# Time-Series Momentum Across Borders

A study of price TSM in 21 countries

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*This Masters Thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.*

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## Abstract

This thesis investigates if a simple technical trading signal, based on absolute price momentum, will realize higher profits across market equity portfolios from 21 different countries. By looking at if the current price ($P_t$) exceeds a historic price ($P_{t-k}$) it determines if an investor is long in the market portfolio or a risk-free asset, the strategy is there for "long only". Hypothesis testing is conducted to find the optimal look-back period and linear regression based on the the Index-model is used to evaluate the size and validity of potential excess return. The results are encouraging, a time-series momentum trading strategy will yield better risk-adjusted returns (higher Sharpe-ratio) than the market portfolio in 16 of the 21 countries tested. The results for excessive return based on the Index-model are encouraging with positive statistically significant alphas in 15 of the 16 countries where momentum also is significant. Several potential sources of the momentum anomaly and different strategies discussed in relevant literature is also included.

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Though this thesis is written with the input of other people the fault for any mistakes or errors, are mine and mine alone.

Anders Lillelien Oslo, June 3, 2013

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# 1 Introduction

In the classic movie "Wall Street" from 1987, the impersonation of speculation Gordon Gekko is quoted stating "Greed for a lack of a better word is; good. Greed works.". Some might say he is right and some will say he is wrong. But it is little doubt that he portrays the world of capitalism, which is most extreme with speculators. Harry Markowitz laid the foundations of modern portfolio theory in 1952, and it has further evolved with the contribution of others, like William Sharpe, Eugene Fama, Kenneth French to name a few. It has helped investors to more effectively evaluate assets and allocate their capital to maximize profits and minimize risk. With the technological advancements and globalization one might think that these advancements might have lead to more efficient markets and that fundamental and technical analysis have become obsolete. One can witness some effects, bid-ask-spreads have narrowed and arbitrage opportunities are gone within milliseconds, capital have become cheaper due to availability etc. But it is still general belief that one can use market inefficiencies to realize abnormal return. Anomalies to equilibrium pricing models can be found and technical trading systems like momentum seems to help investors realize excessive return. Momentum as a technical trading rule relies on the predictability of mass psychology and uninformed trading, among other market inefficiencies such as slow adjustments to shocks and limits to arbitrage. Though technological advancements have also dampened the effects of uninformed trading by making more and more investors informed, the bottom line is that humans are sometimes irrational by nature. A tendency we can exploit.

The studies on momentum where first conducted on the US stock market (De Bondt and Thaler, 1985, Brock *et al.*, 1992, Jegadeesh and Titman, 1993) and focus on cross-sectional (relative) momentum. Further studies have included strategies of both cross-sectional and time-series momentum (absolute) in a variety of markets and on a variety of instruments (further details are provided in Section 2). Faber (2009) found evidence of time-series momentum on the S& P500 using a simple-moving average trading signal. Gwilym *et al.* (2009), Clare, Seaton, Smith and Thomas (2012) find that a similar strategy based on a simple-moving average also produce higher risk-adjusted performance on indexes in different countries. Antonacci (2013) finds that also a strategy that is based solely on evaluating if the current price is higher than the price 12 months ago, yield better results than a buy-and-hold strategy on different indexes. The motivation for this thesis is to look if we can produce similar results as Gwilym *et al.* (2009), Clare, Seaton, Smith and Thomas (2012) with a similar strategy as Antonacci (2013).

The purpose of this thesis can be summarized as;

- Review relevant literature to both present possible sources of the momentum anomaly and the established benefits from trading on momentum and trend-following strategies.
- Test if a time-series momentum strategy will outperform the market portfolio in 21 different countries.

The remainder of this thesis is organized as follows; Section 2 will give an overview of relevant literature and the theory and results contained there. Section 3 will describe portfolio theory, including equilibrium asset pricing models and performance measures that will be used in the analysis. Section 4 discusses market efficiency and empirical results concerning the relevant theories. Market inefficiencies, ways to benefit from it and potential sources will be discussed in Section 5. Section 6 will delve further into the subject of Time-series momentum, which include different strategies and limitations of the implementations of such strategies. Section 7 consists of the methodology used to statistically evaluate the TSM-strategy. Section 8 contains a brief overview of the dataset, the model and the different techniques used to check for robustness. Section 9 contains the empirical results from the tests from Section 7 and the strategy simulation. In Section 10 a summary of the findings can be found.

## 2 Literature Review

The process of fairly pricing assets is founded on equilibrium pricing models like the CAPM, the Fama-French 3 and the Fama-French-Carhart 4 factor model, Arbitrage Pricing Theory etc. The practical problems with these models is the assumptions they make to make the model valid. As we know, the real world can not be efficiently summarized into one simple model. The equilibrium pricing models are therefore too simple to describe to real world. And have a problem explaining the anomalies that seem to persist in the financial world. One of the most persistent and profitable of these anomalies is the momentum anomaly. This anomaly describes the tendency for past prices (and implicitly; returns) and earnings to have an effect on future returns. Research such as Rouwenhorst (1998), Jegadeesh and Titman (2001) and Grinblatt and Moskowitz (2004) have found empirical results that the momentum anomaly experience reversals over different time horizons not only in the US Stock market but also in 12 European countries (Rouwenhorst, 1998). We distinguish between the following time horizons; Short-term (less than one month) momentum show that past losers outperform past winners; intermediate-term (2 up to about 12 months) momentum past winners outperform past losers and long term (more than 24 months) momentum where past losers again outperform past winners. Mentioned explanations for these reversals is that the short-term momentum is caused by price pressure and liquidity as found by Jegadeesh (1990) and Lehmann (1988) or a lead-lag relationship as supported by Lo and MacKinlay (1990). Intermediate-term momentum can be attributed to investor over-reaction to news (De Bondt and Thaler, 1985). According to Fama and French (1996) only long-term momentum can be consistent with a multi factor model. Chiarella, He and Hommes (2005) give evidence that the fundamental price is locally stable for a lag-period of 5 months, if the lag-period is longer the price becomes unstable. These empirical findings lead to believe that markets are not efficient and equilibrium pricing models will only give us an indication of what the fair price of an asset really is. Researchers like Andrade *et al.* (2004) have found that uninformed trading can lead to mis-pricing and support the theory that fundamental and technical analysis can be profitable tools. We look at biases such as herding, disposition, representativeness etc, that gives us an overview over biases that the uninformed trader might possess. Other looks at limits in the Arbitrage Pricing Theory to create consistent price movements, others again look at time-varying equilibrium prices as a source of momentum. These models and relevant theories on market efficiency and inefficiency is further discussed in Sections 3,4 and 5. Scholz and Walther (2011) is one of the studies the studies claiming that the momentum anomaly is not caused by market inefficiencies but rather by the "statistical characteristics of the underlying asset price time series" (Scholz and Walther, 2011). The findings of the study are mixed but they indicate that at least drift and autocorrelation in the assets price path can explain the momentum anomaly.

In the quite extensive literature written on momentum and time-following trading strategies, authors have a tendency to use some different terms for different meanings and definitions. To minimize confusion when reading this thesis the following terms have the following definitions;

**Definition 2.0.1.** *Time-series momentum (TSM) will be used to describe trading strategies that only use the assets own past price movements to predict future price movements. Trading signals will be created with the help of a simple-moving average, trading range break-out etc.*

Remark; This term is dubbed trend-following and time-trending by several authors, for example; (Faber, 2009) and (Gwilym *et al.*, 2009).

**Definition 2.0.2.** *Cross-sectional momentum will be used when describing trading strategies that rank assets performance relative to its peers and use this ranking system to predict future relative price movements. The investor use a strategy that would then long the highest ranked assets and possibly shorting the lowest ranked.*

Remark; Cross-sectional momentum uses the same methodology as relative strength momentum which can be found in the Fama-French-Carhart 4-factor model.

Older literature tend to focus on Cross-sectional momentum, but as empirical results found by Siegel (1998) and Faber (2009) etc, have shown that also Time-series momentum can be profitable focus have become more balanced. Popular strategies for exploiting this anomaly are (but not excluded to) moving averages, trading-range break outs and compound returns. Brandolini and Colucci (2011) find that a bootstrapping method can yield positive results. Different strategies will be discussed further in Section 6.

The literature also makes distinctions about price, earnings and industry momentum. Where price momentum is formed by evaluating past asset returns or price to forecast future returns and prices based on the time horizons already described. Earnings momentum is formed by looking at earnings announcements and by doing so, hopefully capture the return drifts that follow such announcements. Industry momentum is found in by evaluating momentum factors in industries at a whole to benefit from the effect that past performance tend to dictate future performance. Moskowitz and Grinblatt (1999) not only finds evidence of industry momentum but that the intermediate-momentum anomaly already described also is valid for whole industries. They further find that it appears to contribute substantially to individual stock momentum.

With the initial research on momentum being focused on the stocks on NYSE, AMEX and NASDAQ (De Bondt and Thaler, 1985, Brock *et al.*, 1992, Jegadeesh and Titman, 1993),Brock *et al.* (1992) give evidence that momentum is a significant factor also on the Dow Jones. The possibility of the anomaly just being a product of data-snooping where worth examining and researchers have tried the different strategies on both different assets and instruments in the US, but also different assets and instruments in different countries. Rouwenhorst (1998) show that a CSM strategy like the on used in Jegadeesh and Titman (1993) is also profitable across 12

European countries. Griffin, Ji and Martin (2005) investigates price and earnings momentum in a CSM strategy across 39 countries across the globe. They find that all African and American, 10 out of 14 Asian countries and 14 out of 17 European countries display positive price momentum returns. The also find that earnings momentum is positive in 27 out of 34 of the countries (data not available for all 39). They even find that a combination strategy of the two mentioned yield even better results. Fifield *et al.* (2007) states that a filter strategy outperformed the market portfolio in 11 European. Gwilym *et al.* (2009) find both TSM and CSM profitable in 32 country equity markets around the globe. Griffin, Ji and Martin (2003) find that cross-sectional momentum is present in 40 countries. Moskowitz *et al.* (2011) test a TSM strategy on equity indexes, currencies, commodities and bond futures, and find that the TSM-strategy is profitable across 58 liquid instruments. Antonacci (2013) find the CSM, TSM and a combination-strategy as beating indexes in both Europe and the Americas (ex. the US). Papailias and Thomakos (2011) find that using a SMA-strategy will yield positive results over indexes, ETFs and the Euro/USD-axchange rate. There have also been attempts of combining with other types of anomalies, for example Asness (1997) tested a combination of value and momentum trading, but to mixed results. Lee and Swaminathan (2000) find that high turnover and volume is positively related to future returns.

# 3 Modern Portfolio Theory

## 3.1 Asset Allocation

The foundation of modern portfolio theory was laid in 1952 by Markowitz (1952). Markowitz showed that mean-maximizing and variance-minimizing investors will in his model select the same portfolio to meet those conditions. The only way investors vary, is the weight of their portfolio they own in the market portfolio and a risk-free asset. Markowitz showed that his model holds up even if investors are allowed to short assets and borrow/lend at the risk-free rate. Diversification is on the downside limited to the average covariance between the assets available, and is therefore undiversifiable. This risk is called market risk or systematic risk. So, as the available assets in the market increase, one can plot the attainable points in a risk/return space and we get a cluster of potential portfolios. The minimum-variance portfolio will lie to the far left. Since investors are rational and look to maximize the return and minimize the variance, the relevant portfolios is the ones lying on the boundary of the attainable set, only with these portfolios will the investors criteria be met. This boundary is call the efficient frontier. We now know that the efficient frontier is the only portfolios worth considering, but Markowitz claimed that all investors will hold the same portfolio. By noting that the intercept of the return-axis is the risk-free rate, one can draw lines out into the risk/return space. These lines will have the slope of $\frac{\mu - r}{\sigma_p}$. The rational investor would therefore like to maximize this slope, and we find the optimal line a tangent from the $(0, r_f)$ coordinate to the efficient frontier. This line is called the Capital Allocation Line and every rational investor will allocate its capital along this line according to the investors tolerance for risk. As one moves along the line from $(0, r_f)$ the weight of the investors portfolio in the market portfolio increases. And if one moves beyond the tangent point on the efficient frontier, an investor would have to results to borrowing.

## 3.2 Equilibrium Asset Pricing Models

There are many doubts about the usefulness of equilibrium pricing models because the assumptions they make to become valid. Fama and French (2011) among others have tested if the models capture all the sources of average return, as others Fama and French fail to prove that alpha is equal to zero when using regional models, especially when it comes to evaluating portfolios that are heavily tilted towards momentum stocks. Nonetheless, the models are widely used in financial literature and therefore are used in this thesis to analyze the momentum anomaly and its excess return.

### 3.2.1 The CAPM

The Capital Asset Pricing Model (henceforth called the CAPM) was introduced by Sharpe (1964). describes the relationship between a risk premium of a portfolio and the risk premium of the market portfolio compared to a risk-free asset.

$$E(r_i) = r_f + \beta_i(E(r_M) - r_f)$$

To look at the return-beta relationship we can look at the covariance between the two;

$$\begin{aligned} Cov(r_i, r_M) &= Cov(\beta_i r_M + \epsilon_i, r_M) & (3.2.1)\\ &= \beta_i Cov(r_M, r_i) + Cov(\epsilon_i, r_M) & (3.2.2)\\ &= \beta_i \sigma_M^2 & (3.2.3) \end{aligned}$$

The CAPM makes assumptions about the market and its participants to simplify the real world to a state where the CAPM would be valid.(Jensen, 1967) and (Brodie *et al.*, 2008) gives the assumptions as;

- All investors are risk-averse and one-period utility (wealth) maximizers
- The market fulfill the criteria for perfect competition (as in microeconomics)
- Investors therefore have homogeneous expectations about the future
- Investors realize no costs or taxes, this includes the availability to borrow and lend at the risk-free rate
- Investors are mean-variance maximizers
- All assets are available (globally)

In this simplified state the market portfolio will be every investors optimal portfolio and investors will only differ in the proportion of their portfolio that is invested in the market portfolio and the risk-free asset. If an asset is over-priced, it will not be included in the market portfolio and its demand (and by consequence its price) will drop until it is fairly priced, at which point it will be once again included in the market portfolio. If an asset is under-priced, it will be included in every investors market portfolio, its demand will be high and its price will go up until it is fairly priced. This means that long-term every asset will be included in the market portfolio.

So how does the CAPM hold up in the real world? Well, first of all the global market portfolio will be an unachievable portfolio, the notion of including every asset in the world in the same portfolio is simply unrealistic. The number of trades and implications (liquidity, foreign exchange rates, government restrictions, taxes etc) of keeping such a portfolio would be tremendous. Investors also care very much about costs, the technological advancements have narrowed the bid/ask-spread of borrowing and lending. But investors in the real-world will see their profits diminish by costs and might not have capital available at all times, let alone at the risk-free rate. The flow and availability of information may have contributed to make investors more homogeneous, but to think that every investor in the market have the same expectations about the future would be generalizing a bit too much. Many investors also think long-term and to view the future as a one-period deal will also not be valid for most. So what does the CAPM give us if it is too simple to portray the real-world? Well, it gives us an indication of what a fair price for an asset should be, and in lack of a better model (the real-world is in any case too complicated to generalize into one model anyhow) the CAPM is widely used as a forecasting tool.

### 3.2.2 The Index-Model

So the CAPM gives us an ex-ante pricing model, but we can only make expectations of the future, how can we use the model to evaluate the past (ex-post returns)? To do this we can use the Index-model described by Jensen (1967);

$$R_i = \alpha_i + \beta_i R_M + \epsilon_i$$

Where $R_i = r_i - r_f$ and $R_M = r_M - r_f$. To prove that the CAPM and Index-model describes the same relationship ex-ante and ex-post we can compare the covariance in both models. The covariance in the Index-model is;

$$Cov(R_i, R_M) = Cov(\beta_i R_M + \epsilon_i, R_M) \tag{3.2.4}$$

$$= \beta_i Cov(R_M, R_i) + Cov(\epsilon_i, R_M) \tag{3.2.5}$$

$$= \beta_i \sigma_M^2 \tag{3.2.6}$$

As 3.2.3 is the same as 3.2.6 the index-model and CAPM gives the same relationship between return and beta. And since the CAPM expects all assets to be fairly priced, the global alpha in the Index-model is expected to be zero. History has shown that individual assets and portfolios can have an alpha different than zero but the Index-model expects alpha to be distributed around zero (Jensen, 1967).

The Index-model is easy to estimate using linear regression and is in this thesis used to analyze the alpha of a TSM-strategy and determine if this strategy will indeed outperform the market portfolio in each country.

### 3.2.3 Multi-factor Models

**The Arbitrage Pricing model (APT)** was introduced by Ross (1976) and is based on the notion that expected return of an asset is related to at least one factor and is determined by the law of one price. As in the CAPM-model it assumed that a linear relationship between the expected return of the asset and the sensitivities to the factors included in the model. The factors are believed to be the same for all assets but the sensitivity to the specific factors is individual. The arbitrage mechanism works in the way that if the price of an asset lies over or below its equilibrium line investors would either long or short it depending on where it lies and bring the price back to equilibrium. The theory can be expressed mathematically as;

$$r_j = a_j + b_{j1}F_1 + b_{j2}F_2 + b_{ji}F_i + \epsilon_j \tag{3.2.7}$$

where $r_j$ is the return of a risky asset, $a_j$ is a constant, $F_i$ is the factors, $b_{ji}$ is the sensitivity (or beta) of the asset to factor $F_i$ and $\epsilon_i$ is the idiosyncratic risk. The expected return of an asset according to the APT would be;

$$E(r_j) - r_f = r_f + b_{j1}RF_1 + b_{j2}RF_2 + b_{ji}RF_i \tag{3.2.8}$$

Where RF is the risk-premium of the factor F. In assumptions the APT is superior to the CAMP (Brodie *et al.*, 2008). If the factor loadings can describe assets prices, there is enough assets to diversify idiosyncratic risk, the market consists of at least one rational investor who is willing to take an infinite large position in the arbitrage opportunity. And therefore could single-handedly bring the asset price into equilibrium.

**Fama-French 3-Factor Model** was conceived in 1993 in the work by Fama and French (1993) to try to better explain assets returns and eliminate some of the anomalies associated with the CAPM. The 3-factor model introduces two new proxies for risk, namely; HML (high minus low), which gets determined by ranking all the stocks in the market portfolio by their book-to-market ratio and take look at the difference in return from the 30% highest ranked firm (highest B/M) minus the return from the 30% lowest ranked firms; SMB (small minus big), which gets determined by ranking stocks after their market capitalization (size) and subtracting the return from the 30% highest ranked firms (largest) from the return of the 30% lowest ranked firms (smallest). These two proxies tries to explain the anomalies found in the CAPM that small firms tend to outperform large firms (SMB) and that firms with high book-to-market ratio tend to outperform firms with low book-to-market ratios. The model can be expressed mathematically as;

$$E(r_i) = r_f + \beta_{iMKT}(E(rm) - rf) + \beta_{iSMB}E(SMB) + \beta_{iHML}E(HML)$$

where the first part of the expression is identical to the CAPM and the betas $\beta_{iM}$ and $\beta_{iH}$ is the sensitivity (or systematic risk) to the proxies SMB and HML of stock i.

**Fama-French-Carhart 4-Factor Model** was purposed by Carhart (1997) after he conducted research on the 3-factor model and found it insufficient to explain the return of stock portfolios, and as an answer to the research done by Fama and French (1996) that showed that the 3-factor model could not explain the momentum anomaly exept the long term reversals that can be consistent with the 3-factor model. Carhart purposed another proxy for risk in addition to the 3-factor model to account for momentum. Carhart defines the momentum proxy (MOM) as the return on the highest 30% ranked firms minus the return on the lowest ranked 30% firms, when ranked after eleven-month prior return lagged one month.

$$E(r_i) = r_f + \beta_{iMKT}(E(rm) - rf) + \beta_{iSMB}E(SMB) + \beta_{iHML}E(HML) + \beta_{iMOM}$$

The addition gives Carhart a much better model to explain return in the stock portfolios he examined. But as mentioned, research like Fama and French (2011) have shown serious doubts about even the ability of the four-factor model in explaining the momentum anomaly.

## 3.3 Performance Measures

### 3.3.1 The Sharpe-ratio

From its inception in 1966 the Sharpe-ratio, named after its inventor William Sharpe, have become a widely used ratio to measure risk-adjusted performance. Originally named *reward-to-variability ratio* it was conceived to rank mutual funds performance not only based on excessive return, but also taking into account the risk the managers where taking on to realize that return. It gives us an easy way to measure portfolios against each other, and is relevant in this thesis to see if the momentum strategy have better risk-adjusted performance than the market portfolio.

William Sharpe and others have since 1966 added to the literature about the Sharpe-ratio and its uses. Sharpe (Sharpe, 1994) defines both an ex-ante (predicting) and an ex-post (evaluating) Sharpe-ratio. Since this thesis evaluates past returns we will concentrate on the ex-post ratio. But at the same time we imply that past returns have some predictability of future returns, this is discussed further in the theory of efficient markets and its critics. The ex-post Sharpe-ratio is defined as;

$$S_h \equiv \frac{\bar{D}_t}{\sigma_t} \tag{3.3.1}$$

Where

$$\bar{D} = \frac{1}{T}\sum_{t=1}^{T} E(A_r) - r_f$$

and denotes the excessive return of investment A over rhe risk-free rate over the period from t to T and

$$\sigma_D = \sqrt{\frac{\sum_{t=1}^{T}(D_t - \bar{D}_t)^2}{T-1}}$$

As the reader will later see is that this version of the Sharpe-ratio have a strong relationship with the t-statistic used in testing for coefficient validity, this relationship can be expressed mathematically;

$$\text{T-statistic} = S_h\sqrt{T}$$

#### 3.3.2 Jensen's alpha

In his work from 1967, Jensen (1967), Jensen describes the alpha of a portfolio as the intercept with the y-axis in the linear relationship in a benchmark-asset return space. In a perfect model or a fully efficient market this alpha should be zero, but as Jensen show evidence of when using the Fama-French 3-factor model; alpha is not zero. Jensen also states that it should not be the case of having negative alphas, if investors are rational and learn from their mistakes, it should not be plausible to realize lower than the return of market portfolio. If you consistently do worse then the market portfolio, you should buy the market portfolio. But as he show, funds exhibit that they can indeed realize negative alphas. The alpha is the same for the CAPM and the multi-factor models, but is generally believed to be smaller when one introduces relevant proxies for risk since alpha really is describing the risk-premium one can not efficiently describe with one or more proxies for risk. In this thesis we evaluate alpha in the context of the Index-model and see if it is positive and statistical significant.

## 4 The Efficiency of Markets

The definition of an efficient market is; "A market is efficient with respect to information set $\Phi_t$ if it is impossible to make economic profits by trading on the basis of information set $\Phi_t$".(Jensen, 1978) This implies that investors are rational (they use the information to maximize wealth), that new information is quickly reflected in the market price and that the information available is fully reflected in the market price.

### 4.1 Efficient Market Hypothesis

(Fama, 1970) gives us three forms of efficient markets;

- Weak Form Efficient; available information consists only of historical data. This makes technical analysis (discussed in Section 5.2) obsolete because all historic data is already reflected in the market price and investors will use the data in such a way that assets will be fairly priced. Investors can use fundamental analysis (also discussed in Section 5.1) to find asset that are not fairly priced.

- Semi-Strong Form Efficient; prices will adjust to new information that are obviously publicly available in an efficient manner. Examples of these types of information is dividend pay-outs, earnings etc and includes everything except inside information. When the new information is released investors use it to buy or sell the stock, and ultimately the stock will be fairly priced once again. If a market is Semi-Strong Efficient investors will not benefit from either technical or fundamental analysis.

- Strong Form Efficient; this form of market efficiency requires that all relevant information is reflected in the market price.This means that not even inside information will be beneficial, analysis will be obsolete.

So if this model holds up technical analysis will certainly not be beneficial, and fundamental analysis will only be beneficial if the market is Weak-Form-Efficient. But for a market to be fully Strong-Form-Efficient one has to make do with some assumptions. (Fama, 1970) list the assumptions as;

- No transaction costs
- All information is costless available to all participants
- Investors are homogeneous in the expectations about implications of current information and distribution of future prices

These assumptions do not have to strictly hold for the market to be efficient, for example (Fama, 1970) argue that if enough investors have the relevant information the market may be efficient and investors can have heterogeneous expectations they just cannot beat the market consistently. But the in the real world all of these assumptions are unlikely to adequately hold at the same time. Research done by Russell and Thaler (1985) show that unless the market is strong form efficient, only having some rational agents is not sufficient to secure an efficient market, and that agents not all agents is rational.

## 4.2 Random Walks

The random walk hypothesis are closely related to the theory of efficient markets. Random walks is explained both in (Fama, 1970) and (Feller, 1957) and states that stock prices should reflect available information. In other terms this theory implies that future stock prices are independent and that the expected return from not having information should be the same as the expected return when having information.

$$E(r_i) = E(r_i|\Phi_t)$$

where $\Phi_t$ denotes the information set at time t.
One would therefore assume that asset price change instantly with the introduction of new information in a random fashion (no one knows on beforehand if the news are good or bad). The stock price process can therefore be expressed as;

$$P_t = \beta + P_{t-1} + \epsilon_t$$

where $P_t$ denotes the price at time t, $P_{t-1}$ denotes the price at time $t-1$, $\beta$ represents drift and $\epsilon$ represents the error terms or "information shock".
In a semi-strong efficient market information is absorbed instantly, and the drift in Equation 4.2 would therefore be zero. The price can therefore be expressed as the initial state plus the error-terms;

$$P_t = P_0 + \epsilon_t + \epsilon_{t-1} + \epsilon_{t-2} + \cdots + \epsilon_0$$

As there should not be any predictability in the model the error-terms are assumed to be distributed around zero, with an expectation of $\sum_{j=1}^{t} E(\epsilon_j) = 0$. The random walk hypothesis seems applicable in the real world in the sense that if a stock price decreases one day, no one can with 100% predictability say how the price will evolve tomorrow. The study of Scholz and Walther (2011) however, find that drift is not zero, and that it takes time for investors to absorb information.

# 5 The Inefficiency of Markets

So, if we have efficient markets, why do investment firms use so much resources on presumed fruitless analysis? Well, that is because many believe that markets are not efficient and there exists potential benefits for the investor who are more enlightened than his peers. Those who do not believe that markets are efficient two types of analysis is the most popular, namely technical and fundamental analysis. Here I will represent the features of both;

## 5.1 Fundamental analysis

Fundamental analysis uses ratios, cash-flow projections etc to determine if an asset is fairly priced according to its fundamental value. If a stock is trading at \$ 50, but an investor have solid information that future earnings justifies a stock price of \$ 52, the stock is under-priced in the market and the investors longs the asset in the belief that the rest of the market will eventually catch up to his calculations and bid the stock price up. In the same sense stock prices can be over-priced and the investor should then short the stock. In other words fundamental analysts believe that the equilibrium asset pricing models give a good indication for the fair price of an asset. Another option to benefit from fundamental analysis is using options where one has limited need of capital and if one has a long position in the options; have a floor on potential loss if the prediction do not come true.

## 5.2 Technical analysis

Technical analysis on the other hand looks at tendencies in the market and uses these tendencies in hopes to predict future price movements. Momentum, the January effect etc are examples of such a tendencies. Investors evaluates and actively seek out indicators that can effectively describe a tendency, and then create a trading system to maximize the benefits from this tendency. This whole thesis is an example of technical analysis and my model for a TSM-strategy is an example of such a trading system.

## 5.3 Uninformed trading

One source of inefficiency can be uninformed trading. When investors disregard or misinterpret the available information or act irrationally in any other way, they can drive prices away from their fundamental value. This concept is called uninformed trading. Uninformed trading is a popular explanation for the momentum anomaly not only because it can drive prices away from the fundamental value, but also because uninformed trading can also limit arbitrage. When arbitrageurs find an arbitrage opportunity in the market, it is believed to be risk-free, but when when in fact the forces of uninformed trading can contribute to drive the fundamental price of an asset even further away for equilibrium. Arbitrageurs must therefore consider this risk, and if they are risk-averse might not pursue the arbitrage opportunity and then allow the mispricing to persist (Barberis *et al.*, 1998). When accounting for uninformed trading it is natural to think that individuals will be the strongest force acting uninformed, and research such as Andrade *et al.* (2004) support that notion. But a study done by Wermers (1999) indicate that also institutional investors show signs of uninformed trading.

### 5.3.1 Herding

Research done by Wermers (1999) indicate that herding in mutual fund trading have a relation to future stock prices. Herding is the common term for the theory that investor "cluster" and "flock together" and end up buying or selling the same stocks.

According to Wermers the four most popular theories about the occurrence of herding is;

- Investors might disregard private information and trade in the direction of the herd in fear of being wrong
- Investors might trade on the same information for example by analyzing the same indicators
- Investors might use information from better-informed investors prior trades and use that in the present
- Investors might share an aversion for stocks with the same characteristics (riskiness, liquidity etc)

### 5.3.2 Disposition

Disposition is the propensity for investors to sell "winners" and hold "losers". The psychological effect is that investors tend to sell "winners" to realize gains and eliminate the possibility of future loss. And hold "losers" in hope to break even in the future (Shefrin and Statman, 1985) This even despite the investor have information that the stock will increase or decrease further in value Kahneman and Tversky (1979). Shefrin and Statman (1985) find evidence that this bias exists in the real-world financial markets and not just in theory, even when accounted for tax considerations. Disposition could therefore be bad news for momentum traders in the sense that irrational investors will dampen the price movements and hinder momentum investors to fully exploit momentum.

### 5.3.3 Confirmation effects

Investors usually have on some form of belief when it comes to stocks, bond, markets etc. This could be in the form of "if it rains over a certain amount there will be a bad harvest and a shortage of wheat and the price will go up" or "gold prices are always going up!". When evaluating information investors with confirmation bias will favor information that support their beliefs (Pouget and Villeneuve, 2012). This could be either by only take into account the information that support those beliefs or actively seek out information that does the same. The effect of confirmation bias on momentum is unknown, but this bias could lead to momentum just being a self fulfilling prophecy in the sense that if enough investors believe that past 6 months winners will outperform past 6 months losers, and trade on this information. Demand for past 6 month winners will be abnormal high and drive the price up and therefore contribute to the assets out-performance of their peers.

### 5.3.4 Anchoring

When evaluating prices, investors can have a tendency to use known values to make an assumption on what the value of something else should be, in other terms they can use one value as an anchor for calculating other values(Tversky and Kahneman, 1974). This might work if the relationship between the values are totally transparent, but this is not always the case in the real world. Which in turn can lead to investors making irrational decisions.

A common example of anchoring when a fundamental investor believes an asset should have a certain value, say \$ 50. The asset is currently trading for \$ 48, in other words; if the analysis of the investor is correct and the asset is liquid, there is potential for serious gain. The investor starts to buy the asset, say 20 000 shares, and suddenly the price is driven up to $\$48\frac{5}{8}$. The investors analysis still allows for potential gain, but the investor stops buying in belief that the only cause of the increase in price is his own price pressure and therefore hopes that the price will fall back towards \$ 48 again. The problem is that other investors also have done the same analysis, and shortly after the price is bid up to \$ 50. The investor have therefore missed an opportunity to make a lot more profit just because he had the stock price anchored at \$ 48. When it comes to momentum and anchoring, anchoring can both have a positive or negative effect, but it would certainly lead to market inefficiency.

### 5.3.5 Representativeness

The representativeness bias is usually employed when ”people are asked to judge the probability that an object or event A belongs to class or process B”. (Tversky and Kahneman, 1974). An example of this bias in the financial markets is if investors are asked if certain stocks with i history of persistent earnings growth is classified as growth stocks. Most investors would say that they are indeed growth stocks, but the probability of a firm growing indefinitely is very small, and some of the stocks should therefore not be classified as growth stocks (Barberis *et al.*, 1998).

### 5.3.6 The Effects on Momentum

When considering the effects of uninformed trading on momentum it can be useful to summarize;

| Type | | Effect on MOM |
|---|---|---|
| Herding | ⇒ | increase |
| Disposition | ⇒ | decrease |
| Confirmation | ⇒ | unknown |
| Anchoring | ⇒ | unknown |
| Representativeness | ⇒ | unknown |

### 5.4 Time-Varying Equilibrium

Another source of inefficiency can be time-varying equilibrium returns (Brock *et al.*, 1992). Research such as Chiarella, Dieci and He (2011) show that when the market have heterogeneous investors conditional beta can change over time and therefore assets can experience a change in their equilibrium price. This change in equilibrium is mostly caused by speculation and might therefore have no foundation in change in fundamental value (Chiarella, Dieci and He, 2011).

### 5.5 Tax-loss selling

The works of Jegadeesh and Titman (1993), Grinblatt and Moskowitz (2004) find evidence that show that a good part of the momentum reversals take part in January, which can be caused by tax-loss selling. Tax-loss selling occurs when investors at the end of the year sell assets that have incurred losses through the year to realize the losses within the years end to lower the tax on capital gains in that particular year. The stocks affected by tax-loss selling would therefore decrease in price in December as a result of the selling pressure, only to rebound in January when investors find out that the stock are under-priced. This could explain the short-term momentum reversal and is contradictory of the belief that uninformed trading is the cause of the short-term momentum anomaly. Starks *et al.* (2006) find evidence that suggests that the return of municipal bond closed-end funds are abnormal in January because of tax-loss selling the previous year and that January returns are positively correlated with trading volume at previous year's end.

## 6 Time-Series Momentum and Cross-Sectional Momentum

As mentioned in Section 2, a TSM-strategy uses the asset's own price or earnings in forecasting and is therefore more applicable when trying to benefit from the momentum anomaly in single assets or portfolios, than a CSM-strategy which need more than one asset to rank them against each other (into quartiles, deciles etc). Because of the effect that a long only CSM-strategy can be consistently long in assets that are declining, but declining less than their peers, make a long only CSM-strategy susceptible to consistent losses in a bear market. Most investors therefore use CSM as a zero-investment portfolio where one would long the highest ranking assets and short the lower ranked ones. This should ensue a portfolio that do not experience consistent loss in a bear market, but only if the momentum anomaly exists in the assets ranked. According to research TSM follows the same time-horizon for the momentum reversals as explained in Section 2 (Chan *et al.*, 1996, Asness *et al.*, 2000, Moskowitz *et al.*, 2011) as established in the CSM context (Rouwenhorst, 1998, Chiu *et al.*, 2000, Jegadeesh and Titman, 2001).

The benefits of momentum-trading are according to Faber (2009) are;

1. Purely analytical
2. Easy to implement
3. Same for every asset class

A time-series momentum trading strategy can be based on the model used in this thesis, that one buys an asset that has a higher price than at a certain point-of-time in the past ($P_k > P_{k-t}$) or an asset that has a positive cumulative return over the same period ($k - t$). And if $P_k < P_{k-t}$ or the cumulative return is negative, one would sell the asset and invest risk-free. In this way one is more likely to not be long in an asset when it realizes a long downward trend, and therefore limit the draw-downs. Time-trend-trading is also a way of using past returns to realize higher returns based on the momentum phenomenon. But in a time-trend-strategy investors can use indicators such as a moving average to create buy/sell-signals. If an asset is trading over its n-month moving average an investor should buy the asset, if it trades under the n-month moving average one should sell. Researchers have of course been trying to find the optimal way to benefit from momentum, and moving averages with look-back periods of 10 or 12 months are among the most popular. One argument against trading on momentum is that since the anomaly can not be explained by researchers, it is not certain that the anomaly even exists and can mis-lead traders into trading on a signal that is not valid (Scholz and Walther, 2011). The main risk is then "bleed-out", in the sense that if momentum is not present it will lead to the investor making many trades with losses that will exhaust the investors capital.

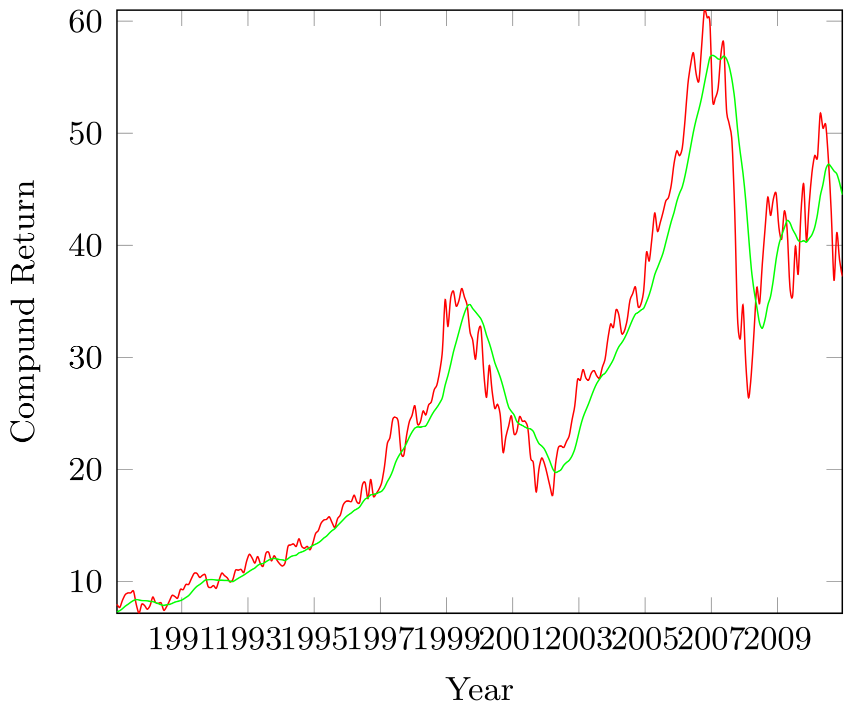
## 6.1 Different strategies

After deciding to analyze whether to use CSM or TSM one can also choose between different strategies . Park and Irwin (2005) presents a nice overview covering most strategies. The ones encountered multiple times in the literature is presented here;

### 6.1.1 Moving Average

A moving average is a well known tool to smooth out price movements. (lower volatility) In the example below we have a snapshot of the compound return of the market portfolio of France (initial investment of \$ 1 in 1975), in addition to the return of the market portfolio we have the 10 month simple-moving average of the same portfolio. We witness both the smoothing the simple moving average exhibits, but also the lag compared to the market return. This is a key feature of moving average strategies in the sense that trading signals can come to late to either gain from price increases or avoid loss from price decreases.

Figure 1: Illustration of a SMA on the French Market Portfolio




**Simple Moving Average (SMA)** ; One of the most popular strategies, mainly because its simplicity. Uses an equally weighted moving average and the current price. Trading rules;

$$\text{Buy if } P_t > SMA_{t-k} \tag{6.1.1}$$

$$\text{Sell if } P_t < SMA_{t-k} \tag{6.1.2}$$

Literature such as Faber (2009) etc implements a SMA strategy with positive results.

**Moving Average Crossover** ; Uses two SMAs of different lengths. If the shorter MA is higher than the longer MA, the underlying is considered to be in an up-trend. If the shorter MA is lower than the longer MA, the underlying is considered to in a down-trend. Trading rules;

$$\text{Buy if } MA_{t-k} > MA_{t-l} \tag{6.1.3}$$

$$\text{Sell if } MA_{t-k} < MA_{t-l} \tag{6.1.4}$$

where $l > k$.

Moving average strategies can also be used with bands to limit whiplash/whipsaw trading. Although not commonly used, one can also use different ways to weigh the moving average other than equal-weighted (SMA).

### 6.1.2 Trading Range Breakout

A trading range breakout or channel strategy evaluates the current price up against the maximum and minimum price during the look-back period. It consider the underlying to be in an up-trend when the current price is higher than the local maximum. And in a down-trend when the current price is lower than the local minimum. Trading rules;

$$\text{Buy if } P_t > LH_t \tag{6.1.5}$$

$$\text{Sell if } P_t < LL_t \tag{6.1.6}$$

Where LH denotes the local high and LL denotes the local low. The extreme case of this strategy in terms of buy-signals is the one described in Wilcox and Crittenden (2005) where the look-back period is infinite and the investors use the all-time high as the buy-signal and a average true range trailing stop as the sell-signal.

### 6.1.3 Filter

The common way to use a filter strategy is to use the following trading rules (Fifield *et al.*, 2007);

$$\text{Buy if } P_{\text{closing}} > LL * X\% \tag{6.1.7}$$

$$\text{Hold to } P_{\text{closing}} < LH * (1 - X\%) \tag{6.1.8}$$

Where LL is the local low and LH is the local high. In words the system can be described as being long when the closing price is above the local low times a given percentage point. The asset is then held until the closing price drops below the local high times 1-the given percentage point. Fifield *et al.* (2007) use this strategy with encouraging results on the indexes in eight emerging markets in Europe.

### 6.1.4 Combination strategies

As mentioned many researchers use more than one (usually two) strategies in a combination strategy to hopefully realize even higher excess return. One example is (Gwilym *et al.*, 2009) which analyses a strategy where a portfolio is formed based on past performance and divided into quartiles with Q4 being the quartile of assets with highest momentum. A SMA-strategy is then implemented to create a trading signal to buy/sell the Q4 portfolio. The signal is created by evaluating the current price against the SMA, just like (Faber, 2009). This combination does not yield higher returns (than the momentum and SMA strategies individually), but lower the variance to create a higher risk-adjusted return. Antonacci (2013) also give evidence that a combination strategy like the one already mentioned provide superior results, but Clare, Seaton, Smith and Thomas (2012) find that a combination of CSM and TSM does not outperform a pure TSM-strategy.

## 6.2 Short-selling

If using a time-trending strategy will help the investor being long in a risky asset when it is more likely to realize positive return and out of the asset when the risky asset is more likely to realize negative return, why not short-sell the asset when it has negative momentum? Well, short-selling can be troublesome and will incur more costs. Secondly, the results show that when $E(r_{sell}) < E(r_{buy})$, $E(r_{sell})$ is not always negative (and when it is negative not often less than $-0.4\%$), see table IV. This will limit the potential return of short-selling. And it will be a rather bold assumption to assume that a short-selling position is available at every period in 21 countries dating back to 1975 (for most countries). This thesis will therefore use the same considerations regarding shortselling as Wilcox and Crittenden (2005) and only implement a long-only strategy.

## 6.3 Costs and Limitations

When considering an active investment strategy one has to remember to consider the costs that occurs by trading actively. Some literature implies that the excess return from momentum-trading are nullified by the increase in costs (Lesmond et al., 2002). The study indicates that the momentum of individual stocks is higher in lower volume stocks that results in higher trading costs. But again studies such as Korajczyk and Sadka (2002) find that momentum strategies realize excessive returns despite trading costs. Though the study of Lesmond et al. (2002) find that the excessive return is nullified by trading costs. The strategy in this thesis the underlying is an equity index, so the notion that the TSM-strategy in this thesis only demands illiquid stocks is wrong and the results in Lesmond et al. (2002) would be more relevant. It certainly is one aspect of momentum trading that investors must take into account though, since as Jensen (1967) shows, the abnormal returns that active managers realize often is nullified by costs. Further considerations have to be done by the international investor. The movement of capital from one country to another, different tax-rules, the absence of a liquid risk-free asset etc can limit the profitability of an active international trading strategy.

### 6.3.1 Transaction costs and Commissions

Any active strategy will have to take transaction costs and commissions into account when evaluating return. In this thesis we look at portfolio turn-over to determine how active a TSM-strategy really is and if it is likely that potential excessive return is diminished by costs. There is some debate in different literature about how to estimate costs. Korajczyk and Sadka (2002) find that spreads and price impact of trades do not fully explain the momentum anomaly since investors realize abnormal return even after accounting for these costs. Grundy and Martion (2001) show that if the transaction costs of one round-trip-trade is 1.77%, then a cross-sectional momentum trader will realize zero abnormal return. Jegadeesh and Titman (1993) is a one-way transaction cost of 0.5% and find that even accounting for that their momentum strategy realize abnormal profits.

### 6.3.2 Tracking error

The dataset this thesis is conducting analysis on contains the returns on the market portfolio of 21 countries. To implement the same strategy in the real-world an investor would have to use an ETF (Exchange traded fund) to represent the market portfolio. ETFs makes it possible for investors to use momentum in on indexes and other entities that consists of different equities, for example the S&P500. This has made the costs of implementing a diversified momentum-strategy much smaller. Where, before one had to calculate and buy/sell many different equities to benefit from diversification. But when using ETFs one also bring the risk of tracking error into the mix. The goal of an ETF is to replicate an index or other collection of equities as best as possible. But what the ETF is tracking is often changing, to replicate a value-weighted index for example the ETF has to conduct trades to get the correct weight in the different equities, this does not only increase costs (the buyer of a share in an ETF will ultimately pay for the costs in form of a lower market price for that share) but can also lead to error in the return when the weights are not correct. This tracking error can limit the benefits of a TSM-strategy by not correctly tracking the index one is trying to implement the strategy on.

### 6.3.3 Portfolio turnover

Most momentum strategies consists of trading rules that rely on numbers that can be very close to each other, for example the current price can lie close to the SMA of the last k months for a substantiation period of time. This can result in the TSM-strategy trading in and out of the market portfolio at a high frequency, so called whiplash trading. This can diminish the return by increasing costs and it can therefore be insightful to look at the portfolio turn-over to determine how active a TSM-strategy really is. (Gwilym *et al.*, 2009) Portfolio turn-over is a widely used measure to give investors an indication of how many trades a fund etc performs during a given time period (usually a year). Though a "correct" turnover ratio does not exists due to the fact that different strategies will result in different levels of activity, the ratio will give an overview of how much extra costs an active strategy will incur compared to a passive strategy. Usually the measure is used in the following form;

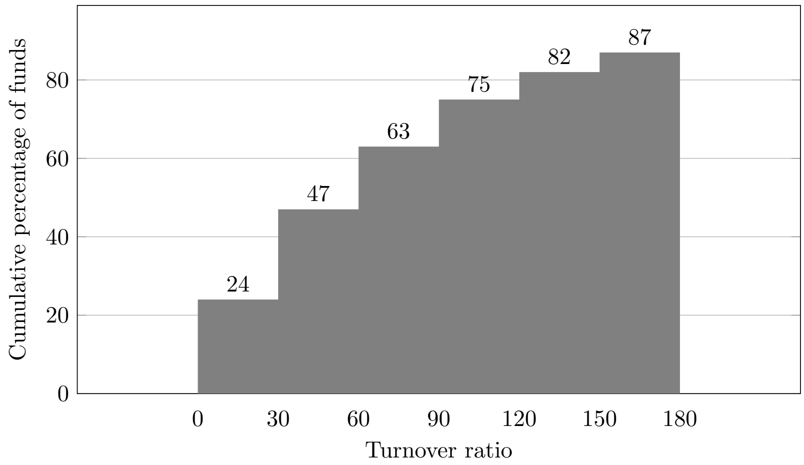
$$\text{Annual Portfolio Turnover} = \frac{\text{The lower of purchases or sales}}{\text{Average Assets}} \tag{6.3.1}$$

(6.3.1) is not applicable in this thesis and different approach is used, but the same concept remains; the more trades the more costs. As mentioned, some claim that the excessive return is eliminated by costs, so turnover is a useful measure to how active this strategy really is. In our context turnover ratio will be calculated equation (6.3.2);

$$\text{Portfolio Turnover} = \frac{\text{The lower of buy- or sell-periods}}{\text{Total periods}} \tag{6.3.2}$$

Morningstar classifies a portfolio with 20%-30% turnover ratio as a "buy-and-hold"-portfolio and a portfolio with over 100% turnover ratio as very active (ICI, 2013). Figure 2 shows how stock funds are distributed across portfolio turnover (ICI, 2013);

Figure 2: Turnover ratio of Stock Funds




# 7 Method

## 7.1 Hypothesis Testing

With hypothesis testing we look to see if a hypothesis ($H_1$) have statistically validity against a null-hypothesis ($H_0$). By testing the two hypothesis against each other we either keep or reject the null-hypothesis. To do this we need to set a level of significance or confidentiality interval (both methods will yield the same result) to know when to keep or reject. In this thesis two types of hypothesis testing will be used to find out if TSM is significant in each fo the 21 countries and to evaluate the coefficients in the regression based on the Index-model. When conducting hypothesis testing one has to determine at which level of confidence (which we denote with $\alpha$) or confidentiality interval one should reject the null ($H_0$), with the relationship being $1 - \text{Confidence Interval} = \alpha$. The confidentiality interval tells how confident we can be that the true value of an estimate lies within the range. At a 95% confidence interval we can be 95% certain, which in turn equals a level of conficence of $\alpha = 5\%$. The easiest way to evaluate a hypothesis is to see if the p-value is lower than the determined $\alpha$. The p-value is the probability that the data might occur by chance. If the p-value is lower than $\alpha$ we can be confident that the data has not been created by chance and we can confidently reject the null at that level of confidence. One also calculate the test-statistic which differs depending on which test one conducts. But the decision to keep or reject the null, can be done by calculate if the test-statistic is larger than the critical value. The critical value is a value that is conveniently calculated by mathematicians and can be found in tables in most statistical textbooks and is easily available online. The critical value depend on the level of confidence and the degrees of freedom of the test-statistic.

### 7.1.1 t-test

$$\text{H}_0; E(r_{buy}) <= E(r_{sell}) \tag{7.1.1}$$

$$\text{H}_1; E(r_{buy}) > E(r_{sell}) \tag{7.1.2}$$

Where $(\text{H}_0)$ and $(\text{H}_1)$ are the hypothesis and $E(r_{buy})$ and $E(r_{sell})$ is the mean of the return in the buy and sell-periods respectively.

The test-statistic for this test can be derived with;

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}} \tag{7.1.3}$$

Where $\bar{X}_1$ is the mean of the sample $X_1$, $s_1^2$ is the variance of sample $X_1$ and $N_1$ is the sample size of $X_1$.

The degrees of freedom can be derived as;

$$v = \frac{(\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2})^2}{\frac{s_1^4}{N_1^2(N_1-1)} + \frac{s_2^4}{N_2^2(N_2-1)}} \tag{7.1.4}$$

Where $s_1$ is the standard deviation of sample $X_1$, and $N_1$ is the sample size of $X_1$.

We then end up with the following decision rules;
Where $t_{crit}$ is a given value that can be found in a t-table and is dependent on the degrees of

Keep $H_0$ if $t < t_{crit}$ or if $p > \alpha$
Dismiss $H_0$ if $t > t_{crit}$ or if $p < \alpha$

freedom and the level of confidence.

In a regression of the Index-model we get a constant (intercept with y-axis) $\alpha$ and the coefficient with the market portfolio $\beta_M$. If we where regressing a multi-factor model we would get a constant and a coefficient for every proxy for risk we introduce. To analyze the model it is useful to test if the coefficients are statistically significantly different from zero. Most regression software does this automatically and present the results in a ANOVA-table. The test can be expressed as;

$$\text{H}_0; \beta_i = 0 \tag{7.1.5}$$

$$\text{H}_1; \beta_i \neq 0 \tag{7.1.6}$$

Where $\beta_i$ denotes the estimated coefficients using a regression model. (As mentioned we will have one coefficient for every proxy of risk in the model plus one for the constant term).

The test statistic is;

$$T = \frac{\beta_i}{\sigma_{\beta_i}} \tag{7.1.7}$$

$\sigma_{\beta_i}$ is the standard deviation of coefficient $\beta_i$.

After calculating the mentioned values, we act on the following decision rules;

$$\begin{array}{ll} \text{Keep} & H_0 \text{ if } T < t_{crit} \text{ or if } p > \alpha \\ \text{Dismiss} & H_0 \text{ if } T > t_{crit} \text{ or if } p < \alpha \end{array}$$

### 7.1.2 F-test

When conducting a t-test for equal mean, we assume that the two populations have different variances. So to solidify our results from the t-test we also conduct a F-test to test if the population do indeed have different variances. The hypothesis will then be as follows;

$$\text{H}_0; \sigma_{buy} >= \sigma_{sell} \tag{7.1.8}$$

$$\text{H}_1; \sigma_{buy} < \sigma_{sell} \tag{7.1.9}$$

Where $\sigma_{buy}$ and $\sigma_{sell}$ is the variance of the buy and sell periods respectively and are determined by;

$$\sigma_X^2 = \frac{1}{n-1} \sum_{i=1}^{2} (X_i - \bar{X})^2 \tag{7.1.10}$$

$$\sigma_Y^2 = \frac{1}{m-1} \sum_{i=1}^{2} (Y_i - \bar{Y})^2 \tag{7.1.11}$$

Where n and m is the sample sizes, $X_i$ and $Y_i$ is the observed sample values of X and Y, $\bar{X}$ and $\bar{Y}$ is the mean of the samples.

We have following test statistic;

$$F = \frac{\sigma_x}{\sigma_y} \tag{7.1.12}$$

The test statistic is in this case just a simple fraction of the two populations standard deviation. This test have the following decision rules;

$$\begin{array}{ll} \text{Keep} & H_0 \text{ if } F < f_{crit} \text{ or if } p > \alpha \\ \text{Dismiss} & H_0 \text{ if } F > f_{crit} \text{ or if } p < \alpha \end{array}$$

### 7.2 Linear Regression

When it comes to portfolio performance, one of the things investors are most interested in is $\alpha$ . $\alpha$ denotes the excessive return an asset or a portfolio realizes compared to the benchmark (in this thesis; the market portfolio). As already mentioned this alpha can be found in an estimation of the Index-model. And to estimate the Index-model I have used linear regression.

Linear regression is a way to estimate the relationship between two or more variables. In this thesis we look at the relationship between market return and the return using a time-series momentum strategy. A two-variable linear regression model will look like this;

$$TSM_i = \alpha_i + \beta_i R_M + \epsilon_i \tag{7.2.1}$$

Where $TSM_i$ is the dependent variable, in our case the return of the time-series momentum strategy minus the risk-free rate. $R_M$ is the independent variable and represent the return of the market portfolio minus the risk-free rate. $\alpha$ represents the intersect (the value of $TSM$ when $x = 0$) and the excessive return of the model, if $\alpha > 0$ it means that the strategy is realizing higher returns than the market and vice versa. $\beta_i$ represents the coefficient between the TSM and the market (or in geometric terms; the slope of the regression line) and describes how sensitive TSM is to a change in $R_M$, i.e if $\beta_i = 0.8$ a change in $R_M$ of 1 would equal a change in TSM equal to 0.8. $\epsilon$ denotes the error-term or the residuals, meaning the change in $TSM_i$ that can not be explained by $R_M$.

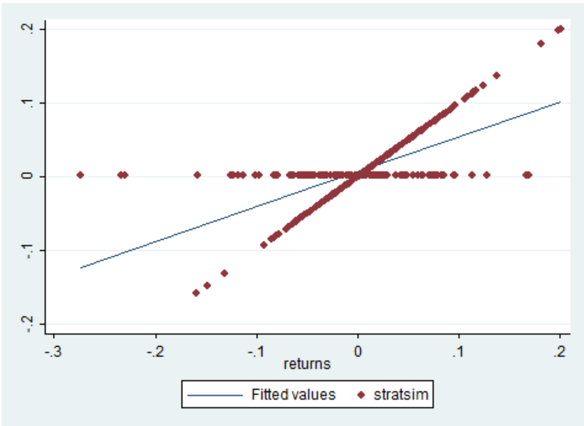
Linear regression is a form of estimating and when we estimate we have to use certain assumptions for our model to represent the real world. We make the following assumptions concerning the residuals (Brooks, 2008);

Table I: Assumptions concerning $\epsilon_i$

| Technical notation | Interpretation |
|---|---|
| (1) $E(\epsilon_i) = 0$ | The errors have zero mean |
| (2) $Var(\epsilon_i) = \sigma^2 < \infty$ | The variance of the errors is constant and finite over all values of xt |
| (3) $Cov(\epsilon_i, \epsilon_j) = 0$ | The errors are linearly independent of one another |
| (4) $Cov(\epsilon_i, x_i) = 0$ | There is no relationship between the error and corresponding x variate |
| (5) $\epsilon_i \sim N(0, \sigma^2)$ | i.e. that $\epsilon_i$ is normally distributed |

Before one conducts a linear regression it is wise to look at a scatterplot of the data. A scattorplot is a two-dimensional plot that plots the data in question which we can use to see if there are any clustering. If the data are wide-spread without exhibiting any relationship, the regression model will exhibit a lot of residuals and might not be significant. Even though the data exhibit an apparent relationship, observations that significantly differ from the clustering, known as "outliers", can have an impact on the regression line if the data point lies far away from the other observation in an horizontal line. These outliers will be present in the scatterplot and give the modeler an idea of what can impact his model.

Figure 3: TSM returns vs Market returns




The most common method to model a linear regression is to use the ordinary-least-square estimator, more commonly known as the OLS estimator. The OLS estimator creates the line that best fits the data by squaring the horizontal distance from each observation to a line (residual) and then adjusting the line to minimizing the sum of the squares. Since every distance is squared it does not matter if the distance is positive or negative, the residual will be the same.The estimated model will look like this;

$$\hat{y_i} = \hat{\alpha} + \hat{\beta} x_i + \hat{\epsilon_i}$$

If the assumptions in Table I hold the OLS estimator will have a set of properties popularly called BLUE (Brooks, 2008);

- **B**est, if the OLS estimator $\hat{\beta}$ has minimum variance among the class of linear unbiased estimators (Proved by the Gauss-Markov theorem (Schaffer, 1991))
- **L**inear estimator, $\hat{\alpha}$ and $\hat{\beta}$ are linear estimators that will give a linear combination of the random variables.
- **U**nbiased, on average the estimators $\hat{\alpha}$ and $\hat{\beta}$ are equal to the true value of $\alpha$ and $\beta$
- **E**stimators, in the sense that $\hat{\alpha}$ and $\hat{\beta}$ are estimators of the true value of $\alpha$ and $\beta$

Most regression software will give an ANOVA-table (ANalysis Of VAriance) as an output. This table is very helpful tool because if will give us an analysis of the residuals (says a lot about the fit of the model) and p-values for the parameters. In our model this will give us an overview over how good fit the linear regression of the CAPM is and if the parameters (most interesting $\alpha$) is significant. If $\alpha$ is significant, we can be pretty sure that out TSM-strategy will outperform the market.

From the ANOVA-table we can also get the $R^2$-measure. This can be a helpful indicator of how good a fit the model is. $R^2$ is defined as $R^2 = \frac{ESS}{TSS}$. Where ESS is Explained Sum of Squares and TSS is Total Sum of Squares. The measure will lie between 0 and 1, where a $R^2$-measure close to 1 can be interpreted as almost every change in the dependent variable can be explained by the independent variable. And a $R^2$ close to 0 would indicate that change in the dependent variable can not be explained by the independent variable. we will use this measure to evaluate our estimate of the Index-model later on.

# 8 The Model

## 8.1 The Dataset

The dataset used in this thesis is from the Kenneth French Data Library[1]. It contains the monthly market return from 21 different countries around the globe, but mostly established economies. The data varies in length with most countries dataset dating back to January 1975 (n=444) and countries like Malaysia and Ireland that dates from the early 90s. As mentioned several times in this thesis most models have been adapted to reflect that the data is in returns not prices, but the analysis should yeild the same results. The data also consists of returns for the factors in the Fama-French three-factor-model, but is not consistent through time with many data points missing (noted as 99.99% ), so this thesis will only use the Index-model as to not present invalid results.

Kenneth French have also provided the data in both local currency and US-dollars. The hypothesis testing have been conducted to both sets to see if results are consistent, but in further analysis only local-currency returns are used.

## 8.2 The Model

We have already looked at different possible strategies using momentum in Section 6.1, and the strategy used in this thesis can be looked as an adaption of a filter rule. The strategy is a simple binary time-series momentum strategy with a one-month holding period and monthly re-evaluations. The trading signals can be expressed in price-terms as;

$$\text{Buy if } P_t > P_{t-k} \tag{8.2.1}$$

$$\text{Sell if } P_t \leq P_{t-k} \text{ and buy } r_f \tag{8.2.2}$$

[1]http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

But since the dataset only consists of monthly returns we have to use the notion that (8.2.1) implies that $r_{t-k} > 0$ and (8.2.2) implies that $r_{t-k} \leq 0$. The model will therefore be amended to be;

$$\text{Buy if } r_{t-k} > 0 \tag{8.2.3}$$

$$\text{Sell if } r_{t-k} \leq 0 \tag{8.2.4}$$

where $r_{t-k}$ denotes the compund return over period $t-k$.
To simplify the simulation process, we use (8.2.5) to express (8.2.3) and (8.2.4) as;

$$r_{t-k} = \sum_{i=1}^{k} ln(r_k) \tag{8.2.5}$$

$$\text{Buy if } \sum_{i=1}^{k} ln(r_k) > 0 \tag{8.2.6}$$

$$\text{Sell if } \sum_{i=1}^{k} ln(r_k) \leq 0 \tag{8.2.7}$$

Thus, we will look at the logarithmic return to determine if the price of the underlying has increased or decreased over the period. This in turn will determine if the we are long in the risky asset or the risk-free asset. The returns from this portfolio can be expressed as;

$$R_{TSM} \begin{cases} r_{k+1} & \text{if buy} \\ r_f & \text{if sell} \end{cases} \tag{8.2.8}$$

Note that $R_{TSM}$ is lagged one period to be most realistic as one investor in real time would evaluate TSM and then invest in either the market or risk-free asset the following month and realize the corresponding return. The model does therefore not consist of a skip period that researchers such as Jegadeesh and Titman (1993) among others are proponents of. The strategy will be totally rebalanced each month.

To effectively simulate a TSM-strategy, a software called MatLab has been used. This is a powerful simulation and analytic tool that is used in a variety of researchers. The specific code used in this thesis can be found at [2]

## 8.3 Robustness

To test for robustness of the model, the total sample-period for each country has been divided into three sub-periods and the same tests have been conducted to see if the results are consistent.

[2] https://docs.google.com/file/d/0B76_j2m_ErgSdkpTS3pQNEwxOHM/edit?usp=sharing

The data also represent 21 different countries from all parts of the world (exept Africa), which give the sample a broad specter of data.

# 9 Results

## 9.1 Results from hypothesis testing

Table II displays the p-values of the t-test conducted to test for equal mean of buy and sell periods described in Section 7.1.1. Significant p-values (at the 5% confidence-level) are in bold. The optimal k for each country will be the k with the lowest p-value (a summary of these will be found in Table IV). Table II shows us that TSM is a significant trend in 16 of the 21 countries and optimal k varies from 2 to 12 months. Most of the literature uses k up to 12 months, but the results in Table II seem to indicate that the intermediate momentum effect is strongest across countries at a look-back period of 6 months or less. of the countries not showing an intermediate price momentum effect, only the UK is situated in Europe, the four other countries is situated in Asia. This contradicts the findings of (Rouwenhorst, 1998) which find intermediate momentum effects in all of the Asian markets studied (this can be attributed to the different strategies used as Rouwenhorst (1998) use a cross-sectional momentum strategy).

Table III displays the p-values of the F-test conducted to test if the buy and sell periods have different variance described in Section 7.1.2. Significant p-values (at the 95% confidence-level) are in bold. The results show that the buy and sell periods from the optimal k from II for countries Italy, Norway, Singapore, Spain and Switzerland does not have significant different variance. This weaken the results for the mentioned countries from Table II. But the optimal k from Table II is still used in further analysis to look compare Sharpe-ratio, turn-over ratio etc. The rest of Table III is encouraging in the sense that most results indicate that the TSM-strategy will yield lower volatility compared to a buy-and-hold strategy. This is the same findings as Faber (2009) who shows that trading on a SMA strategy will help lower volatility. When looking only at the variance, k=13 is the evaluation period where the most countries (17) will experience lower variance using a TSM-strategy.

Table IV gives a summary of the data provided by the hypothesis analysis. The table shows optimal k varies from 2 to 12 months with an average of 6. This is somewhat contradictory of most literature on TSM which normally uses 10 or 12 months as a optimal k. This might be a consequence of the trading rules applied or the method being used to derive optimal k. As Table V will show us in the next section in some cases a k of 10 months will indeed provide a higher Sharpe-ratio than the optimal k listed in Table IV. Which in turn indicates that the optimal method of deriving k is having the goal of maximizing the Sharpe-ratio and disregard the statistical significance of different mean and variance. To keep the scope of this thesis within the boundaries already set this indication is left to others to analyze.

In Table IV the number of buy- and sell-periods are also displayed which make it possible to calculate the turn-over measure described in formula 6.3.2. Turn-over ratio varies from 29% to 46%, which indicate that a TSM-strategy falls into the category defined by Morningstar as "buy-and-hold". Costs might still play a important part in the profitability of the strategy, but with a relative low turn-over ratio when trading on just one asset, we can pretty confidently say that it will not totally eliminate any excess return realized by using the strategy. The conclusion would of course be totally different if the respectively countries do not provide an ETF that track track the market portfolio in each country. The momentum investor would then form his own market portfolio, and buy and sell many assets each time the strategy experience a change in trading signal. Though with ETFs growing popularity and markets sophisticating as a results of technological advancements and globalization, the assumption that one can trade on an ETF in the 21 countries listed should not be unrealistic. One can also see from IV the difference in expected return from the buy and sell periods. Expected return from the buy periods is positive in all of the 16 countries that displayed a significant momentum anomaly. Of these 16 countries, 10 have an expected return from the sell periods that is negative (with the highest expected return from sell periods in a country being 0.23%). This is a good indication that the TSM-strategy is indeed efficiently timing the market to avoid consistent losses.

Table II: P-values Local Returns t-test for equal mean

| — | Look-back period, months (k) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Australia | 0,7361 | 0,4770 | 0,1661 | 0,2700 | 0,1096 | 0,1092 | 0,3584 | 0,2610 | 0,1198 | 0,2470 | 0,2606 | 0,2953 | 0,3903 | 0,6959 |
| Austria | **0,0017** | **0,0225** | **0,0105** | **0,0360** | 0,0870 | **0,0364** | 0,1022 | 0,0977 | 0,0670 | 0,0504 | 0,2338 | 0,0890 | 0,0555 | 0,1503 |
| Belgium | **0,0284** | **0,0188** | **0,0266** | **0,0277** | **0,0127** | 0,0555 | 0,0903 | 0,0592 | **0,0425** | 0,1578 | **0,0311** | 0,0758 | 0,0517 | 0,0525 |
| Canada | 0,1422 | 0,0989 | 0,0955 | 0,1980 | 0,2834 | 0,0958 | 0,2204 | 0,1014 | 0,2109 | 0,1953 | 0,5630 | 0,3474 | 0,4518 | 0,5173 |
| Denmark | 0,0660 | **0,0168** | **0,0082** | **0,0037** | **0,0038** | **0,0085** | **0,0015** | **0,0139** | 0,0573 | 0,1190 | 0,1260 | 0,1580 | 0,3830 | 0,3797 |
| Finland | **0,0267** | **0,0082** | **0,0139** | **0,0431** | 0,1102 | 0,0742 | **0,0247** | **0,0127** | **0,0080** | **0,0220** | **0,0025** | 0,0511 | 0,1490 | 0,0655 |
| France | 0,6338 | 0,2066 | 0,1393 | 0,1260 | 0,1415 | **0,0496** | 0,0587 | 0,1653 | **0,0251** | 0,1023 | 0,3353 | 0,3027 | 0,3393 | 0,1492 |
| Germany | 0,2902 | 0,1152 | **0,0176** | **0,0322** | 0,1081 | 0,1660 | 0,0978 | 0,1081 | **0,0191** | 0,0637 | 0,2004 | **0,0462** | 0,3147 | 0,4111 |
| HongKong | 0,1083 | 0,3829 | 0,7263 | 0,2243 | 0,4176 | 0,4603 | 0,4529 | 0,2694 | 0,4193 | 0,3025 | 0,4084 | 0,4166 | 0,2712 | 0,3308 |
| Ireland | **0,0141** | 0,0791 | 0,0541 | 0,0837 | **0,0473** | 0,0558 | 0,0808 | **0,0353** | 0,1210 | 0,1999 | 0,1236 | **0,0343** | **0,0264** | **0,0289** |
| Italy | 0,1510 | **0,0086** | 0,2804 | 0,0554 | **0,0290** | **0,0120** | 0,0628 | 0,0580 | 0,1775 | 0,1502 | 0,1001 | **0,0399** | 0,1174 | 0,2188 |
| Japan | **0,0212** | **0,0375** | **0,0087** | **0,0319** | 0,0900 | **0,0409** | 0,0635 | **0,0334** | **0,0058** | **0,0018** | **0,0050** | **0,0261** | **0,0269** | **0,0141** |
| Malaysia | **0,0186** | 0,5561 | 0,6431 | 0,6933 | 0,3292 | 0,2661 | 0,2588 | 0,2345 | 0,3035 | 0,3223 | 0,4165 | 0,3916 | 0,5446 | 0,4368 |
| Netherlands | 0,1432 | 0,1859 | **0,0327** | **0,0144** | 0,0773 | 0,1409 | 0,5138 | 0,2013 | 0,1311 | 0,1045 | 0,0662 | 0,0674 | 0,1119 | 0,2922 |
| New Zealand | 0,8837 | 0,5441 | 0,6716 | 0,9459 | 0,8525 | 0,8017 | 0,7268 | 0,4972 | 0,4091 | 0,6037 | 0,7910 | 0,8933 | 0,7627 | 0,9167 |
| Norway | 0,3093 | **0,0218** | 0,2957 | 0,2723 | **0,0253** | 0,2482 | 0,3920 | 0,0652 | 0,0691 | **0,0140** | 0,0549 | 0,0778 | 0,2061 | 0,3090 |
| Singapore | **0,0102** | **0,0122** | **0,0040** | **0,0045** | 0,0838 | 0,0696 | 0,1033 | 0,4092 | 0,1270 | 0,0633 | 0,0989 | 0,1196 | 0,3000 | 0,2328 |
| Spain | 0,1754 | 0,1978 | **0,0166** | **0,0369** | **0,0146** | 0,0708 | 0,1445 | **0,0307** | **0,0166** | **0,0044** | **0,0196** | **0,0419** | **0,0224** | **0,0254** |
| Sweden | **0,0219** | **0,0019** | **0,0234** | **0,0313** | **0,0197** | **0,0186** | 0,0543 | 0,1296 | 0,0721 | 0,0586 | 0,0642 | 0,0795 | 0,0687 | 0,3022 |
| Switzerland | **0,0119** | **0,0118** | 0,0771 | **0,0255** | **0,0348** | 0,2284 | 0,2831 | 0,1350 | **0,0174** | **0,0137** | **0,0368** | 0,0657 | 0,0900 | 0,1061 |
| UK | 0,5742 | 0,8715 | 0,7343 | 0,2537 | 0,3877 | 0,3626 | 0,5941 | 0,2939 | 0,1846 | 0,2935 | 0,4128 | 0,2635 | 0,2905 | 0,4437 |

Table III: P-values Local Returns F-test for equal variance

| — | Look-back period, months (k) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Australia | 0,2398 | 0,2205 | 0,7992 | 0,7697 | 0,7906 | 0,3187 | 0,2377 | 0,4550 | 0,2970 | 0,1215 | 0,1082 | 0,1312 | 0,1125 | 0,1651 |
| Austria | **0,0014** | **0,0019** | **0,0148** | **0,0065** | **0,0099** | 0,0660 | 0,4417 | 0,2673 | 0,1436 | 0,0828 | 0,0709 | **0,0425** | 0,1762 | 0,2311 |
| Belgium | **0,0017** | 0,2107 | **0,0048** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0005** |
| Canada | **0,0000** | **0,0000** | **0,0008** | **0,0205** | 0,0503 | **0,0293** | **0,0044** | **0,0063** | **0,0234** | **0,0216** | 0,0790 | 0,0627 | 0,0676 | **0,0023** |
| Denmark | **0,0005** | **0,0001** | **0,0000** | **0,0001** | **0,0000** | **0,0002** | **0,0000** | **0,0004** | **0,0042** | **0,0014** | **0,0160** | **0,0119** | **0,0244** | **0,0117** |
| Finland | **0,0125** | **0,0044** | **0,0001** | **0,0002** | **0,0003** | **0,0005** | **0,0002** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0003** | **0,0035** | **0,0024** |
| France | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0004** | **0,0137** | **0,0007** | **0,0016** | **0,0010** | **0,0000** | **0,0000** | **0,0068** |
| Germany | **0,0000** | **0,0002** | **0,0004** | **0,0001** | **0,0001** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0007** | **0,0003** | **0,0000** | **0,0001** | **0,0002** |
| HongKong | 0,1676 | 0,0790 | **0,0186** | 0,0574 | **0,0245** | **0,0425** | **0,0125** | **0,0089** | **0,0025** | **0,0242** | **0,0005** | **0,0006** | **0,0019** | **0,0003** |
| Ireland | **0,0010** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0002** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| Italy | 0,6060 | 0,6122 | 0,6664 | 0,2661 | 0,2892 | **0,0333** | **0,0170** | 0,1123 | **0,0381** | **0,0194** | **0,0470** | **0,0358** | **0,1711** | 0,2976 |
| Japan | **0,0010** | **0,0000** | **0,0003** | **0,0000** | **0,0005** | **0,0000** | **0,0007** | **0,0011** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0000** |
| Malaysia | 0,0586 | **0,0005** | **0,0002** | 0,0620 | **0,0120** | **0,0176** | **0,0126** | **0,0131** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| Netherlands | **0,0000** | **0,0001** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| New Zealand | 0,0561 | 0,1811 | 0,0869 | **0,0322** | **0,0484** | **0,0204** | **0,0188** | **0,0044** | **0,0087** | **0,0020** | **0,0008** | **0,0010** | **0,0014** | **0,0826** |
| Norway | **0,0028** | **0,0277** | **0,0296** | 0,5327 | 0,2460 | 0,3144 | 0,2283 | 0,1872 | 0,2275 | 0,1359 | 0,1325 | 0,5225 | 0,4522 | 0,2982 |
| Singapore | **0,0558** | 0,5378 | 0,4588 | 0,1672 | 0,1747 | **0,0124** | **0,0098** | 0,0732 | **0,0053** | **0,0267** | **0,0047** | **0,0025** | **0,0085** | **0,0007** |
| Spain | 0,6415 | 0,3190 | 0,2610 | 0,2604 | 0,4082 | 0,3319 | 0,3000 | 0,1510 | 0,1218 | 0,2164 | 0,3112 | 0,2288 | 0,2469 | 0,4201 |
| Sweden | **0,0000** | **0,0000** | **0,0003** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0002** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| Switzerland | **0,0095** | 0,0968 | 0,0549 | **0,0365** | **0,0029** | **0,0075** | 0,0579 | 0,0787 | **0,0007** | **0,0037** | **0,0233** | **0,0285** | **0,0254** | 0,0559 |
| UK | **0,0052** | **0,0005** | **0,0006** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0003** | **0,0005** | **0,0002** | **0,0002** | **0,0008** | **0,0011** | **0,0015** |

Table IV: Detailed Summary of Results from Hypothesis Testing

| Country | Period | Optimal k | N(Buy) | N(Sell) | $E(r_{buy})$ | $E(r_{sell})$ | Turn-over |
|---|---|---|---|---|---|---|---|
| *Australia* | 1975 - 2012 | - | | | | | |
| *Austria* | 1987 - 2012 | 2 | 175 | 123 | 1,76 % | -0,55 % | 41,28% |
| *Belgium* | 1975 - 2012 | 6 | 307 | 131 | 1,43 % | 0,12 % | 29,91% |
| *Canada* | 1977 - 2012 | - | | | | | |
| *Denmark* | 1989 - 2012 | 8 | 181 | 87 | 1,56 % | -0,77 % | 32,46% |
| *Finland* | 1988 - 2012 | 12 | 173 | 103 | 2,27 % | -1,01 % | 37,32% |
| *France* | 1975 - 2012 | 10 | 297 | 137 | 1,53 % | 0,05 % | 31,57% |
| *Germany* | 1975 - 2012 | 4 | 290 | 150 | 1,26 % | 0,01 % | 34,09% |
| *HongKong* | 1975 - 2012 | - | | | | | |
| *Ireland* | 1991 - 2012 | 2 | 161 | 89 | 1,37 % | -0,38 % | 35,60% |
| *Italy* | 1975 - 2012 | 3 | 238 | 203 | 1,67 % | -0,05 % | 46,03% |
| *Japan* | 1975 - 2012 | 11 | 272 | 161 | 1,07 % | -0,56 % | 37,18% |
| *Malaysia* | 1994 - 2012 | 2 | 42 | 50 | 2,31 % | -2,07 % | 45,65% |
| *Netherlands* | 1975 - 2012 | 5 | 311 | 128 | 1,46 % | 0,10 % | 29,16% |
| *New Zealand* | 1998 - 2012 | - | | | | | |
| *Norway* | 1975 - 2012 | 11 | 274 | 159 | 1,79 % | 0,23 % | 36,72% |
| *Singapore* | 1975 - 2012 | 4 | 270 | 170 | 1,61 % | -0,18 % | 38,64% |
| *Spain* | 1975 - 2012 | 11 | 288 | 145 | 1,60 % | -0,04 % | 33,49% |
| *Sweden* | 1975 - 2012 | 3 | 297 | 144 | 2,10 % | -0,05 % | 32,65% |
| *Switzerland* | 1975 - 2012 | 3 | 286 | 155 | 1,13 % | 0,09 % | 35,15% |
| *UK* | 1975 - 2012 | - | | | | | |
| *Average* | | 6 | | | 1,62% | -0,32% | 36,06% |

### 9.2 TSM-strategy simulation

In Table V the results gathered from the TSM-strategy simulation. Here we compare the expected return, standard deviation and Sharpe-ratio for a portfolio using the optimal k from Table IV, a portfolio using k=10 and a portfolio which is 100% long in the market portfolio for the whole duration. In two (Australia and Hong Kong) of the total twenty-one countries did a TSM-strategy (optimal k or k=10) yield a worse Sharpe-ratio than the market portfolio. In three (Germany, Malaysia and Switzerland) of the sixteen countries with a statistically significant optimal k, using the optimal k yielded worse results than using the commonly used k=10. In all other instances the TSM-strategy using the optimal k beat the market portfolio, indicating that there in fact is substantial benefits from this strategy.

Figure 4 gives us an illustration of how the TSM-strategy works. Figure 4 contains a snapshot of the compound return of 1 unit of currency invested in 1975. We see that in a very bullish market as in 1997 to 2000 (dot-com bubble) the market portfolio catches up to the TSM-strategy in terms of compound return. But in the bear market that follows, 2000 to 2002, the TSM benefits greatly of being long in a risk-free asset and not the market portfolio. This is consistent with theory on TSM, that it should benefit from not being long in the market in a bear market. And benefit less than the market portfolio in a bull-market due to the lag in the model.

Figure 4: TSM vs Market Portfolio France

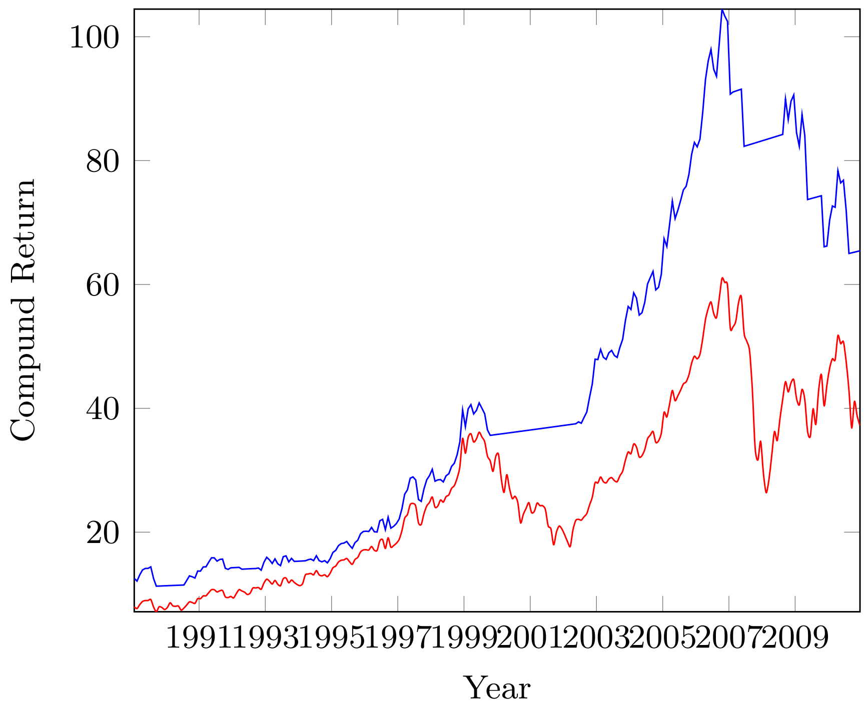


Table V: TSM-Strategy Simulation

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | optimal k | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Australia* | - | - | - | 1,0119 | 4,4436 | 0,19056 | 1,1619 | 5,1707 | 0,19278 |
| | optimal k = 2 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Austria* | **1,104** | **4,4003** | **0,21336** | 0,8757 | 4,9455 | 0,14368 | 0,772 | 6,4576 | 0,09397 |
| | optimal k = 6 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Belgium* | **1,0517** | **3,7165** | **0,23853** | 1,0217 | 3,6539 | 0,23442 | 1,0782 | 4,9871 | 0,18308 |
| | optimal k | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Canada* | - | - | - | **0,8816** | **3,9353** | **0,18205** | 0,9743 | 4,6992 | 0,17219 |
| | optimal k = 8 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Denmark* | **1,1065** | **3,7085** | **0,25383** | 0,847 | 3,949 | 0,17268 | 0,8509 | 5,2971 | 0,12946 |
| | optimal k = 12 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Finland* | **1,4835** | **5,7938** | **0,22754** | 1,371 | 5,832 | 0,20676 | 1,0873 | 8,4898 | 0,10861 |
| | optimal k = 10 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *France* | **1,0963** | **5,1115** | **0,18217** | - | - | - | 1,113 | 6,7743 | 0,13991 |
| | optimal k = 4 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Germany* | 0,8881 | 4,062 | 0,1779 | **0,926** | **4,0981** | **0,18566** | 0,8833 | 5,4875 | 0,13088 |
| | optimal k | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *HongKong* | - | - | - | 1,2483 | 6,7196 | 0,16119 | 1,6997 | 8,3922 | 0,18286 |
| | optimal k = 2 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Ireland* | **0,9393** | **3,9663** | **0,19517** | 0,8012 | 3,926 | 0,16201 | 0,8164 | 5,6973 | 0,1143 |
| | optimal k = 3 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Italy* | **0,977** | **5,6316** | **0,14416** | 0,8508 | 5,7941 | 0,118341 | 0,9092 | 7,5834 | 0,09812 |
| | optimal k = 11 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Japan* | **0,7326** | **3,6438** | **0,15574** | 0,6804 | 3,6073 | 0,14282 | 0,4969 | 5,2299 | 0,06343 |
| | optimal k = 2 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Malaysia* | **1,1458** | **5,9711** | **0,16424** | 0,2417 | 4,5563 | 0,01681 | -0,165 | 10,2904 | -0,03212 |
| | optimal k = 5 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Netherlands* | **1,0818** | **3,9656** | **0,23115** | 1,0285 | 4,1907 | 0,20600 | 1,1096 | 5,2954 | 0,17836 |
| | optimal k | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *New Zealand* | - | - | - | **0,3832** | **3,7029** | **0,05888** | 0,4494 | 5,1203 | 0,05552 |
| | optimal k = 11 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Norway* | **1,1911** | **5,413** | **0,18954** | 1,061 | 5,462 | 0,16401 | 1,1681 | 6,9629 | 0,14404 |
| | optimal k = 4 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Singapore* | **1,0511** | **5,3932** | **0,16427** | 0,9159 | 5,1857 | 0,14477 | 1,0755 | 7,2735 | 0,12515 |
| | optimal k = 11 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Spain* | **1,1179** | **4,8243** | **0,19748** | 1,0614 | 4,7467 | 0,18882 | 1,0552 | 5,9991 | 0,14836 |
| | optimal k = 3 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Sweden* | **1,4683** | **4,6612** | **0,27957** | 1,2506 | 5,0137 | 0,2165 | 1,4215 | 6,4918 | 0,19353 |
| | optimal k = 10 | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *Switzerland* | 0,7918 | 3,4979 | 0,17915 | **0,8212** | **3,446** | **0,19039** | 0,8276 | 4,5726 | 0,14487 |
| | optimal k | | | k = 10 | | | Market | | |
| | E[r] | Std | Sharpe | E[r] | Std | Sharpe | E[r] | Std | Sharpe |
| *UK* | - | - | - | **1,0398** | **4,054** | **0,21575** | 1,343 | 5,6178 | 0,20965 |

## 9.3 Results from regression analysis

Table VI shows the results from the linear regression analysis using the described OLS-method based on the Index-model. Statistically significant coefficient is highlighted in **bold**. 15 of the 16 countries with statistically TSM give evidence of a statistical significant $\alpha$ at the 5% confidence level. Austria is the exception where $\alpha$ is only marginally invalid at the 5% level, p value = 0.051. The statistically valid $\alpha$'s varies between 0,1062% to 0,9153% (monthly). All $\beta$ coefficients are also statistically significant. Most $R^2$ measures lies in the interval (0.5 , 0,6) for all countries which indicates that the regression analysis could have been much better in explaining the relationship between the TSM-strategy and the market portfolio. Though when looking at the scatter plot in Figure 3 we see that though the clustering indicates a strong relationship, the distribution of the data will hinder the model into concluding with a very good fit for the regression line. As mentioned earlier as a critique on equilibrium pricing models, these results can be caused by the badness of fit of the model and not the strength of the TSM-strategy. If we had a multi-factor model we probably would see that $\alpha$ would drop and might even be zero. Table VII shows the same regression used with K=10. And k=10 outperforms optimal k in two countries, namely Germany and Switzerland which is in line with the results from V. Curiously enough only Switzerland had a not significant inequality in the test for equal variances of the populations. In V Malaysia also had the best results with k=10, but show no indication of having so in VII. Other than mentioned two countries optimal k outperforms k=10 for the remainder of the countries.

Table VI: Linear regression based on the Index-model

| Country | optimal k | $\alpha_i$ | | $\beta_i$ | | $R^2$ |
|---|---|---|---|---|---|---|
| | | coefficient | p-value | coefficient | p-value | |
| *Australia* | - | | | | | |
| *Austria* | 2 | 0,3461% | 0,051 | 0,5129 | 0,000 | 0,3719 |
| *Belgium* | 6 | **0,3967%** | 0,001 | **0,5616** | 0,000 | 0,5621 |
| *Canada* | - | | | | | |
| *Denmark* | 8 | **0,6224%** | 0,000 | **0,5007** | 0,000 | 0,5112 |
| *Finland* | 12 | **0,9153%** | 0,000 | **0,4588** | 0,000 | 0,4668 |
| *France* | 10 | **0,4085%** | 0,011 | **0,5835** | 0,000 | 0,5842 |
| *Germany* | 4 | **0,3531%** | 0,007 | **0,5515** | 0,000 | 0,5527 |
| *HongKong* | - | | | | | |
| *Ireland* | 2 | **0,4772%** | 0,007 | **0,5124** | 0,000 | 0,5173 |
| *Italy* | 3 | **0,4168%** | 0,021 | **0,5537** | 0,000 | 0,5551 |
| *Japan* | 11 | **0,4204%** | 0,001 | **0,4921** | 0,000 | 0,4977 |
| *Malaysia* | 2 | **0,1062%** | 0,037 | **0,3480** | 0,000 | 0,3597 |
| *Netherlands* | 5 | **0,3990%** | 0,002 | **0,5768** | 0,000 | 0,5774 |
| *New Zealand* | - | | | | | |
| *Norway* | 11 | **0,3940%** | 0,018 | **0,6024** | 0,000 | 0,6019 |
| *Singapore* | 4 | **0,4248%** | 0,008 | **0,6142** | 0,000 | 0,6167 |
| *Spain* | 11 | **0,3817%** | 0,006 | **0,6448** | 0,000 | 0,6465 |
| *Sweden* | 3 | **0,6658%** | 0,000 | **0,5169** | 0,000 | 0,5191 |
| *Switzerland* | 3 | **0,2593%** | 0,014 | **0,6110** | 0,000 | 0,6118 |
| *UK* | - | | | | | |

Table VII: Linear regression based on the Index-model k=10

| Country | optimal k | $\alpha_i$ | | $\beta_i$ | | $R^2$ |
|---|---|---|---|---|---|---|
| | | coefficient | p-value | coefficient | p-value | |
| *Australia* | 10 | 0,1285% | 0,240 | 0,7498 | 0,000 | 0,7438 |
| *Austria* | 10 | 0,1441% | 0,408 | 0,6183 | 0,000 | 0,4674 |
| *Belgium* | 10 | **0,3746%** | 0,002 | **0,5396** | 0,000 | 0,5384 |
| *Canada* | 10 | 0,1379% | 0,216 | 0,6875 | 0,000 | 0,6835 |
| *Denmark* | 10 | **0,3308%** | 0,043 | **0,5542** | 0,000 | 0,5554 |
| *Finland* | 10 | **0,7979%** | 0,002 | **0,4653** | 0,000 | 0,4707 |
| *France* | 10 | **0,4085%** | 0,011 | **0,5835** | 0,000 | 0,5842 |
| *Germany* | 10 | **0,3818%** | 0,004 | **0,5631** | 0,000 | 0,5653 |
| *HongKong* | 10 | 0,1642% | 0,405 | 0,6434 | 0,000 | 0,6381 |
| *Ireland* | 10 | 0,3528% | 0,053 | 0,4886 | 0,000 | 0,4897 |
| *Italy* | 10 | 0,2127% | 0,240 | 0,5844 | 0,000 | 0,5830 |
| *Japan* | 10 | **0,3702%** | 0,003 | **0,4819** | 0,000 | 0,4860 |
| *Malaysia* | 10 | 0,2090% | 0,632 | 0,1739 | 0,000 | 0,1745 |
| *Netherlands* | 10 | **0,2891%** | 0,019 | **0,6385** | 0,000 | 0,6374 |
| *New Zealand* | 10 | 0,6138% | 0,677 | 0,5648 | 0,000 | 0,5643 |
| *Norway* | 10 | 0,2633% | 0,113 | 0,6115 | 0,000 | 0,6090 |
| *Singapore* | 10 | 0,2566% | 0,124 | 0,5465 | 0,000 | 0,5451 |
| *Spain* | 10 | 0,3318% | 0,021 | 0,6172 | 0,000 | 0,6167 |
| *Sweden* | 10 | **0,3694%** | 0,020 | **0,5846** | 0,000 | 0,5811 |
| *Switzerland* | 10 | **0,2884%** | 0,007 | **0,6000** | 0,000 | 0,6015 |
| *UK* | 10 | 0,1883% | 0,084 | 0,7043 | 0,000 | 0,7005 |

### 9.4 Robustness analysis

To not overwhelm the reader of this thesis with data, the tables containing results from the robustness analysis can be found in the Appendix. But to summarize; the results are not encouraging. Not one country yielded a consistent significant price momentum tendency. But contradictory of the notion that the benefits of TSM and CSM have declined over the years due to more knowledge about the strategies (Park and Irwin, 2005). 19 out of the 21 countries had a significant price momentum tendency in the last period (usually ranging from late 90's to 2011). So combining the sub-period analysis with the broad horizontal specter of 21 different countries and it seems that the TSM-strategy is not as good as the relevant literature have proclaimed an SMA-strategy to be.

## 10 Summary

This thesis sets out in hopes of finding a technical trading system based solely on past price movements as an effective way to benefit from the momentum anomaly described in financial literature. The strategy can be summarized as; long market portfolio if $P_t > P_{t-k}$ and long a risk-free asset if $P_t < P_{t-k}$. The initial results from hypothesis testing and strategy simulation is encouraging, with 16 out of 21 countries showing a significant benefit from trading on the strategy, which is corresponding with the closely related research of GCST09,CSST12. Our optimal look-back period has shorter duration (average =6 months) than most literature acknowledge as the optimal, this can be caused by the difference in strategies. Serious doubts about the results arise when we test for robustness. Not one country displays consistent significant price momentum when divided the sample period intro three sub-periods. Results are very good for the last period which include the recent financial turmoil where a the TSM-strategy benefits greatly of being out of market and therefore avoiding consistent losses. The results is therefore somewhat skewed in that one periods significant results make up for not significant results the other two periods. We have reviewed relevant financial literature and found that researchers are still trying to explain the momentum anomaly, the source(s) of this anomaly being present and persistent is under much debate and no-one has found a clear cut explanation yet. This should make investors skeptical about the results the momentum strategies have produced and be cautious when applying the strategies out-of-sample (as they must). The results in this thesis consistent with the existing literature, namely that trading on momentum when it is significant (both price and earnings momentum) yield better risk-adjusted results than a buy-and-hold strategy. With low turnover the strategy will also most likely still realize abnormal returns after accounting for transaction costs since the underlying is an equity index and one only needs an ETF to implement the strategy and therefore also only need to trade two asset, the ETF and a risk-free asset. The international investor might be discouraged because VIII show that the results from hypothesis testing using data containing returns in dollars, yield even more scattered results than using local currency. This indicates that an investor trying to benefit from regional momentum might see his profits evaporate when exchanging local currency to dollars. There is no doubt that the momentum anomaly will be subject to further research and scrutiny until researchers find a general accepted explanation for it, and in the process most likely will eliminate any abnormal returns by making the information available to the public.

# Appendix

## Additional results

Table VIII and IX displays the results from hypothesis testing using the data with dollar-returns. The rest of the tables in the Appendix displays the results from hypothesis testing when dividing the full sample period into three sub-periods.

Table VIII: p-values Dollar Returns t-test for equal mean

| — | Look-back period, months (k) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| *Australia* | 0,3718 | 0,4486 | 0,2510 | 0,7457 | 0,7450 | 0,6187 | 0,3722 | 0,7921 | 0,7815 | 0,5175 | 0,5378 | 0,5940 | 0,4943 | 0,5948 |
| *Austria* | 0,0803 | 0,3553 | 0,1330 | 0,0726 | **0,0037** | 0,0628 | 0,0564 | 0,1232 | 0,1308 | 0,3927 | 0,4647 | 0,1155 | 0,0515 | 0,1441 |
| *Belgium* | **0,0009** | **0,0476** | 0,1795 | 0,1644 | 0,1458 | 0,1457 | 0,1628 | 0,1759 | 0,1246 | 0,0904 | 0,0775 | 0,0625 | **0,0254** | 0,0905 |
| *Canada* | 0,3033 | 0,1844 | 0,1519 | 0,0979 | 0,2560 | **0,0379** | 0,2177 | 0,3807 | 0,2619 | 0,3607 | 0,2830 | 0,4430 | 0,6620 | 0,8176 |
| *Denmark* | 0,6213 | 0,4833 | 0,1463 | 0,0502 | 0,0773 | 0,2081 | 0,2420 | 0,2830 | 0,1602 | 0,1828 | 0,0935 | 0,2107 | 0,2121 | 0,3819 |
| *Finland* | 0,1913 | **0,0479** | 0,0618 | 0,0502 | 0,0773 | **0,0235** | **0,0152** | 0,0615 | 0,1051 | 0,0544 | 0,0895 | 0,0642 | **0,0362** | 0,1103 |
| *France* | 0,4289 | 0,1288 | 0,1802 | 0,0941 | **0,0416** | **0,0144** | 0,0595 | 0,1726 | **0,0381** | 0,1064 | 0,2554 | 0,1627 | 0,1366 | 0,0558 |
| *Germany* | 0,2192 | 0,0997 | 0,2258 | 0,0933 | 0,3150 | **0,0425** | 0,2844 | 0,2120 | 0,1134 | 0,2545 | 0,3579 | 0,1118 | 0,0778 | 0,2468 |
| *HongKong* | **0,0371** | 0,5105 | 0,7403 | 0,3541 | 0,4087 | 0,2410 | 0,4928 | 0,3536 | 0,2898 | 0,2320 | 0,4834 | 0,3086 | 0,2211 | 0,5143 |
| *Ireland* | 0,2188 | 0,2327 | 0,1250 | 0,0922 | 0,2299 | **0,0171** | 0,0527 | 0,2981 | 0,1762 | 0,4095 | 0,2912 | 0,2305 | 0,2133 | 0,2932 |
| *Italy* | 0,4087 | **0,0173** | 0,1199 | **0,0037** | 0,0639 | **0,0251** | **0,0309** | **0,0446** | **0,0213** | 0,1175 | **0,0273** | **0,0489** | 0,0802 | 0,2541 |
| *Japan* | 0,0622 | **0,0329** | **0,0027** | **0,0299** | 0,1817 | 0,1845 | **0,0295** | **0,0004** | **0,0010** | **0,0040** | **0,0045** | 0,0586 | **0,0120** | 0,0581 |
| *Malaysia* | **0,0386** | 0,2797 | 0,1997 | 0,2486 | 0,1613 | 0,1175 | 0,0876 | 0,2274 | 0,0992 | 0,1113 | 0,1756 | 0,3380 | 0,4262 | 0,3669 |
| *Netherlands* | 0,4719 | 0,1087 | 0,3053 | 0,1356 | 0,5155 | 0,4619 | 0,4292 | 0,3690 | 0,1615 | 0,4326 | 0,4175 | 0,2849 | 0,1089 | 0,1212 |
| *New Zealand* | 0,6218 | 0,1388 | 0,4832 | 0,6429 | 0,2351 | 0,1754 | 0,2045 | 0,3845 | 0,1455 | 0,5259 | 0,2656 | 0,3092 | 0,2563 | 0,3770 |
| *Norway* | 0,1996 | **0,0400** | 0,1530 | 0,1132 | 0,0543 | 0,2849 | 0,1461 | 0,0582 | **0,0425** | 0,1323 | 0,0931 | 0,1293 | 0,1176 | 0,5194 |
| *Singapore* | **0,0020** | 0,1159 | **0,0193** | **0,0153** | 0,1416 | 0,1056 | 0,1191 | 0,2962 | 0,1736 | 0,1569 | 0,2544 | 0,1958 | **0,0467** | 0,0910 |
| *Spain* | 0,1902 | 0,0554 | 0,1735 | 0,1513 | 0,0639 | **0,0269** | **0,0346** | **0,0410** | **0,0064** | **0,0369** | 0,0938 | 0,2210 | 0,3957 | 0,0731 |
| *Sweden* | 0,5010 | **0,0282** | 0,2425 | **0,0437** | **0,0098** | 0,0571 | 0,1150 | 0,1024 | 0,0855 | 0,0539 | 0,2745 | 0,1975 | 0,2742 | 0,2274 |
| *Switzerland* | 0,1824 | 0,2088 | 0,2510 | 0,2202 | 0,1878 | 0,3820 | 0,2113 | 0,3401 | 0,1500 | 0,1191 | 0,1818 | 0,1047 | 0,0968 | 0,3742 |
| *UK* | 0,5000 | 0,6717 | 0,3935 | 0,5870 | 0,5791 | 0,6692 | 0,5154 | 0,2941 | 0,1491 | 0,1481 | 0,1963 | 0,3056 | 0,3234 | 0,3096 |

Table IX: p-values Dollar returns F-test for equal variance

| — | Look-back period, months (k) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| *Australia* | **0,0045** | **0,0008** | 0,1320 | **0,0153** | **0,0022** | **0,0130** | **0,0072** | **0,0326** | **0,0097** | **0,0101** | **0,0036** | **0,0210** | **0,0043** | **0,0157** |
| *Austria* | **0,0115** | 0,3111 | 0,1559 | **0,0233** | **0,0141** | **0,0357** | 0,1717 | 0,1768 | **0,0227** | **0,0316** | 0,0980 | 0,0617 | **0,0363** | 0,0634 |
| *Belgium* | **0,0044** | **0,0322** | **0,0064** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0009** |
| *Canada* | **0,0001** | **0,0010** | **0,0005** | **0,0002** | **0,0007** | **0,0018** | **0,0029** | **0,0004** | **0,0000** | **0,0001** | **0,0000** | **0,0016** | **0,0080** | **0,0128** |
| *Denmark* | **0,0030** | **0,0002** | **0,0000** | **0,0000** | **0,0001** | **0,0002** | **0,0003** | **0,0002** | **0,0001** | **0,0000** | **0,0003** | **0,0001** | **0,0003** | **0,0004** |
| *Finland* | **0,0060** | **0,0033** | **0,0000** | **0,0001** | **0,0006** | **0,0008** | **0,0006** | **0,0003** | **0,0001** | **0,0000** | **0,0000** | **0,0003** | **0,0023** | **0,0246** |
| *France* | **0,0003** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0033** | **0,0001** | **0,0000** | **0,0008** | **0,0000** | **0,0015** | **0,0021** |
| *Germany* | **0,0250** | **0,0001** | **0,0006** | **0,0002** | **0,0002** | **0,0000** | **0,0003** | **0,0010** | **0,0001** | **0,0001** | **0,0001** | **0,0001** | **0,0001** | **0,0016** |
| *HongKong* | **0,0416** | 0,0694 | **0,0067** | **0,0127** | **0,0080** | **0,0012** | **0,0063** | **0,0047** | **0,0004** | **0,0005** | **0,0000** | **0,0000** | **0,0001** | **0,0000** |
| *Ireland* | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| *Italy* | 0,6388 | 0,3568 | 0,2789 | 0,5177 | 0,0699 | 0,0582 | 0,0744 | **0,0451** | 0,0615 | **0,0467** | 0,1630 | 0,1587 | 0,3444 | 0,5380 |
| *Japan* | **0,0134** | **0,0006** | **0,0232** | **0,0029** | **0,0042** | **0,0061** | **0,0072** | **0,0163** | **0,0047** | **0,0015** | **0,0002** | **0,0006** | **0,0002** | **0,0002** |
| *Malaysia* | **0,0021** | **0,0009** | **0,0369** | **0,0144** | **0,0132** | **0,0178** | **0,0127** | **0,0000** | **0,0001** | **0,0001** | **0,0001** | **0,0000** | **0,0000** | **0,0000** |
| *Netherlands* | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| *New Zealand* | 0,2498 | **0,0390** | 0,2254 | 0,2242 | 0,1036 | **0,0236** | **0,0130** | **0,0003** | **0,0155** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| *Norway* | **0,0022** | **0,0007** | **0,0138** | **0,0232** | **0,0290** | **0,0190** | **0,0125** | **0,0102** | **0,0079** | **0,0225** | **0,0263** | 0,1396 | 0,0962 | 0,5048 |
| *Singapore* | **0,0006** | 0,1091 | 0,1476 | **0,0257** | **0,0037** | **0,0001** | **0,0000** | **0,0025** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0002** | **0,0000** |
| *Spain* | 0,0792 | 0,0563 | **0,0278** | **0,0205** | **0,0060** | **0,0177** | **0,0086** | **0,0273** | **0,0119** | **0,0102** | **0,0017** | **0,0030** | **0,0121** | 0,1257 |
| *Sweden* | **0,0001** | **0,0000** | **0,0000** | **0,0001** | **0,0005** | **0,0003** | **0,0001** | **0,0001** | **0,0001** | **0,0000** | **0,0000** | **0,0002** | **0,0001** | **0,0001** |
| *Switzerland* | **0,0040** | **0,0128** | **0,0074** | **0,0255** | **0,0011** | **0,0254** | 0,1190 | 0,1443 | 0,0575 | **0,0142** | **0,0292** | **0,0171** | 0,1051 | 0,1415 |
| *UK* | **0,0005** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0003** | **0,0012** |

Table X: Robustness Analysis Australia

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total period (n=444) | | | | | | | | |
| p-value (equal mean) | 0,7361 | 0,4770 | 0,1661 | 0,2700 | 0,1096 | 0,1092 | 0,3584 | 0,2610 | 0,1198 | 0,2470 | 0,2606 | 0,2953 | 0,3903 | 0,6959 |
| p-value (equal variance) | 0,2398 | 0,2205 | 0,7992 | 0,7697 | 0,7906 | 0,3187 | 0,2377 | 0,4550 | 0,2970 | 0,1215 | 0,1082 | 0,1312 | 0,1125 | 0,1651 |
| | | | | | | Sub-period 1 (n=1-148) | | | | | | | | |
| p-value (equal mean) | 0,8834 | 0,7672 | 0,1450 | 0,1138 | 0,0329 | 0,0967 | 0,2246 | 0,1009 | **0,0448** | 0,1378 | 0,1321 | 0,0638 | 0,0843 | 0,4274 |
| p-value (equal variance) | 0,0815 | 0,1871 | 0,3282 | 0,6611 | 0,6423 | 0,4402 | 0,3354 | 0,4876 | 0,6148 | 0,2812 | 0,2912 | 0,3551 | 0,2945 | 0,1238 |
| | | | | | | Sub-period 2 (n=149-296) | | | | | | | | |
| p-value (equal mean) | 0,9501 | 0,7775 | 0,8247 | 0,9629 | 0,9055 | 0,6650 | 0,8775 | 0,8756 | 0,6980 | 0,8302 | 0,5584 | 0,7482 | 0,7108 | 0,9736 |
| p-value (equal variance) | 0,9989 | 0,9838 | 0,9999 | 0,9932 | 0,4655 | 0,0958 | **0,0249** | 0,2545 | **0,0400** | 0,2316 | 0,1510 | 0,3159 | 0,2385 | 0,4577 |
| | | | | | | Sub-period 3 (n=297-444) | | | | | | | | |
| p-value (equal mean) | **0,0312** | 0,0578 | 0,1184 | 0,1536 | 0,0533 | 0,0525 | 0,1422 | 0,2273 | 0,2313 | 0,1620 | 0,3189 | 0,3116 | 0,5968 | 0,5153 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0004** | **0,0000** | **0,0002** | **0,0000** | **0,0002** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0007** |

Table XI: Robustness Analysis Austria

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total period (n=444) | | | | | | | | |
| p-value (equal mean) | **0,0017** | **0,0225** | **0,0105** | **0,0360** | 0,0870 | **0,0364** | 0,1022 | 0,0977 | 0,0670 | 0,0504 | 0,2338 | 0,0890 | 0,0555 | 0,1503 |
| p-value (equal variance) | **0,0014** | **0,0019** | **0,0148** | **0,0065** | **0,0099** | 0,0660 | 0,4417 | 0,2673 | 0,1436 | 0,0828 | 0,0709 | **0,0425** | 0,1762 | 0,2311 |
| | | | | | | Sub-period 1 (n=1-148) | | | | | | | | |
| p-value (equal mean) | 0,1050 | 0,1687 | **0,0378** | 0,0519 | 0,1626 | 0,1951 | 0,3463 | 0,2090 | 0,0599 | 0,0526 | 0,2995 | 0,1156 | 0,0739 | 0,0870 |
| p-value (equal variance) | 0,5066 | 0,4052 | 0,7268 | 0,6072 | 0,8264 | 0,9865 | 0,9998 | 0,9996 | 0,9994 | 0,9969 | 0,9991 | 0,9952 | 0,9978 | 0,9963 |
| | | | | | | Sub-period 2 (n=149-296) | | | | | | | | |
| p-value (equal mean) | **0,0468** | 0,5324 | 0,7216 | 0,9610 | 0,9206 | 0,9097 | 0,9566 | 0,9754 | 0,9080 | 0,9103 | 0,9175 | 0,6929 | 0,6726 | 0,8670 |
| p-value (equal variance) | 0,0655 | 0,0989 | 0,6516 | 0,8039 | 0,7784 | 0,8654 | 0,9895 | 0,9165 | 0,8170 | 0,9251 | 0,6400 | 0,1663 | 0,9116 | 0,8900 |
| | | | | | | Sub-period 3 (n=297-444) | | | | | | | | |
| p-value (equal mean) | **0,0108** | **0,0118** | **0,0163** | **0,0172** | **0,0323** | **0,0143** | **0,0318** | 0,0530 | 0,1118 | 0,0863 | 0,1247 | 0,1508 | 0,1520 | 0,2159 |
| p-value (equal variance) | **0,0002** | **0,0009** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0001** |

Table XII: Robustness Analysis Belgium

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0284** | **0,0188** | **0,0266** | **0,0277** | **0,0127** | 0,0555 | 0,0903 | 0,0592 | **0,0425** | 0,1578 | **0,0311** | 0,0758 | 0,0517 | 0,0525 |
| p-value (equal variance) | **0,0017** | 0,2107 | **0,0048** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0005** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1236 | 0,2030 | 0,2425 | 0,0823 | **0,0133** | 0,4228 | 0,3437 | 0,2262 | 0,1398 | 0,3203 | 0,1766 | 0,2866 | 0,2250 | 0,1573 |
| p-value (equal variance) | 0,2755 | 0,9595 | 0,9210 | 0,5733 | 0,8184 | **0,0473** | 0,0553 | 0,0995 | 0,2227 | 0,1150 | 0,1247 | 0,2886 | 0,0648 | 0,1242 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,3868 | 0,2531 | 0,4850 | 0,8747 | 0,7829 | 0,6680 | 0,8298 | 0,8544 | 0,4779 | 0,6213 | 0,5778 | 0,6939 | 0,7020 | 0,4349 |
| p-value (equal variance) | 0,0657 | 0,8137 | **0,0498** | **0,0162** | **0,0008** | **0,0003** | **0,0007** | **0,0037** | **0,0336** | 0,0704 | **0,0368** | **0,0274** | 0,0582 | 0,0960 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0379** | **0,0421** | **0,0302** | **0,0031** | **0,0058** | **0,0079** | **0,0111** | **0,0037** | **0,0072** | **0,0337** | **0,0334** | **0,0421** | **0,0270** | 0,1133 |
| p-value (equal variance) | **0,0093** | **0,0016** | **0,0009** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |



Table XIII: Robustness Analysis Canada

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1422 | 0,0989 | 0,0955 | 0,1980 | 0,2834 | 0,0958 | 0,2204 | 0,1014 | 0,2109 | 0,1953 | 0,5630 | 0,3474 | 0,4518 | 0,5173 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0008** | **0,0205** | **0,0503** | **0,0293** | **0,0044** | **0,0063** | **0,0234** | **0,0216** | **0,0790** | **0,0627** | **0,0676** | **0,0023** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,5008 | 0,6831 | 0,6023 | 0,4212 | 0,3033 | 0,3009 | 0,4684 | 0,1132 | 0,3135 | 0,3398 | 0,6168 | 0,3976 | 0,3844 | 0,6327 |
| p-value (equal variance) | **0,0135** | 0,0963 | 0,2724 | 0,0677 | 0,2547 | 0,2046 | 0,1494 | 0,0415 | 0,2944 | 0,2661 | 0,0838 | 0,0553 | **0,0404** | **0,0184** |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,4612 | 0,2535 | 0,3261 | 0,7271 | 0,8528 | 0,4568 | 0,7110 | 0,4454 | 0,7563 | 0,7194 | 0,8680 | 0,8483 | 0,8871 | 0,9329 |
| p-value (equal variance) | **0,0231** | **0,0074** | **0,0025** | 0,7967 | 0,7787 | 0,6945 | 0,4438 | 0,4946 | 0,7504 | 0,7342 | 0,8688 | 0,8597 | 0,8414 | 0,7640 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0198** | **0,0131** | **0,0269** | 0,0537 | 0,1848 | 0,0657 | 0,0706 | 0,2642 | 0,0993 | 0,1306 | 0,2425 | 0,1627 | 0,3259 | 0,1185 |
| p-value (equal variance) | **0,0047** | **0,0001** | **0,0004** | **0,0075** | **0,0004** | **0,0003** | **0,0001** | **0,0091** | **0,0000** | **0,0000** | **0,0081** | **0,0050** | **0,0100** | **0,0000** |

Table XIV: Robustness Analysis Denmark

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,0660 | **0,0168** | **0,0082** | **0,0037** | **0,0038** | **0,0085** | **0,0015** | **0,0139** | 0,0573 | 0,1190 | 0,1260 | 0,1580 | 0,3830 | 0,3797 |
| p-value (equal variance) | **0,0005** | **0,0001** | **0,0000** | **0,0001** | **0,0000** | **0,0002** | **0,0000** | **0,0004** | **0,0042** | **0,0014** | **0,0160** | **0,0119** | **0,0244** | **0,0117** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,5551 | 0,2066 | 0,2197 | 0,4092 | 0,3491 | 0,1862 | 0,1713 | 0,4094 | 0,5979 | 0,7333 | 0,8447 | 0,7983 | 0,9520 | 0,8087 |
| p-value (equal variance) | 0,4907 | 0,1114 | 0,0621 | 0,0578 | **0,0243** | **0,0190** | **0,0258** | 0,0585 | 0,1188 | 0,0750 | 0,2363 | 0,1450 | 0,2183 | 0,1743 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,3006 | 0,4266 | 0,1215 | 0,0552 | **0,0307** | 0,0706 | **0,0460** | 0,0684 | 0,0671 | 0,1598 | 0,1141 | 0,2387 | 0,2752 | 0,4356 |
| p-value (equal variance) | 0,1020 | 0,1920 | **0,0477** | 0,3350 | 0,3770 | 0,4404 | 0,4547 | 0,6606 | 0,7274 | 0,4626 | 0,7377 | 0,6700 | 0,7574 | 0,6894 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0258** | **0,0074** | **0,0209** | **0,0151** | **0,0233** | 0,0891 | **0,0252** | 0,0787 | 0,2385 | 0,2414 | 0,1894 | 0,2167 | 0,3272 | 0,4188 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0001** | **0,0003** | **0,0005** | **0,0007** | **0,0008** | **0,0009** |



Table XV: Robustness Analysis Finland

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0267** | **0,0082** | **0,0139** | **0,0431** | 0,1102 | 0,0742 | **0,0247** | **0,0127** | **0,0080** | **0,0220** | **0,0025** | **0,0511** | 0,1490 | 0,0655 |
| p-value (equal variance) | **0,0125** | **0,0044** | **0,0001** | **0,0002** | **0,0003** | **0,0005** | **0,0002** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0003** | **0,0035** | **0,0024** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1378 | 0,0524 | 0,0591 | 0,1657 | 0,5626 | 0,6298 | 0,4934 | 0,2988 | 0,1997 | 0,3542 | 0,1359 | 0,1723 | 0,2388 | 0,1526 |
| p-value (equal variance) | 0,1701 | 0,0583 | 0,0552 | **0,0092** | **0,0216** | **0,0098** | **0,0199** | **0,0167** | 0,0631 | 0,0518 | **0,0121** | **0,0241** | **0,0192** | **0,0322** |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0461** | 0,1959 | 0,1659 | 0,2449 | 0,1564 | 0,0844 | **0,0447** | **0,0288** | **0,0215** | **0,0275** | **0,0113** | 0,0636 | 0,2094 | 0,1994 |
| p-value (equal variance) | 0,0521 | 0,0981 | **0,0118** | 0,0592 | **0,0451** | 0,0507 | **0,0187** | **0,0064** | **0,0083** | **0,0164** | **0,0142** | 0,0609 | 0,2737 | 0,3333 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,4257 | **0,0406** | **0,0224** | **0,0412** | **0,0462** | 0,0576 | 0,0645 | **0,0387** | 0,0882 | 0,1095 | 0,0632 | 0,1231 | 0,2106 | 0,1684 |
| p-value (equal variance) | **0,0032** | **0,0003** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0001** | **0,0001** |

Table XVI: Robustness Analysis France

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,6338 | 0,2066 | 0,1393 | 0,1260 | 0,1415 | 0,0496 | 0,0587 | 0,1653 | **0,0251** | 0,1023 | 0,3353 | 0,3027 | 0,3393 | 0,1492 |
| p-value (equal variance) | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0004** | **0,0137** | **0,0007** | **0,0016** | **0,0010** | **0,0000** | **0,0000** | **0,0068** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,4526 | 0,1863 | 0,1938 | 0,2246 | 0,2795 | 0,1437 | 0,1313 | 0,0678 | **0,0053** | **0,0264** | 0,0970 | 0,0667 | 0,1616 | **0,0081** |
| p-value (equal variance) | 0,1570 | **0,0483** | **0,0285** | 0,0749 | 0,0773 | 0,7631 | 0,6905 | 0,9085 | 0,7988 | 0,8723 | 0,8620 | 0,0934 | 0,1328 | 0,6976 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,9774 | 0,9285 | 0,6203 | 0,9082 | 0,9675 | 0,6552 | 0,6260 | 0,8961 | 0,6091 | 0,6532 | 0,9550 | 0,9692 | 0,9470 | 0,9723 |
| p-value (equal variance) | **0,0003** | 0,0703 | **0,0011** | **0,0006** | **0,0190** | **0,0027** | **0,0082** | 0,1312 | 0,1665 | 0,4151 | 0,1388 | 0,2296 | 0,0943 | 0,6594 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1832 | 0,0569 | 0,1510 | **0,0221** | **0,0335** | **0,0405** | 0,0753 | 0,3670 | 0,2617 | 0,4906 | 0,4256 | 0,3910 | 0,2778 | 0,3290 |
| p-value (equal variance) | **0,0043** | **0,0002** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0007** | **0,0015** |

Table XVII: Robustness Analysis Germany

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,2902 | 0,1152 | **0,0176** | **0,0322** | 0,1081 | 0,1660 | 0,0978 | 0,1081 | 0,0191 | 0,0637 | 0,2004 | **0,0462** | 0,3147 | 0,4111 |
| p-value (equal variance) | **0,0000** | **0,0002** | **0,0004** | **0,0001** | **0,0001** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0007** | **0,0003** | **0,0000** | **0,0001** | **0,0002** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,8391 | 0,3571 | 0,1949 | 0,4793 | 0,7869 | 0,7968 | 0,2641 | 0,5933 | 0,0610 | 0,2319 | 0,5591 | 0,4542 | 0,5417 | 0,7957 |
| p-value (equal variance) | 0,8572 | 0,9036 | 0,6718 | 0,7531 | 0,7865 | 0,6805 | 0,7810 | 0,8586 | 0,8920 | 0,9544 | 0,9317 | 0,8527 | 0,7984 | 0,9233 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,4393 | 0,7076 | 0,0837 | 0,2747 | 0,3588 | 0,5055 | 0,8026 | 0,7994 | 0,6366 | 0,5665 | 0,8824 | 0,5781 | 0,7186 | 0,7295 |
| p-value (equal variance) | **0,0057** | 0,1349 | **0,0455** | 0,2651 | 0,1145 | 0,2712 | 0,4521 | 0,9317 | 0,9796 | 0,9754 | 0,9889 | 0,9860 | 0,9820 | 0,9972 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,1205** | **0,0413** | 0,1605 | **0,0257** | **0,0382** | **0,0730** | **0,0435** | 0,1006 | 0,0513 | 0,0604 | 0,0777 | 0,0544 | 0,2072 | 0,1793 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0002** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |

Table XVIII: Robustness Analysis Hong Kong

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total period (n=444) | | | | | | | | | |
| p-value (equal mean) | **0,1083** | 0,3829 | 0,7263 | 0,2243 | 0,4176 | 0,4603 | 0,4529 | 0,2694 | 0,4193 | 0,3025 | 0,4084 | 0,4166 | 0,2712 | 0,3308 |
| p-value (equal variance) | 0,1676 | 0,0790 | **0,0186** | 0,0574 | **0,0245** | **0,0425** | **0,0125** | **0,0089** | **0,0025** | **0,0242** | **0,0005** | **0,0006** | **0,0019** | **0,0003** |
| | | | | | Sub-period 1 (n=1-148) | | | | | | | | | |
| p-value (equal mean) | 0,2784 | 0,5828 | 0,8995 | 0,3984 | 0,4436 | 0,5128 | 0,8086 | 0,5757 | 0,4838 | 0,2486 | 0,2273 | 0,2750 | 0,1917 | 0,0896 |
| p-value (equal variance) | 0,4322 | 0,2387 | 0,2630 | 0,2017 | 0,1249 | 0,2642 | 0,3170 | 0,1699 | 0,0952 | 0,1797 | 0,0154 | **0,0266** | **0,0425** | **0,0222** |
| | | | | | Sub-period 2 (n=149-296) | | | | | | | | | |
| p-value (equal mean) | 0,2779 | 0,5958 | 0,8140 | 0,7624 | 0,8541 | 0,7666 | 0,4729 | 0,3384 | 0,4368 | 0,4412 | 0,6991 | 0,5748 | 0,4468 | 0,8361 |
| p-value (equal variance) | 0,3178 | 0,3103 | 0,0966 | 0,3948 | 0,0765 | 0,1208 | 0,0554 | **0,0465** | **0,0236** | **0,0301** | **0,0029** | **0,0060** | **0,0077** | **0,0047** |
| | | | | | Sub-period 3 (n=297-444) | | | | | | | | | |
| p-value (equal mean) | 0,1905 | 0,1299 | 0,1005 | **0,0270** | **0,0496** | 0,2208 | 0,1288 | 0,1494 | 0,3541 | 0,4103 | 0,4031 | 0,4526 | 0,5819 | 0,3314 |
| p-value (equal variance) | **0,0099** | **0,0083** | **0,0125** | **0,0066** | **0,0028** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0002** | **0,0002** |



Table XIX: Robustness Analysis Ireland

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total period (n=444) | | | | | | | | | |
| p-value (equal mean) | **0,0141** | 0,0791 | 0,0541 | 0,0837 | **0,0473** | 0,0558 | 0,0808 | **0,0353** | 0,1210 | 0,1999 | 0,1236 | **0,0343** | **0,0264** | **0,0289** |
| p-value (equal variance) | **0,0010** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0002** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| | | | | | Sub-period 1 (n=1-148) | | | | | | | | | |
| p-value (equal mean) | 0,1320 | 0,1221 | 0,1101 | 0,3769 | 0,2639 | 0,1524 | 0,3212 | 0,5532 | 0,6108 | 0,5074 | 0,6403 | 0,3952 | 0,4493 | 0,1461 |
| p-value (equal variance) | 0,2549 | 0,2920 | 0,3654 | 0,5728 | 0,4952 | 0,3873 | 0,5505 | **0,0327** | **0,0212** | **0,0385** | **0,0167** | **0,0136** | **0,0095** | 0,5517 |
| | | | | | Sub-period 2 (n=149-296) | | | | | | | | | |
| p-value (equal mean) | 0,6034 | 0,9126 | 0,9282 | 0,7092 | 0,7118 | 0,8066 | 0,6599 | 0,3713 | 0,6797 | 0,7243 | 0,6322 | 0,5558 | 0,1752 | 0,4470 |
| p-value (equal variance) | 0,0784 | **0,0024** | **0,0254** | 0,0654 | **0,0472** | 0,0590 | 0,0571 | **0,0242** | **0,0468** | **0,0307** | **0,0231** | 0,0526 | **0,0241** | 0,0687 |
| | | | | | Sub-period 3 (n=297-444) | | | | | | | | | |
| p-value (equal mean) | **0,0166** | **0,0274** | **0,0148** | **0,0454** | **0,0233** | **0,0244** | 0,0514 | **0,0239** | **0,0445** | 0,1489 | 0,0738 | **0,0321** | 0,1160 | 0,1181 |
| p-value (equal variance) | **0,0120** | **0,0020** | **0,0010** | **0,0001** | **0,0001** | **0,0001** | **0,0004** | **0,0003** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0001** |

Table XX: Robustness Analysis Italy

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1510 | **0,0086** | 0,2804 | 0,0554 | **0,0290** | **0,0120** | 0,0628 | 0,0580 | 0,1775 | 0,1502 | 0,1001 | **0,0399** | 0,1174 | 0,2188 |
| p-value (equal variance) | 0,6060 | 0,6122 | 0,6664 | 0,2661 | 0,2892 | **0,0333** | **0,0170** | 0,1123 | **0,0381** | **0,0194** | **0,0470** | **0,0358** | 0,1711 | 0,2976 |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0370** | **0,0461** | 0,3097 | 0,0693 | **0,0235** | **0,0225** | 0,1096 | 0,0895 | 0,2429 | 0,0731 | 0,0672 | **0,0247** | 0,0659 | 0,1570 |
| p-value (equal variance) | 0,8476 | 0,8020 | 0,9627 | 0,9324 | 0,8410 | 0,4836 | 0,7800 | 0,7474 | 0,4532 | 0,3594 | 0,4420 | 0,5679 | 0,6391 | 0,7893 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,5685 | 0,2922 | 0,5631 | 0,6604 | 0,7520 | 0,2844 | 0,5454 | 0,3166 | 0,4074 | 0,3481 | 0,3425 | 0,4911 | 0,4123 | 0,2858 |
| p-value (equal variance) | 0,4890 | 0,8913 | 0,6664 | 0,1471 | 0,4263 | 0,0954 | 0,0709 | 0,1756 | 0,2386 | 0,4245 | 0,4127 | 0,3484 | 0,4167 | 0,4673 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,4079 | **0,0165** | 0,3178 | 0,0625 | 0,0926 | 0,2059 | 0,1115 | 0,4285 | 0,4609 | 0,5362 | 0,6326 | 0,3136 | 0,6195 | 0,5344 |
| p-value (equal variance) | 0,1376 | **0,0136** | **0,0010** | **0,0010** | **0,0003** | **0,0001** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0009** | **0,0004** |



Table XXI: Robustness Analysis Japan

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0212** | **0,0375** | **0,0087** | **0,0319** | 0,0900 | **0,0409** | 0,0635 | **0,0334** | **0,0058** | **0,0018** | **0,0050** | **0,0261** | **0,0269** | **0,0141** |
| p-value (equal variance) | **0,0010** | **0,0000** | **0,0003** | **0,0000** | **0,0005** | **0,0000** | **0,0007** | **0,0011** | **0,0000** | **0,0000** | **0,0001** | **0,0000** | **0,0000** | **0,0000** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,7785 | 0,4844 | 0,5243 | 0,4818 | 0,7656 | 0,7670 | 0,8640 | 0,7920 | 0,8565 | 0,8350 | 0,7090 | 0,6933 | 0,5149 | 0,6574 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,00000** | **0,0000** | **0,0000** |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0117** | **0,0000** | **0,0164** | **0,0038** | **0,0111** | **0,0047** | **0,0415** | **0,0328** | **0,0128** | **0,0133** | **0,0308** | **0,0109** | **0,0152** | **0,0161** |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1930 | 0,3048 | 0,1072 | 0,2488 | 0,1260 | **0,0407** | 0,1109 | 0,2559 | **0,0437** | **0,0420** | 0,0723 | 0,0692 | **0,0220** | **0,0232** |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |

Table XXII: Robustness Analysis Malaysia

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0186** | 0,5561 | 0,6431 | 0,6933 | 0,3292 | 0,2661 | 0,2588 | 0,2345 | 0,3035 | 0,3223 | 0,4165 | 0,3916 | 0,5446 | 0,4368 |
| p-value (equal variance) | 0,0586 | **0,0005** | **0,0002** | 0,0620 | **0,0120** | **0,0176** | **0,0126** | **0,0131** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1899 | 0,4764 | 0,6629 | 0,9655 | 0,9595 | 0,9366 | 0,6936 | 0,9243 | 0,3559 | 0,4339 | 0,7106 | 0,5675 | 0,8722 | 0,9039 |
| p-value (equal variance) | **0,0067** | 0,0900 | 0,1093 | **0,0227** | **0,0164** | 0,1739 | **0,0107** | 0,1328 | 0,0611 | **0,0302** | **0,0302** | 0,1955 | 0,2000 | 0,2234 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 |
| p-value (equal variance) | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1303 | 0,4464 | 0,5925 | 0,7127 | 0,2592 | 0,1482 | 0,4243 | 0,4301 | 0,5596 | 0,7844 | 0,7406 | 0,9519 | 0,8199 | 0,9359 |
| p-value (equal variance) | 0,7217 | 0,7653 | 0,5002 | 0,7709 | 0,7510 | 0,6573 | 0,5857 | 0,6716 | 0,6270 | 0,3187 | 0,2687 | 0,1693 | 0,1616 | 0,2830 |



Table XXIII: Robustness Analysis Netherlands

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1432 | 0,1859 | **0,0327** | **0,0144** | 0,0773 | 0,1409 | 0,5138 | 0,2013 | 0,1311 | 0,1045 | 0,0662 | 0,0674 | 0,1119 | 0,2922 |
| p-value (equal variance) | **0,0000** | **0,0001** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,9375 | 0,9589 | 0,8960 | 0,5849 | 0,8211 | 0,8830 | 0,9606 | 0,7725 | 0,9862 | 0,8085 | 0,8336 | 0,6907 | 0,6243 | NaN |
| p-value (equal variance) | 0,7329 | 0,6087 | 0,8140 | 0,5354 | **0,0026** | 0,6623 | 0,9196 | 0,0732 | 0,8838 | 0,2132 | 0,1160 | **0,0469** | **0,0153** | NaN |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1364 | 0,5021 | 0,4415 | 0,4547 | 0,6624 | 0,8770 | 0,9981 | 0,9182 | 0,5906 | 0,5510 | 0,3758 | 0,4890 | 0,6032 | 0,9723 |
| p-value (equal variance) | **0,0054** | 0,5682 | 0,4017 | 0,3874 | 0,3259 | 0,8900 | 0,8965 | 0,8537 | 0,5119 | 0,5869 | 0,5471 | 0,4897 | 0,5113 | 0,7134 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0828** | **0,0209** | **0,0047** | **0,0034** | **0,0081** | **0,0299** | 0,1266 | 0,1121 | 0,0808 | 0,1241 | 0,0892 | 0,1129 | 0,1371 | 0,1715 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |

Table XXIV: Robustness Analysis New Zealand

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,8837 | 0,5441 | 0,6716 | 0,9459 | 0,8525 | 0,8017 | 0,7268 | 0,4972 | 0,4091 | 0,6037 | 0,7910 | 0,8933 | 0,7627 | 0,9167 |
| p-value (equal variance) | 0,0561 | 0,1811 | 0,0869 | **0,0322** | **0,0484** | **0,0204** | **0,0188** | **0,0044** | **0,0087** | **0,0020** | **0,0008** | **0,0010** | **0,0014** | 0,0826 |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,6438 | 0,3371 | 0,6850 | 0,9657 | 0,8873 | 0,7404 | 0,7556 | 0,4904 | 0,2999 | 0,5655 | 0,8088 | 0,6788 | 0,6579 | 0,5914 |
| p-value (equal variance) | 0,2832 | 0,4223 | 0,5598 | 0,5182 | 0,6193 | 0,2270 | 0,5606 | 0,2909 | 0,3056 | 0,2962 | 0,1836 | 0,1500 | 0,1565 | 0,3924 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,9042 | 0,9196 | 0,8723 | 0,8171 | 0,9226 | 0,8957 | 0,8402 | 0,7977 | 0,8972 | 0,8534 | 0,8597 | 0,9761 | 0,9195 | 0,9985 |
| p-value (equal variance) | **0,0426** | 0,1181 | **0,0411** | **0,0462** | 0,0653 | 0,1556 | **0,0461** | **0,0417** | **0,0399** | **0,0095** | **0,0113** | **0,0196** | **0,0261** | 0,4746 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,6644 | 0,1758 | 0,1470 | 0,3694 | 0,1055 | 0,2098 | 0,1162 | 0,1266 | 0,0900 | 0,2283 | 0,2640 | 0,3718 | 0,2990 | 0,1878 |
| p-value (equal variance) | 0,4661 | 0,2713 | **0,0123** | **0,0015** | **0,02180** | **0,0027** | **0,0056** | **0,0119** | **0,0134** | **0,0105** | **0,0043** | **0,0199** | **0,0321** | **0,0257** |



Table XXV: Robustness Analysis Norway

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,3093 | **0,0218** | 0,2957 | 0,2723 | **0,0253** | 0,2482 | 0,3920 | 0,0652 | 0,0691 | **0,0140** | 0,0549 | 0,0778 | 0,2061 | 0,3090 |
| p-value (equal variance) | **0,0028** | **0,0277** | **0,0296** | 0,5327 | 0,2460 | 0,3144 | 0,2283 | 0,1872 | 0,2275 | 0,1359 | 0,1325 | 0,5225 | 0,4522 | 0,2982 |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,7078 | 0,1151 | 0,8182 | 0,3246 | **0,0376** | 0,1306 | 0,2264 | 0,1174 | 0,1102 | 0,0723 | 0,0721 | 0,0765 | 0,1177 | 0,1433 |
| p-value (equal variance) | 0,5322 | 0,7277 | 0,9304 | 0,9420 | 0,9478 | 0,9060 | 0,8023 | 0,9365 | 0,9354 | 0,9644 | 0,9591 | 0,9929 | 0,9748 | 0,9574 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,2909 | 0,0538 | 0,4831 | 0,7143 | 0,5345 | 0,6030 | 0,7273 | 0,3674 | 0,3852 | 0,0770 | 0,1301 | 0,3557 | 0,5688 | 0,4871 |
| p-value (equal variance) | 0,0678 | 0,0987 | **0,0231** | 0,3815 | 0,3090 | 0,1224 | 0,3854 | 0,0573 | 0,0811 | **0,0122** | **0,0190** | 0,1983 | 0,1787 | 0,0535 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1487 | 0,2555 | **0,0372** | 0,1335 | **0,0423** | 0,3458 | 0,2882 | 0,0896 | 0,0905 | 0,0967 | 0,2504 | 0,1335 | 0,2915 | 0,3892 |
| p-value (equal variance) | **0,0002** | **0,0027** | **0,0036** | 0,0956 | **0,0048** | **0,0250** | **0,0007** | **0,0014** | **0,0017** | **0,0010** | **0,0008** | **0,0023** | **0,0027** | **0,0071** |

Table XXVI: Robustness Analysis Singapore

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total period (n=444) | | | | | | | | | |
| p-value (equal mean) | **0,0102** | **0,0122** | **0,0040** | **0,0045** | 0,0838 | 0,0696 | 0,1033 | 0,4092 | 0,1270 | 0,0633 | 0,0989 | 0,1196 | 0,3000 | 0,2328 |
| p-value (equal variance) | 0,0558 | 0,5378 | 0,4588 | 0,1672 | 0,1747 | **0,0124** | **0,0098** | 0,0732 | **0,0053** | **0,0267** | **0,0047** | **0,0025** | **0,0085** | **0,0007** |
| | | | | | Sub-period 1 (n=1-148) | | | | | | | | | |
| p-value (equal mean) | 0,0730 | 0,0639 | **0,0209** | **0,0075** | 0,1474 | 0,1228 | 0,1085 | 0,2205 | 0,1883 | **0,0465** | 0,1272 | 0,0774 | 0,2863 | 0,1349 |
| p-value (equal variance) | 0,9536 | 0,7327 | 0,8592 | 0,9242 | 0,9745 | 0,8055 | 0,7612 | 0,7601 | 0,7684 | 0,9410 | 0,4953 | 0,9790 | 0,5346 | 0,5705 |
| | | | | | Sub-period 2 (n=149-296) | | | | | | | | | |
| p-value (equal mean) | 0,1322 | 0,2839 | 0,2666 | 0,5580 | 0,5712 | 0,4064 | 0,3682 | 0,5924 | 0,1223 | 0,1891 | 0,2115 | 0,2243 | 0,3596 | 0,6758 |
| p-value (equal variance) | **0,0042** | 0,7439 | 0,7229 | 0,4665 | **0,0203** | **0,0157** | **0,0199** | 0,0833 | **0,0055** | **0,0079** | **0,0168** | **0,0002** | 0,0766 | **0,0009** |
| | | | | | Sub-period 3 (n=297-444) | | | | | | | | | |
| p-value (equal mean) | 0,0716 | **0,0484** | **0,0481** | **0,0125** | **0,0267** | 0,0655 | 0,1563 | 0,3254 | 0,2450 | 0,1670 | 0,2020 | 0,1480 | 0,2563 | 0,1698 |
| p-value (equal variance) | 0,0528 | 0,0501 | **0,0098** | **0,0001** | **0,0002** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |

Table XXVII: Robustness Analysis Spain

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total period (n=444) | | | | | | | | | |
| p-value (equal mean) | 0,1754 | 0,1978 | **0,0166** | **0,0369** | **0,0146** | 0,0708 | 0,1445 | **0,0307** | **0,0166** | **0,0044** | **0,0196** | **0,0419** | **0,0224** | **0,0254** |
| p-value (equal variance) | 0,6415 | 0,3190 | 0,2610 | 0,2604 | 0,4082 | 0,3319 | 0,3000 | 0,1510 | 0,1218 | 0,2164 | 0,3112 | 0,2288 | 0,2469 | 0,4201 |
| | | | | | Sub-period 1 (n=1-148) | | | | | | | | | |
| p-value (equal mean) | 0,0576 | 0,2135 | **0,0045** | **0,0127** | **0,0225** | 0,1673 | 0,0856 | 0,1305 | 0,0967 | **0,0045** | **0,0140** | **0,0213** | **0,0291** | **0,0069** |
| p-value (equal variance) | 0,8223 | 0,4199 | 0,9216 | 0,6779 | 0,7365 | 0,6850 | 0,6927 | 0,6575 | 0,6035 | 0,9257 | 0,7852 | 0,7918 | 0,5860 | 0,8657 |
| | | | | | Sub-period 2 (n=149-296) | | | | | | | | | |
| p-value (equal mean) | 0,6313 | 0,6069 | 0,4541 | 0,8028 | 0,5937 | 0,6689 | 0,7436 | 0,4595 | 0,2548 | 0,2944 | 0,5589 | 0,6649 | 0,6343 | 0,6380 |
| p-value (equal variance) | 0,9371 | 0,8174 | 0,7311 | 0,9635 | 0,6099 | 0,6056 | 0,4979 | 0,5897 | 0,3175 | 0,1266 | 0,5863 | 0,2461 | 0,2912 | 0,1989 |
| | | | | | Sub-period 3 (n=297-444) | | | | | | | | | |
| p-value (equal mean) | 0,4905 | 0,2864 | 0,0945 | **0,0332** | **0,0432** | 0,0590 | 0,1698 | **0,0218** | 0,0801 | 0,2016 | 0,2141 | 0,3399 | 0,1111 | 0,1488 |
| p-value (equal variance) | **0,0049** | **0,0030** | **0,0016** | **0,0016** | **0,0008** | **0,0002** | **0,0006** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0026** | **0,0097** |

Table XXVIII: Robustness Analysis Sweden

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0219** | **0,0019** | **0,0234** | **0,0313** | **0,0197** | **0,0186** | 0,0543 | 0,1296 | 0,0721 | 0,0586 | 0,0642 | 0,0795 | 0,0687 | 0,3022 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0003** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0001** | **0,0002** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1450 | **0,0202** | 0,2114 | 0,3616 | 0,2421 | 0,1726 | 0,1792 | 0,1294 | 0,0462 | 0,1241 | 0,1762 | 0,1002 | 0,2899 | 0,5113 |
| p-value (equal variance) | 0,3815 | 0,4289 | 0,7907 | 0,8289 | 0,9253 | 0,9296 | 0,8160 | 0,8041 | 0,9215 | 0,9475 | 0,9122 | 0,9382 | 0,7389 | 0,5836 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,4266 | 0,3836 | 0,5862 | 0,7072 | 0,7158 | 0,5621 | 0,7836 | 0,8959 | 0,8573 | 0,6554 | 0,5878 | 0,5436 | 0,2128 | 0,6344 |
| p-value (equal variance) | **0,0000** | **0,0000** | **0,0021** | **0,0027** | **0,0025** | **0,0003** | **0,0003** | **0,0177** | **0,0173** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0002** |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0101** | **0,0061** | **0,0099** | **0,0041** | **0,0025** | **0,0164** | **0,0083** | **0,0236** | **0,0238** | **0,0467** | 0,0843 | 0,0942 | 0,1574 | 0,1853 |
| p-value (equal variance) | 0,0898 | **0,0001** | **0,0010** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |

Table XXIX: Robustness Analysis Switzerland

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0119** | **0,0118** | 0,0771 | **0,0255** | **0,0348** | 0,2284 | 0,2831 | 0,1350 | **0,0174** | **0,0137** | **0,0368** | 0,0657 | 0,0900 | 0,1061 |
| p-value (equal variance) | **0,0095** | 0,0968 | 0,0549 | **0,0365** | **0,0029** | **0,0075** | 0,0579 | 0,0787 | **0,0007** | **0,0037** | **0,0233** | **0,0285** | **0,0254** | 0,0559 |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,2447 | 0,6605 | 0,9053 | 0,6658 | 0,4500 | 0,7522 | 0,5508 | 0,3210 | 0,3447 | 0,3604 | 0,4550 | 0,6005 | 0,7517 | 0,5684 |
| p-value (equal variance) | 0,2280 | 0,6262 | 0,2510 | 0,1267 | **0,0217** | 0,3059 | 0,7589 | 0,6651 | 0,2084 | 0,3884 | 0,5217 | 0,2994 | 0,3370 | 0,1490 |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,1221 | 0,1583 | 0,3205 | 0,2125 | 0,3296 | 0,6646 | 0,7602 | 0,5755 | 0,1492 | 0,1588 | 0,4508 | 0,3690 | 0,3591 | 0,6374 |
| p-value (equal variance) | 0,3300 | 0,6577 | 0,6906 | 0,6121 | 0,1388 | 0,4089 | 0,4244 | 0,4118 | 0,1390 | 0,3455 | 0,8152 | 0,7348 | 0,8063 | 0,9842 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | **0,0361** | **0,0036** | **0,0070** | **0,0030** | **0,0021** | **0,0417** | 0,0971 | 0,1773 | **0,0454** | 0,0502 | **0,0433** | 0,0980 | 0,0711 | 0,0833 |
| p-value (equal variance) | **0,0002** | **0,0002** | **0,0002** | **0,0008** | **0,0001** | **0,0000** | **0,0003** | **0,0007** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |

Table XXX: Robustness Analysis The UK

| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total period (n=444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,5742 | 0,8715 | 0,7343 | 0,2537 | 0,3877 | 0,3626 | 0,5941 | 0,2939 | 0,1846 | 0,2935 | 0,4128 | 0,2635 | 0,2905 | 0,4437 |
| p-value (equal variance) | **0,0052** | **0,0005** | **0,0006** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0003** | **0,0005** | **0,0002** | **0,0002** | **0,0008** | **0,0011** | **0,0015** |
| Sub-period 1 (n=1-148) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,6196 | 0,7918 | 0,9634 | 0,5476 | 0,7998 | 0,7210 | 0,9187 | 0,8592 | 0,6204 | 0,8951 | 0,8723 | 0,9031 | 0,9582 | NaN |
| p-value (equal variance) | 0,4013 | 0,1663 | 0,0826 | **0,0175** | **0,0122** | **0,0062** | **0,0022** | **0,0040** | **0,0010** | **0,0048** | **0,0029** | **0,0308** | 0,2471 | NaN |
| Sub-period 2 (n=149-296) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,8144 | 0,9794 | 0,8560 | 0,9573 | 0,9078 | 0,8795 | 0,9745 | 0,6667 | 0,6743 | 0,6155 | 0,7461 | 0,7951 | 0,7692 | 0,9240 |
| p-value (equal variance) | **0,0206** | **0,0126** | 0,2479 | 0,1404 | **0,0012** | **0,0014** | **0,0246** | 0,2165 | 0,3520 | 0,1634 | 0,1111 | 0,1164 | 0,5570 | 0,1922 |
| Sub-period 3 (n=297-444) | | | | | | | | | | | | | | |
| p-value (equal mean) | 0,3318 | 0,2795 | 0,1475 | **0,0144** | **0,0209** | **0,0792** | **0,0388** | 0,0645 | 0,0604 | 0,0870 | 0,2292 | 0,0776 | 0,1125 | 0,2625 |
| p-value (equal variance) | **0,0008** | **0,0007** | **0,0001** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** | **0,0000** |

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