserts that both firms and individuals, as rational agents, have expectations that are optimal forecasts using all available information'. In the stock market context, this means that the difference between the one-period-ahead price forecast and today's price, ie the forecast error conditioned on information available at the end of the current period, is not correlated with any information or linear combination of information available at the end of the current period.

The financial models of the 1970s incorporated rational expectations. Among the noteworthy studies of the decade are Merton (1973), An Intertemporal Capital Asset Pricing Model, and Lucas (1978), Asset Prices in an Exchange Economy. Since the 1970s, many academic papers have raised considerable doubt about the rationality of financial markets. In the 1980s the focus turned to econometric evidence on time series properties of prices, dividends and earnings, as noted by Shiller (2003). In the 1990s behavioural finance introduced psychological factors into the discussion of financial markets, which allowed one to relax the assumption of pure investor rationality.

An excellent summary of the development of the rationality concept over time is available in Doukas (2002), which is a collection of panellists' views from a meeting of the European Financial

Management Association. The discussion sheds much light on the different viewpoints on rationality and summarises the course of development over time. As we know, full rationality per se is a very strong assumption. In the context of economic models that incorporate rational expectations, it implies that agents process all information perfectly (Doukas 2002). But a rationality shortfall does not immediately prove that markets are inefficient. A market can be efficient even though the participants make random errors, and errors are by no means systematic. It is not necessary that all market participants be rational in a market that incorporates rational expectations, if there are enough arbitrageurs to immediately take advantage of any unexploited profit opportunities. In this respect, Shiller's survey (1987) is of interest because it documents the fact that prior to the crash of 1987 there was widespread belief among investors – buyers and sellers – that the market was overvalued.

My own view of rationality is that it holds most of the time in the markets. One can usually explain market participants' behaviour on the basis rationality. The real problem is that spells of overoptimism do occur from time to time. The issue is then whether these spells of overoptimism should be considered signs of irrationality? The answer seems to be two-fold: overoptimism that obtains because of a lack of information should not be considered a sign of irrationality, whereas overoptimism based on exuberance that is not founded in available data should certainly be taken as a symptom of irrationality. In practice, it may be very difficult to distinguish the two cases.

**II.II a) EMH assumption that asset prices fully reflect all available information on fundamentals: Is all relevant new information immediately incorporated into market prices?**

Speed of incorporating new information into prices: According to EMH, prices should adjust immediately to new information. As mentioned in Fama (1991), many event studies indicate that prices do adjust quickly and efficiently to firm-specific information. On the other hand, Chan, Jegadeesh and Lakonishok (1996) present evidence that documented momentum in stock returns could be partially accounted for by the slow adjustment of the market to past profit surprises. Their evidence suggests that the market responds only gradually to new information. A recent study (Chan 2003) finds very pronounced drifts after bad news, which is viewed as evidence that investors react quite slowly to this kind of information. The study also finds reversals after extreme price movements unaccompanied by public news.

Reactions to information could differ from period to period. For example, Veronesi (1999) reports that because of uncertainty about the level of future dividend flows, investors are inclined to 'hedge' against changes in the level of uncertainty, overreacting to bad news in good times and underreacting to good news in bad times. This makes the price of an asset more sensitive to news in good times than in bad times.

Concerning the different kinds of systems, there might be some difference in the incorporation of information into prices. Vives (1995) wrote an article concerning the incorporation of private information into prices (of course private information makes this a special case, while there is true informational advantage) and concluded that in systems where there are market makers present the incorporation is much faster. According to Vives, 'in any case the asymptotic precision of prices is negatively related to the degree of risk aversion and the amount of noise in the system'.

Costs of acquiring information: In today's world, although the flow of information available to investors is overwhelming, there could be some differences in costs of acquiring information (eg a news service), which may affect the speed at which different investor-groups learn of new information. Trading costs of course also affect the speed at which new information is incorporated into prices. As Fama (1991) puts it, 'since there are surely positive information and trading costs, the extreme version of the market efficiency hypothesis is surely false'.

Excess volatility: The academic literature concerning excess volatility burgeoned in the 1980s. The main results of this work are that stock prices seem to be more volatile relative to what would be predicted by efficient market models[52] in which valuations are based on fundamentals. As Shiller (2000) writes, 'Fluctuations in stock prices, if they are to be interpretable in terms of the efficient market's theory, must instead be due to new information about the long run outlook for real dividends. Yet in the entire history of the US stock market we have never seen such fluctuations, since dividends have fairly closely followed a steady growth path.' In fact, in (1988a), Campbell and Shiller estimated that 27% of the annual return volatility of the US stock market is explained by information about

[52] Shiller (1981) was later criticised for misspecified fundamental values. But it did not remain as the only study to generate similar results, as witnessed by Leroy and Porter (1981), Campbell and Shiller (1987, 1988b), and Campbell and Ammer (1993). Reviews of this literature are available, as eg Cochrane (1991).

future dividends[53]. Thus prices clearly seem to react not only to information concerning changes in fundamentals but also to other arriving information[54].

**II.II b) The EMH assumption that asset prices fully reflect all available information on fundamentals: What kinds of information are actually incorporated into market prices?**

A pricing process is a martingale if the best guess for next period's price is today's price, when expectations are formed in the current period and are thus conditioned on currently available information. The efficient market hypothesis and martingale process are equivalent concepts.

Instead of reacting only to currently available information concerning fundamentals, stock prices seem to react to non-information: For example, there was no new astounding news concerning fundamentals just before the 1987 stock market crash, at least not of a magnitude that would justify the draconian correction in stock values of 19 October. Therefore it would seem that the correction was based on other factors (Beechey, Gruen and Vickery 2000). In fact, Cutler et al (1991) studied the 50 largest one-day movements in stock prices in the United States since World War II and found that many of the movements occurred on days when there were no major announcements concerning fundamentals. Moreover, Roll (1988) found that news of fundamentals was not the only factor that impacted prices and price changes. Another interesting development is that of Daniel and Titman (2003), who separated information that moves stock prices into the categories tangible and intangible[55] and found evidence that 'Intangible information reliably

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[53] In their latest study, Campbell and Shiller (2001) found that price-earnings ratios and dividend-price ratios are poor forecasters of dividend growth, earnings growth, and productivity growth. Contrary to the simple EMH, these ratios seem to be useful for forecasting movements in stock price changes.

[54] An interesting addition to this anomaly is that some researchers have suggested that the present value model's inability to account for price fluctuations could owe to the inadequacy of dividends as a proxy for total payoffs to shareholders. Teselle (1998) notes that tests using 'narrow dividends' suggest that stock prices fluctuate too much compared to what can be explained by a simple present value hypothesis, whereas some tests using 'broad dividends' (narrow div + share liquidation proceeds) do not detect such excess volatility.

[55] Tangible information is performance information such as sales, earnings, and cash flow growth, which can be extracted from the firm's accounting statement and intangible information comprises the other determinants of a stock's past returns. Thus tangible returns are linked to accounting growth numbers and intangible returns to changes in expectations about future cash flows or discount rates.

predicts future stock returns. However, in contrast to previous research, we find that tangible returns have no forecasting power.'

There is an interesting new genre in the literature that focuses on asset prices and the impact of non-information on them. This literature is concerned with the balance between market demand and supply. The earliest studies to document a demand impact on prices were Shleifer (1986) and Harris and Gurel (1986), which presented evidence that adding a stock to the S&P500 increased the demand for it and caused a permanent price change of about 2%[56]. Later Warther (1995) analysed US data on mutual fund flows and found that a 1% increase in mutual funds' stock holdings leads to a permanent increase of 5.7% in stock prices. Wermers (1999)[57] presented evidence of herding by equity mutual funds. A fresh contribution to this literature is Evans (2003), which finds that innovations in net issues, mutual fund flows, and foreign portfolio investment explain a significant proportion of variance in stock prices.

Some of the documented anomalies under this heading are the 'weekend', 'January' and 'holiday' effects, which reflect repeating patterns in the stock markets[58]. But some analysts have argued that these fairly small seasonal movements in returns may be explained in terms of market microstructure (see eg Fama 1991).

Informational cascades[59]: An informational cascade is said to occur when some investors' actions are viewed as an additional source of information to others. The latter investors may then decide to act on the information extracted from market behaviour, which is not necessarily related to news that would affect the fundamentals. As Hirshleifer and Teoh (2003) put it, 'Cascades tend to be associated with informational blockages. Such blockages are an aspect of an

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[56] The reason for a demand increase is easily seen in portfolio managers' behaviour, especially if they closely track the components of benchmark indices. For example, Chan, Chen and Lakonishok (2002) show that mutual funds have their own investment styles in that they tend to cluster around certain broad indexes. This kind of behaviour will increase a fund's demand for a particular stock when that stock is added to the fund's favourite index.

[57] Wermer's study has been criticised for not sufficiently accounting for fundamentals. If this is true, there is a definite risk that one will conclude that mutual fund flows are driven by investor sentiment rather than fundamentals and hence that the price level is also driven by sentiment due to increased demand.

[58] Thaler (1987) reports that stock prices tend to rise in January, particularly prices of small firms and firms whose prices have declined in the past few years. Rogalski (1984), in contrast, found that prices rose on Mondays from open to close, which meant that the documented negative returns on weekends all occurred between the close on Friday and opening on Monday, a period that is hardly the busiest time for company announcements.

[59] There is much literature on informational cascades; see eg Banerjee (1992), Welch (1992) or Bikhchandani et al (1992).

informational externality: An individual making a choice may do so for private purposes with little regards to the potential information benefit to others.' Therefore acting according to information attained from other market participants' trades (ie on times to buy, sell or hold) cannot be described as purely informed trading, which should be directly related to news on fundamentals.

Of course when an informational cascade develops, one must assume the presence of informational asymmetry in the market. In such case, it is presumed that there are some investors in the market who possess, or at least have access to, superior information. One would then assume that the trades in question reveal some of that superior information. An informational cascade can also be seen as an opportunity for investors to exploit others' information on market conditions. As Hirshleifer and Teoh (2003) write, informational cascades one can refer to 'observational learning in which the observation of others (their actions, payoffs, or even conversation) is so informative that an individual's action does not depend on his own private signal'.

When an investor is thought to possess some private or superior information, it might be wise for others to imitate that investor's actions[60]. But it should be noted that if people merely imitate each others' actions, actions of later imitators – possibly even from the first imitator onwards – will not necessarily reveal any new information, as the information content of trades and prices will diminish as more and more trades occur.

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[60] The problem might arise in an asymmetric information situation if the actions of the masses would somehow hurt the investor possessing superior information. In this case, the better informed investor would not have an incentive to reveal his superior information eg by trading at a price more in line with fundamentals. An example of such a situation would be where the better informed investor knows that a stock is overvalued compared to fundamental value – normally a time to sell out. But if he were to sell a large number of shares, this might be a sign to other market participants that the stock is overvalued. Then the less-well informed investors would also be inclined to sell. This would put further downward pressure on the price of the stock and might prevent the better informed investor from liquidating his entire holding at the higher price. The better informed investor might do better by selling in small amounts and thus hiding his information in the hope that the period of overpricing will last long enough for him to be able to liquidate his entire holding. For more on this subject, see eg Spulber (1999) and Barclay and Warner (1993). Barclay and Warner suggest that informed investors engage in 'stealth-trading', ie medium-sized trades that enable them to hide within the uninformed flow.

### II.III EMH assumption linked to trades being uncorrelated. Can trades of nonrational investors be considered random and uncorrelated and hence without price effects?

Investors who act irrationally, ie those whose demand for a risky asset is based of beliefs that are not justified by fundamentals, are often called 'noise traders'[61]. These are typically individuals and other less sophisticated investors.

Black (1986) wrote that noise traders base their investment decisions purely on past price movements and so become more aggressive as a speculative bubble increases and positive feedback from rising prices accumulates. With the price thus elevated, arbitrage may entail risk, which will dampen arbitrage activities in the market[62]. Shleifer and Summers (1990) divided investors into two groups: arbitrageurs, whose expectations of equity returns are rationally developed, and noise or liquidity traders, whose opinions and trading are systematically biased.

The problem concerning irrational traders seems to be that their trades tend to be correlated rather than uncorrelated. This is one reason for the abundance of literature on uninformed individual investor trading on the basis of sentiment, ie herding[63] (behaviour convergence), which may seem rational for the individual but produces inefficient outcomes at market level. A good source for the literature on individual investors' herding behaviour is Nosfinger and Sias (1999).

One of the reasons for herding behaviour among individual investors is related to the manner in which they make trading decisions. Both Shiller (1984) and De Long et al (1990) claim that influences of fashion and fad are likely to impact an individual investor's investment decisions. Shleifer and Summers (1990) suggest that individual investors may herd because they respond to the same signals. Similarly, Hirshleifer and Teoh (2003) argue that the trades of individuals are irrationally correlated as 'a result of herding (which involves interaction between the individuals), or merely a common irrational influence of some noisy variable on individuals' trades'. On the other hand, Lakonishok, Shleifer and Vishny (1994) write that

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[61] A noise trader trades for noninformational reasons.

[62] Evans (2003) makes an important point concerning Black's (1986) concept of noise traders: 'By simply changing the wording in Black's noise trading model reveals a closer association to Shiller's fad model than the efficient markets model it attempts to reclaim'.

It is true that if every investor were rational and understood information perfectly, there would be very little trading, as informed traders are not inclined to trade with each other. Thus it is the noise traders who provide the market with the necessary liquidity.

[63] An excellent summary of herding can is found in Hirshleifer and Teoh (2003).

individuals may extrapolate past growth rates and therefore engage in irrational trading in an environment of rising prices. It also seems that individuals are easily influenced by decisions made by other individuals in their immediate surroundings. For example, Kelly and O'Grada (2000) and Hong et al (2001) provide evidence that social interactions between individuals affect their decisions concerning equity participation and other financial matters. DeLong, Shleifer, Summers and Waldmann (1990) state that 'Individual investors typically fail to diversify, holding instead a single stock or a small number of stocks[64]. They often pick stocks through their own research or on the advice of the likes of Joe Granville or 'Wall Street Week'.'

The above research results clearly show that the issues of correlation and randomness of individual trades is not at all clear-cut. This is the case particularly as regards individual investors' herding behaviour. Concerning the validity of EMH, it is crucial to know whether individual herding is constantly or only now and then present in the market. Constant presence would seriously violate EMH. Another factor is of course whether there are enough rational arbitrageurs in the market to eliminate irrational traders' possible effects on prices.

**II.IV EMH assumption regarding rational arbitrageurs' correctional influence on market prices. If there are irrational traders whose trades are correlated, are there enough rational arbitrageurs to eliminate price-effects of the irrational and correlated traders?**

The basic question seems to be about exactly which investors can be deemed rational? A typical response is that they are the institutional investors, who are generally more sophisticated and have an information advantage. But unfortunately it has been shown that even this group is not completely rational. There is documented institutional herding behaviour based on irrational psychological factors etc.

As Nofsinger ans Sias (1999) write, 'one popular view holds that institutional herding is primarily responsible for large price movements of individual stocks, and, moreover, it destabilizes stock prices'. The evidence that institutional herding moves prices is not necessarily a bad thing. If institutional investors are actually better informed and their herding behaviour is based on information, they

[64] Lewellen, Schlarbaum and Lease (1974).

may move prices closer to true fundamental values[65]. But when institutional herding is not based on information, institutional herding can certainly hamper the price-formation process. There are many possible reasons for uninformed institutional herding[66]. These include irrational psychological factors, agency problems, rewarding profiles, reputational incentives and stocks' desirable characteristics[67].

Another problem is whether there will be an adequate amount of rational arbitrage. The process of arbitrage in the markets might not be trouble-free. As Shleifer (2000) writes, 'With a finite risk-bearing capacity of arbitrageurs as a group, their aggregate ability to bring prices of a broad group of securities into line is limited as well'. Briefly stated, arbitrage cannot bring prices down to fundamentals if there is some risk inherent in arbitrage. Such risk may derive from a lack of perfect asset substitutes or – with perfect substitutes – from uncertainty about future price movements of mispriced securities. The latter risk is due to the possibility that mispricing will become more severe (eg due to noise traders' actions) before finally disappearing. An arbitrageur should be able to get through such a period of negative revenues. These sources of risk to arbitrageurs are discussed eg in Figlewski (1979), Shiller (1984), Campbell and Kyle (1987), Shleifer and Summers (1990), and De Long et al (1990).

Another problem regarding fully functioning arbitrage is the possible constraints on short selling. To short sell an asset one must first borrow the asset. Borrowing costs of stocks can be so high that it is not profitable to carry out such a strategy (see eg Cochrane 2003). Lamont and Thaler (2003), show that short-sale constraints eliminate arbitrage opportunities.

Some of the strongest arguments questioning the validity of EMH can be found in the above-mentioned studies, which show that arbitrageurs might not act rationally all the time (due to uninformed herding, risks, or operational limitations on arbitrage). Once again the crucial question concerning the validity of EMH is whether arbitrageurs are able to act rationally. If not, EMH is clearly on a shaky foundation.

[65] Eg Lakonishok, Shleifer and Vishny (1992).

[66] Interestingly, Chan, Chen and Khorana (2000) find cross-country differences in stock market herding. They say that herding seems to be more common in emerging markets, where it seems to be related to macroeconomic rather than firm-specific factors.

[67] Good overviews of the literature on these topics can be found eg in Hirshleifer and Teoh (2003) and Nofsinger and Siah (1999).

## II.V Validity of the efficient market hypothesis

As the previous examples show, the assumptions behind market efficiency are by no means unambiguous. Many of the results from studies conflict with the basic assumptions of market efficiency. The main question is whether the arguments against market efficiency are so strong that we should reject EMH at all times. To my mind, they are not. But I would certainly accept the hypothesis of occasional deviations from EMH. Total rejection of EMH would require that these deviations would always be occurring, and the current evidence does not warrant this. On the other hand, finding bubbles in asset prices provides evidence that at least sometimes there are serious deviations from the assumptions of EMH. Such deviations could derive from several sources and be due to a variety of reasons, but these are not the main concern of this study.

# Appendix 2

## Summary of bubble tests

Table A2.1 **Summary of bubble tests**

| Author | Data | Method | Bubble? |
|---|---|---|---|
| Balke & Wohar (2001) | S&P500 data from 1881–1999 | Determine whether market fundamentals can explain observed price peaks in stock markets. | **Not** necessarily: plausible changes in expectations of real dividend growth and discount rate can explain stock prices in the late 1990s. |
| Diba & Grossman (1984, 1987, 1988) | S&P composite stock price index 1871–1986, annual, divided by wholesale price index for1988. | When nonstationarity of dividends accounts for nonstationarity of stock prices, the two series are cointegrated. Tests for cointegration of prices and dividends. 1988 version takes into account the ‘unobserved’ variable. | **No**: stock prices do not contain explosive rational bubbles. |
| Flood & Garber (1980) | | Pioneering article on bubbles that focuses on deterministic component of hyperinflation model. | |
| Flood & Hodrick & Kaplan (1987) | S&P data for 1871–1980 and modified Dow-Jones index for 1928–1978. Both datasets include annual real stock price indices and related dividend payments. | Extends and modifies West’s work and testing procedure. | ‘Conditional on having the correct model and no process switching, the rejection has been taken to be evidence of bubbles. Since we find the model inadequate, we conclude that the bubble tests do not give much information about bubbles.’ |

| Author | Data | Method | Bubble? |
|---|---|---|---|
| Hamilton & Whiteman (1985) | German hyperinflation and US stock market. | Two important points: interpretation of bubble tests → especially what does rejection mean. Also points out that all bubble tests are subject to concern that what appears to be a speculative bubble could 'instead have arisen from rational agents responding solely to economic fundamentals not observed by the econometrician'. | |
| Koustas & Serletis (2005) | S&P500 data incl. dividends data, annual, 1871–2000. | Examines the empirical validity of permanent deviations from present-value model of stock prices and focuses on possible nonlinearities in variance of log dividend yield. Fractional integration. | **Tests based on fractional integration: No bubble**. Evidence presented points to long memory in log dividend yield. |
| Dezhbakhsh & Demirquc-Kunt (1990) | S&P500, annual and divided by PPI, dividend data corrected slightly eg from West's (1987), data, covers 1871–1981 and 1871–1988. | Builds on West's procedure with a modification concerning West's indirect test. | **No Bubble.** Contrary to West's (1987) result 'no-bubble' hypothesis is not rejected. |
| West (1987) | S&P500, annual data 1871–1980 divided by PPI and sum of yearly dividends deflated by average of year's PPI.<br><br>Modified Dow Jones index 1928–1978. | The basic idea relates to Hausman's specification test. The test compares two sets of estimates of the parameters needed to calculate the expected present discount value. The sets will not be equal if the stock price constructs from two components: efficient market model implied price + a speculative bubble. Speculative bubbles are tested by seeing whether the two sets of estimates are the same (apart from sampling error). | **Bubble.** The data reject null hypothesis of no bubble. |

| Author | Data | Method | Bubble? |
|---|---|---|---|
| Evans (1991) | | Points out that an important class of rational bubbles can not be detected by traditional tests. | |
| Flood & Hodrick (1990) | | Survey of the testing literature and of observed shortages. | |
| Froot & Obstfeld (1991) | Estimation is based on annual deflated S&P index data, period 1900–1988. | Intrinsic bubble | **Bubble.** Incorporating intrinsic bubble into simple present value model helps to account for long-run variability of US stock market data. |
| Craine (1993) | – Annual composite index data S&P, 1872–1988. – Value weighted New York stock market data, annual, 1927–1989. – Value weighted New York stock market data, quarterly, 1926(2) –1989(4). | Craine's model extends Campbell's & Shiller's (1987) cointegration restriction by allowing stochastic discount factors in expected present value model. | **Bubble.** 'Results of the paper indicate that either the price-dividend ratio contains a rational bubble, or the discount factor must be stochastic and contain a large predictable component'. |
| Campbell & Shiller (1987, 1988 a and b) | S&P composite stock price index, real annual prices and dividends, 1871–1986. | Validity of present value model, cointegration. 1988 papers make some modifications. | Spread between stock prices and dividends moves too much and deviations from present value model are quite persistent (results sensitive to discount rate). |
| Pastor & Veronesi (2004) | Nasdaq, end of 1990s data. Purpose is to try to match prices observed on Nasdaq 10 Mar 2000 with prices given by Pastor's and Veronesi's valuation model. | Calibrate a stock valuation model that incorporates uncertainty about average future profitability in to the valuation model. | **Not** necessarily: The fundamental value of the firm increases with uncertainty. This could explain some of the valuations observed in the markets in the late 1990s. |

| Author | Data | Method | Bubble? |
|---|---|---|---|
| McGrattan & Prescott (2001) | US data<br><br>Focuses first on 1929 and later on 2000. | Estimates fundamental value of corporate equity in 1929 using data on stock of productive capital and tax rates. | **No bubble**: Evidence strongly suggests that stocks were undervalued even at their 1929 peak.<br><br>**No bubble** in 2000. In theory, market value of equity + debt liabilities should equal the value of productive assets + debt assets. In 2000 the net value of debt is low, so that market value of equity should approx. equal market value of a productive asset. |
| Siegel (2003) | Cowles Foundation data from 1871–1926 and the CRSP value-weighted data from 1926–2001. | Highlights the importance of long-term cash flow in determining the price of equity. | **No** bubble: in 1929 or 1987. Subsequent returns justified the price paid at market peak. After 1929 one had to wait for the cash flows of the 1940s.<br><br>**Bubbles** in 2000 and 1932 (negative). |
| Adam & Szafarz (1992) | | Focuses on difficulties in defining rational expectations bubble. | |

| Author | Data | Method | Bubble? |
|---|---|---|---|
| Van Norden & Schaller (1997)<br>research (1993) | US stock market data for 3 subperiods: 1929–1945, 1946–1972, 1973–1989.<br>(1993): From 1926–1989. | Testing for fads and bubbles using empirical strategy based on switching-regression econometrics. | **Mixed**: ‘Our results suggest that there is more in the data than fads. The specific ways in which the data conflict with the fads model frequently is consistent with the bubbles model, but the evidence in favour of the bubbles is not decisive.’<br><br>Research for 1994. Based on idea that overvaluation increases probability and expected size of stock market crash, evidence of speculative behaviour found in US market data. Evidence also found that prior to crashes of 1929 and 1987 the probability of collapse rose (not true for some other documented crashes). |
| Van Norden & Vigfusson (1996) | | Examines the power properties of regime-switching bubble tests via Monte Carlo experiments using Evan’s data generating process. | |
| Funke & Hall & Sola (1994) | | New test strategy for for bubbles that allows for possibility of switching regimes in the data’s time series properties.<br><br>Funke & Hall & Sola tried this test on Poland’s hyperinflation. | |

| Author | Data | Method | Bubble? |
|---|---|---|---|
| Wu (1997) | Real S&P500 and real dividends (deflated by CPI), annual observations, 1871–1992. | Bubble treated as an unobservable state vector in state space model and is estimated with Kalman filter. | **Bubble.** Estimated bubble components account for substantial portion of US stock prices and fit the data well. |
| Bohl & Siklos (2002) | S&P stock price index data 1871:1–2001:9 (Shiller's web page http://aida.econ.yale.edu/~shiller). | Momentum threshold autoregressive technique to detect asymmetric short-run adjustments to long-run equilibrium. | For the **long run**, the present value model seems to work well, but for the **short run** US stock prices exhibit large and persistent bubble-like departures from present value prices followed by a crash. |
| Wu & Xiao (2004) | S&P500 data, weekly, 1974:01–1998:09.<br>Hang Seng index data, weekly, 1974:01–1998:09. | New improved testing procedure is a modification of traditional unit root test. | **Not in USA.** Bubble evidence for US market is weak.<br><br>**Bubble** in Hong Kong. Fairly strong evidence of a bubble in Hong Kong. |
| Donaldson & Kamstra (1996) | S&P500 data, monthly, 1899:01–1934:12. Focuses on crash of 1929. | Introduces new procedure for estimating fundamental stock prices as present value of expected future cash flows. Future dividend paths (conditional on available info) are forecasted with Monte Carlo simulation. | **No bubble**. Finds fundamentals-related explanation.<br><br>Without Donaldson's & Kamstra's simulation method, bubble cannot be rejected. |
| Rappoport & White (1993) | US stock market data, 1929 boom. | Behaviour of interest rates on brokers' loans to investors for stock purchases. Dramatic rise in risk premia indicates that stock markets might collapse and value of collateral might be jeopardised. | **Bubble.** 'Traditional accounts of a bubble in the market cannot be so easily dismissed'. |

# Appendix 3

## Bubble indications from the US stock markets 1871–2004

Table A3.1 **Bubble indications with various rolling window-lengths**

| Periods commonly regarded as bubbles and crashes | Bubble indications, rolling sub-samples. *) 36 months indications, **60 months indications** and *100 months indications* | Period when the indicator-value starts rising steeply, 36 months rolling sub-sample |
|---|---|---|
| 1873: speculative peak in March 1873, crash in September 1873 | | |
| 1884 | October 1883 – November 1883<br>**June 1884**<br><br>November 1885<br>February 1886<br>June 1886 – November 1886<br>**November 1886** | |
| 1893: Speculative peak in December 1892, crash in May 1893 | July 1893 – August 1893<br>**(close to 0 (-0.009) in July – August 1893)** | *Since April 1893** |
| 'Rich-man's panic', crash in October 1903 | October 1903 – November 1903 | *Since November 1902** |
| 1907: sustained boom since 1904, crash started October 1907 | August 1907 – February 1908<br>**October – November 1907**<br>(close to 0 (-0.008) in November 1907) | *Since November 1906** |
| 1916 market reaches new high in October, bottoms December 1917 | September 1917 – December 1917<br>**October – December 1917**<br>*October – December 1917* | *Since November 1916** |
| Strong growth 1921–1929, from spring 1928 until Autumn 1929 prices surge. Crash in October 1929 | September 1928<br>November 1928 – September 1929<br>**November 1928 – September 1929**<br>January, August – September 1929 | *Since October 1927** |
| Stockmarket strongly bearish until bottoms in July 1932 | **April – June 1932**<br>(close to 0 in May – June 1932) | |
| Prices peak October 1937, indices turn down until bottoms reached in May 1938 | October 1937 – January 1938<br>March 1938 – May 1938<br>**(close to 0 (-0.007) in May 1938)** | *Since April 1936** |
| Expansion from April 1942 until summer 1946. Prices sunk approximately 20% until October 1946 | May 1943<br>March 1946 – June 1946<br>**October 1945 – January 1946 (stays close to 0 until July (max distance: -0.009)**<br>**May – June 1949** | *Since September 1945** |
| Strong market increase from September 1953 until December 1955 | November 1954 – December 1955<br>**September 1954, December 1954 – December 1955**<br>August – December 1955<br>February – summer 1956 | *Since October 1951* and June 1954**<br>*June 1958** |
| 1960's boom end at January 1966, prices sunk during September – October 1966 | August 1966 – September 1966 | *Since March 1966** |

| Periods commonly regarded as bubbles and crashes | Bubble indications, rolling sub-samples. *) 36 months indications, **60 months indications** and *100 months indications* | Period when the indicator-value starts rising steeply, 36 months rolling sub-sample |
|---|---|---|
| Strong downward correction in prices during December 1968 – May 1970, partly related to 'Penn-Station' | May 1970 – June 1970<br>**(close to 0 (-0.009) in summer 1970)** | *Since December 1969** |
| Speculative peak in 1973, decline starts in November 1973 and lasts until October 1974. Prices start to rise again in January 1975. | April 1974 – January 1975<br>**August – December 1974**<br>September 1974, stays close to 0 until December 1974 | *Since October 1973** |
| Strong appreciation in prices during March 1978 – November 1980 | February 1978 – March 1978 | |
| Strong rise in stock prices start in summer 1984, crash in October 1987 (19th of October) | March 1986 – September 1987<br>**May – June 1986, close to 0 in January 1987**<br>*January – September 1987* | *Since September 1985** |
| The Soviet Union breaks up in 1991<br><br>Period of strong growth from middle of 1990's until 2000 (spring of 2000): Short slump in 1998 as LTCM and Russia defaulted. | September 1995 – June 1996<br>November 1996 – February 1997<br>May 1997 – September 1997<br>March/April – June 1998<br>**February 1996 – June 1996**<br>**October 1996 – July 1998**<br>**November 1998 – February 1999, April 1999**<br>*May – June 1996, November 1996*<br>*January 1997 – September 2000*<br><br>September – October 2002<br>January – February 2003 | *Since March 1995**<br><br><br><br><br><br><br><br><br><br><br>*Since November 2001** |

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