Network for Studies on Pensions, Aging and Retirement

Netspar THESES

Lien Bui

Mean Reversion in International Stock Price Indices

An Error-Correction Approach

MSc Thesis 2011-021

Utrecht University

Utrecht School of Economics

MEAN REVERSION IN INTERNATIONAL STOCK PRICE INDICES

AN ERROR-CORRECTION APPROACH

Master Thesis

Bui Huong Lien

Student ID: 3560015

MSc. International Economics and Business

Thesis Supervisor: Prof. Dr. J.A. Bikker

Second Supervisor: Prof. Dr. L. Spierdijk

July, 2011

Abstract

This research investigates the mean reverting behavior of international stock price indices using an error-correction approach. Estimations are conducted in both time series datasets of individual countries and panel datasets of many developed countries. The individual countries are: Denmark for the period 1922-2010, Sweden for the period 1919-2010 and the United States for the largest period from 1871 to 2010. Two panel datasets are established – the pooled panel dataset of the above mentioned 3 countries for the period 1922-2010, and the panel dataset of 15 MSCI developed countries for the period 1971-2010. Constructing many possible proxies for the fundamental value of stock prices, we find strong evidence of mean reversion in stock prices for almost all proxies. The estimated speed of mean reversion varies across datasets, proxies and models but in general it is higher than all previous studies on the same topic. Applying the same approach of rolling-window estimation of Spierdijk et al. (2010), this thesis also confirms their findings on the dynamics of the mean reversion process. The highest speed of mean reversion is found during the time of World War I, the Great Depression and the start of World War II. These results imply that the speed of the mean reverting process of stock prices is dramatically higher in the periods of an unsustainable economy than those of normal economic conditions.

Contents

1. Introduction

There is a long-standing belief held in stock trading that the stock price tends to rise (fall) after hitting a minimum (maximum). This is referred among many analysts to mean reversion of stock prices where an extreme drop of stock prices is expected to be followed by an increase, and vice versa. Many investors convince themselves to this perception in mean reversion of stock prices by looking back at a historically extreme stock market high being followed thereafter by a subsequent fall. For instance, after the 1974 market low was reached, the stock market was obviously overvalued and hit its high in the summer 1987 and finally ending its mean reverting process by the 1987 stock market crash. Recently financial analysts have debated again on the existence of mean reversion in stock prices after witnessing a severe drop in the stock market in March 2009 during the sub-prime crisis that followed the 2007 peak. The process continues with the recovery of the market at the end of 2009 which strengthens the perception of the mean reverting property of stock prices among investors.

Discussions on the existence of mean reversion of stock prices attract special concerns of financial analysts and investors because of its importance in investment strategies. Balvers et al. (2000) argue that exploiting mean reversion of stock prices could help gain significant excess returns in contrarian trading strategy[1]. In addition, Campbell & Shiller (2001) emphasize the crucial role of the mean reverting behaviour of stock prices on the predictability of excess returns. Furthermore, mean reversion in stock prices is economically important to the attractiveness of the stock market for pension funds (Vlaar, 2005). If low returns are followed by higher expected future returns thanks to the presence of mean reversion, pension funds will have more stimulation to invest in equity after a downfall of the stock market (Spierdijk et al., 2010), which then in turn helps accelerate its recovery.

Its important economic implications encourage a lot of authors to find the answer on the existence of the mean reverting process of stock prices. This process is tested by two approaches in the literature. One is the absolute mean reversion approach which defines a mean reverting process indirectly by negative autocorrelation in returns. The other is the relative mean reversion approach which examines mean reversion directly by the relationship between the stock price and its fundamentals. While the empirical evidence of absolute mean reversion are heterogeneous (mean reversion is first found statistically significant by Fama & French (1988b) and Porterba & Summers (1988) but later rejected by Jorion (2003) and Malkiel (2004)), empirical results on relative mean reversion are consistent until the moment. Balvers et al. (2000) and Spierdijk et al. (2010) adopt a panel data approach to estimate mean reversion through

[1] Contrarian strategy is an investment style whereby an investor attempts to profit by going against the trend.

the stationary relationship between the fundamental processes of cross-country stock prices and the stock prices by eliminating those fundamental processes, and they both establish significant mean reversion. Cochran & DeFina (1995), in contrast, estimate mean reversion of stock market prices directly through the fundamental process of stock prices by an error-correction approach. Despite applying a different approach from Balvers et al. (2000) and Spierdijk et al. (2010), Cochran & DeFina (1995) still confirm statistically significant evidence of mean reversion of stock prices.

Mean reversion, if it exists, is argued to be a time-varying process. For instance, Kim et al. (1991) find that mean reversion is a phenomenon that exists only during periods when the stock markets are highly volatile. Spierdijkk et al. (2010) reaffirm a non-constant speed of mean reversion through their findings that the highest speed of mean reversion is found in the period of high economic uncertainty including the Great Depression and the start of the World War II.

This research is conducted with two main objectives. First, it answers the question of whether the stock price reverts to its mean in the long run. Second, it examines the previous finding of Spierdijk et al. (2010) on a time-varying mean reversion of stock prices. Following Cochran & DeFina (1995), to examine the mean reverting behavior of stock prices we apply an error-correction approach which allows economic and financial fundamentals such as dividends and earnings to have significant transitory effects on the stock prices. Moreover, as mean reversion is likely to occur slowly and thus, can be detected only in long time series (Balvers et al., 2000), annual data are used in this research. Mean reversion is investigated in both time series datasets of 3 countries – Denmark, Sweden and the United States and panel datasets of these 3 countries from 1922 to 2010 as well as of 15 developed countries from 1971 to 2010. Constructing many possible proxies for the fundamental value of the stock price, we find strong evidence of mean reversion of stock prices for almost all proxies. Moreover, applying the rolling window estimation of Spierdijk et al. (2010) we confirm their findings on a non-constant speed of mean reversion over time.

The remainder of this thesis is organized as follows. Section 2 reviews the literature on mean reversion over the past 20 years in which two distinct approaches on mean reversion study are discussed. The explanation of the chosen approach for this thesis to test for mean reversion is presented in section 3. Section 4 provides the description of the data used for empirical analysis. Section 5 and section 6 discuss the empirical results for the two representatives of stock prices – the stock price index and the total return index respectively. Finally, section 7 concludes the thesis with the highlighting of all the results from the previous sections. Some implications and limitations will be mentioned along with further discussions to extend the research.

2. Theoretical framework on mean reversion

A great number of studies have been dedicated to the research on mean reversion of stock prices over the past 20 years. Two main economic theories dominating those studies in explaining the mean reverting behavior of the stock prices are the market efficiency, and the speculative process hypothesis. According to the efficient market hypothesis (EMH), all available information is fully reflected in the stock prices (Fama, 1991) which are then determined by the expected returns per share. With the findings that the expected returns follow a stationary process (Conrad & Kaul, 1988), mean reversion of stock prices is possibly explained under the hypothesis of market efficiency (Fama & French, 1988b). In contrast, Poterba & Summers (1988) argued that the transitory component in the stock prices is caused by noise trading under an inefficient market. This argument is confirmed by Cutler et.al (1991) that variations in ex-ante returns arise primarily from noise traders who are not rational in the conventional sense of trading on the basis of all publicly available information. Then mean reversion is the consequence of the speculative process itself.

Among the very first literature on mean reversion of stock prices, Summers (1986) proposed a basic model of the mean reversion process which is then further developed by Fama & French (1988b):

$$p_t = p_t^* + u_t, \tag{2.1}$$

where p_t is the stock price at time *t*. According to Summers (1986) and Fama & French (1988b), the stock price p_t - a non-stationary process is the sum of a permanent price component or the fundamental value of the stock price p_t^* which follows a random walk, and a temporary component u_t which is modeled as a stationary process:

$$u_t = \alpha\, u_{t-1} + v_t, \tag{2.2}$$

where $0 \leq \alpha \leq 1$, i.e. u_t follows a stationary first-order autoregressive process, and v_t is a white noise. Fama & French (1988b) argue that each month price's shock is contributed by a shock from p_t^* which is incorporated permanently in the stock price, and a temporary shock from u_t which is eliminated gradually. Accordingly, the slowly decaying stationary price component u_t implies a mean-reverting process of stock prices in the long-run. The stationary property of this process is tested by two approaches in the literature. One is the absolute mean reversion approach which argues that mean reversion of the stationary price component u_t causes negative autocorrelation in returns. Therefore, in this approach α is estimated indirectly from the regression of the stock return on its lags to find the evidence of negative autocorrelation in stock returns which in turn will be the proof of mean reversion of stock prices (Fama & French, 1988b). In their paper, Fama & French (1988b) use continuously compounded real returns for all New York Stock Exchanges stocks and find strong evidence that stock prices have a slowly decaying stationary component. Alternatively, the relative mean reversion approach estimates α directly from equation (2.2) after the regression of the stock price on its fundamental value in equation (2.1). In this case, the fundamental value of the stock price has to be specified. Both approaches test the null hypothesis that α is equal to one which means that the stock price follows a random walk and thus does not revert to its mean, against the alternative hypothesis that α is smaller than one which implies mean reversion of stock prices.

2.1 Absolute mean reversion

Initially when only short time horizons[2] were used to estimate equation (2.1), research on mean reversion of stock price only comes to inconclusive results. Because mean reversion in equation (2.1) is proved once negative autocorrelation of stock returns is found, or in other words α is expected to be close to one, long horizons are a prerequisite condition for statistical inference. Fama & French (1988b) and Poterba & Summers (1988) were the first to find significant results in testing mean reversion at long horizons. With several time horizons between one year and ten years, Fama & French (1988b) find significant evidence of mean reversion which explains the 25-40% of the variation of the returns at 3- to 5-year horizon. Like Fama & French (1988b), Poterba & Summers (1988) use monthly overlapping data to increase the sample size when examining the stationary process of the temporary price component u_t. They use the variance-ratio test of Cochrane (1988) to find evidence of mean reversion. The variance ratio is a measure of the randomness of a return series. It is computed by dividing the variance of returns estimated from longer intervals by the variance of returns estimated from shorter intervals, (for the same measurement period), and then normalizing this value to one by dividing it by the ratio between the duration of the two intervals. If the variance-ratio is equal to one, the return variance is proportional to the return horizon which occurs when the logarithm of the stock price follows a random walk. With significant evidence that over long horizons return variances rise less than proportional to the time interval, Poterba & Summers (1988) conclude on mean reversion over long horizons. However, both findings of mean reversion from Poterba

[2] Time horizon or later mentioned as horizon refers to the length of time over which the stock returns are calculated. Normally short horizons refer to the time interval of less than 1 year while long horizons mention the periods of more than 1 year.

& Summers (1988) and Fama & French (1988b) encounter two main problems which are criticized in the later literature.

First, the reliability of their findings is questioned on the autocorrelation of stock returns. Both sets of research are based on overlapping data which reduce the independence of the observations. This in turn causes biased and inconsistent estimates of the standard errors, and reduces the accuracy of the autocorrelation measurement in the returns. To account for the bias due to overlapping samples, the method of Hansen & Hodrick (1980) is applied where a moving average structure of the standard errors is taken into account. This method is based on the assumption of the asymptotic normal distribution of the stock returns which is violated due to the small sample property of the long-run stock returns. Addressing this weak assumption Kim et al. (1991) find no significant evidence of mean reversion. The issue of the small sample bias is also criticized by Richardson & Smith (1991). They find that the evidence of long-term mean reversion which is proved by Fama & French (1988b) using the generalized method of moment (GMM) test procedures of Hansen & Hodrick (1980) disappears if they remove the small sample bias. Another issue of using monthly overlapping returns is raised by Jegadeesh (1991). His regression model using 1-month returns as the dependent variable and the lagged multi-year returns as the independent variables shows significant evidence of mean reversion in January only, which supports his argument of the seasonal patterns in stock price mean reversion. This seasonality is ignored by Fama & French (1988b) when all calendar months are considered equally.

Secondly, heteroskedasticity is blamed for the overestimation of mean reversion. Periods with high volatility of stock prices show more trend of mean reversion while in other periods, evidence of mean reversion is insignificant or even mean aversion is found in the research of Jorion (2003) on 31 countries where interruption-suffering markets display a larger than one variance-ratio – represent mean aversion. Thus the inclusion of those highly-volatile stock return periods would overstate the test result. Fama & French (1988b) already realized this problem in their paper that "the strong negative autocorrelation of 1926-1985 period maybe largely due to the first 15 years". But due to the limitation of the simple statistical technique they use, resolution for heteroskedasticity of stock returns is only introduced until McQueen (1992) applies weighted least squares (WLS) which gives a lower weight to observations with a higher variability.

2.2 Relative mean reversion

The absolute mean reversion literature discussed above examines the mean reverting process of stock prices through finding evidence for negative autocorrelation in stock returns. Many researches from many authors were devoted to find convincing evidence for the absolute mean reversion but the final answer as to whether the stock price reverts to its mean in the long run has not yet been arrived at. In the alternative approach of the relative mean reversion, Balvers et al. (2000) argue that mean reversion may be detected from stock price indices relative to a reference index under the assumption that difference between trend path of one country's stock price index and that of the reference index is stationary. Under this approach, Balvers et al. (2000) take into account the fundamental process of the stock price which was ignored in the previous research:

$$p_{t+1}^{i} - p_{t}^{i} = \alpha^{i} + \lambda^{i} (p_{t+1}^{*i} - p_{t}^{i}) + \varepsilon_{t+1}^{i} . \tag{2.3}$$

Equation (2.3) is regarded as the simple mean reversion model or simple model later in this thesis, where p_t^i represents the natural logarithm of the stock price index for country *i* that includes dividends at the end of year t so that ($p_{t+1}^{i} - p_{t}^{i}$) equals the continuously compounded return an investor realizes in period (t+1). p_{t+1}^{*i} indicates the natural logarithm of the fundamental value of the stock price index in country *i*. α^i is a country-specific constant and ε_{t+1}^{i} is a stationary shock term with an unconditional mean of zero. The parameter λ^i measures the speed of reversion. Mean reversion exists when $\lambda^i > 0$.

Nevertheless, arguing that the fundamental process p_{t+1}^{*i} is difficult to specify, Balvers et al. (2000) assume a stationary relationship between the fundamental process of one country's stock price and its reference's as follows:

$$p_{t}^{*i} = p_{t}^{*r} + z^{i} + \eta_{t}^{i} , \tag{2.4}$$

where z^i is a country-specific constant, η_t^i is a zero-mean stationary process that can be serially correlated. The superscript *r* indicates a reference index. By using this assumption and the other that the speed of mean reversion - λ^i across countries is equal to λ , the fundamental value process is eliminated and the following relation is estimated instead of equation (2.3):

$$r_{t+1}^{i} - r_{t+1}^{r} = \alpha^{i} + \lambda (p_{t}^{i} - p_{t}^{r}) + \omega_{t+1}^{i} , \tag{2.5}$$

where r_{t+1}^{i} and r_{t+1}^{r} are continuously compounded returns of country *i* and of the reference index at time (t+1) respectively. ω_{t+1}^{i} is a stationary process with an unconditional mean of zero.

Regression of equation (2.5) allows a direct estimation of the mean reversion coefficient λ without the need to identify the fundamental process. By this innovative technique in investigating the mean reverting process of stock prices, Balvers et al. (2000) find evidence at 5- to 1- percent significance level of mean reversion of the market price indices of 18 countries from 1969 to 1996. Applying the same approach, Spierdijk et al. (2010) use a longer annual dataset of more than one century from 1900 to 2009 to analyze mean reversion in international stock markets. Their findings of unbiased estimates of the speed of mean reversion differ substantially from the results obtained by Balvers et al. (2000) in that they observe a much lower speed of mean reversion.

Both Balvers et al. (2000) and Spierdijk et al. (2010) estimate mean reversion indirectly through the stationary relation between the fundamental processes of cross-country stock prices and the stock prices by eliminating those fundamental processes. Cochran & DeFina (1995), in contrast, estimate mean reversion of the stock market price directly through the fundamental process of stock prices by an error-correction approach which allows economic and financial variables to have significant transitory effects on the stock prices. They use dividends and industrial production growth rates as proxies for the fundamentals of the stock prices. The error-correction term is the long-run trend in the stock price which is described by the regression of the logarithm of the stock price on dividends and fuel prices. The mean reversion model is then estimated by the regression of the continuously compounded return on the correction term, the dividend growth and such other economic control variables as lags and leads of the industrial production growth, term spreads, default spreads, and so on. With the error-correction approach, Cochran & DeFina (1995) conclude that autocorrelation in the proxies of the fundamentals - specifically the dividends in their research - could account for a portion of serial correlation in stock prices. Or in other words, mean reversion of stock prices is found in their study in the estimation using the data on New York Exchange Security stocks for the period from 1947 to 1990.

The most important factor in estimating the mean reverting process of stock prices by the error-correction model is the determination of the fundamental values. Because those values are unobservable, finding sufficient proxies for them is crucial to the accuracy of the estimated model. Cochran & DeFina (1995) use only one proxy of dividend for the fundamental value of the stock price. However, depending on the current dividend it-self could not yield a reliable result for the test of mean reversion. The fundamental value of a stock price is expressed as the discounted future cash flows earned by the stock while current dividends only represent for current cash flows. Defining a correct specification of the proxy is an essential task of the empirical test on relative mean reversion. The better proxy is found the more powerful the test will be. Determination on the proxy for the fundamental of the stock price is discussed in details in the next part.

3. Mean reversion model

In this section, various models of the mean reversion process are discussed first, and based on given arguments the choice for the models applied in this thesis is presented. After the decision on the model has been made, necessary procedures to estimate the model accurately are considered.

3.1 Model specification

Following Cochran & DeFina (1995), Balvers et. al (2000) and Spierdijk et al. (2010) this thesis is interested in the relative mean reversion process in which the specified mean of the stock prices are taken into account. However, there is of course not only one way to estimate relative mean reversion of stock prices.

3.1.1 Simple mean reversion model

Balvers et al. (2000) is the first to explicitly consider the fundamental process of stock prices which is presented in equation (2.3). Nevertheless, the idea of this equation has actually been implied in previous literature. In the study of return predictability, Fama (1991) forecasts returns from such valuation ratios as dividend yields (D/P), earnings/price ratios (E/P). Their estimation of the predictive power of these valuation ratios is in nature of the estimation of equation (2.3) (aforementioned in the previous section) in which the fundamentals of the stock prices are proxied by dividends or earnings:

$$p_{t+1}^{i} - p_{t}^{i} = \alpha^{i} + \lambda^{i} \, (p_{t+1}^{*i} - p_{t}^{i}) + \varepsilon_{t+1}^{i} . \tag{2.3}$$

If $p_{t+1}^{*i} = d_{t+1}^{*i} \, (d_{t+1}^{*i}$ is the logarithm of dividends), equation (2.3) could be presented as the regression of stock returns on the logarithm of dividend yields:

$$r_{t+1}^{i} = \alpha^{i} + \lambda^{i} \log (D_{t+1}^{i} / P_{t}^{i}) + \varepsilon_{t+1}^{i} , \tag{3.1}$$

where $r_{t+1}^{i} = p_{t+1}^{i} - p_{t}^{i}$. r_{t+1}^{i} is the continuously compounded capital gain if p_{t}^{i} is the stock price index or the continuously compounded return if p_{t}^{i} is the total return index.

Equation (3.1) is used by Fama & French (1988a) to investigate the power of the valuation ratios or particularly dividend yields in their research in forecasting stock returns. Their findings show that the slopes in the regression of equation (3.1) - λ^{i} increase with the return horizons. The increase of the slope is approximately proportional to the return horizon for the horizons to one year, but less than proportional to the return horizons of two years to four years. This behavior of the slopes suggests that the expected returns are highly auto-correlated but slowly mean-reverting, which implies the mean reversion of the stock price in long time horizons (Fama & French, 1988a). The regressor of equation (3.1) could be the logarithm of the earnings-price ratio (E/P) if earnings are considered as the proxy for the fundamental value of the stock prices. A similar to that of the estimation with D/P that there is a slow mean-reverting process in the stock price is found when E/P is used to forecast stock returns (Fama & French, 1988a). Campbell & Shiller (1989) also agree on this mean reverting process, with the argument that "if the stocks are underpriced relative to the fundamental value, returns tend to be high subsequently, the converse holds if stocks are overpriced"[3]. In comparison with Fama & French (1988a), Campbell & Shiller (1989) use both dividends and earnings and ten- and thirty-year of earnings as proxies for the fundamentals of stock prices. By the conclusion on the significantly predictive power of these valuation ratios of dividend yields, earnings-price ratios and earnings-price ratios based on a moving average of earnings, Campbell & Shiller (1989) confirm the evidence of mean reversion in stock prices.

Both the findings of Fama & French (1988a) and Campbell & Shiller (1989) which derive from the long-horizon returns of one year to ten years support the long-run mean reverting process. Nonetheless, longer time horizon reduces the sample size dramatically. As a result, their estimation is likely to expose to a small sample bias. Cutler et al. (1991), using MSCI[4] dataset of 13 equity markets, find much weaker results of mean reversion than expected based on the earlier findings of Fama & French (1988a) for the US market after small sample bias robustness. The small sample bias is generally the most potential problem in most studies on the long-term mean reverting process of stock prices.

Another problem in estimating mean reversion of stock prices by the simple mean reversion model employed by Fama & French (1988a) and Campbell & Shiller (1989) is the stochastic properties of the explanatory variables or particularly their orders of integration. According to Torous et al. (2004) if the regressor in the predictive equation (3.1) contains a unit root, the ignorance of its non-stationary property in the regression would likely lead to biased estimation. When they account for the possibility of a unit root in the explanatory variables, contrary results to the earlier findings of Fama & French (1988a) and Campbell & Shiller (1989) are found that the evidence of the predictability of the stock returns by the variance ratio or mean reversion of stock prices is reliable at shorter rather than longer horizons. This limitation of the simple mean reversion model could be improved by using the error-correction model where the mean reverting process is estimated in the presence of non-stationary variables.

[3] Campbell & Shiller (1988) – page 664.
[4] MSCI: Morgan Stanley Capital International.

3.1.2 Error-correction model

The simple mean reversion model allows us to examine the mean reverting process through accounting for the valuation ratios which have the strongest advantage of their availability for estimation. However some arguments against the insufficiency of the simple mean reversion model are found in the literature. According to Gropp (2004), using valuation ratios could yield downward bias of the mean reversion coefficient. The expected changes in the dividends will have an immediate impact on the fundamental value of the stock price which is measured by the expected future cash flows of the stocks while those changes are only reflected in those ratios in the later periods. This lag of essential information incorporating in the variables shows the disadvantage of the simple mean reversion model in estimating the mean reverting behavior of the stock prices. In addition, Marsh and Merton (1987) argue that firm managers target their dividend-price ratio for a period of time and make changes to dividends in response to changes in the firm's stock price in order to keep this targeted ratio unchanged. Thus, using a relatively stable indicator of the valuation ratio to forecast a highly fluctuating stock price could not yield reliable estimates. One can suggest that using another valuation ratio - specifically the earnings-price (E/P) ratio - as a substitute would likely be a good solution to this problem. Nevertheless, Fama & French (1988a) indicate that E/P tends to have less explanatory power than D/P in estimating equation (3.1). This argument not only represents the disadvantage of the simple mean reversion model but also gives rise to a new approach to examine the mean reversion behavior of the stock prices – an error-correction approach which could overcome the limitation above mentioned of the conventional approach. Cochran & DeFina (1995) mention two main advantages of using the error-correction model (ECM) for stock price mean reversion estimation. First, unlike previous dominating approaches, it allows the incorporation of a long-term constraint on short-term stock price movements which then, in turn, helps specify precisely the mean to which stock prices revert. The approach of Balvers et al. (2000) is very powerful in examining the mean reverting process of stock prices. But by that way of estimation where the fundamental value is eliminated in the estimated equation, the mean that the stock prices revert to cannot be identified. The error-correction approach, instead, accounts for the presence of the mean. Second, because it allows non-stationary stochastic trends in the variables, as once discussed above, it is expected to give better estimation than the simple mean reversion model does.

The error-correction model and its closely related theory of a co-integrated process are introduced by Engle & Granger (1987). Co-integration is the process of two or more variables which both have unit roots and thus possess non-stationary stochastic trends. While these variables are non-stationary, it is possible that a linear combination of them is stationary. If that is the case, the variables are said to be co-integrated. Co-integration implies a long-run relationship between these variables and constrains the dynamics of the system. Deviations (errors) from the long-run relation can arise as transitory shocks impact on each variable, but since the errors are stationary by definition, they should eventually be eliminated. Engle & Granger (1987) show that movements in co-integrated variables can be represented as a model known as error-correction model. If the two variables y_t and x_t are co-integrated, then y_t - $\beta' x_t = u_t$ is a stationary process. An error-correction model for y_t and x_t can be written as follows:

$$\Delta y_t = \alpha_o + \alpha_1 \Delta y_{t-1} + \beta_0 \Delta x_t + \beta_1 * \xi_{t-1} + u_t, \tag{3.2}$$

where ξ_{t-1} is the correction term,

$$\xi_{t-1} = y_{t-1} - \beta_2 x_{t-1}, \tag{3.3}$$

β_2 represents the long-run relationship between y_t and x_t,

β_1 < 0.

Depending on the availability of the correction term or whether the long-run relationship between two variables are identified or not, there are two ways to estimate equation (3.2). If ξ_{t-1} is known, equation (3.2) is used to estimate the co-integrating process of the two variables. If ξ_{t-1} is unknown, the predicted values of ξ_{t-1} is derived from estimating equation (3.3) and then (3.2) is estimated with those predicted values.

Following Cochran & DeFina (1995), the error-correction model is employed in this thesis to estimate the mean reverting process of stock prices in the presence of the non-stationary stochastic trends of the variables:

$$\Delta p_t^i = \alpha^i + \beta_0^i \Delta p_t^{*i} + \beta_1^i * \xi_{t-1} + \psi_t^i, \tag{3.4}$$

where, ξ_{t-1} is the correction term of country *i* at time (t-1),

$$\xi_t = p_t^i - \beta_2^i p_t^{*i}, \tag{3.5}$$

β_0^i Short term effect of a change in p_t^{*i} on the change in p_t^i,

β_1^i < 0 ~ mean reversion process. | β_1^i | measures the speed of mean reversion,

β_2^i Long term effect of a change in p_t^* on the change in p_t. If $\beta_2^i = 1$ → a 1% increase in p_t^{*i} will lead to 1% increase in p_t^i in the long run which implies a fully co-integrating relation between the stock price and its fundamental value. When $\beta_2^i \neq 1$ the co-integrating relation between them is not stable.

When $\xi_{t-1} = 0$ p^i_{t-1} and p^{*i}_{t-1} are in their equilibrium state,

$\xi_{t-1} > 0$ p^i_{t-1} is above its equilibrium state. Therefore Δp^i_t should decrease so that p^i_t will be brought back toward equilibrium. This requires $\beta^i_1 < 0$.

$\xi_{t-1} < 0$ p^i_{t-1} is below its equilibrium state. Therefore Δp^i_t should increase so that p^i_t will be brought back toward the equilibrium. This requires $\beta^i_1 < 0$ as well.

In his very early literature, Fama (1965) finds the non-stationary property of the stock prices. Also, dividend yields which are the conventional proxy for the fundamental value of the stock prices are found to have unit roots. Thus, the error-correction model could be an appropriate solution to describe the stock price movements or the mean reverting process which is of our interest. Following Engle & Granger (1987), two ways of estimation discussed above are taken into consideration.

3.1.2.1 Engel & Granger Two-Step Error-correction model

In their original idea of the error-correction model, Engle & Granger (1987) apply a two-step estimator in their procedure. "In the first step, the parameters of the co-integrating vector are estimated and in the second these are used in the error correction form" (Engle & Granger, 1987). Applying in the case of mean reversion of stock prices, it is the error component ξ^i_t - the long-run relationship between the stock price and its fundamentals:

$$\xi^i_t = p^i_t - \beta^i_2 \, p^{*i}_t . \tag{3.5}$$

In the second step, predicted value of the deviation of the stock price from its fundamental value - $\hat{\xi}^i_t$ is used to estimate mean reversion model (3.4):

$$\Delta p^i_t = \alpha^i + \beta^i_0 \, \Delta p^{*i}_t + \beta^i_1 * \hat{\xi}^i_t + \psi^i_t . \tag{3.6}$$

Engle & Granger (1987) state that this procedure is convenient because it is not necessary to specify the mean reversion process until the error correction structure has been estimated. Moreover, under their argument the two-step estimator of a single equation of an error correction system obtained by taking the predicted value of the deviation of the stock price from its fundamental value $\hat{\xi}^i_t$ as the true value is proved to have the same limiting distribution as the maximum likelihood estimator using the true value of ξ^i_t. Thus, least squares standard errors will be consistent estimates of the true standard errors. Agree with Engle & Granger (1987), Bachmeier & Griffin (2006) reaffirm that because β^i_2 can be estimated super-consistently by OLS regression, the inference on the parameters of (3.6) can be proceeded as though β_2^i is known as certainty.

3.1.2.2 Generalized One-Step Error-correction model

According to Engle & Granger (1987) if ξ_t^i is known, equation (3.2) is used singly to estimate the co-integrating process of the two variables. But in almost cases, ξ_t^i is unknown. However, we could still estimate the mean reversion model by the error correction approach in only one step which is referred to the generalized one-step error-correction model. The generalized one-step error-correction model (GECM) which is first introduced by Banerjee et al. (1993, 1998) is a transformation of an autoregressive distributed lag (ADL) model:

$$\Delta y_t = \lambda_1 + \beta_0 \, \Delta x_t + \beta_1 \, (y_{t-1} - \beta_2 \, x_{t-1}) + \lambda_2 \, x_{t-1} + \psi_t \, .$$

The error correction term in the GECM is given by ($y_{t-1} - \beta_2 \, x_{t-1}$). Unlike the two-step method, using the single equation GECM, the long-run relationship, the disequilibrium and the short-run dynamics are estimated simultaneously. According to De Boef (2000) the single equation GECM is both theoretically appealing and also statistically superior to the two-step estimator in many cases, because it is asymptotically equivalent to more complex, full-information, maximum-likelihood and fully modified estimators.

Whether the stock price movement is a mean reverting process depends on the sign of the coefficient β_1 . Of most interest is the estimation of β_1 . Thus, applying the single-equation GECM we could plug (3.5) into (3.4) to estimate equation (3.4) directly as follows:

$$\Delta p_t^i = \alpha^i + \beta_0^i \, \Delta p_t^{*i} + \beta_1^i \, (p_{t-1}^i - \beta_2^i \, p_{t-1}^{*i}) + \psi_t^i \, . \tag{3.7}$$

3.1.3 Choice of model

For its improvement against previous conventional approaches in examining the mean reversion behavior of the stock prices, the error-correction model is our key method of estimation. As aforementioned the generalized one-step ECM is statistically superior to the Engle-Granger two-step estimator, and therefore the generalized one-step is the preferred specification. Nonetheless, as the long-run relationship between the stock price and its fundamental is unknown, the two-step ECM is also applied as the suggested theory by Engle & Granger (1987). Finally, the simple mean reversion model is also applied for comparison purpose.

3.2 Fundamental value of stocks

Key variables in the Error-Correction Model which we will use to examine whether the stock price movement is a mean reverting process are the stock price and its fundamental value. Thus defining the fundamental value of the stock price is a crucial part of our research.

3.2.1 Theories on fundamental value of stocks

3.2.1.1 Fundamental efficiency theory

The market efficiency hypothesis is often referred to whether a certain set of information is incorporated instantaneously into the current market prices. Nonetheless, this popular understanding of this hypothesis only represents one aspect of the market efficiency - that is "informational" efficiency. The missing one of the two dimensions of the stock market efficiency is called "fundamental efficiency" which measures whether stock prices exclusively reflect the underlying or fundamental profits of a corporation, conditioned on the available information (Ayres, 1991). Few authors distinguish between these two forms of market efficiency. After Ayres (1991), Elton and Gruber (1995) also make the distinction between the conventional form of "informational" efficiency and the other one which is called "market rationality" in their paper. According to them, the fundamental efficiency or market rationality hypothesis deals with the question whether stock prices precisely reflect investors' expectations about the present value of future cash flows. In line with the definition of Elton and Gruber (1995), Engelen (2005) argues that "fundamental efficiency requires that security prices are equal to the present value of the future cash flows investors expect the company to generate, discounted by the appropriate risk-adjusted rate of return". He also links these two forms of efficiency that the investors base their expectations about future cash flows on available information in the market which is based on the degree of informational efficiency of the market. The application of the fundamental efficiency theory is further developed in the next sub-section on Asset Pricing Model where the relation between the stock price and its fundamentals are presented physically by the model.

3.2.1.2 Asset Pricing Model

The most basic Asset Pricing Model which is called the martingale model or the random walk model of the stock prices is represented with the assumption that an asset has a constant expected return (Samuelson, 1965). The more general model developed later that allows a fluctuant expected return is:

$$P_t = \frac{E_t\,(P_{t+1} + D_{t+1})}{1 + r_{t+1}}. \tag{3.8}$$

If the expected discounted future price has a limit of zero or $\lim_{k\to\infty}\left(E_t P_{t+k} / (1+r_{t+k})^k\right) = 0$, (3.8) becomes the fundamental value equation of an asset price (Campbell, 2000):

$$P_t = E_t \sum_{i=1}^{\infty} \frac{D_{t+i}}{(1+r_{t+1})^i}, \tag{3.9}$$

where the right-hand side of equation (3.9) is called the fundamental value of an asset price (denoted as P_t^*) (Campbell, 2000). Because an efficient market is assumed, the stock price is exactly equal to its fundamental value.

More generally, if it allows for the expected return to change over time, the fundamental value of the stock price is described as:

$$P_t^* = E_t \sum_{i=1}^{\infty} \left(\prod_{j=1}^{i} \frac{1}{1+r_{t+j}}\right) D_{t+i}, \tag{3.10}$$

where $D_{t+i} = D_{t+i-1}(1+g_{t+i})$ in which g_{t+i} is the growth rate of the dividends at time *(t+i)*

In the special case that the dividend growth rate and the expected return are constant over time, the model of Gordon (1959) is obtained:

$$P^* = \mathrm{D}\frac{1+g}{r-g}. \tag{3.11}$$

3.2.2 Proxies for fundamental value process

As discussed in the previous sub-section, the fundamental value of the stock price is the present value of expected future cash flows of the stock as described in equation (3.10). In order to identify this value precisely, we need to know all expected future cash flows as well as the expected return used to discount these cash flows. However, it is impossible to account for infinite cash flows obtained in the future or in other words the fundamental value of stock prices is unobservable, and therefore we need to find a plausible proxy for the fundamental. The following sub-sections consider possible variables that could be used as proxies for fundamental values of stock prices and discuss choices of the discount rate applied to discount the future cash flows.

3.2.2.1 Proxies for the fundamental value of stock prices

a. Current dividends

Current dividend is a conventional measure of the fundamental value of stock prices. In their paper on mean reversion in stock prices using an error-correction approach, Cochran & DeFina (1995) employ dividends along with fuel prices as the proxies for the fundamental value of the stock price and find evidence of the long-run relationship between the stock prices and the dividends and the fuel prices at significance level of 5%. In spite of the fact that current dividends contain little information to determine stock prices, we still follow Cochran & DeFina (1995) to examine the mean reverting process of the stock prices when dividends are used as a measure of the fundamental value and the results are compared to other proxies.

b. Smoothed earnings

The idea of using smoothed earnings instead of yearly earnings as the proxy for the fundamental value of stock prices originates from the suggestion of Graham & Dodd (1934). They recommend to "shift the original point of departure, or basic computation, from the current earnings to the average earnings, which should cover the period not less than five years, and preferably from seven to ten years"[5]. In line with Graham & Dodd (1934), Campbell & Shiller (1989) argue that a moving average of earnings is used instead of yearly earnings due to the fact that yearly earnings which could have negative value are too noisy to represent for the fundamental value of the stock prices. Thus, they employ ten- and thirty-year moving average of real earnings in calculating the earnings-price ratio without accounting for a discount rate. Following Campbell & Shiller (1989), in this thesis, ten- and thirty-year moving average of real earnings are used as potential proxies for the fundamental value of the stock prices.

c. Perfect foresight price

Studying volatility in stock prices, Shiller (1981) introduces a concept of a "perfect foresight" stock price which is defined as the present value of the actual subsequent dividends over the future periods:

$$P_t^* = \frac{Div_{t+1}}{1+r_{t+1}} + \frac{Div_{t+2}}{(1+r_{t+2})^2} + \frac{Div_{t+3}}{(1+r_{t+3})^3} + \frac{Div_{t+4}}{(1+r_{t+4})^4} + \frac{Div_{t+5}}{(1+r_{t+5})^5} + \ldots.$$

This measure is calculated from the actual subsequent dividends over time but not from the expected future dividends based on available information at the current period. Thus, employing this measure as a proxy for the fundamental value of the stock prices means that we assume perfect information about future dividends in the present. Moreover, the further the future cash flow, the smaller the discount factor applied

[5] Graham & Dodd (1934) – page 452.

to it or in other words the less important it is in determining the stock price. Considering the above mentioned argument of Graham & Dodd (1934) to use cash flows from not less than 5 years to calculate the price, a 5-year horizon may be sufficient for the calculation. Hence we use 5-year subsequent dividends to calculate the perfect foresight price as the proxy for the fundamental value of the stock price.

A similar estimation for the perfect foresight price suggested by Shiller (1981) is to use actual subsequent earnings over the future periods instead of subsequent dividends. In that case, the perfect foresight price is calculated as follows:

$$P_t^* = \frac{Earnings_{t+1}}{1+r_{t+1}} + \frac{Earnings_{t+2}}{(1+r_{t+2})^2} + \frac{Earnings_{t+3}}{(1+r_{t+3})^3} + \frac{Earnings_{t+4}}{(1+r_{t+4})^4} + \frac{Earnings_{t+5}}{(1+r_{t+5})^5} + \ldots$$

Compared to the calculation of the smoothed earnings, this method is advantageous in taking into account the discount rate to discount all cash flows to the present values. Therefore the proxy estimated by this approach is expected to better reflect the real fundamental value of the stock price than the proxies of dividends and smoothed earnings.

d. Hindsight price

Theoretically, only expected future cash flows are taken into account in stock pricing. Nevertheless, investors in reality normally base their expectations on historical information of stock prices. In real stock trading, one can insist that investors find no attractions from stocks that only show a decrease trend in the past. Also in their article distinguishing the difference between the foresight and the hindsight price, Statman & Scheid (2002) emphasize the importance of the hindsight price. According to them, forecasted future cash flows as well as the expected return that is used to discount the expected future cash flows to their present values are based on the information and the fluctuation of stock prices in the past at a certain level. Therefore, with the assumption that investors base their expectations on the historical information of the stock prices, dividends and earnings realized in the nearest years in the past are employed to calculate another measure of the fundamental value of the stock price – the hindsight price. Symmetric to the perfect foresight price, 5-year antecedent dividends and earnings are used in which the most recent one which is considered to have the most predictive value for future expectation is discounted at lower rate.

When the dividends are used the estimated hindsight price is calculated as:

$$P_t^* = \frac{Div_{t-1}}{1+r_{t-1}} + \frac{Div_{t-2}}{(1+r_{t-2})^2} + \frac{Div_{t-3}}{(1+r_{t-3})^3} + \frac{Div_{t-4}}{(1+r_{t-4})^4} + \frac{Div_{t-5}}{(1+r_{t-5})^5} + \ldots$$

And here's the calculation of the hindsight price when the earnings are used:

$$P_t^* = \frac{Earnings_{t-1}}{1+r_{t-1}} + \frac{Earnings_{t-2}}{(1+r_{t-2})^2} + \frac{Earnings_{t-3}}{(1+r_{t-3})^3} + \frac{Earnings_{t-4}}{(1+r_{t-4})^4} + \frac{Earnings_{t-5}}{(1+r_{t-5})^5} + \ldots.$$

e. Gordon model

Gordon growth model is considered the simplest fundamentals-based approach to predict stock prices. Heaton & Lucas (1999) use the price estimated by this model as a measure of the fundamental of the stock price when quantifying the potential impact of fundamental effects on stock price movements. In line with Heaton & Lucas (1999), in examining the mean reversion process of the stock price, Manzan (2003) consider both static and dynamic Gordon growth model. In a static model, both the expected return and the dividend growth rate are assumed to be constant over time. In contrast, the dynamic model allows for the dynamic adjustment of the expected return and the dividend growth rate. However, Manzan (2003) find that the results from these two approaches are not significantly different from each other. Consequently, the static model is used by Manzan (2003) to estimate mean reversion of stock prices using the stock price indices from S&P 500 for the period from 1871 to 2003, but accounting for a structural break of both discount rates and dividend growth rates in the 1950's. Following Manzan (2003) the static Gordon model (equation 3.11) is also employed in this thesis as a proxy of the fundamental value of the stock prices. If a structural break of the discount rate is not considered in the whole period the estimation result with the natural logarithm of Gordon price is exactly the same as the natural logarithm of dividend. Nonetheless, as later found in sub-section 4.2 a structural break is found in the discount rate applied to calculate the Gordon price. Hence, the result from the regression with the Gordon price is expected to be different from the dividend.

In addition to the original static Gordon model, an alternative approach is applied to calculate the Gordon price in which earnings are used to estimate the Gordon price instead of dividends. In that case equation (3.11) becomes:

$$P^* = \text{Earnings}\,\frac{1+g}{r-g}.$$

3.2.2.2 Discount rate

Good defined proxies need an appropriately estimated discount rate which is the required rate of return in discounting expected future cash flows. According to Fama & French (2002), "average return on a broad portfolio of stocks is typically used to estimate the expected market return". And in their paper, fundamentals of stocks are used to estimate the expected stock return. Fama & French (2002) consider two alternatives to estimate expected stock return. One is the average stock return which is calculated by adding the average dividend yield to the average rate of capital gain:

$$A(R_t) = A(D_t / P_{t-1}) + A(GP_t), \tag{3.12}$$

where $A(R_t)$ is the average stock return,

$A(D_t / P_{t-1})$ is the geometric mean of dividend yields,

$A(GP_t)$ is the geometric mean of the rate of capital gains.

The other is referred to growth model:

$$A(RD_t) = A(D_t / P_{t-1}) + A(GD_t), \tag{3.13}$$

where, $A(R_t)$ is the expected stock return,

$A(D_t / P_{t-1})$ is the geometric mean of dividend yields,

$A(GD_t)$ is the geometric mean of the growth rate of dividends.

Fama & French (2002) argue that the estimation with the fundamentals yields a more precise expected return. In order to examine the reliability of the estimates from two above equations, they use S&P index from 1872 to 2000 and find that the standard error of the estimate from the dividend growth model (3.13) is less than half from the average return (3.12). In the same attempt to use valuation models to estimate expected returns, Claus & Thomas (2001) instead use forecasts by security analysts to estimate the discount rate when calculating the expected cash flows. However, Claus & Thomas (2001), in the end, find that analysts' forecasts are biased. In this thesis, the expected return is calculated in both two ways as in the research conducted by Fama & French (2002), and the comparison is made to choose the most appropriate one. The details of discount rate estimation will be discussed in Section 4.2.

3.3 Test for unit root and co-integration

In their in-depth research on the relationship between the co-integration property and the error-correction model, Engle & Granger (1987) suggest two crucial conditions for the error-correction model to give unbiased and consistent estimates. First, both of the interested variables – dependent and independent are integrated of order one. Or in other words the model requires the variables to contain a unit root. Another necessary requirement for a valid error-correction mechanism is the co-integration in the long-run relationship between these variables. Co-integration implies that deviations from the long-run equilibrium are stationary (Engle & Granger, 1987). With respect to the two-step ECM, De Boef (2000) emphasizes that "estimates using Engel-Granger two-step estimator perform well only under limited conditions: permanent memory, or unit roots, and co-integrating regression without serially correlated errors". Thus, test for unit roots and co-integration of all variables in the regression is inevitable. For the time series dataset, the augmented Dickey Fuller test (Dickey & Fuller, 1979) is applied. Nevertheless, for the panel datasets alternative procedures need to be implemented. According to Hoang & McNown (2006), three most common tests for unit roots in panel data in practice are Levin-Lin (LL), Im-Pesaran-Shin (1997) (IPS) and Maddala-Wu (1999) (Fisher test) in which LL test is then improved by the updated version of Levin-Lin-Chu (2002). Based on the characteristics of our balanced dataset with moderate panels[6], we use Levin et al.'s (2002) approach (LLC) which tests the null hypothesis that all the panels contain unit roots against the alternative hypothesis that each panel is stationary. However, the LLC test is proved to be too restrictive in most studies which compare the test power of different tests for panel data unit roots (Hoang & McNown (2006), Maddala & Wu (1999)). The reason is that in LLC test the null hypothesis of unit roots in all panels is tested with an assumption that the autoregressive parameter is the same in all panels. Instead, the IPS test relaxes this assumption by allowing each panel to have its own autoregressive parameter. The Fisher test is directly comparable to the IPS test (Maddala & Wu, 1999). The asymptotic validity of each test depends on different conditions. For the IPS test, whether N (number of panels) is going to infinity has a decisive effect on the asymptotic results of the test while for the Fisher test it depends on whether T (number of years) is going to infinity. In this research, the LLC test and the Fisher test is employed based on the characteristics of the datasets.

3.4 Methods of estimation

3.4.1 Time series data

At first, the original equation is estimated with the Ordinary Least Squares (OLS) estimator. In order to ascertain the estimates from the regression to be unbiased and consistent, the empirical procedure is followed by three tests. The omitted variables test (Ramsey, 1969) is implemented to test whether the original regression has omitted variables. If there are omitted variables, the estimated coefficients will be biased. In such cases, the lags of the dependent variables (capital gain/total return) are added to the regression and the Ramsey test is carried out again to make sure that omitted variables problem is improved. In testing for autocorrelation, three different tests are employed simultaneously: Durbin-Watson test (Durbin & Watson, 1950), Durbin's alternative test (Durbin, 1970), Breusch-Godfrey Lagrange Multiplier (LM) test (Breush & Godfrey, 1981). The purpose of implementing all three tests is to ensure

[6] A panel of moderate size is defined by Levin et al. (2002) to have 10 to 250 individuals with 25 to 250 time series observations per individual.

that the unbiased estimates are obtained reliably. In all cases the results of the three tests are consistent to each other, which implies that we could solely rely on the results. The final test is the heteroskedasticity test which examines whether the variance of the error terms are constant across all observations. If this is not the case, the standard errors reported from the regression will be biased which in turn affect the results of the test statistics for the significant evidence of the mean reversion process. In addition, three tests for heteroskedasticity are carried out: LM test for autoregressive conditional heteroskedasticity (ARCH), White's test for homoskedasticity (White, 1980), Breusch-Pagan/Cook-Weisberg test (Breusch & Pagan, 1979) for constant variance. The implementation of all three tests not only affirms the trustworthy of the test resutlts but also helps finding the heteroskedastic function of the error terms' variance. To account for autocorrelation and heteroskedasticity, the solution of adding lags of the capital gain is considered first. If this solution could correct for all problems the result from the regression with the lags is reported as the final result after correction. Otherwise, alternative procedures are followed. To correct for serial correlation, Prais-Winston/Cochrane-Orcutt method (Prais & Winsten (1954), Cochrane & Orcutt (1949)), which is very powerful in autocorrelation correction is applied. As for heteroskedasticity problem, the Weighted Least Squares (WLS) estimator is implemented. The WLS estimation is iterated with different possible heteroskedastic functions and the one that could eliminate heteroskedasticity and at the same time ensure no autocorrelation is chosen as the best estimation.

3.4.2 Panel data

In each model estimation, the original regression with fixed effect or random effect (choice of regression with fixed effect or random effect based on Hausman test (Hausman, 1978)) is estimated first. In order to ascertain the estimates from the regression to be unbiased and consistent, the empirical procedure is followed by the tests for autocorrelation and heteroskedasticity. As for the autocorrelation test, the Wooldridge test for autocorrelation in panel data is employed while the Likelihood-ratio test is used to investigate the heteroskedastic property of each regression. If serial correlation between error terms is found after the regression with fixed effects or random effects, the Prais-Winsten estimator (Prais & Winsten, 1954) is applied to estimate the model with panel-corrected standard errors. STATA allows estimating the Prais-Winsten regression with and without heteroskedasticity. If the original regression appears to encounter both serial correlation and heteroskedasticity two solutions could be used to yield unbiased estimates: Prais-Winsten estimation with heteroskedasticity, and feasible generalized least squares (FGLS) for panel data which allows estimation in the presence of AR(1) autocorrelation within panels and cross-sectional correlation and heteroskedasticity across panels (Davidson & MacKinnon, 1993). In general the results from these two methods are very similar to each other.

4. Data

4.1 Data description

"Mean reversion, if it exists, is likely to occur slowly, and can therefore be detected only in long time series" (Balvers et al., 2000). Thus, instead of using monthly data as a traditional approach in mean reversion research, following Balvers et al. (2000) and Spierdijk et al. (2010) yearly data are used in this thesis to investigate the existence of mean reversion in international stock price indices. Moreover, as in the findings of Fama & French (1988b) the mean reverting process of monthly stock prices is concentrated in January, using annual data is expected to avoid this seasonal effect.

Annual data are collected for two kinds of series used in this thesis. The long datasets which cover the long time period of 90 years and more are assembled for 3 countries: Denmark, Sweden and the United States. The short panel dataset covers a shorter time frame but includes as large as 15 developed countries with long-history stock markets.

In all series, figures on the stock price index, total return index and dividend yield which are our main variables of interest are compiled. The U.S dataset however, contains more information. All indices are year-end figures and if not available as the real values in the original datasets they will be translated to real figures by data on exchange rates and inflation rates (or indirectly from consumer price indices) to eliminate the difference in inflation's and exchange rates' fluctuations between countries. The real figures, denominated in US Dollars, are obtained in the end for empirical analysis. These datasets are explained in more details in the following sub-sections.

4.1.1 Time series data

The long datasets for 3 countries are compiled from different sources.

<u>The United States</u>

The United States with the most developed and long-standing stock market has the longest dataset from 1871 to 2010 which is used by Shiller (2000)[7]. It includes data on Standard & Poor's stock price index, dividend, earnings and also the U.S's consumer price which allows us to calculate real stock price indices, real dividends and real earnings. For the purpose of this research on mean reversion, the dividend yield and the total return index are then calculated from the available numbers.

[7] This dataset is downloaded from Shiller's website http://www.econ.yale.edu/~shiller/data.htm.

Sweden

Starting in December 1918, the weekly Swedish financial chronicle Affärsvärlden published a composite stock price index that would later be called Affärsvärldens Generalindex (AFGX). AFGX is a capital-weighted index and included up to 1998 only firms on the Stockholm Stock Exchange A-list. From 1998 onwards AFGX also includes firms on the so-called O-list, containing the (previously) unlisted firms (Waldenström, 2007). These data on stock price indices, total return indices from 1919 to 2006 are provided by The Swedish Riksbank - Sveriges Riksbank. The original data obtained from the Swedish Bank are nominal figures. Thus, exchange rates and inflations rates from Dimson-Marsh-Staunton Global Returns Data (DMS Global) are employed to calculate the real values of these indices. Data for the later period 2006-2010 is compiled from Morgan Stanley Capital International (MSCI) and then incorporated into the 1919-2006 dataset.

Denmark

Danish Institute for National Economy (Institut for Nationaløkonomi) has published a long time series of stock returns for Denmark from 1922 to 1999 (Nielsen & Risager, 2001). In their paper, the estimate of the total annual stock return equals the sum of the dividend yield and the capital gain. The dividend yield is estimated on the basis of a large sample of listed stocks which account for 50 to 80 percent of the total market capitalization on the Copenhagen Stock Exchange. The capital gain data is constructed based on the value-weighted Danish Share Price Index published by Statistics Denmark. This dataset after being transformed into real US dollar value is also incorporated with MSCI data for the later period 1999-2010 to establish the long dataset from 1922 to 2010.

4.1.2 Panel data

The first panel data is the 1970-2010 data base from MSCI. It includes the stock price indices, total return indices and dividend yields of the stock markets from 15 countries[8]. The indices are expressed both in home currency as nominal indices and in real US dollar values (Real exchange rates which account for the difference in inflation rates between the US and other countries are applied to translate nominal indices into real US dollar indices). In the dataset, the dividend yield is calculated by the change in the total return indices (total stock return) subtracted by the change in the stock price indices (capital gain) which is consistent with the calculation of the dividend yield in time series datasets used in this thesis.

The second panel dataset is the pool of three different time series of Denmark, Sweden and the U.S. Among them, the Danish database has the shortest time horizon from 1922-2010. Therefore, we reset the base year of 1921 for the other two datasets to obtain a consistent panel dataset of three countries.

[8] List of countries in MSCI database: the Netherlands, Germany, France, Belgium, Australia, Denmark, Italy, Japan, Canada, Norway, Spain, Sweden, Switzerland, United Kingdom, and the United States.

Table 1 represents some summary statistics of our dataset. The geometric mean of the continuously compounded capital gain (later called as the capital gain)[9] and of the continuously compounded total return (later called as the total return)[10] are computed for the panel dataset of 15 countries from 1970 to 2010.

Table 1 - Summary statistics of Panel data 15 countries

Country	Code	Mean capital gain 1970-2010*	Mean total return 1970-2010*	Mean total return Balvers et al.(2000) 1970-1996	Standard Error of total return*	Mean Dividend Yield*
Netherlands	1	0.145	0.162	0.153	0.208	0.047
Germany	2	0.158	0.193	0.113	0.256	0.029
Fance	3	0.177	0.177	0.116	0.252	0.032
Belgium	4	0.102	0.163	0.144	0.281	0.032
Australia	5	0.164	0.198	0.089	0.259	0.043
Denmark	6	0.145	0.156	0.132	0.255	0.028
Italy	7	0.163	0.143	0.058	0.300	0.029
Japan	8	0.137	0.174	0.140	0.281	0.014
Canada	9	0.156	0.177	0.096	0.210	0.031
Norway	10	0.180	0.194	0.126	0.371	0.032
Spain	11	0.172	0.167	0.093	0.279	0.047
Sweden	12	0.180	0.186	0.153	0.278	0.032
Switzerland	13	0.123	0.164	0.127	0.203	0.024
UK	14	0.115	0.175	0.126	0.267	0.043
US	15	0.095	0.138	0.111	0.179	0.031

(*Source: Calculated from MSCI database)

The statistics of Balvers et al. (2000) on stock returns from 1970 to 1996 from the same source of MSCI data base are also presented in Table 1 for comparison purpose. In our dataset, the total return varies from the highest of 19.8% for Australia to the lowest of 13.8% for the United States. Norway has the highest standard deviation of the total return of 37.1% while the United States has the smallest of 17.9%.

4.2 Discount rate calculation

As aforementioned in sub-section 3.2.2, the discount rate applied to calculate proxies for the fundamental values of the stock prices is calculated using Fama & French's (2002) approach:

[9] Continuously compounded capital gain$_n$ = ln(stock price index)$_n$ – ln(stock price index)$_{n-1}$.
[10] Continuously compounded total return$_n$ = ln(total return index)$_n$ – ln(total return index)$_{n-1}$.

$$A(RD_t) = A(D_t / P_{t-1}) + A(GD_t) . \qquad (3.13)$$

For the panel data of 15 countries, the same discount rate is applied for the whole period 1970-2010 for each individual country. The summary statistics are shown in Table 2.

Table 2 - Discount rate (in %) to calculate proxies – Panel data 15 countries

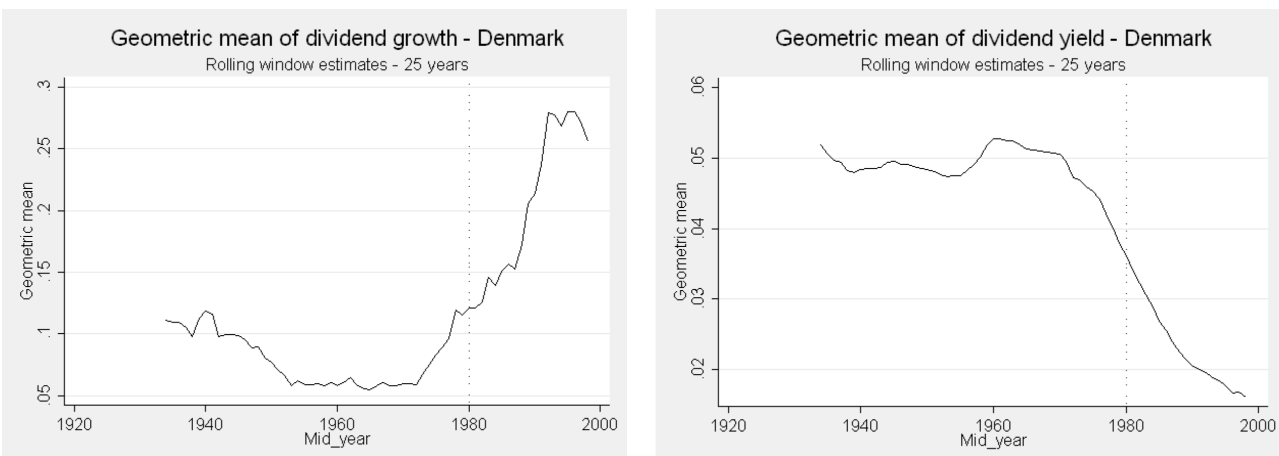
Country	Code	Dividend growth rate (Geometric mean) %	Dividend yield (Geometric mean) %	Discount rate %
		(a)	(b)	(a)+(b)
Netherlands	1	13.19	4.68	17.87
Germany	2	21.01	2.87	23.88
Fance	3	16.58	3.23	19.81
Belgium	4	11.77	3.23	15.00
Australia	5	13.83	4.35	18.18
Denmark	6	16.38	2.76	19.14
Italy	7	18.10	2.92	21.02
Japan	8	12.43	1.39	13.82
Canada	9	8.83	3.10	11.93
Norway	10	16.88	3.16	20.04
Spain	11	9.86	4.71	14.57
Sweden	12	12.08	3.22	15.30
Switzerland	13	11.82	2.39	14.21
UK	14	14.72	4.25	18.97
US	15	7.97	3.11	11.08

Table 3 - Discount rate to calculate proxies - individual countries

	Dividend growth rate (%)	Dividend yield (%)	Discount rate (%)	Gordon discount factor
	(a)	(b)	(a)+(b)	
United States				
1871-2010	5.18	4.25	9.43	24.77
1871-1950	6.38	5.27	11.65	20.20
1951-2010	3.78	3.15	6.93	32.90
Sweden				
1919-2010	14.16	3.94	18.09	29.00
1919-1980	11.02	4.54	15.56	24.44
1981-2010	24.36	2.93	27.29	42.47
Denmark				
1922-2010	11.05	3.66	14.71	30.34
1922-1980	7.58	5.20	12.78	20.69
1981-2010	26.23	1.83	28.07	68.81

For the long time series dataset of 3 countries we find structural breaks in the dividend growth rate and the dividend yield both for Denmark, Sweden and the US (Table 3). Sweden and Denmark has the same structural break in the 1980s. The difference between the estimated discount rate for the periods before and after 1980 is very significant. The United States, nonetheless, has dramatically different discount rates for the periods before and after 1950 which is in line with the earlier findings of Fama & French (2002). Their estimate for the period 1872-1950 is 8.07% while it is 4.74% for the later period 1951-2000. The difference of the Gordon discount factor between 2 periods before and after the break is even larger. As a result, we do not employ the same discount rate to estimate the proxies (the foresight price, hindsight price, Gordon price) for the whole period but instead calculate them separately to obtain more precise estimation. We confirm a structural break in the discount rate of 3 countries which results from the structural breaks in the dividend growth rate and the dividend yield by using rolling window estimates of the geometric mean of the dividend growth rate and the dividend yield with the time intervals of overlapping 25 years. Figure 1 displays the rolling window estimates of the geometric mean of these series over time, taking Denmark for illustration.

Figure 1 - Rolling window estimates - Geometric mean of dividend growth and dividend yield



It is obvious from Figure 1 that the geometric mean of the dividend growth rate and the dividend yield of Denmark change dramatically after 1980. The geometric mean of the dividend growth rate increases sharply after the year 1980 while the geometric mean of the dividend yield decrease considerably after this year. However, because of much larger magnitude of the dividend growth rate compared to the dividend yield, the combination of these opposite changes lead to a significant increase in the geometric mean of the discount rate for the period after 1980. Thus, applying different discount rates for the period before and after 1980 is necessary to obtain precise estimates of mean reversion of the stock price.

Different discount rates applied to calculate the proxies for the fundamental value of the stock price is expected to affect the empirical results. Therefore in section 5.2.3 will be found the robustness check for the discount rate sensitivity in which we use the alternative proxies calculated with a consistent discount rate for the whole sample period for estimations.

5. Empirical results – Stock price index

In this thesis, to investigate the mean reverting behaviour of the stock price two variables are used as the market stock price – the stock price index and the total return index. The stock price index measures the price performance of markets without including dividends. The total return index measures the price performance of markets with the income from constituent dividend payments[11]. The empirical results presented in this section are based on the regressions with the stock price index. The results with the total return index are found in Section 6.

5.1 Test for unit roots and co-integration

5.1.1 Time series data

The Dickey Fuller (DF) test and the augmented Dickey Fuller (ADF) test are applied to test for unit roots and co-integration of the time series dataset of 3 countries. Two variables are used as the dependent variable: the natural logarithm of the stock price index and the natural logarithm of the total return index. Independent variables include all proxies of the fundamental value of the stock price (all are expressed in natural logarithm): dividends, perfect foresight price, hindsight price and Gordon price. In addition, because of the availability of data on real earnings, 5 more proxies are used for the US data base: foresight earnings, hindsight earnings, Gordon earnings and smoothed earnings of 30 years and of 10 years. The results of the tests for unit roots and co-integration are presented in Table 4 and Table 5.

Table 4 - Unit root tests - individual countries

Variables (log)	Denmark		Sweden		United States	
	t-statistics	Unit root	t-statistics	Unit root	t-statistics	Unit root
Stock price index	-1.097	Y	-2.518	Y	-2.220	Y
Total return index	-1.549	Y	-2.692	Y	-2.764	Y
Dividends	-1.846	Y	-2.376	Y	-3.907	Y
Foresight price	-2.438	Y	-1.562	Y	-3.586	Y

[11] Index definitions from MSCI http://www.msci.com/products/indices/tools/

Variables (log)	Denmark		Sweden		United States	
	t-statistics	Unit root	t-statistics	Unit root	t-statistics	Unit root
Hindsight price	-2.006	Y	-1.615	Y	-3.723	Y
Gordon price	-2.846	Y	-2.841	Y	-3.163	Y
Foresight earnings					-3.021	Y
Hindsight earnings					-3.162	Y
Gordon earnings					-3.620	Y
Smoothed earnings 30					-1.617	Y
Smoothed earnings 10					-1.828	Y

The ADF test's critical value is -4.071 (1% significance level), -3.464 (5% significance level), -3.158 (10% significance level). The ADF test tests the null hypothesis that the variable contains a unit root against the alternative that the variable is stationary. We could see from Table 4 that we cannot reject the null hypothesis even at 10% significance level for most of the variables used. Thus, all these variables are then used to test whether there is a co-integration relationship between the stock price index and the fundamental. The results for the test with the total return index are presented in Section 6.

Table 5 - Co-integration test - individual countries

Variables (log)	Denmark		Sweden		United States	
	t-statistics	Co-integration	t-statistics	Co-integration	t-statistics	Co-integration
Dividends	-4.064***	Y	-4.593***	Y	-4.924***	Y
Foresight price	-3.092**	Y	-5.332***	Y	-3.375**	Y
Hindsight price	-2.666*	N	-3.546**	Y	-3.523**	Y
Gordon price	-2.035	N	-4.264***	Y	-4.001***	Y
Foresight earnings					-4.094***	Y
Hindsight earnings					-3.457**	Y
Gordon earnings					-4.32***	Y
Smoothed earnings 30					-2.742*	N
Smoothed earnings 10					-2.998***	Y

*** *Significant at 1% confidence level.*
** *Significant at 5% confidence level.*
* *Significant at 10% confidence level.*

Across three countries, 2 proxies show a consistent relationship of co-integration with stock price index in all 3 countries: the dividends and the foresight price. The test for the Gordon price displays very significant results for Sweden and the United States. All additional proxies for the United States show significant co-integration relationships with the stock price index except the smoothed earnings of 30 years. All proxies of the fundamentals that show a co-integration relationship with the stock price index will be used as the independent variables in the regressions using the Engle-Granger two-step ECM which requires a strict condition of a co-integration relationship between variables in the model to yield unbiased estimates. The other proxies which are not co-integrated with the stock price index are still used for estimation using the simple mean reversion model. The results of three models' estimations are presented in the next section.

5.1.2 Panel data

As described in Section 3.3 the Levin-Lin-Chu test (LLC test) and the Fisher test are applied to test for unit roots in panel data. Results from the two-tests are similar. All variables are found to contain unit roots in the short panel dataset of 15 countries as well as the long dataset of 3 countries. Detailed results are found in Table 6.

Table 6 - Unit root test - Panel data

Variables (log)	Panel 15 countries				Panel 3 countries			
	LLC test		Fisher test		LLC test		Fisher test	
	Adjusted t*	p-value	Modified chi-squared	p-value	Adjusted t*	p-value	Modified chi-squared	p-value
Stock price index	-0.792	0.214	-3.046	0.999	-0.342	0.366	0.118	0.453
Total return index	-0.480	0.316	-3.063	0.999	-0.467	0.320	-0.077	0.531
Dividends	2.403	0.992	-0.451	0.674	2.809	0.998	-0.561	0.713
Foresight price	3.735	1.000	-1.507	0.934	2.098	0.982	0.004	0.499
Hindsight price[12]	6.102	1.000	N/A	N/A	2.074	0.981	N/A	N/A
Gordon price	2.403	0.992	-0.451	0.674	-1.204	0.114	-1.179	0.881

For the LLC test the adjusted t-statistic are the basis for the conclusion on a unit root while it is the modified chi-squared for the Fisher test. The results for unit root tests are consistent between the LLC test and the Fisher test. Both prove the existence of a unit root in all variables. Thus, all proxies are employed in the test for co-integration relationship with the stock price index. In these two panel datasets, we use the Westerlund test for panel co-integration (Westerlund, 2007) to test whether the proxies of the fundamentals are co-integrated with the stock price index. The Westerlund (2007) test reports the results for the test of the null hypothesis that there's no co-integration in the whole panel data against two kinds of alternative hypotheses that there's co-integration for at least one cross-sectional unit and that there's co-integration for all cross-sectional units. Therefore, rejection of the null hypothesis in the first case would be taken as the evidence of co-integration for the panel as a whole while rejection of the second null hypothesis would be interpreted as the evidence of co-integration for at least one cross-sectional unit. The two tests yield the same results for all variables. Hence, only the results of the first test that demonstrate a

[12] The Fisher test cannot be applied to the hindsight price because the first variable of the dataset is missing.

co-integration relationship between the proxies and the stock price index for the whole panel are presented in Table 7.

Table 7 - Co-integration test - Panel data

Variables (log)	Panel 15 countries		Panel 3 countries	
	Z-statistics	p-value	Z-statistics	p-value
Dividends	1.272	0.898	-1.592*	0.056
Foresight price	-5.447***	0.000	-3.870***	0.000
Hindsight price	-1.916**	0.027	-1.675**	0.047
Gordon price	-4.515***	0.000	-10.10***	0.000

Among 4 proxies, the dividends show the weakest evidence of the co-integration relationship with the stock price index. The results are significant for the foresight price, the hindsight price and the Gordon price in two panels.

5.2 Estimation results

As mentioned in Section 3.1 to examine whether the stock price index reverts to its mean in the long run three models are estimated and compared. The three models are:

<u>Engle-Granger two-step error-correction model:</u>

First step: $\xi_t = p_t^i - \beta_2^i \, p_t^{*i}$.

Second step: $\Delta p_t^i = \alpha^i + \beta_0^i \, \Delta p_t^{*i} + \beta_1^i * \hat{\xi}_t^i + \psi_t^i$.

In this model, β_2 is estimated through the first step and the predicted values of the residuals are used to estimate mean reversion in the second step. The results reported for this model includes β_o, β_1 and β_2. The sign of β_1 concludes the existence of mean reversion of the stock price index.

<u>Generalized one-step error-correction model:</u>

$\Delta p_t^i = \alpha^i + \beta_0^i \, \Delta p_t^{*i} + \beta_1^i \, (p_{t-1}^i - \beta_2^i \, p_{t-1}^{*i}) + \psi_t^i$.

This model is estimated immediately with 3 independent variables Δp_t^{*i}, p_{t-1}^i and p_{t-1}^{*i}. Therefore the coefficients reported in this model are β_0^i, β_1^i, (- $\beta_1^i \, \beta_2^i$). The coefficient β_2^i which is calculated indirectly from the regression's estimation is also reported.

<u>Simple mean reversion model:</u>

$\Delta p_t^i = \alpha^i + \lambda^i \, (p_{t+1}^{*i} - p_t^i) + \varepsilon_{t+1}^i$.

In this model, the estimated value of λ is reported because it determines whether the stock price reverts to its mean in the long-run.

5.2.1 Individual countries

5.2.1.1 Denmark

The estimation results for Denmark are presented in Table 8. Based on the co-integration test results (Table 5), the hindsight price and the Gordon price are not co-integrated with the stock price index. Therefore they are not used for the Engle-Granger two-step ECM estimation. Nevertheless, they are still used for the generalized one-step ECM which does not require a strict condition of co-integration, and the simple model. The last column shows unbiased estimates of the coefficients of interest.

Table 8 - Estimation results - Denmark

GENERALIZED ONE-STEP ECM

	β_o	β_1	$-\beta_1\beta_2$	β_2
Dividends	0.486***	-0.118***	0.177***	1.496
Foresight price	0.034	-0.087**	0.189***	2.164
Hindsight price	-0.065	-0.019	0.078	4.005
Gordon price	0.259	-0.056	0.088	1.559

ENGLE-GRANGER TWO-STEP ECM

	β_o	β_1	β_2 (+)[13]
Dividends	0.456***	-0.102*	1.441***
Foresight price	0.166	-0.084*	1.479***

(+) shows significance level of β_2's difference from 1.

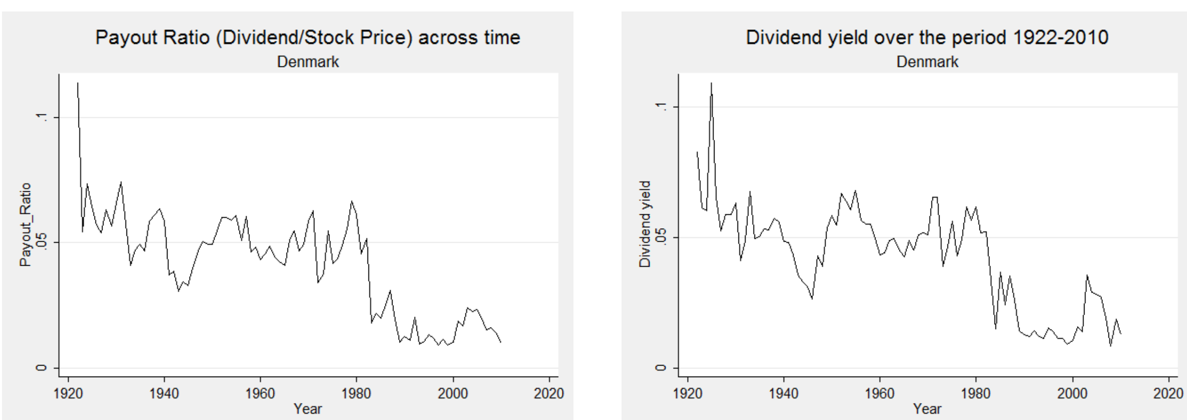
SIMPLE MODEL

	λ
Dividends	0.034
Foresight price	0.028
Hindsight price	-0.017
Gordon price	0.088**

[13] The estimates of β_2 in the two-step ECM are derived from the first-step regression of the stock price index on the proxy of the fundamental ($\xi_t = p_t^i - \beta_2^i p_t^{*i}$ - Equation (3.5)). In order to test whether β_2 is different from 1, the transformation of Equation 3.5 is obtained and estimated: $p_t^i - p_t^{*i} = \alpha^i + p_t^{*i}(\beta_2^i - 1) + \xi_t$ (Equation (3.5a)). Then we can use a normal t-test to test β_2's significant difference from 1 after equation (3.5a) estimation.

In almost all regressions with the Danish dataset no autocorrelation is found while most of the time heteroskedasticity is a problem. Thus, for Denmark the final results are mainly obtained from adding lags of the capital gain and using robust standard errors or from the WLS estimator. The estimation with the foresight price is the only one that does not contain heteroskedasticity or encounter omitted variables bias (based on the results of Ramsey (1969) test for omitted variables) in the original regression. Therefore it is used as the final result for this proxy. In the original regressions with fixed effect or random effect, mean reversion is found for all proxies except the hindsight price in the estimation with the generalized one-step ECM. However, after correcting for omitted variables, autocorrelation and heteroskedasticity, the results change in the opposite way for the dividends and the Gordon price. As for the dividends, evidence of mean reversion is even more significant than before correction. On the contrary, the result with the Gordon price becomes insignificant which confirm the important property of the co-integration relationship of the two variables in estimating the error-correction model. The results from the Engle-Granger two-step ECM are similar to the generalized ECM although the evidence of mean reversion is less significant. In contrast to the two-step ECM, the simple mean reversion model confirms the existence of mean reversion only for the Gordon price. Also shown in Table 8 the long-run relationship coefficient β_2 estimated on the Danish dataset is significantly different from 1 which implies that the payout ratio of dividend (dividend/stock price) is decreasing over time. Figure 2 shows an explicitly decreasing trend in this ratio over the period 1922-2010 which is in line with the findings of Bekaert et al. (2001). Holmen et al. (2007) also find similar results on the decreasing payout ratio of dividend.

Figure 2- Dividend payout ratio across time



5.2.1.2 Sweden

The empirical results for the Swedish dataset show more significant evidence of mean reversion of the stock price than Denmark's. After correcting for omitted variables, autocorrelation and heteroskedasticity, the existence of mean reversion is found in the estimations with all proxies except the hindsight price.

Especially the mean reversion coefficient β_1 is significant at 1% confidence level for the dividends, the foresight price and the Gordon price. Table 9 presents detailed results for the estimations with three models separately.

Table 9 - Estimation results - Sweden

GENERALIZED ONE-STEP ECM

	βo	β_1	$-\beta_1 \beta_2$	β_2
Dividends	0.708***	-0.306***	0.349***	1.140
Foresight price	-0.484**	-0.432***	0.539***	1.248
Hindsight price	-0.134	0.063	-0.062*	0.991
Gordon price	0.631***	-0.279***	0.297***	1.063

ENGLE-GRANGER TWO-STEP ECM

	βo	β_1	β_2 (+)
Dividends	0.690***	-0.295***	1.138***
Foresight price	-0.941***	-0.657***	1.161***
Hindsight price	-0.457	0.168*	1.267***
Gordon price	0.610***	-0.267***	1.024

(+) shows significance level of β_2's difference from 1.

SIMPLE MODEL

	λ
Dividends	0.706***
Foresight price	0.179***
Hindsight price	-0.025
Gordon price	0.689***

In comparison with the results of Denmark, the Swedish stock price index shows much more significant evidence of the mean reverting process with dramatically higher values of the mean reversion coefficient β_1. Nonetheless, the long-run relationship co-efficient β_2 is not as far from 1 as in the case of Denmark. The existence of mean reversion is found consistently among the simple mean reversion model, the Engle-Granger two-step ECM and the generalized one-step ECM.

5.2.1.3 The United States

Different from the stock price index database of Denmark and Sweden, the United States do not show autocorrelation in all estimations. Heteroskedasticiy (if any) is due to some outliers but not the dependence of the variance of the error terms on the independent variables. As a result, robust standard errors are used to correct for heteroskedasticity. The estimated coefficients of the estimations by three models are found in Table 10.

Table 10 - Estimation results- The United States

GENERALIZED ONE-STEP ECM

	β_0	β_1	$-\beta_1\beta_2$	β_2
Dividends	0.145	-0.05	0.053	1.062
Foresight price	0.908***	-0.188***	0.298***	1.583
Foresight earnings	0.134	-0.189***	0.215***	1.139
Hindsight price	-0.096	-0.076	0.097	1.266
Hindsight earnings	-0.244	-0.049	0.038	0.780
Gordon price	0.201	-0.106**	0.108**	1.020
Gordon earnings	0.253	-0.107***	0.088**	0.821
Smoothed earnings 30	-0.493	-0.078**	0.103**	1.327
Smoothed earnings 10	-0.574	-0.059	0.068	1.154

ENGLE-GRANGER TWO-STEP ECM

	β_0	β_1	β_2(+)
Dividends	0.163	-0.052	1.581***
Foresight price	0.885***	-0.198***	1.443***
Foresight earnings	0.129	-0.190***	1.019
Hindsight price	-0.096	-0.076	1.442***
Hindsight earnings	-0.231	-0.066	1.031
Gordon price	0.204	-0.107**	1.076**
Gordon earnings	0.252***	-0.107***	0.818***
Smoothed earnings 30	-1.104	-0.002	1.269***
Smoothed earnings 10	-0.925*	0.015	1.168***

(+) shows significance level of β_2's difference from 1.

SIMPLE MEAN REVERSION

	λ
Dividends	0.046
Foresight price	0.135***
Foresight earnings	0.183***
Hindsight price	0.064
Hindsight earnings	0.061
Gordon price	0.108**
Gordon earnings	0.127***
Smoothed earnings 30	0.075**
Smoothed earnings 10	0.075*

Thanks to the availability of real earnings in the United States' database, more proxies are used in all 3 models: foresight earnings, hindsight earnings, Gordon earnings and two smoothed earnings of 30 and 10 years. Among these additional proxies, the estimations with the foresight earnings, the Gordon earnings and the 30-year smoothed earnings show significant evidence of mean reversion. The results with the proxies estimated from earnings are consistent with the results with the proxies estimated from dividends. The values of β_1 for the US's are similar to Denmark's estimates. Moreover, for all 3 countries, the mean reversion coefficient obtained from the estimations with the dividends and the Gordon price is different because we apply a structural break in the required rate of return when calculating the Gordon price. In addition, in almost all estimations using dividends as the proxy, the Danish and Swedish datasets show significant evidence of mean reversion while no evidence is found for the US dataset. The speed of mean reversion of the stock prices which is measured by the coefficient λ in the simple model is similar to the findings of Balvers et al. (2000) which is based on a shorter time period 1970-1996. As for the results from the estimations by the two-step error-correction model which is in line with the approach of Cochran & DeFina (1995). Their estimated mean reversion coefficient β_1 ranges in value from -0.198 to -0.107 statistically significant at 5% to 1% confidence level. Cochran & DeFina (1995) also investigate the mean reversion behavior of the stock prices for all NYSE stocks but they use quarterly data from a shorter period 1947-1990 compared to our US dataset. Applying the same approach of the two-step error-correction model but using a shorter period and different frequency of data, Cochran & DeFina (1995) find a smaller speed of the mean reverting process of the stock price than our results which range from -0.125 to -0.078. All the estimated mean reversion coefficients in their results are negative and statistically significant at 5% to 1% level for different estimations with different control variables.

5.2.2 Panel data

5.2.2.1 Denmark, Sweden and the United States

To take the advantage of the long-time periods of 3 countries Denmark, Sweden and the United States we pool them together to have a long panel data from 1922 to 2010. All regressions with the Panel 3 countries contain autocorrelation but no heteroskedasticity. Thus, the Prais-Winsten/ Cochrane-Orcutt estimator is employed to yield unbiased estimates. The coefficient from Prais-Winsten regression is found to be smaller than from the original regression with fixed effect or random effect. The results with all the generalized one-step ECM, the Engle-Granger two-step ECM and the imple model are presented in Table 11.

Table 11 - Estimation results - Panel 3 countries

GENERALIZED ONE-STEP ECM

	βo	β1	-β1β2	β2	Half-life[14]	95% C.I
Dividends	0.492***	-0.088***	0.12***	1.365	7.5	(4.5, 20.9)
Foresight price	-0.011	-0.115***	0.174***	1.506	5.7	(3.7, 11.2)
Hindsight price	-0.082	0.003	0.013	-4.558		
Gordon price	0.459***	-0.239***	0.249***	1.043	2.5	(1.8, 3.9)

ENGLE-GRANGER TWO-STEP ECM

	βo	β1	Half-life	95% C.I
Dividends	0.471***	-0.036**	19	(10.5, 91.6)
Foresight price	-0.046	-0.088***	7.5	(5.1, 13.6)
Hindsight price	-0.007	-0.014		
Gordon price	0.445***	-0.193***	3.2	(2.3, 5)

SIMPLE MODEL

	λ	Half-life	95% C.I
Dividends	0.093***	7.1	(4.3, 17.5)
Foresight price	0.07***	9.5	(5.3, 36.7)
Hindsight price	-0.01		
Gordon price	0.344***	1.6	(1.3, 2.2)

The estimated coefficients are very consistent with the results for individual countries when they are estimated separately as time series data. The estimations with the dividends, the foresight price and the Gordon price show very significant evidence of mean reversion at 1% confidence level. Again when the hindsight price is included in the regression the existence of mean reversion could not be proved for any of the three models. Among the three proxies that show strong evidence of mean reversion the estimated coefficient β_1 from the regression with the Gordon price is very significantly different from zero. There's also large variation in the estimated speed of mean reversion when we use different proxies for the fundamental values of the stock prices. In this panel dataset of 3 countries the Gordon price consistently show the strongest evidence of mean reversion with a very high value of λ of 0.344 compared to the earlier results of Balvers et al. (2000) and Spierdijk et al. (2010). Balvers et al. (2000) who also use the MSCI dataset but with a shorter sample period of 1970-1997 for their estimation report the largest unbiased estimate of λ equal to 0.202[15] when the US index is used as the reference index. The results of Spierdijk et al. (2010) which are based on Dimson et al. (2002) dataset for 110 years from 1900 to 2009

[14] All estimates of the half-life and their corresponding 95% confidence intervals of the mean reversion process are presented in years.

[15] Balvers et al. (2000) – page 755.

even show less significant speed of mean reversion with the highest reported speed equal to 0.042[16] using Germany index as the benchmark. In contrast to the result with the Gordon price, the estimations with the dividends and the foresight price are not as high as the results from separate time series regression for each country. The half-life of mean reversion is also presented for the regression with significant evidence of mean reversion. This half-life is calculated by $\ln(0.5)/\ln(1-\lambda)$ for the simple mean reversion model following Balvers et al. (2000) and Spierdijk et al. (2010) while it is calculated by $\ln(0.5)/\ln(1+\beta_1)$ for the error-correction model. The results are substantially dissimilar between different proxies and different models. Among the three models, the generalized one-step ECM seems to yield more reliable results with the estimated half-life varying from 2.5 years to 7.5 years. This means that approximately 2.5 years to 7.5 years are required to eliminate 50% of the pricing error. The corresponding 95% confidence interval ranges from (1.8, 3.9) years to (4.5, 20.9) years. The estimated half-life from the two-step model varies from 3.2 years to 9.1 years. However the 95% confidence interval is much larger than that from the one-step model with the lowest value of 2.3 years and the highest value of 91.6 years, which shows the more uncertainty of the estimates from the two-step compared to the one-step model. Our estimates are larger than the average half-life of 1.75 years reported by Cochran & DeFina (1995). Compared to Balvers et al. (2000) and Spierdijk et al. (2010) our panel data of 3 countries give more diverse estimates of mean reversion corresponding to different proxies as well as different models used to estimate. This stresses the effects of choosing a suitable proxy for the fundamental of the stock price on the empirical evidence of stock price mean reversion.

5.2.2.2 Panel 15 countries

The second panel dataset as described in Section 4.1.2 contains the data of 15 countries from 1970 to 2010. Despite of the disadvantage of a short time period, the results from this panel data with more countries could contribute to the earlier findings of Balvers et al. (2000) and Spierdijk et al. (2010) that mean reversion of stock price indices if exist is not only the case for the US stock market. In the first regressions with fixed effect or random effect, mean reversion is found in all estimations even with the hindsight price which gives no evidence of mean reversion at all when being included in the previous regressions with the time series and the panel 3-country datasets. However, in all original regressions for the panel dataset of 15 countries, very strong evidence of autocorrelation and heteroskedasticity is found. As aforementioned, to account for these problems, the FGLS estimator and the Prais-Winsten method is used simultaneously to obtain unbiased estimates. The unbiased estimates are reported in Table 12.

[16] Spierdijk et al. (2010) – page 29.

Table 12 - Estimation results - Panel 15 countries

GENERALIZED ONE-STEP ECM

	βo	β_1	$-\beta_1 \beta_2$	β_2
Dividends	0.746***	-0.095***	0.107***	1.126
Foresight price	-0.88***	-0.162***	0.225***	1.394
Hindsight price	-0.338	-0.032	0.017	0.535
Gordon price	0.751***	-0.146***	0.166***	1.133

ENGLE-GRANGER TWO-STEP ECM

	βo	β_1
Dividends	0.747***	-0.061**
Foresight price	-0.898***	-0.144***
Hindsight price	-0.422	-0.004
Gordon price	0.751***	-0.079***

SIMPLE MODEL

	λ
Dividends	0.229***
Foresight price	0.113***
Hindsight price	0.06
Gordon price	0.332***

After correcting for autocorrelation and heteroskedasticity, the results for the Panel dataset of 15 countries from 1970 to 2010 are again consistent with our earlier findings with time series data of 3 individual countries as well as the Panel dataset pooling 3 countries from 1922 to 2010. Especially the speed of mean reversion estimated with the Gordon price as the proxy for the fundamental value of the stock price is not different from the result of the first panel. The reported value of λ is 0.334 for the first panel and 0.332 for the second panel. And both estimates are significant at 1% confidence level. As for the estimation with the ECM, the results from the Engle-Granger two-step ECM are lower in comparison with the generalized one-step ECM which is also found in the estimations within different used datasets in general. In addition, except for the estimation with the hindsight price, all regressions yield unbiased estimates of all coefficients with expected signs. The long-run relationship coefficient β_2 is positive which implies the co-integration relationship between the stock price index and its fundamental value across time. Nevertheless, the value of β_2 is different from one that leads to the conclusion that 1% change in the fundamentals lead to more than 1% change in the stock price index. This outcome could be explained by the decreasing trend of dividend payout ratio in reality mentioned in the previous section.

5.2.3 Robustness check for discount rate sensitivity

All the empirical results presented above are based on the estimations using the proxies calculated with different discount rates applied for different periods. The discount rate used to estimate the proxies for the fundamental value of the stock price is expected to affect the empirical results. Thus, in this section, we will use alternative proxies for estimation to check whether the different discount rate applied has a significant effect on the evidence of mean reversion of stock prices. These alternative proxies are calculated in the same way with the current used proxies using the equations discussed in section 3.2.2. The only change in the calculation is the discount rate. This robustness check of the discount rate sensitivity is applied to the panel data of 3 countries (Denmark, Sweden, the United States). So for instance, instead of applying the two separate discount rates of the two periods 1922-1980 and 1981-2010 for Denmark we will apply one consistent discount rate for the whole period 1922-2010. The discount rate applied for each country is still different[17]. The empirical results for the alternative proxies are presented in Table 13. The results for the main proxies are re-presented for comparisons.

Table 13 - Discount rate sensitivity check - Panel 3 countries

GENERALIZED ONE-STEP ECM

	βo	β1	-β1β2	β2	Half-life	95% C.I
Dividends	0.492***	-0.088***	0.12***	1.365	7.5	(4.5, 20.9)
Foresight price	-0.011	-0.115***	0.174***	1.506	5.7	(3.7, 11.2)
Foresight price 2	-0.077	-0.165***	0.224***	1.36	3.9	(2.7, 6.4)
Hindsight price	-0.082	0.003	0.013	-4.558		
Hindsight price 2	-0.019	-0.023	0.047	2.058		
Gordon price	0.459***	-0.239***	0.249***	1.043	2.5	(1.8, 3.9)
Gordon price 2	0.493***	-0.093***	0.128***	1.372	7.1	(4.3, 18.1)

ENGLE-GRANGER TWO-STEP ECM

	βo	β1	Half-life	95% C.I
Dividends	0.471***	-0.036**	19	(10.5, 91.6)
Foresight price	-0.046	-0.088***	7.5	(5.1, 13.6)
Foresight price 2	-0.126	-0.063***	10.7	(7.3, 19.1)
Hindsight price	-0.007	-0.014		
Hindsight price 2	-0.009	-0.025		
Gordon price	0.445***	-0.193***	3.2	(2.3, 5)
Gordon price 2	0.471***	-0.038***	17.7	(10, 72.3)

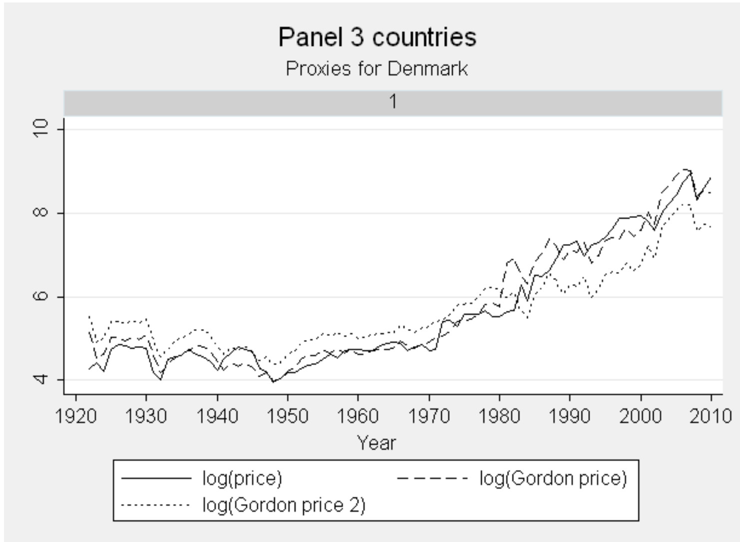
[17] Details of the discount rates applied for the estimations are presented in Table 3.

SIMPLE MODEL

	λ	Half-life	95% C.I
Dividends	0.093***	7.1	(4.3, 17.5)
Foresight price	0.07***	9.5	(5.3, 36.7)
Foresight price 2	0.116***	5.6	(3.6, 11.8)
Hindsight price 2	0.003		
Hindsight price	-0.01		
Gordon price	0.344***	1.6	(1.3, 2.2)
Gordon price 2	0.103***	6.3	(4.0, 14.0)

Foresight price 2, hindsight price 2 and Gordon price 2 are the alternative proxies which are applied one consistent discount rate in calculation. The others are used for empirical results presented in the previous section. It is apparently seen in Table 13 that similar results are found when the alternative proxies are used. The estimations with the foresight price 2 show significant evidence of mean reversion in all three models at 1% confidence level which is exactly the same result for the foresight price. Similarly, the regressions with the hindsight price 2 yield the same result with the hindsight price. None of the estimations with those two proxies shows the existence of mean reversion of the stock price indices. Like the Gordon price, the Gordon price 2 also confirms mean reversion of the stock prices at 1% significance level. Therefore, using different discount rates does not affect the empirical results on the evidence of the mean reverting process in the stock price indices. The results are consistent for the same kind of proxy. However, the magnitude of the mean reversion coefficients or the speed of mean reversion changes when we use the same discount rate for the whole sample period, therefore, leads to changes in the half-life estimation. Especially, the estimated speed of mean reversion with the Gordon price 2 is dramatically smaller than the Gordon price. The reason is the Gordon discount factor applied in the later period for each country is much larger than that in the first period and the average of the whole period. As a result, the Gordon price 2 is larger in the first period and smaller in the later period compared to the Gordon price. Figure 3 illustrates this comparison, taking Denmark as an example. Moreover, because of applying the same discount rate for the entire sample period, the results with the Gordon price 2 are similar to the results with the dividends as expected when we use all variables in the logarithm form. They are not exactly the same but slightly different because we use unequal discount rates for each country. In short, applying different discount rates does not affect the empirical evidence on the existence of mean reversion in the stock price indices. Nonetheless, the speed of mean reversion varies when the discount rate changes. So the question is which discount rate gives more precise result. The answer could be derived from Figure 3.

Figure 3 - Discount rate sensitivity



It is clearly seen that the estimated proxy following the Gordon model using the discount rate with a structural break is more in line with the stock price index than using one consistent discount rate for the entire sample period. Consequently, the stock price index are observed to show clearer and faster mean reverting behaviour to its fundamental value when we use a fluctuant discount rate rather than an unchanged one for the whole period. In other words, using a structural break in the discount rate better reflects the expected future cash flows of the stock which then determine the stock price. Hence, we can conclude on the robustness of the empirical results found with the currently used proxies for the fundamental value of the stock price.

5.3 Time-varying mean reversion

Even though the existence of mean reversion of the stock price indices proves to be consistent at a very significant level among all above datasets with different time spans, the speed of mean reversion is found to vary dramatically across these data. In addition, the findings of the fluctuant dividend growth rates and stock returns in section 4.2 also suggest that there's a time-varying speed of mean reversion across time. Furthermore, in their paper, Spierdijk et al. (2010) apply the same approach as Balvers et al. (2000) in examining the mean-reverting property of stock prices but they find large difference in their results. The main reason is attributed to the difference in the time interval (Spierdijk et al. 2010). While based on MSCI database for the stock market price indices within the time interval 1970-1996 Balvers et al. (2000) find a significant speed of mean reversion with the unbiased estimate of λ equal to 0.182, the estimated speed of mean reversion by Spierdijk et al. (2010) is only 0.0491 between 1900 and 2008 (nearly four times smaller than Balvers's et al. (2000)) for the case where the world index is the benchmark. Thus, it is plausible to argue that the estimates of the speed of mean reversion of stock market indices depend on the time interval. This section is devoted to research on the varying speed of mean reversion across time by applying a rolling window estimation approach.

5.3.1 Panel data 3 countries

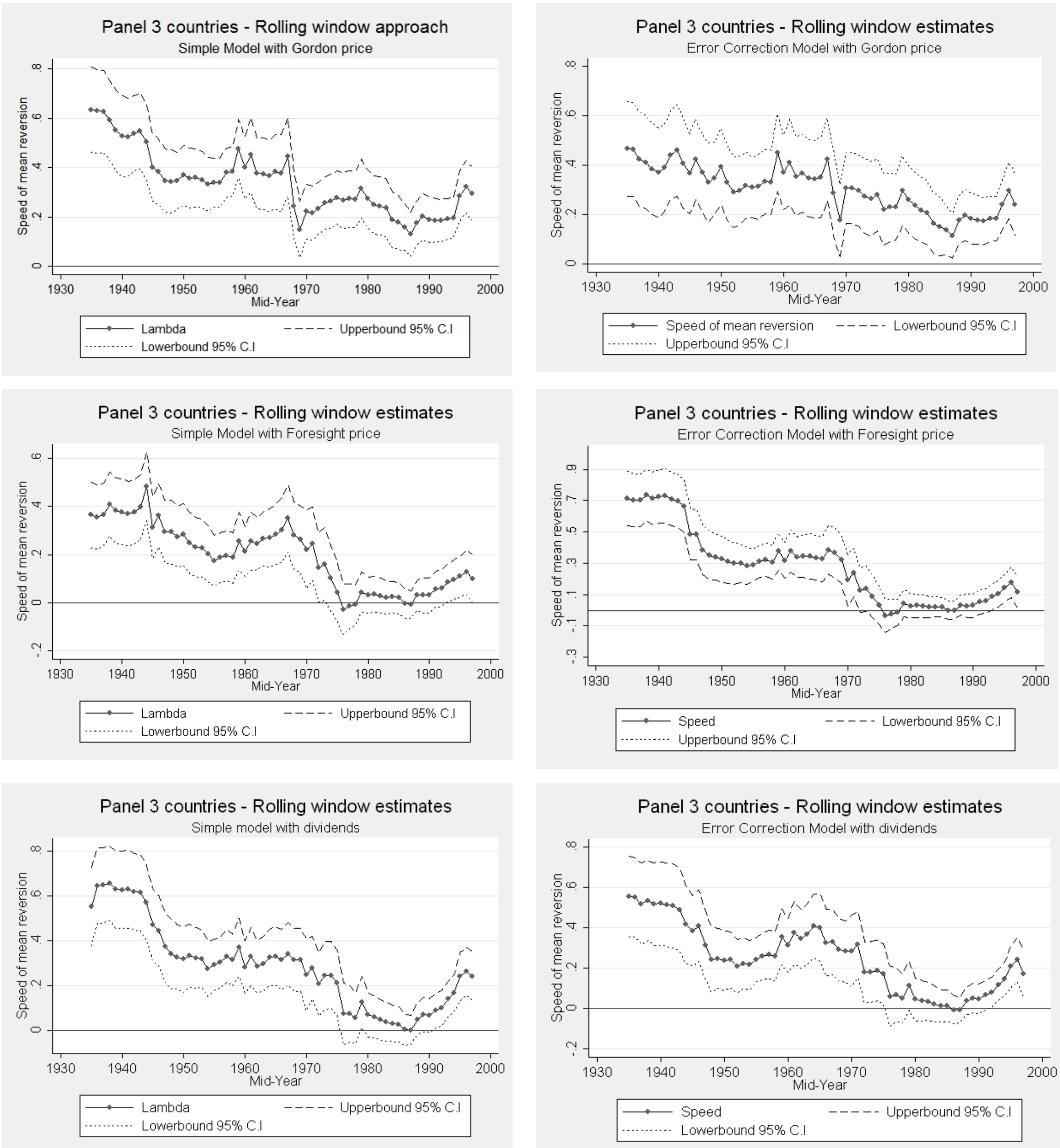
Many previous studies question the assumption of a constant speed of mean reversion over time. Kim et al. (1991) argue that mean reversion is a phenomenon of the periods when the stock markets are highly volatile, not a feature of the post-war era. In addition, according to Poterba and Summers (1988) the results of mean reversion change substantially with the inclusion and exclusion of the Depression years. Spierdijk et al. (2010) give more insight on the fluctuant speed of mean reversion of the stock market index by applying rolling window estimations on the panel data of 17 countries with the overlapping time intervals of 27 years. They find apparent evidence of time-varying mean reversion with only 2 out of 84 intervals show insignificant evidence. The estimates of the speed of mean reversion across different intervals range from the largest value of 0.296 in the interval 1918-1944 to the smallest of 0.030 in the interval 1900-1926 which is almost 10 times smaller.

Following Spierdijk et al. (2010), we apply rolling window estimations to our long panel data of 3 countries with the time interval of overlapping 27 years long. The rolling window estimation is only applied to the regressions that yield strong evidence of mean reversion. Figure 4 displays the unbiased estimates of the mean reversion coefficient for the error-correction model and the simple model with the Gordon price, the foresight price and the dividends and their corresponding 95% confidence intervals against the mid-year of the 27-year rolling-window period[18]. As for the simple model, the speed of mean reversion is the value of λ and it is the absolute value of β_1 for the error-correction model. All the estimations show a clearly non-constant speed of mean reversion of the stock price across time. Moreover the evidence of mean reversion is found for nearly 100% of all time intervals during the whole sample period. For the same proxy, the results from the ECM and the simple model are comparable to each other. As for the estimations with the same model for different proxies the results, on the one hand, show an analogous trend in the fluctuation of mean reversion across time, but on the other hand, display diverse magnitudes of the speed of mean reversion for the estimations. For example, the simple model with the Gordon price yields the highest value of the speed of mean reversion equal to 0.634 for the first time interval 1922-1948 (mid-year 1935) while the same model with the foresight price gives the highest value of 0.485 also for the time interval 1931-1957. The highest value and the lowest value of the speed of mean reversion obtained from the estimation by the ECM with the Gordon price are 0.466 which are

[18] All rolling-window estimates with associated 95% confidence intervals plotted in later figures are also against the mid-year of the 27-year rolling-window period.

found in the first time interval 1922-1948 and 0.115 in the time interval of 1974-2000 respectively, these values are lower compared to the regression by the simple model.

Figure 4 - Rolling window estimates - Panel 3 countries



Reviewing the fluctuation of the speed of mean reversion displayed in the six graphs, the common trend is apparently recognized with the same peaks found in some of the same time intervals. First, the highest values found among the total of 63 time intervals are in the periods before 1945 which is in line with the findings of Spierdijk et al. (2010) (Figure 5). In addition, this time period with a very large speed of mean reversion coincides with the timing of the Great Depression as well as the World War II which made tremendous impact on the economies all over the world in general and on the international stock markets in particular. The Great Depression started in about 1929 and lasted until the late 1930s or early 1940s. The World War II which involved most of the world's nations lasted from 1939 to 1945. Incorporating our findings with the timing of these noteworthy historical and economic events, we could strengthen the arguments of many previous papers on this topic that in the periods of the instable economy, the stock price is likely to revert to its fundamental value faster than of normal conditions. Spierdijk et al. (2010) also find the largest speed of reversion during the mid-year 1930 and conclude on a faster mean reverting process of the stock price during the periods of uncertainty about the sustainability of the economy. Our findings also confirm part of the conclusion of Kim et al. (1991) who argue that the mean reversion is primarily a phenomenon of the 1926-1946 period which includes the Great Depression and the World War II but not likely to occur in the post-war era. Their argument that the mean reverting process of stock price mainly occurs in the periods when the stock markets are highly volatile is strongly corroborated by our results. Nonetheless, in the normal market condition, mean reversion of stock price still exists, though with a smaller magnitude.

In Figure 5, the speed of mean reversion is estimated using the panel data model in combination with the bootstrap approach. The solid line represents the median unbiased estimate of the speed of mean reversion and the two dashed lines constitute the corresponding 95% confidence interval[19].

[19] Spierdijk et al. (2010) – page 32.

Figure 5 - Results of Spierdijk et al. (2010) – Rolling-window estimates of speed of mean reversion (benchmark: Wolrd Index)

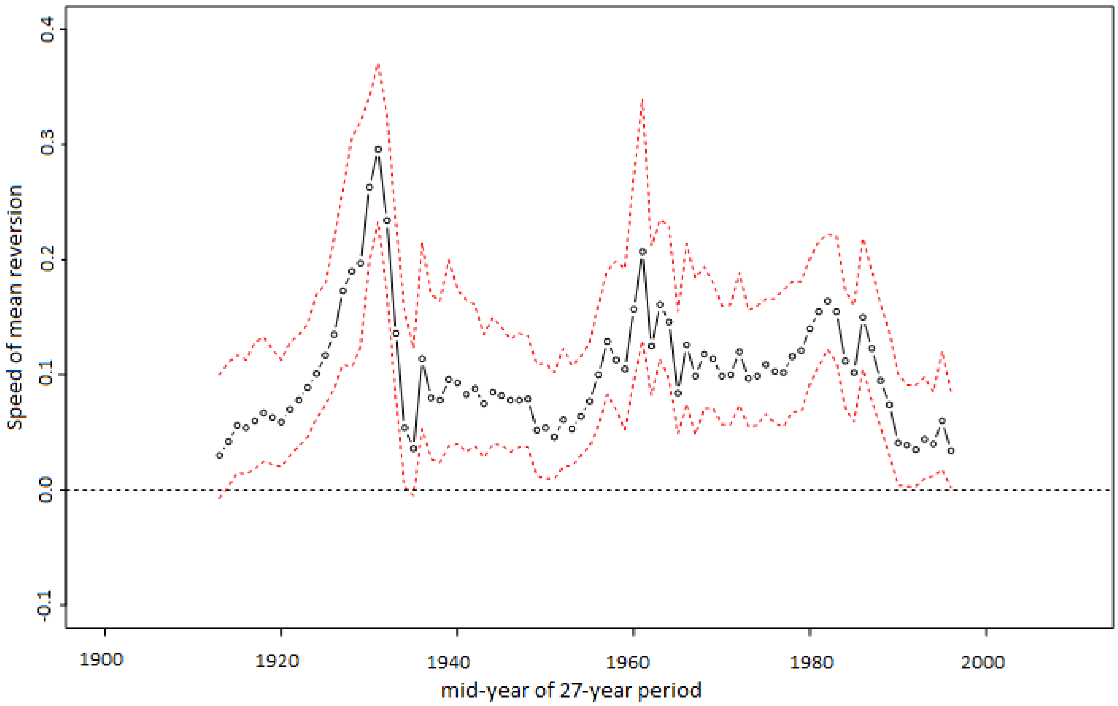
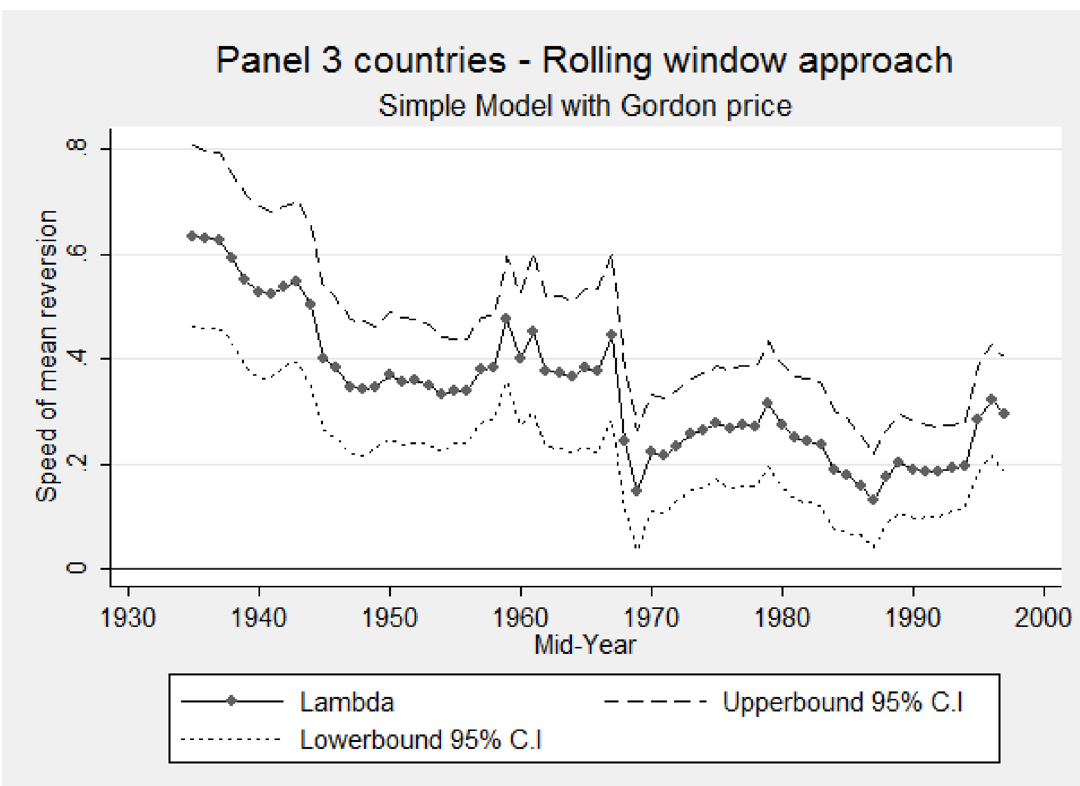


Figure 6 - Rolling window estimates - Panel 3 countries with Gordon price



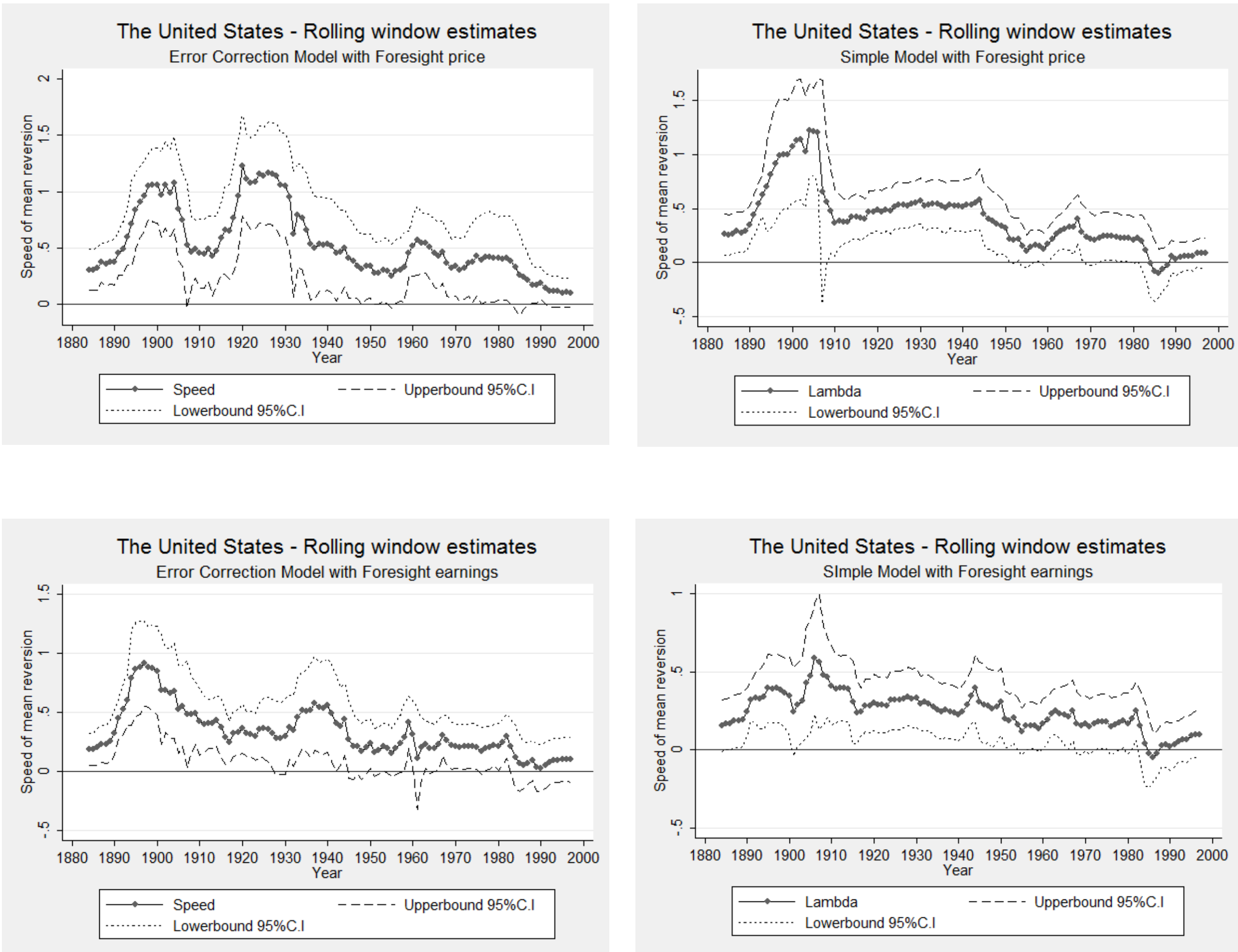
As clearly seen in Figure 6, the speed of the reverting process is highest during the Great Depression (the late 1930s), reduces gradually afterwards, then keeps its high value and slightly climbs again during the World War II (1939-1945). After that it decreases in the post-war periods. The speed of reversion goes down after the war but still keeps its value stable and significantly different from zero. Moreover, being consistent with the finding of Spierdijk et al. (2010), the mean reverting process of the stock price reaches its other peaks again around the 1960s. These periods are in the timing of the two phases of 1953-1962 and 1962-1979 of the Cold War as well as the stock market crash 1973-1974 due to the Vietnam War and the Watergate Scandal in the US. After these highly unstable periods, the mean reverting speed of the stock market decreases again in normal market conditions before moving to a slight peak around the mid-year 1980. Some tensions could be attributed to this small peak such as the 1987 Black Monday. However, this market crash lasted for only a few days. So its effect and severity are said to be not as large as the worst market crash 1930-1932 in the stock market history or the 1973-1974 crash which all lasted for more than 1 year. As a result, the speed of mean reversion only slightly increases during these periods. In line with Spierdijk et al. (2010), the outcomes of our rolling regressions also show a decrease trend after 1980 and then the speed increases again until the mid-year 1997 because of the mini-crash of the stock market which occurred due to the economic crisis in Asia.

Briefly speaking, based on the results from the rolling estimations of the panel data of 3 countries – Denmark, Sweden and the United States during the sample period 1922-2010, we could conclude on the time-varying property of the stock market indices. The speed of the mean reverting process is dramatically higher in the periods of unsustainable economy than in periods of normal economic conditions.

5.3.2 The United States

The time-varying property of the stock market index is strongly confirmed with the panel dataset of 3 countries. Nonetheless, the panel dataset even though takes the advantage of the large sample size after pooling the separate long time series of 3 countries only covers the period from 1922 to 2010. The stock database of the United States with a long-standing history of the stock market which covers a much longer time span from 1871 to 2010 is expected to give more insight on the fluctuant speed of mean reversion of the stock price. For that reason, in this section we apply the rolling window estimation to the United States' dataset to see if we find a consistent result to the findings with the panel dataset of 3 countries. The time interval of 27 years is also used for comparison purpose. The mid-year of each time interval ranges between 1884 and 1997. The first interval covers the 1871-1897 period and the last interval is of 1984-2010 period. The rolling window estimates are displayed in Figure 7 for regressions by the ECM and the simple model with the foresight price and the foresight earnings which show very strong evidence of mean reversion.

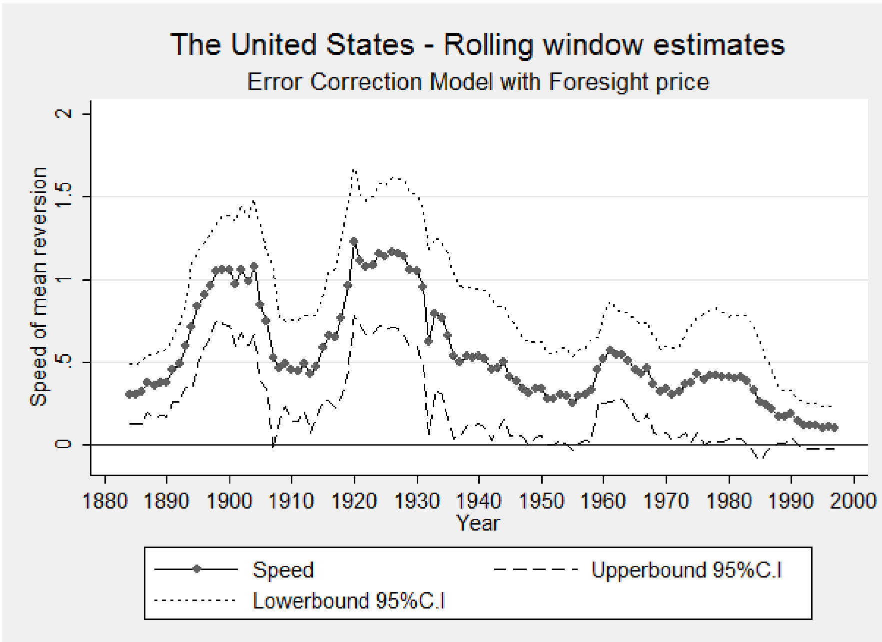
Figure 7 - Rolling window estimates - The United States



The error-correction model seems to give more reliable results when mean reversion is found in almost every time interval for the whole sample period. Only 11 out of 114 time intervals show insignificant evidence of mean reversion. Moreover, the estimations by the ECM show more consistent results between different proxies than by the simple model. The rolling-window estimates obtained from the simple model for time intervals for the mid-year between 1910 and 1920 fluctuate in the opposite trend for the two proxies – the estimates with the foresight price only demonstrate a continuously increasing trend while the estimates with the foresight earnings show a slight decrease. Furthermore, a huge drop is observed for the estimations with the foresight price after the mid-year 1900 while it is a gradual decrease with the foresight earnings. Estimations with the simple model actually give larger difference in the results with different proxies than the ECM. Therefore the error-correction model is more reliable in estimating the mean reverting process of the stock price indices.

In line with the findings of the panel 3 countries mean reversion is found to reach its highest value over the whole sample period during the 1930s which coincides with the timing of the Great Depression. The speed of the mean reverting process is in a decreasing trend afterwards but still at a very high value during the timing of the World War II. In addition, a small peak around the 1960s is also found for the US like in the results of the Panel data.

Figure 8 - Rolling window estimates - The United States - Foresight price



More interesting result from the US's data compared to that from the panel data is that it includes the time period before 1922 or in other words before the mid-year 1935 which could help compare our results with the findings of Spierdijk et al. (2010) for larger time periods. The start time interval of Spierdijk et al. (2010) is the period 1900-1926 corresponding to the mid-year 1913. According to their results, the speed of mean reversion has a continuously increasing trend from the first time interval to the mid-year 1930. This is found to be similar to our results where the estimated speed also follows a rising trend from the mid-year 1913 to 1929 which contains the period of the World War I (1918-1929). In addition, our larger period also shows the fluctuation of the reverting speed from the interval 1871-1897 to the interval 1899-1925 which is not included in the data used by Spierdijk et al. (2010). The mean reversion of the stock price index in the US stock market is very significant around the 1900s. This could be plausibly explained by the 1873 Depression which is a severe international economic depression both in Europe and the United States that lasted until 1879, the stock market crash 1901-1903 because of the assassination of President William McKinley and the 1906-1907 stock market crash due to a credit crunch in New York. In sum, the results from rolling window estimations with the US database again confirm that the mean reversion of the stock market index is a non-constant process with the highest speed found in periods of volatile stock market in the instable economy.

6. Empirical results – Total return index

Both Balvers et al. (2000) and Spierdijk et al. (2010) investigate the mean reverting behavior of the stock price using the market total return stock index which includes the income from dividend payments. Our main empirical results above presented in Section 5 are based on the stock price index which measures the price performance of markets without including dividends. The question is which index provides better results for estimation. For the research of Balvers et al. (2000) and Spierdijk et al. (2010) mean reversion is detected from total return indices relative to a reference index. Therefore using the total return index for estimation is plausible. However, in this thesis, we use a different approach which directly uses the fundamental value of the stock price for estimation to study the mean reverting behavior of the stock price. The fundamental of the stock price is theoretically determined without the assumption that the dividends are reinvested to purchase additional units of stocks which is used in the calculation of the total return index. As a result, the estimated fundamental value of the stock price will better reflect the stock price index rather than the total return index of the market. The results with the stock price index in this way of estimation are more reliable than those with the total return index. Nevertheless, for the robustness check and comparison purpose, this section shows the results of the regressions with the total return index. The empirical procedures for the estimations with the total return index are exactly the same as used with the stock price index in section 5.

6.1 Test for co-integration

In section 5.1, the augmented Dickey Fuller test shows a unit root in the total return index for all datasets. This section presents the test results for co-integration relationship between the total return index and all proxies for the fundamental value of the stock price.

Table 14 - Co-integration test with total return index - individual countries

Variables (log)	Denmark		Sweden		United States	
	t-statistics	Co-integration	t-statistics	Co-integration	t-statistics	Co-integration
Dividends	-3.395*	N	-2.750*	N	-4.496***	Y
Foresight price	-3.218*	N	-2.719*	N	-3.929**	Y
Hindsight price	-2.618*	N	-2.556	N	-4.086***	Y
Gordon price	-3.145**	Y	-3.093**	Y	-3.364*	N
Foresight earnings					-3.706**	Y
Hindsight earnings					-3.335*	N
Gordon earnings					-3.930**	Y
Smoothed earnings 30					-1.732	N
Smoothed earnings 10					-2.087	N

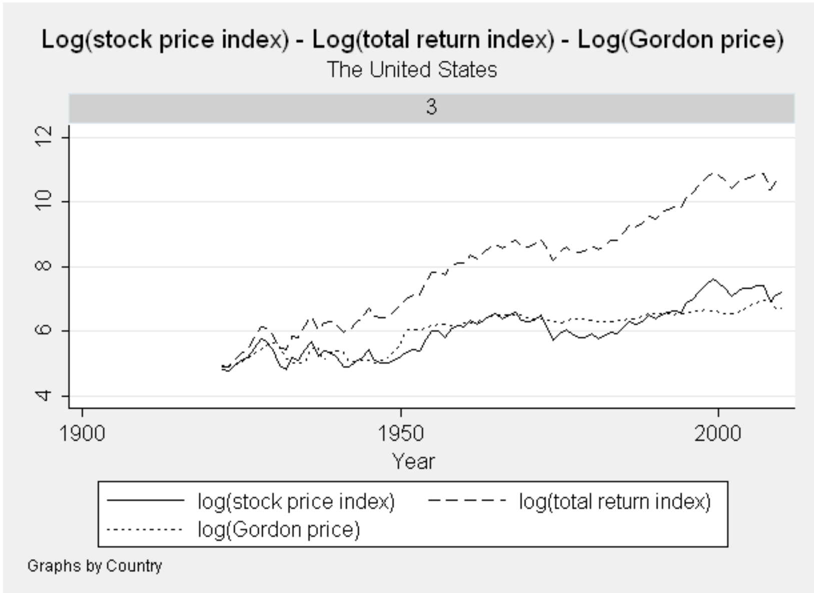
Table 14 shows that the evidence of the co-integration relationship between the total return index and the proxies for the fundamental is less significant than the results with the stock price index. Similar results are found with the panel data in Table 15.

Table 15 - Co-integration test with total return index - Panel data

Variables (log)	Panel 15 countries		Panel 3 countries	
	Z-statistics	p-value	Z-statistics	p-value
Dividends	1.789	0.963	-2.118**	0.017
Foresight price	-2.683***	0.004	-2.651***	0.004
Hindsight price	1.165	0.878	-1.327*	0.092
Gordon price	-2.093**	0.018	-4.772***	0.000

The less significant evidence of the co-integration relationship with the fundamental found in the total return index compared with the stock price index (all in natural logarithm) could also be illustrated by Figure 9 of the stock price index, the total return index and one of the proxy – the Gordon price.

Figure 9 - Co-integration relationship between the stock price and the fundamental



Even though the co-integration relationship with the Gordon price is found both in the stock price index and the total return index, it can be apparently seen from Figure 9 that the stock price index is strongly co-integrated with the Gordon price while the total return index show less clear evidence. The Z-statistics is (-10.100) for the stock price index against (-4.772) for the total return index. The weaker the evidence of the co-integration relationship, the less significant evidence of mean reversion of the stock price is expected. The following section will give empirical supports for this argument.

6.2 Estimation results

Based on the test results of the co-integration relationship between the total return index and the proxies for the fundamental value of the stock price, only the proxies which are co-integrated with the total return index are used for estimations with the Engle-Granger ECM. For the generalized one-step ECM all proxies are used. The results for the time series data of each country as well as for the panel data of 3 countries and 15 countries are presented below.

Table 16 - Estimation results with total return index - Denmark

GENERALIZED ONE-STEP ECM

	βo	β_1	$-\beta_1 \beta_2$	β_2
Dividends	0.192	-0.022	0.059	2.682
Foresight price	-0.007	-0.003	0.123***	4.100
Hindsight price	-0.138	0.014	-0.009	0.643
Gordon price	0.307**	-0.054**	0.100***	2.185

ENGLE-GRANGER TWO-STEP ECM

	βo	β_1	β_2 (+)
Dividends	0.404***	-0.012	2.299***
Foresight price	0.111	-0.031	2.514***
Hindsight price	-0.072	0.013	2.710***
Gordon price	0.278**	-0.054**	1.684***

(+) shows significance level of β_2's difference from 1.

SIMPLE MODEL

	λ
Dividends	-0.004
Foresight price	-0.003
Hindsight price	-0.013
Gordon price	0.007

The results with the Danish dataset only show evidence of mean reversion at 5% significance level for the regression with the Gordon price using the error-correction model. The co-efficient is small (-0.054) and consistent between the two-step and one-step procedure. No mean reversion is found with the simple model.

Similar results are found for the Swedish dataset. All estimations with the simple model show no evidence of mean reversion (Table 17). The ECM confirms the mean reverting process for only one proxy. However instead of the Gordon price, only the estimations with the foresight price show significant evidence of mean reversion. The value of the coefficient or the speed of mean reversion is smaller than in the same regression with the stock price index. The results are also consistent between the one-step and two-step procedure.

Table 17 - Estimation results with total return index - Sweden

GENERALIZED ONE-STEP ECM

	βo	β_1	$-\beta_1 \beta_2$	β_2
Dividends	0.641***	-0.017	0.033	1.887
Foresight price	-1.028***	-0.383***	0.711***	1.854
Hindsight price	-0.351	0.052	-0.080	1.540
Gordon price	0.533***	-0.038	0.070	1.854

ENGLE-GRANGER TWO-STEP ECM

	βo	β_1	$\beta_2(+)$
Dividends	0.644***	-0.017	1.667***
Foresight price	-1.013***	-0.434***	1.743***
Hindsight price	-0.242	0.045	1.818***
Gordon price	0.629***	-0.057	1.519***

(+) shows significance level of β_2's difference from 1.

SIMPLE MODEL

	λ
Dividends	-0.001
Foresight price	-0.015
Hindsight price	-0.015
Gordon price	0.008

Like the results with the Swedish dataset, the United States' only confirm the existence of mean reversion of the market stock price when the foresight price and the foresight earnings are used as the proxies for the fundamental value of the stock price (Table 18). The regressions with the dividend, the hindsight price, etc. even show unexpected sign of the mean reversion co-efficient.

Table 18 - Estimation results with total return index - United States

GENERALIZED ONE-STEP ECM

	βo	β_1	$-\beta_1 \beta_2$	β_2
Dividends	-0.056	0.038**	-0.247**	6.567
Foresight price	1.097***	-0.061***	0.31***	5.115
Foresight earnings	0.246	-0.047**	0.176**	3.714
Hindsight price	-0.347	0.014	-0.102	7.090
Hindsight earnings	-0.387**	0.020	-0.094	4.752
Gordon price	0.071	0.012	-0.066	5.319
Gordon earnings	0.204***	-0.005	0.000	0.037
Smoothed earnings 30	-1.063	-0.009	0.031	3.397
Smoothed earnings 10	-0.909**	0.010	-0.055	5.677

ENGLE-GRANGER TWO-STEP ECM

	βo	β_1	$\beta_2(+)$
Dividends	0.235*	0.072***	5.183***
Foresight price	1.025***	-0.008	4.912***
Foresight earnings	0.190	-0.003	3.508***
Hindsight price	-0.238	0.064***	4.837***
Hindsight earnings	-0.091	0.072***	3.461***
Gordon price	0.185	0.058***	2.689***
Gordon earnings	0.235***	0.027	4.502***

(+) shows significance level of β_2's difference from 1.

SIMPLE MEAN REVERSION

	λ
Dividends	0.004
Foresight price	0.005
Foresight earnings	0.006
Hindsight price	0.005
Hindsight earnings	0.004
Gordon price	0.005
Gordon earnings	0.009
Smoothed earnings 30	0.005
Smoothed earnings 10	0.005

In contrast to the results of Denmark and Sweden with the simple model, the US dataset shows a right sign of the mean reversion coefficient. Nonetheless, none of the regression shows significant evidence of the mean reverting process of the stock price.

Analogous to the results with time series dataset of individual countries, the panel dataset of 3 countries and the panel dataset of 15 countries do not present as strong evidence of mean reversion with the total return index as that with the stock price index. Table 19 and Table 20 show the detailed results with the panel dataset of 3 countries and the panel dataset of 15 countries respectively.

Table 19 - Estimation results with total return index - Panel 3 countries

GENERALIZED ONE-STEP ECM

	βo	$\beta 1$	$-\beta 1 \beta 2$	$\beta 2$	Half-life	95% C.I
Dividends	0.471***	-0.013	0.029	2.231		
Foresight price	-0.047	-0.021*	0.065**	3.095		
Hindsight price	-0.126	0.015	-0.02	1.333		
Gordon price	0.441***	-0.033**	0.056**	1.697	20.5	(11.2, 112.5)

ENGLE-GRANGER TWO-STEP ECM

	βo	β1	Half-life	95% C.I
Foresight price	-0.072	-0.013**	51.3	(28.4, 250.9)
Gordon price	0.436***	-0.011*		

SIMPLE MODEL

	λ
Dividends	0.004
Foresight price	0.001
Hindsight price	-0.009
Gordon price	0.015

The estimations with the total return index for the panel data of 3 countries yield very different results from the estimations with the stock price index. Due to insignificant evidence of mean reversion the estimated half-life is very large ranging from 20.5 years to 63.8 years while it is from 2.5 years to 19 years for the stock price index. Moreover, based on the corresponding 95% confidence intervals of the estimated half-life of these estimations, the estimates from the regressions with the total return index are more uncertain compared to those with the stock price index.

Table 20 - Estimation results with total return index - Panel 15 countries

	βo	β_1	$-\beta_1\beta_2$	β_2
Foresight price	-0.935***	-0.148***	0.252***	1.702
Gordon price	0.746***	-0.071***	0.095***	1.339

ENGLE-GRANGER TWO-STEP ECM

	βo	β_1
Foresight price	-0.835***	-0.083***
Gordon price	0.745***	-0.026*

SIMPLE MODEL

	λ
Dividends	0.119***
Foresight price	0.069*
Hindsight price	0.06
Gordon price	0.116***

The results with the panel of 15 countries (Table 20) are approximate to the same estimations with the stock price index (Table 12). For instance, the estimated speed of mean reversion with the foresight price is equal to 0.148 for the total return index and 0.162 for the stock price index. Nevertheless, like the estimations with the other datasets, the absolute value of β_1 from the regressions with the total return index is smaller than that with the stock price index.

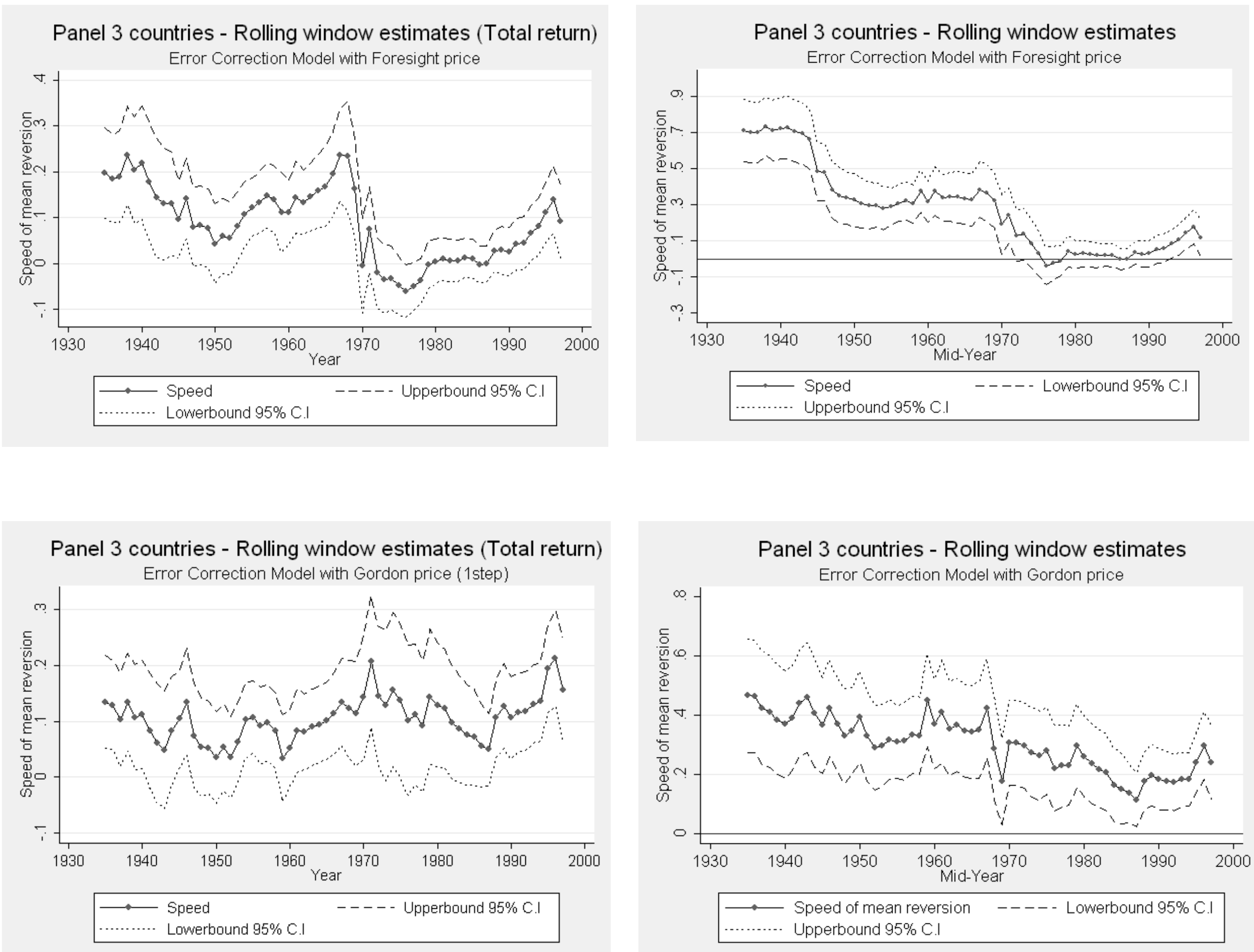
In sum, the estimations with the total return index show less significant evidence of mean reversion in stock prices compared to those with the stock price index. The reason is the stronger co-integration relationship between the estimated fundamental value of the stock price and the stock price index than the total return index which is clearly seen in Figure 9. More interestingly, the longer period the dataset covers, the larger the difference is observed between the estimations with the stock price index and the total return index. For instance, the estimates obtained from the regressions with the US dataset – the longest dataset among others show the largest difference between one with the stock price index and one with the total return index while the estimations from the panel 15 countries dataset which covers the shortest period from 1970 to 2010 yield similar results for the two indices. This could be plausibly explained by the dividend payouts which is accumulated in the total return index over time but is not accounted for in the stock price index. Hence, it is the accumulated dividend payout that makes the gap between the two indices become larger and larger and whereby leads to more dissimilar estimation results derived from these two series over time.

6.3 Time-varying mean reversion

The time-varying mean reversion of the total return index is examined with the panel data of 3 countries and the results are compared with the stock price index. Because only the estimations with the foresight price and the Gordon price applying the ECM show significant evidence of mean reversion of the stock price, these two regressions are used for rolling window estimations with the intervals of overlapping 27 years. Figure 10 displays the rolling window estimates of the speed of mean reversion over time obtained from the two regressions.

The two graphs on the left display the rolling window estimates with the total return index. And on the right are found the rolling window estimates with the stock price index which are also presented in section 5.3. In general, the rising or decreasing trend across time of the speed of the mean reverting process is similar between the stock price index and the total return index. However, the time of the highest peak is totally different. While the regressions with the stock price index show the largest value of the mean reversion speed at the first time interval of 1922-1948, the regressions with the total return index display the highest peak around the mid-year 1970. This time period includes some tensions of the Cold War (such as the Berlin Crisis of 1961 and the Cuba Crisis of 1962) as well as the Oil Crisis of 1973 which then lead to the 1973-1974 stock market crash. Nevertheless, those historical and economic events are said not to leave such severe affect to the stock markets as the Great Depression in the late 1930s and the World War II (1939-1945). Consequently, the results from the estimations with the stock price index are more reliable and could be more plausibly explained than the total return index.

Figure 10 - Rolling window estimates - Stock price index and Total return index comparison



Furthermore, the time-varying property of the stock price index is more consistent among different estimations with different proxies than the total return index. It is obviously seen from Figure 10 that the highest peak of the rolling estimates with the foresight price is found before the mid-year 1970 while after the mid-year 1970 for the rolling estimates with the Gordon price. This inconsistence again confirms that the stock price index gives more reliable evidence of the mean reverting behaviour of the market stock price than the total return index.

7. Conclusions

This research investigates the mean reverting behaviour of stock prices using an error-correction approach which accounts for the fundamental value of stock prices. Among the two error-correction models – Engle-Granger two-step ECM and generalized one-step ECM, the generalized one-step is our preferred method thanks to its superior efficiency in estimation to the other. However, mean reversion of stock prices is examined by both of these two models plus the simple mean reversion model to see the effect of model choice on the results. Moreover, estimations are conducted in both time series datasets of individual countries and panel datasets of many developed countries. The individual countries are Denmark for the period 1922-2010, Sweden for the period 1919-2010 and the United States for the longest period from 1871 to 2010. Two panel datasets are established – the pooled panel dataset of the above mentioned 3 countries for the period 1922-2010, and the panel dataset of 15 MSCI developed countries for the period 1971-2010. Constructing many possible proxies for the fundamental value of stock prices, we find strong evidence of mean reversion in stock prices for almost all proxies. The estimated speed of mean reversion varies across datasets, proxies and models but in general it is higher than that of all previous studies on the same topic. The highest speed of mean reversion found in the estimation of Sweden with the foresight price using the generalized one-step ECM is equal to 0.432 (the absolute value of the mean reversion coefficient) while only 0.125 in Cochran & DeFina (1995), 0.202 in Balvers et al. (2000) and 0.042 in Spierdijk et al. (2010). In addition, for the pooled panel dataset of 3 countries as well as the panel data of 15 countries the evidence of mean reversion is also statistically significant and consistent with the findings on the time series data. The strongest evidence of mean reversion found in the estimation with the Gordon price for the panel 3 countries is -0.239 at 1% confidence level. Our significant results in all datasets reaffirm the arguments of Balvers et al. (2000) and Spierdijk et al. (2010) that mean reversion of stock prices is not only the phenomenon of the US but also of the international stock markets. In addition, our outcomes also show that the choice of the proxy affects the empirical results at a certain level. Among others, the foresight price and the Gordon price are found as suitable proxies for the fundamental value of stock prices when they show consistent evidence of strong mean reversion in every regression.

Applying the same approach of rolling-window estimation of Spierdijk et al. (2010) this thesis confirms their findings on the dynamics of the mean reversion process. For example, for the estimation with the Gordon price, an average half-life of 2.5 year is reported for the deviation of the stock price from its fundamental value to be eliminated during the period 1922-2010. Nonetheless, based on the results on the rolling-window estimation of overlapping 27-year intervals, the half-life ranges from 1.1 years to 5.7 years corresponding to the highest speed of 0.466 and the lowest speed of 0.115 respectively. The time duration for the stock price to absorb half of the shock is reported longer for the estimations with the other proxies. But in general, all the rolling-window estimates show a very fluctuant speed of mean reversion across time. The highest speed of mean reversion is found during the time of World War I, the Great Depression and the start of World War II. Additionally, the very fast speed is also observed in the period containing the Cold War, the 1873 Depression, the 1901-1903, 1906-1907 and 1973-1974 stock market crashes. These results imply that the speed of the mean reverting process of stock prices is dramatically higher in the periods of an unsustainable economy than in periods of normal economic conditions.

Balvers et al. (2000) argue that exploiting mean reversion of stock prices could help gain significant excess returns in contrarian trading strategy. In addition, Campbell & Shiller (2001) emphasize the crucial role of the mean reverting behaviour of stock prices on the predictability of excess returns. To ensure the success of the investment strategy, a choice on the mean reversion parameter must been made properly. Nonetheless, our results show a very diverse magnitude of the mean reverting speed which not only depends on the model, and the sample period but also on the choice of the proxy for the fundamental value of stock prices. In our thesis, we employ such 4 proxies as dividends, foresight price, hindsight price and Gordon price for the fundamental. The foresight price and the Gordon price are found to be efficient proxies with highly consistent results they give across different models and datasets. However, each has its advantages and disadvantages in estimation. The advantage of the foresight price is its consideration of a changing cash flow for every future year but the fundamental value estimated in this way is based on the actual realized future cash flows, not the expected future cash flows at the moment of pricing. Also, the foresight price only accounts for the future cash flows of only 5 leading years. The Gordon price, on the contrary, is advantageous in accounting for infinite cash flows. Nevertheless, the disadvantage of the Gordon price is that only the current dividend is taken into consideration. Furthermore, both these two proxies have the same limitation of using a fixed discount rate in estimation for the whole sample period. Even though we apply a structural break in the discount rate for both 3 countries datasets, it still could not reflect the dynamics of the expected rate of return in reality and hence is not close enough to the real fundamental value. As a result, for further improvement of the mean reversion estimation we suggest to find a more appropriate proxy that could better reflect the fundamental value of the stock price.

List of Figures

List of Tables

References

Ayres, I. (1991). Back to basics: Regulating how corporations speak to the market. *Virginia Law Review, 77*(5), 945-999.

Bachmeier, L. J., & Griffin, J. M. (2006). Testing for market integration: Crude oil, coal, and natural gas. *The Energy Journal, 27*(2), 55-72.

Balvers, R., Wu, Y., & Gilliland, E. (2000). Mean reversion across national stock markets and parametric contrarian investment strategies. *The Journal of Finance, 55*(2), 745-772.

Banerjee, A., Dolado, J., & Galbraith, J.D. hendry (1993), cointegration, error correction and the econometric analysis of non stationary data.

Bekaert, G., Harvey, C. R., & Lumsdaine, R. L. (1999). The dynamics of emerging market equity flows.

Breusch, T. S., & Godfrey, L. G. (1981). A review of recent work on testing for autocorrelation in dynamic simultaneous models. *Macroeconomic Analysis, Croom Helm, London,* , 63-105.

Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica: Journal of the Econometric Society,* , 1287-1294.

Campbell, J. Y. (2000). Asset pricing at the millennium.

Campbell, J. Y., & Shiller, R. J. (1989). Stock prices, earnings and expected dividends.

Campbell, J. Y., & Shiller, R. J. (2001). Valuation ratios and the long-run stock market outlook: An update.

Claus, J., & Thomas, J. (2001). Equity premia as low as three percent? evidence from analysts' earnings forecasts for domestic and international stock markets. *The Journal of Finance, 56*(5), 1629-1666.

Cochran, S. J., & DeFina, R. H. (1993). Mean reversion in stock prices: An error-correction approach. *Managerial Finance, 21*(7), 25-42.

Cochrane, D., & Orcutt, G. H. (1949). Application of least squares regression to relationships containing auto-correlated error terms. *Journal of the American Statistical Association, 44*(245), 32-61.

Cochrane, J. H. (1988). How big is the random walk in GNP? *The Journal of Political Economy, 96*(5), 893-920.

Conrad, J., & Kaul, G. (1988). Time-variation in expected returns. *The Journal of Business, 61*(4), 409-425.

Cutler, D. M., Poterba, J. M., & Summers, L. H. (1991). Speculative dynamics and the role of feedback traders.

Davidson, R., & MacKinnon, J. G. (1993). Estimation and inference in econometrics. *OUP Catalogue,*

De Boef, S. (2001). Modeling equilibrium relationships: Error correction models with strongly autoregressive data. *Political Analysis, 9*(1), 78.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*(366), 427-431.

Dimson, E., Marsh, P. R., & Staunton, M. (2002). *Triumph of the optimists: 101 years of global investment returns* Princeton Univ Pr.

Dodd, D., & Graham, B. (1934). Security analysis.

Durbin, J. (1970). Testing for serial correlation in least-squares regression when some of the regressors are lagged dependent variables. *Econometrica: Journal of the Econometric Society,* , 410-421.

Durbin, J., & Watson, G. S. (1950). Testing for serial correlation in least squares regression: I. *Biometrika, 37*(3/4), 409-428.

Elton, E. J., Gruber, M. J., & Blake, C. R. (1995). Fundamental economic variables, expected returns, and bond fund performance. *The Journal of Finance, 50*(4), 1229-1256.

Engelen, P. (2005). Remedies to information asymmetries in securities markets. *Antwerpen: Intersentia Publishers,*

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica: Journal of the Econometric Society,* , 251-276.

Fama, E. F. (1991). Efficient capital markets: II. *Journal of Finance,* , 1575-1617.

Fama, E. F., & French, K. R. (1988). Dividend yields and expected stock returns* 1. *Journal of Financial Economics, 22*(1), 3-25.

Fama, E. F., & French, K. R. (1988). Permanent and temporary components of stock prices. *The Journal of Political Economy, 96*(2), 246-273.

Fama, E. F., & French, K. R. (2002). The equity premium. *The Journal of Finance, 57*(2), 637-659.

Gordon, M. J. (1959). Dividends, earnings, and stock prices. *The Review of Economics and Statistics, 41*(2), 99-105.

Gropp, J. (2003). Mean reversion of size-sorted portfolios and parametric contrarian strategies. *Managerial Finance, 29*(10), 5-21.

Gropp, J. (2004). Mean reversion of industry stock returns in the US, 1926-1998. *Journal of Empirical Finance, 11*(4), 537-551.

Hansen, L. P., & Hodrick, R. J. (1980). Forward exchange rates as optimal predictors of future spot rates: An econometric analysis. *The Journal of Political Economy, 88*(5), 829-853.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the Econometric Society,* , 1251-1271.

Heaton, J., & Lucas, D. (2000). Stock prices and fundamentals.

Hoang, N. T., & McNown, R. F. (2006). Panel data unit roots tests using various estimation methods. *University of Colorado Bulletin, 6*, 33-66.

Holmen, M., Knopf, J. D., & Peterson, S. (2008). Inside shareholders' effective tax rates and dividends. *Journal of Banking & Finance, 32*(9), 1860-1869.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels* 1. *Journal of Econometrics, 115*(1), 53-74.

Jegadeesh, N. (1991). Seasonality in stock price mean reversion: Evidence from the US and the UK. *The Journal of Finance, 46*(4), 1427-1444.

Jorion, P. (2003). The long-term risks of global stock markets. *Financial Management, 32*(4), 5-26.

Kim, M. J., Nelson, C., & Startz, R. (1991). Mean reversion in stock prices? A reappraisal of the empirical evidence.

København, H. I., Nielsen, S., & Risager, O. (2007). STOCK RETURNS AND BOND YIELDS.

Levin, A., Lin, C. F., & James Chu, C. S. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics, 108*(1), 1-24.

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics, 61*(S1), 631-652.

Malkiel, B. G. (2004). Models of stock market predictability. *Journal of Financial Research, 27*(4), 449-459.

Manzan, S. (2004). Nonlinear mean reversion in stock prices. *Computing in Economics and Finance 2004,*

Marsh, T. A., & Merton, R. C. (1987). Dividend behavior for the aggregate stock market. *The Journal of Business, 60*(1), 1-40.

McQueen, G. (1992). Long-horizon mean-reverting stock prices revisited. *Journal of Financial and Quantitative Analysis, 27*(01), 1-18.

Prais, S. J., & Winsten, C. B. (1954). Trend estimators and serial correlation. *Chicago: Cowles Commission Discussion Paper,*

Ramsey, J. B. (1969). Tests for specification errors in classical linear least-squares regression analysis. *Journal of the Royal Statistical Society.Series B (Methodological), 31*(2), 350-371.

Richardson, M., & Smith, T. (1991). Tests of financial models in the presence of overlapping observations. *Review of Financial Studies, 4*(2), 227.

Samuelson, P. (1965). Proof that properly anticipated prices fluctuate randomly. *Management Review, 6*(2), 41-49.

Shiller, R. J. (1981). Do stock prices move too much to be justified by subsequent changes in dividends?

Shiller, R. J. (2000). Measuring bubble expectations and investor confidence. *Journal of Behavioral Finance, 1*(1), 49-60.

Spierdijk, L., Bikker, J., & Van Den Hoek, P. (2010). *Mean reversion in international stock markets: An empirical analysis of the 20th century* De Nederlandsche Bank.

Statman, M., & Scheid, J. (2002). Buffett in foresight and hindsight. *Financial Analysts Journal,* , 11-18.

Summers, L. H. (1986). Does the stock market rationally reflect fundamental values? *The Journal of Finance, 41*(3), 591-601.

Torous, W., Valkanov, R., & Yan, S. (2004). On predicting stock returns with nearly integrated explanatory variables. *Journal of Business,* , 937-966.

Vlaar, P. (2005). *Defined benefit pension plans and regulation* De Nederlandsche Bank.

Waldenström, D. (2007). Swedish stock prices and returns and bond yields, 1856–2006. *Found on Http://www.Riksbank.com/templates/Page.Aspx,*

Westerlund, J., & Edgerton, D. L. (2007). A panel bootstrap cointegration test. *Economics Letters, 97*(3), 185-190.

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica: Journal of the Econometric Society,* , 817-838.

Wooldridge, J. M. (2002). *Econometric analysis of cross section and panel data* The MIT press.