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Fundamental Indexing: A Comparison Between Capitalization-, Equal- and Fundamental Weighted Indices

Abstract

For my thesis, I investigate whether fundamental weighted indices outperform the common capitalization-weighted indices. I use data from the German DAX, Swiss SMI, French CAC, European EuroStoxx 50 and U.S. S&P 100. I introduce a new weighting method, namely operating income. Furthermore, I try to avoid the subjective annual rebalancing date by sticking to a standard monthly rebalancing frequency. I find that, on average, fundamental weighted portfolios outperform both capitalization- and equal-weighted portfolios in terms of absolute and risk-adjusted performance. The outperformance of fundamental weighted portfolios is partly based on exposure to risk factors size, value and momentum, but they still produce statistically significant alpha after controlling for these risk factors. I find that the newly introduced weighting method, operating income, is the second best performing in terms of absolute and risk-adjusted performance and producing alpha, right after the best performing metric: income. Finally, I find strong evidence in favor of fundamental indexing for the DAX, CAC, EuroStoxx 50 and S&P 100 and weak evidence for the SMI.

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1. Introduction

Many researchers have found that capitalization-weighted indices are inefficient. Markowitz (2005), for example, concludes that when some of the strict CAPM assumptions fail to hold in the real world, the market portfolio is no longer efficient. Besides the obvious advantages of capitalization-weighted portfolios such as low turnover, low costs, diversification benefits and exposure to broad equity markets, it has perhaps less obvious downsides. Hsu (2006) explains that capitalization-weighted indices suffer from a 'performance drag' as they assign additional weight to stocks that are overvalued relative to their fundamentals and underweight stocks that are undervalued relative to their fundamentals. Once markets correctly price these securities, the performance of the index will be 'dragged' down by stocks with this kind of pricing error.

Besides the inefficiency of capitalization-weighted indices, ample research has been done on the (out)performance of actively managed funds. Jensen (1968), for example, concludes that actively managed funds do not generate alpha, net of fees and expenses. Hence, the growing popularity of Exchange Traded Funds or ETF's. So, if investors are attracted towards index funds, but these index funds are capitalization-weighted and therefore inefficient, a logical result is that one wishes to create an index that maintains the benefits of capitalization-weighted investing, but with a more efficient weighting scheme. This is where Fundamental Indexing comes to light.

An important paper on fundamental indexing by Arnott, Hsu, and Moore (2005) develops the theory and provides evidence about this way of constructing indices. The basic idea is that stocks are weighted based on fundamental parameters, such as revenue or employees, instead of market capitalization. Although some research has been done about this topic, there is no real consensus about which parameters to include, when to rebalance and whether the strategy works for all indices. This is where I try to provide some additional evidence, by adding an additional weighting method, namely operational income, and by sticking to a standard monthly rebalancing frequency instead subjectively choosing an annual rebalancing date. The reason for adding the new operating income measure is partly based on the association between operating income and stock returns (see Chen & Dodd (2001) and Cheng, Cheung, & Gopalakrishnan (1993)) and partly based on intuition. Intuitively, operating income provides a clear view of the core business of a company, and is unaffected by taxes and one-off items that might skew net income or cash flow. Furthermore, I investigate whether the strategy works for indices that have not yet been tested in fundamental

indexing research, namely by testing the DAX, SMI, CAC, EuroStoxx 50 and S&P 100. Most of the literature on fundamental indexing focuses on large U.S. indices, such as the S&P 500 or the Russell 1000, or on large European indices, such as the EuroStoxx 600. In addition, I include equal-weighted indices in my research, as there is evidence that this simple strategy also outperforms capitalization-weighted indices (see, for example, Plyakha, Uppal, and Vilkov (2012)). The aim of my research is to investigate whether fundamentally weighted indices outperform their capitalization- and equal-weighted counterparts in terms of absolute and risk-adjusted performance. Furthermore, I investigate whether fundamental weighted indices produce alpha, after correcting for the Fama & French Three Factor model and the Carhart Four Factor model.

I find statistically significant evidence in favor of fundamental indexing. I find that all composite weighted portfolios outperform their capitalization-weighted counterparts with an average annual outperformance of 0.69%. In addition, I find that three out of five composite weighted portfolios outperform their equal-weighted counterparts with an average annual outperformance of 0.13%[1]. Besides that, I find that four out of five composite weighted portfolios have higher Sharpe Ratios compared to their capitalization-weighted counterparts, and all five composite weighted portfolios have a positive Information Ratio[2]. Additionally, I find that four out of five composite weighted portfolios have a higher Sharpe Ratio compared to their equal-weighted counterparts, and all five composite weighted portfolios have a higher Information Ratio compared to their equal-weighted counterparts. Moreover, I find that four out of five composite weighted portfolios produce statistically significant four factor alpha at the 5% level or higher, even after adjusting for transaction costs. Finally, I find that, overall, the income weighted portfolios produce the most significant four factor alpha and have the highest absolute and risk-adjusted return. The newly introduced method, operating income, is the second best performing parameter. This holds for almost all testes indices.

The rest of this thesis is organized as follows. In Section 2, I discuss the current state of the literature. In Section 3, I describe the dataset and research methodology. In Section 4, I present my results. Finally, in Section 5, I highlight the most important conclusions.

[1] This average includes the underperformance of the two composite portfolios that did not manage to outperform their equal-weighted counterparts.

[2] The capitalization weighted portfolio is used as benchmark in order to calculate the Information Ratio.

2. Literature review

In this section, the current state of the literature will be reviewed.

2.1 The Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) is based on the work of, among others, Bachelier (1900), Hayek (1945) and Samuelson (1965). When markets are informationally efficient, price changes should be unpredictable, according to Samuelson (1965). In efficient markets, prices fully reflect all available information, according to Fama (1970). For all forms (i.e. weak, semi-strong and strong) of the EMH, there is evidence that indeed markets are efficient, and thus both technical trading strategies and fundamental analysis do not lead to excess returns (Fama, 1970).

However, Grossman and Stiglitz (1980) do provide some compelling evidence that markets may entail some form of inefficiency. They argue that due to the fact that it is costly to gather information, security prices cannot perfectly reflect the available information, since if they did, those who spend resources on gathering said information would not receive any compensation for doing so. Therefore, it must be possible to earn excess returns by collecting information and trading on it. As a result, it is likely that markets do exhibit some kind of inefficiency (Grossman & Stiglitz, 1980).

2.2 The Capital Asset Pricing Model

The Capital Asset Pricing Model by Sharpe (1964), Litner (1965) and Black (1972) builds on the theoretical framework that markets are efficient. In combination with the "mean-variance" optimization of Markowitz (1952, 1959), it leads to conclude that investors are best off holding the CAPM market portfolio, which is a portfolio combined of all the risky assets weighted by their respective market values, as it provides the best risk-reward tradeoff.

A number of studies have tested the CAPM using capitalization-weighted portfolios, and found that the CAPM relationship does not hold. This leads to either a rejection of the mean-variance optimality of the market portfolio, or to a rejection of the equity market portfolio as the CAPM market portfolio (i.e. there should be other assets included in the CAPM market portfolio besides equities). There are numerous papers that reject the efficiency of capitalization-weighted market indices, such as Ross (1978), Gibbons (1982), Jobson and Korkie (1982),

Shanken (1985), Kandel and Stambaugh (1987), Gibbons, Ross, and Shanken (1989), Zhou (1991), and MacKinlay and Richardson (1991). Roll (1977) concludes that it is not possible to test the CAPM unless the true market portfolio and its exact composition are known, implying that all assets should be used in the CAPM test and not only equities as proxy for the market portfolio. Furthermore, he states that the mean-variance efficiency of the proxy does not imply that the market portfolio itself is efficient, and vice versa.

Additionally, Fama and French (1992) find that average stock returns are not positively related to the market 'beta' and therefore reject the CAPM. Furthermore, Markowitz (2005) concludes that if some of the strict CAPM assumptions are put into real world perspective, in particular, the assumption that investors have unlimited borrowing capacity, it follows that the market portfolio is no longer efficient.

2.3 Capitalization-Weighted Indices

A capitalization-weighted index is an index that is weighted according to the market capitalization of the individual securities within the index. The market capitalization of a company is calculated by multiplying the share price with the firm's outstanding shares. Most stock market indices are capitalization-weighted indices, including the popular Standard and Poor's (S&P) 500 Index.

The constructors of indices often impose extra rules regarding the selection of stocks that are included in the index. For instance, they might have requirements for the minimum free-float of shares or market capitalization to be included in the index. This might lead to an adjustment of the weight of an individual stock within an index. For instance, a company that has a relative small free-float will receive a smaller weight in the index due to the rules imposed by the constructor. In addition, constructors of indices might also put a maximum to the weight each individual stock can have within the index. For instance, the Swiss Market Index (SMI) caps the weight of each individual stock at 20% of the total index.

Investing in capitalization-weighted indices has several benefits, as pointed out by Arnott, Hsu, and Moore (2005). Due to the fact that capitalization-weighted indexing is a passive strategy that requires little trading, it has lower costs compared to active management. Furthermore, by the way of constructing the index, it automatically rebalances and trading is only required when the composition of the index changes. Overall, it is a convenient way for investors to get exposure to broad equity markets whilst maintaining diversification benefits.

Besides the advantages of capitalization-weighted indices, there are also downsides to this strategy. Hsu (2006) examined capitalization-weighted portfolios in a non-CAPM setting. Where a company can lose a substantial portion of its market value within one day, this is usually not the case for fundamental parameters such as sales or employees. Therefore, capitalization-weighting could lead to suboptimal portfolio return characteristics as a company's market capitalization is too noisy relative to its fundamentals (Hsu, 2006). Mathematically, weighting indices based on their market capitalization overweights stocks that are currently overvalued relative to their (unknown) discounted future free cash flows (the true fair value of the stock) and at the same time underweights stocks that are undervalued (i.e. have a price that is currently lower compared to their true fair value). Stocks will move towards their true fair value over time, and subsequently, capitalization-weighted portfolios will experience a larger price decline than other non-capitalization-weighted portfolios, as they have a larger exposure to stocks with this pricing error (Hsu, 2006). He, therefore, concludes that capitalization-weighted indices suffer from a 'performance drag' due to their exposure to stocks with this kind of pricing error. In addition, Treynor (2005) finds that when prices are noisy and therefore do not completely reflect the fundamentals of the firm, capitalization-weighted portfolios are likely to be sub-optimal. Furthermore, Haugen and Baker (1991) provide evidence that, even in informationally efficient markets, following the market is an inefficient investment strategy.

2.4 Exchange Traded Funds and Their (Dis)Advantages

The amount invested in products that seek to replicate the performance of a specific index has grown vastly over the last few years. Exchange Traded Funds (ETF's) or 'index trackers' seek to replicate the performance of a specific index. They make no adjustments regarding the constituents or weighting methodology of the index they seek to replicate, hence the term 'passive investing'. Globally, the ETP & ETF market has grown from $ 79 billion in 2000 to $ 1.7 trillion in 2012 (Aggarwal & Schofield, 2014). As most indices in the world are capitalization-weighted, most ETF's are too. Thus, they provide a good opportunity to reap all the benefits of capitalization-weighted investing.

Similar to stocks, ETF's can be bought and sold in the secondary market rather than being purchased from and sold to a mutual fund. This may provide some benefit to investors when markets are very volatile and they wish to quickly sell their positions (Gastineau, 2001).

Another benefit of ETF's are their relatively low costs compared to mutual funds. ETF's that track broadly diversified indices have expense ratios in the 0.18 – 0.25 percent range (Dellva, 2001). In addition, Wermers (2000), compared mutual funds with the Vanguard Index 500 Fund. He found that between 1976 and 1994, mutual funds on average have expense ratios of 0.79 percent per year and transaction costs of 0.80 percent per year. Whereas the Vanguard Index 500 Fund had, in the same period, an average annual expense ratio of 0.28 percent and average transaction costs of 0.07 percent on an annual basis. However, expense ratios of ETF's have decreased dramatically the last few years (Nowak, 2017). For instance, the annual total expense ratio of the iShares Core S&P 500 ETF is currently 0.04% (Nowak, 2017).

The shift towards 'passive' investing may be a result of some important findings about the performance of actively managed mutual funds. Actively managed funds seek to generate outperformance (or 'alpha') compared to their benchmark (which is often a capitalization-weighted index). Jensen (1968) found that, on average, actively managed funds do not generate alpha, net of fees and expenses. His findings are supported by Busse, Goyal, and Wahal (2010), Barras, Scaillet, and Wermers (2010), and Jones and Wermers (2011).

Besides the previously described benefits of investing in ETF's, several disadvantages must also be highlighted. Shin and Soydemir (2010) find that the tracking errors of ETF's are significantly different from zero and display persistence. The tracking error is the difference between the performance of a portfolio, in this case an ETF, and the performance of a benchmark. In addition, they find that risk-adjusted returns are significantly lower compared to the respective benchmark returns, indicating that investing in capitalization-weighted ETF's leads to an underperformance relative to their capitalization-weighted benchmark. They, therefore, conclude that a passive investment strategy does not provide a significant benefit compared to the benchmark. Although this is not the goal of an ETF, it does indicate that by investing in capitalization-weighted ETF's, investors will systematically underperform the respective indices.

On a more economic level, Israeli, Lee, and Sridharan (2017) argue that an increase in ETF ownership leads to higher trading costs and lower liquidity for stocks that are included in the ETF. Furthermore, they find that an increase in ETF ownership decreases the pricing efficiency of the stocks that are included in the ETF. In addition, they find that an increase in ETF ownership leads to a decrease in the number of analysts that are covering the firms that are included in the ETF. They, therefore, conclude that increased ETF ownership leads to lower benefits from information

acquisition and higher trading costs, resulting in less informative security prices for the firms that are included in an ETF.

Ben-David, Franzoni, and Moussawi (2018) report that stocks that are included in an ETF become more volatile due to non-fundamental reasons, for instance, because much liquidity is 'locked up' by the investment vehicle that operates the ETF. In addition, in times of distress, the liquidity of ETF's dries up which leads to an amplification of the market shock.

2.5 Capitalization Indifferent Strategies

Besides weighting portfolios based on market capitalization, there are other ways of assigning weights to stocks within a portfolio. First, the equal-weighted strategy will be reviewed. Subsequently, the theory about fundamental indexing will be discussed.

2.5.1 Equal-Weighted Portfolios

Plyakha, Uppal, and Vilkov (2012) examine whether equal-weighted portfolios outperform capitalization- and price-weighted portfolios, using stocks from the S&P 500. They find that, even after adjusting for transaction costs, the equal-weighted portfolio significantly outperforms the capitalization- and price-weighted portfolio by 238 and 88 basis points, respectively, on an annual basis. Additionally, they find that the alphas are 2.5 times higher for the equal-weighted portfolio compared to the capitalization- and price-weighted portfolios. They conclude that the outperformance that is generated by the equal-weighted strategy is partly because of its higher exposure to market, size and value risk factors and partly because of the monthly portfolio rebalancing that takes advantage of reversal and idiosyncratic volatility.

Bolognesi, Torluccio, and Zuccheri (2013) also examine whether equal-weighted indices outperform capitalization-weighted indices, but instead using European data of the DJ Euro Stoxx Index. Specifically, they investigate the difference in monthly, quarterly, semiannually and annual rebalancing. They find that all equal-weighted indices significantly outperform their value weighted counterpart. Furthermore, they show that quarterly rebalancing results in the largest positive difference for the equal-weighted indices. They make the implication that reweighting the portfolio into equal weights results in a contrarian investment strategy, as they continuously sell overvalued stocks and buy undervalued stocks at each rebalancing point.

In line with Plyakha et al. (2012) and Bolognesi et al. (2013), Malladi and Fabozzi (2017) find that the excess returns of equal-weighted portfolios with respect to capitalization-weighted portfolios are for 85% due to rebalancing effects and for 15% due to size effects. This leads to the conclusion that rebalancing and the frequency of rebalancing is an important factor in the outperformance of equal-weighted portfolios with respect to capitalization-weighted portfolios.

2.5.2 Fundamental Weighted Portfolios

Arnott, Hsu, and Moore (2005) are the first to provide theoretical evidence for "Fundamental Indexation", which is essentially a way of compiling and weighting indices based on fundamental parameters instead of market capitalization. The origin of fundamental indexing is based on the concern that market capitalization is a volatile way of measuring the size of a company or its true fair value. Arnott et al. (2005) claim that non-capitalization-weighted indices consistently outperform the traditional capitalization-weighted equity market indices at a lower risk level, whilst maintaining many of the benefits of traditional indexing. They construct indices, using U.S. data of the S&P 500, using revenue, book value of equity, sales, dividend, cash flow and total employees as weights. Additionally, they construct a composite index that equally weights book value of equity, cash flow, sales and dividend. Their results show that all fundamental weighted indices provide excess return compared to the capitalization-weighted index, even after adjusting for volatility. Their sales weighted index has the highest absolute excess return (2.56%). Their cash flow weighted index has the highest Sharpe and Information Ratio, 0.459 and 0.57 respectively.

Stotz, Wanzenried, and Döhnert (2010) use European data from the DJ Stoxx 600 in their analysis. Similar to Arnott et al. (2005) they use book value, cash flow, dividend, sales and a composite weighting scheme. They find that all fundamental weighting methods provide excess return compared to the capitalization-weighted index. Even after adjusting for the Carhart (1997) risk factors, they find statistically significant alphas at the 5% level for the cash flow and dividend weighted portfolios and at the 1% level for the book value of equity and the composite weighted portfolios. They also show that fundamentally weighted indices are not riskier than capitalization-weighted indices. They, therefore, conclude that fundamental weights provide a better reflection of the true fair value of a company compared to the market capitalization, as the latter may be biased by the misperceptions of investors about the company's true fair value. In addition, they

claim that using a composite weighting metric is preferred over a single weighting method, as it reduces valuation errors in single fundamental weights. Their results also provide evidence for this claim, as the composite portfolio delivers the highest Jensen's and Fama & French's Alpha.

Walkshäusl and Lobe (2010) provide additional evidence for fundamental indexing using data from 50 developed and emerging countries. They construct country indices by using all stocks that are traded in that country. They find that for 19 countries, fundamental indices have positive alphas that are statistically significant at the 5% level or better. In addition, they find that cash flow, dividends, income and a composite measure have statistically significant alphas at the 1% level, based on the Carhart (1997) Four Factor model. Their conclusion is that fundamental indexing is not just a simple value strategy, but rather a way of producing alpha based on fundamental parameters.

2.5.3 Opponents of Fundamental Indexing

Besides the proponents of fundamental indexing, there are also various opponents of the strategy. Among them is Perold (2007), who concludes that holding a capitalization-weighted portfolio does not necessarily implicate that the portfolio has an intrinsic performance drag (as described in section 2.3). His rationale for this claim is that stocks are randomly mispriced. He claims that fundamental indexing is a value investing strategy that is based on active stock picking. However, he fails to provide any empirical evidence to support his claims.

Other opponents did provide the empirical evidence that was missing in Perolds' (2007) paper. Jun and Malkiel (2008) investigate fundamental indexing using data from the S&P 500 between 1962 and 2007. They find that the outperformance of the fundamental weighted indices is merely based on loadings on the size and value factors. They did not find any statistically significant Fama & French Three Factor Alphas for the fundamental weighted indices. Their findings are supported by Blitz and Swinkels (2008) and Chen, Dempsey, and Lajbcygier (2015). Chen et al. (2015) use data from the Dow Jones Industrial average the Russell 1000 between 1962 and 2009. Blitz and Swinkels (2008) use data from the RAFI 1000 (Research Affiliates Fundamental Index for the top 1000 U.S. based equities) between 1962 and 2005 to support their claims. They conclude that fundamental indexing is an active value investing strategy because: 1) it appears to be at odds with the market equilibrium, 2) it does not represent a simple buy and hold strategy and 3) it requires some subjective choices in constructing the portfolios.

3. Data and Research Methodology

In this section, the data and research methodology will be described.

3.1 Constituent and Index Data

In comparison to Arnott et al. (2005) and Döhnert et al. (2010), who use major U.S. or European stock indices, this thesis will focus on three of the biggest European individual country stock indices, namely the German DAX, the Swiss SMI and the French CAC. The reason for choosing these indices is because they have not been used in fundamental research yet. In addition, the larger EuroStoxx 50 and S&P 100 will also be used, in order to have a robustness check to the findings of the individual country indices.

For the SMI, CAC, EuroStoxx 50 and S&P 100 index the historical index constituents are downloaded from Compustat. For the DAX index, the list of index constituents is retrieved from the official Deutsche Boerse website (Deutsche Boerse is the owner and constructor of the DAX index). The stock returns (using the "RI" symbol), market values (using the "MV" symbol) and free-float market values (using the "FFMV" symbol) are downloaded from Datastream. The data periods for the indices are somewhat different, due to the availability in either Compustat or Datastream. In order to construct the capitalization-weighted index (reference portfolio), the weight of every stock will be its market capitalization as portion of the total market capitalization of the index:

$$w_{i,t} = \frac{FFMC_{i,t}}{\sum_{j=1}^{N} FFMC_{j,t}}$$

Where 'FFMC' is the free-float market capitalization of stock i at time t and N denotes the number of stocks in the index. Note that when free-float market capitalization is not available, the regular market capitalization is used. For most companies, free-float market capitalization is only available since 3/31/1997 via Datastream. The absence of this data could explain some of the tracking error of the reference portfolios compared to the index. The reference portfolios are calculated using monthly returns and monthly weights.

The reproduced returns from the reference portfolio are compared to the returns of the actual index, in order to verify whether the constituent list that is used is a good representation of the actual index. This also makes sure that the results that are generated are well applicable to the actual index.

3.1.1 DAX

The DAX is Germany's best-known index and is often seen as the benchmark for the German equity market. The index was founded on 1 July 1988 and tracks the performance of the 30 largest and most liquid companies in Germany. The DAX represents about 80% of the total German equity market. It is a rule-based index, which means that the constituents are selected based on predetermined rules, and are not subject to a committee that selects the constituents. In order to qualify for a listing in the DAX, companies need to have their registered office or operational headquarters in Germany. Alternatively, they can also have their headquarters in a member state of the European Union but do need to generate a significant portion of their trading turnover on the Frankfurt Stock Exchange. The weight of shares in the index is based on the market capitalization of the shares in free-float. The weight of an individual share is capped at 10%. The index is recomposed on an annual basis and rebalancing occurs on a quarterly basis.

For the analysis, the time period from 31/12/1988 to 31/12/2018 is used, which covers almost the entire lifespan of the DAX index. In the entire period, 59 companies were, at some point in time, included in the index. The entire dataset is converted to Euro's, to make sure that the conversion from the German Marks to Euro does not cause a bias. The reference portfolio is compared to the DAX 30 Performance (Total Return) Index, which tracks the performance of the actual index.

Table 1 shows the descriptive statistics of the DAX and the reference portfolio. In Graph 1, the cumulative return of the DAX and the reference portfolio are displayed. In Graph 2, the relative cumulative performance of the reference portfolio compared to the DAX Index is displayed.

Table 1: Comparison DAX Index and Reference Portfolio DAX

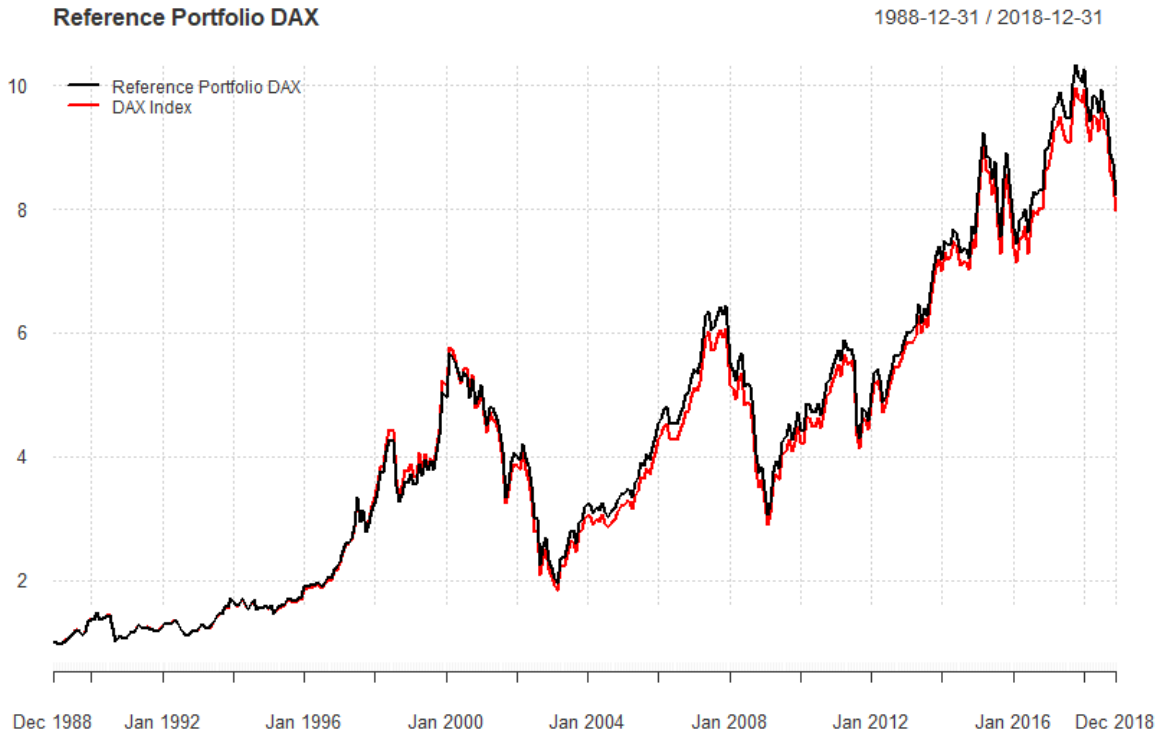
This table includes the Ending Value of €100 invested in either the DAX Index or the Reference Portfolio DAX, over the time period 31/12/1988 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the DAX Index is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
DAX Index	€ 795.18	0.0716	0.2052					
Reference Portfolio DAX	€ 820.92	0.0727	0.2022	0.0183	0.0011	0.9961	0.9811***	0.9921

***, **, * indicate the significance at the 1%, 5%, and 10% levels.

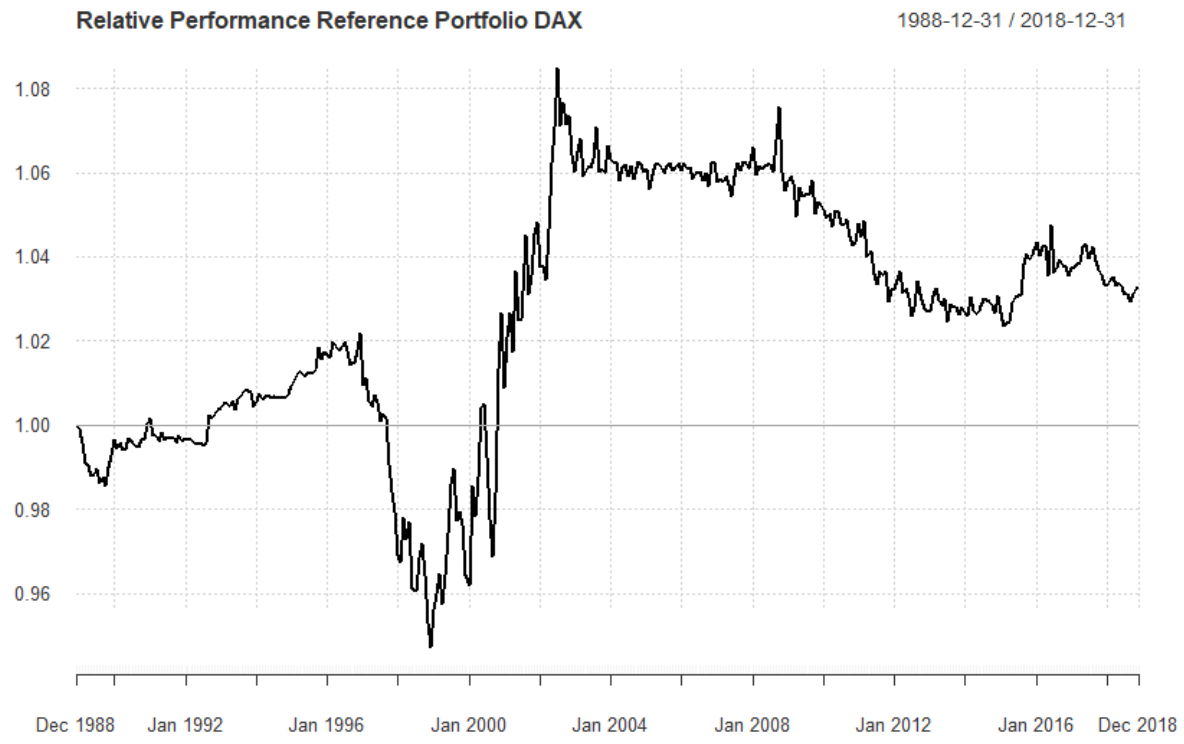
Graph 1: Comparison Cumulative Return DAX Index and Reference Portfolio DAX

This graph shows the Total Return and the Ending Value of €1 invested in either the DAX Index or the Reference Portfolio DAX, over the time period 31/12/1988 – 31/12/2018.



Graph 2: Relative Performance Reference Portfolio DAX

This graph shows the relative cumulative performance of the Reference Portfolio DAX compared to the DAX Index, over the time period 31/12/1988 – 31/12/2018.



As can be seen from both the table and the graphs, the reference portfolio shows great resemblance compared to the actual index. The reference portfolio performs somewhat less around the 2000 crisis compared to the actual index. After that, it performs somewhat better compared to the actual index. Overall, the reference portfolio has an annual outperformance of 0.11% and a tracking error of 1.83% (see Table 1).

3.1.2 SMI

The SMI is Switzerland's best-known index and is often seen as the benchmark for the Swiss equity market. The index was founded on 30 June 1988 and tracks the performance of the 20 largest and most liquid companies in Switzerland. The SMI represents about 80% of the total Swiss equity market. It is a rule-based index, which means that the constituents are selected based on predetermined rules, and are not subject to a committee that selects the constituents. In order to

qualify for a listing in the SMI, companies must be primary listed in Switzerland and the minimum free-float of shares must be equal to or greater than 20%. The weight of shares in the index is based on the market capitalization of the shares in free-float. The weight of an individual share is capped at 20%. The index is recomposed on an annual basis and rebalancing occurs on a quarterly basis.

For the analysis, the time period from 30/04/1993 to 31/12/2018 is used, which covers the largest part of the lifespan of the SMI index. The analysis does not cover the entire lifespan of the SMI as the total return index of the SMI is only available as of 30/04/1993 via Datastream. In the entire period, 42 companies were, at some point in time, included in the index. The reference portfolio is compared to the Swiss Market (Total Return) Index, which tracks the performance of the actual index.

Table 2 shows the descriptive statistics of the SMI and the reference portfolio. In Graph 3, the cumulative return of the SMI and the reference portfolio are displayed. In Graph 4, the relative cumulative performance of the reference portfolio compared to the SMI Index is displayed.

Table 2: Comparison SMI Index and Reference Portfolio SMI

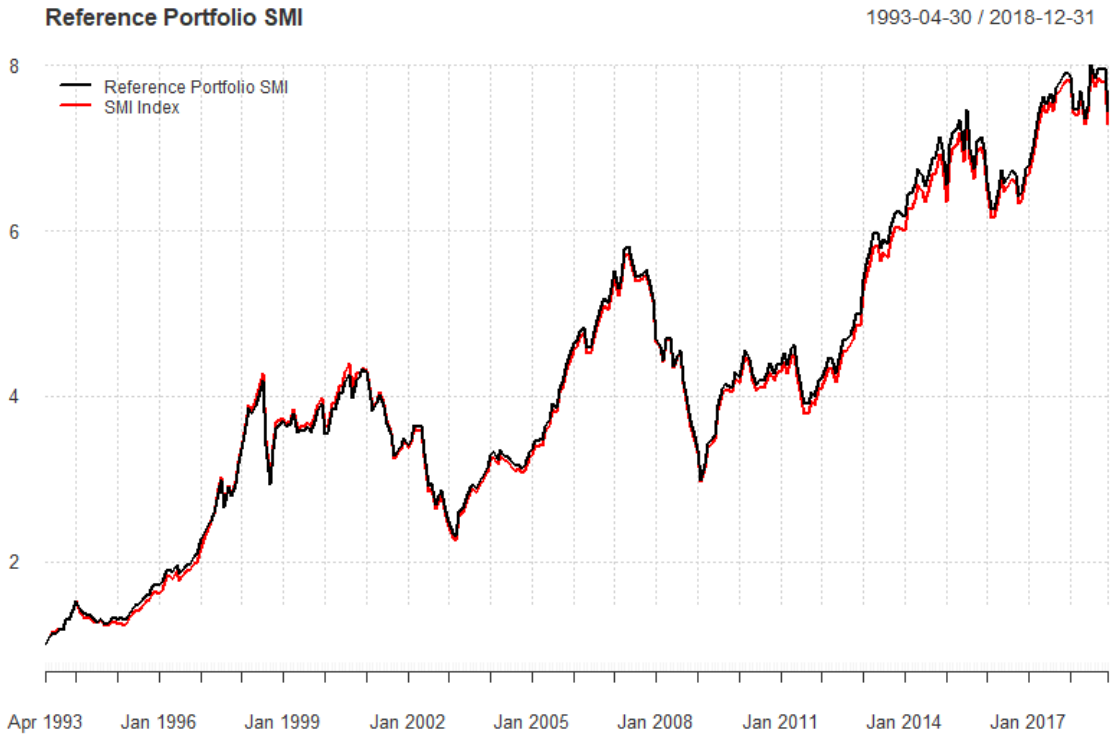
This table includes the Ending Value of €100 invested in either the SMI Index or the Reference Portfolio SMI, over the time period 31/05/1993 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the SMI Index is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
SMI Index	€ 728.00	0.0804	0.1531					
Reference Portfolio SMI	€ 743.43	0.0813	0.1506	0.0162	0.0008	0.9944	0.9786***	0.9888

***, **, * indicate the significance at the 1%, 5%, and 10% levels.

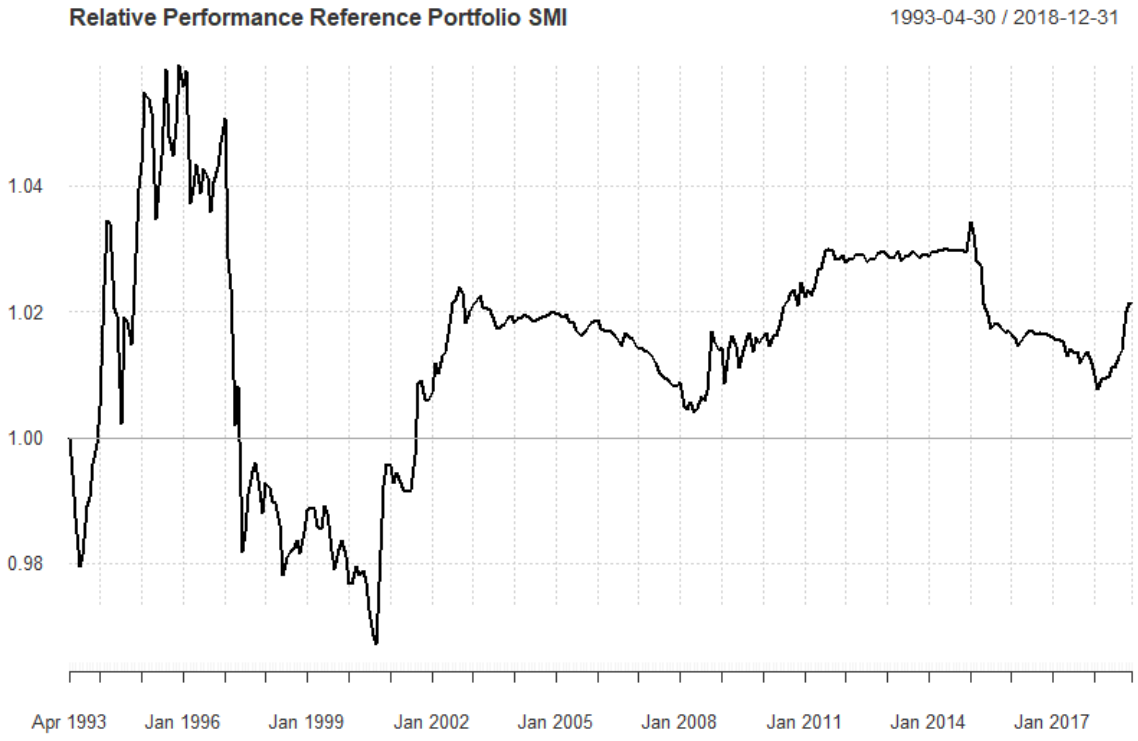
Graph 3: Comparison Cumulative Return SMI Index and Reference Portfolio SMI

This graph shows the Total Return and the Ending Value of €1 invested in either the SMI Index or the Reference Portfolio SMI, over the time period 30/04/1993 – 31/12/2018.



Graph 4: Relative Performance Reference Portfolio SMI

This graph shows the relative cumulative performance of the Reference Portfolio SMI compared to the SMI Index, over the time period 30/04/1993 – 31/12/2018.



As can be seen from both the table and the graphs, the reference portfolio shows great resemblance compared to the actual index. The reference portfolio performs somewhat better in the beginning of the sample period and appears to be performing somewhat less during the 2000 financial crisis. After that, the reference portfolio performs slightly better compared to the actual index. Overall, the reference portfolio has an annual outperformance of 0.08% and a tracking error of 1.62% (see Table 2).

3.1.3 CAC

The CAC is France's best-known index and is often seen as the benchmark for the French equity market. The index was founded in June 1988 and tracks the performance of the 40 largest and most liquid companies in France. The CAC represents about 80% of the total French equity market. It is a rule-based index, which means that the constituents are selected based on predetermined rules, and are not subject to a committee that selects the constituents. In order to qualify for a listing in

the CAC, companies must be primary listed on Euronext Paris and the minimum free-float of shares must be equal to or greater than 20%. Alternatively, companies that have significant presence of business assets and/or head-office activities in France are also eligible for selection. The weight of shares in the index is based on the market capitalization of the shares in free-float. The weight of an individual share is capped at 15%. The index is recomposed on a quarterly basis and rebalancing occurs on a yearly basis.

For the analysis, the time period from 31/12/1988 to 31/12/2018 is used, which covers almost the entire lifespan of the CAC index. In the entire period, 92 companies were, at some point in time, included in the index. The entire dataset is converted to Euro's, to make sure that the conversion from the French Francs to Euro does not cause a bias. The reference portfolio is compared to the France CAC 40 (Total Return) Index, which tracks the performance of the actual index.

Table 3 shows the descriptive statistics of the CAC and the reference portfolio. In Graph 5, the cumulative return of the CAC and the reference portfolio are displayed. In Graph 6, the relative cumulative performance of the reference portfolio compared to the CAC Index is displayed.

Table 3: Comparison CAC Index and Reference Portfolio CAC

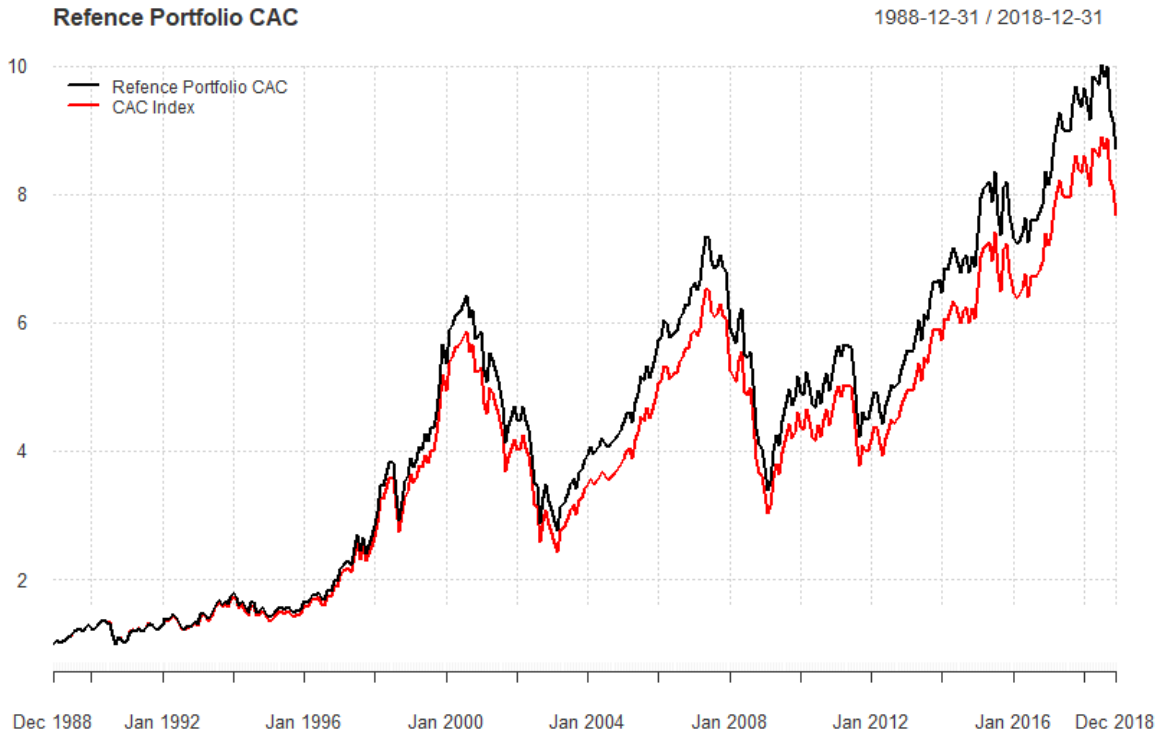
This table includes the Ending Value of €100 invested in either the CAC Index or the Reference Portfolio CAC, over the time period 31/12/1988 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the CAC Index is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
CAC Index	€ 766.91	0.0703	0.1818					
Reference Portfolio CAC	€ 868.74	0.0747	0.1812	0.0074	0.0042	0.9992	0.9957***	0.9984

***, **, * indicate the significance at the 1%, 5%, and 10% levels.

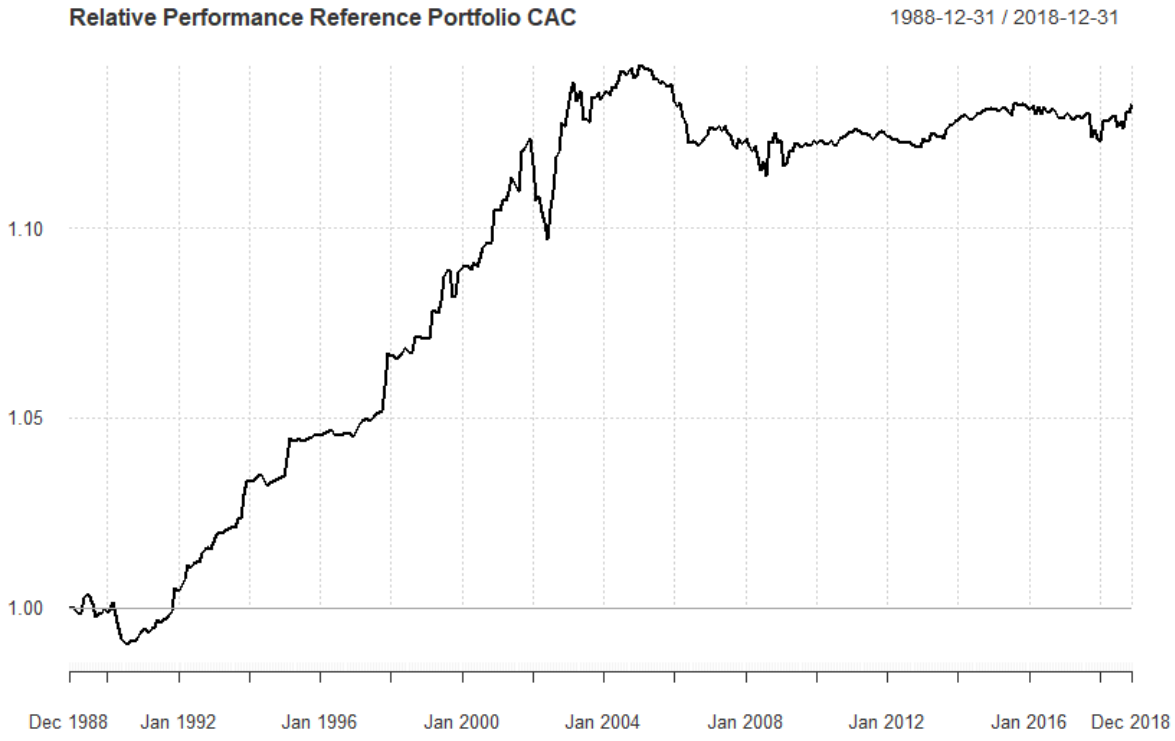
Graph 5: Comparison Cumulative Return CAC Index and Reference Portfolio CAC

This graph shows the Total Return and the Ending Value of €1 invested in either the CAC Index or the Reference Portfolio CAC, over the time period 31/12/1988 – 31/12/2018.



Graph 6: Relative Performance Reference Portfolio CAC

This graph shows the relative cumulative performance of the Reference Portfolio CAC compared to the CAC Index, over the time period 31/12/1988 – 31/12/2018.



As can be seen from both the table and the graphs, the reference portfolio shows great resemblance compared to the actual index. The reference portfolio appears to perform increasingly better starting in 1992 until 2004. This 'drift' in performance indicates that something is going wrong in the first half of the dataset. This problem could be caused by errors in the constituent list or missing data of older companies. After that, the reference portfolio maintains a higher performance that is relatively stable. Overall, the reference portfolio has an annual outperformance of 0.42% and a tracking error of 0.74% (see Table 3).

3.1.4 EuroStoxx 50

The EuroStoxx 50 is a European blue-chip index, which includes the 50 largest companies in terms of free-float market capitalization in 11 Eurozone countries, namely Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. The index was founded on 31 December 1991. The EuroStoxx 50 represents about 60% of the total European

equity market. It is a rule-based index, which means that the constituents are selected based on predetermined rules, and are not subject to a committee that selects the constituents. The index is constructed by taking all the companies of the 19 EURO STOXX Supersector indices and ranking them by free-float market capitalization. The largest 50 stocks are included in the index. The weight of shares in the index is based on the market capitalization of the shares in free-float. The weight of an individual share is capped at 10%. The index is recomposed on an annual basis.

For the analysis, the time period from 31/01/2001 to 31/12/2018 is used, which covers the largest part of the lifespan of the EuroStoxx 50 index. The analysis does not cover the entire lifespan as the total return index of the EuroStoxx 50 is only available as of 31/01/2001. In the entire period, 107 companies were, at some point in time, included in the index. The entire dataset is converted to Euro's, to make sure that the different currencies do not cause a bias. The reference portfolio is compared to the EuroStoxx 50 (Total Return) Index, which tracks the performance of the actual index.

Table 4 shows the descriptive statistics of the EuroStoxx 50 and the reference portfolio. In Graph 7, the cumulative return of the EuroStoxx 50 and the reference portfolio are displayed. In Graph 8, the relative cumulative performance of the reference portfolio compared to the EuroStoxx 50 Index is displayed.

Table 4: Comparison EuroStoxx 50 Index and Reference Portfolio EuroStoxx 50

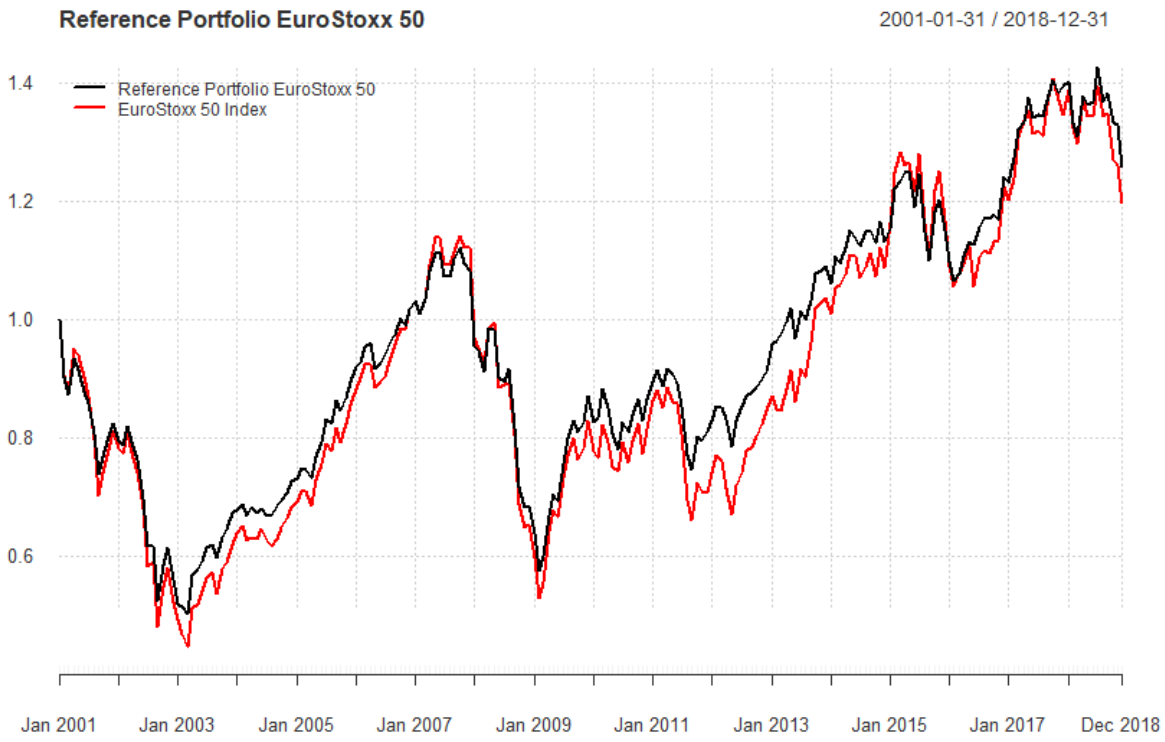
This table includes the Ending Value of €100 invested in either the EuroStoxx 50 Index or the Reference Portfolio EuroStoxx 50, over the time period 31/01/2001 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the EuroStoxx 50 Index is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
EuroStoxx 50 Index	€ 119.42	0.0100	0.1822					
Reference Portfolio EuroStoxx 50	€ 125.42	0.0127	0.1498	0.0541	0.0027	0.9657	0.7935***	0.9322

***, **, * indicate the significance at the 1%, 5%, and 10% levels.

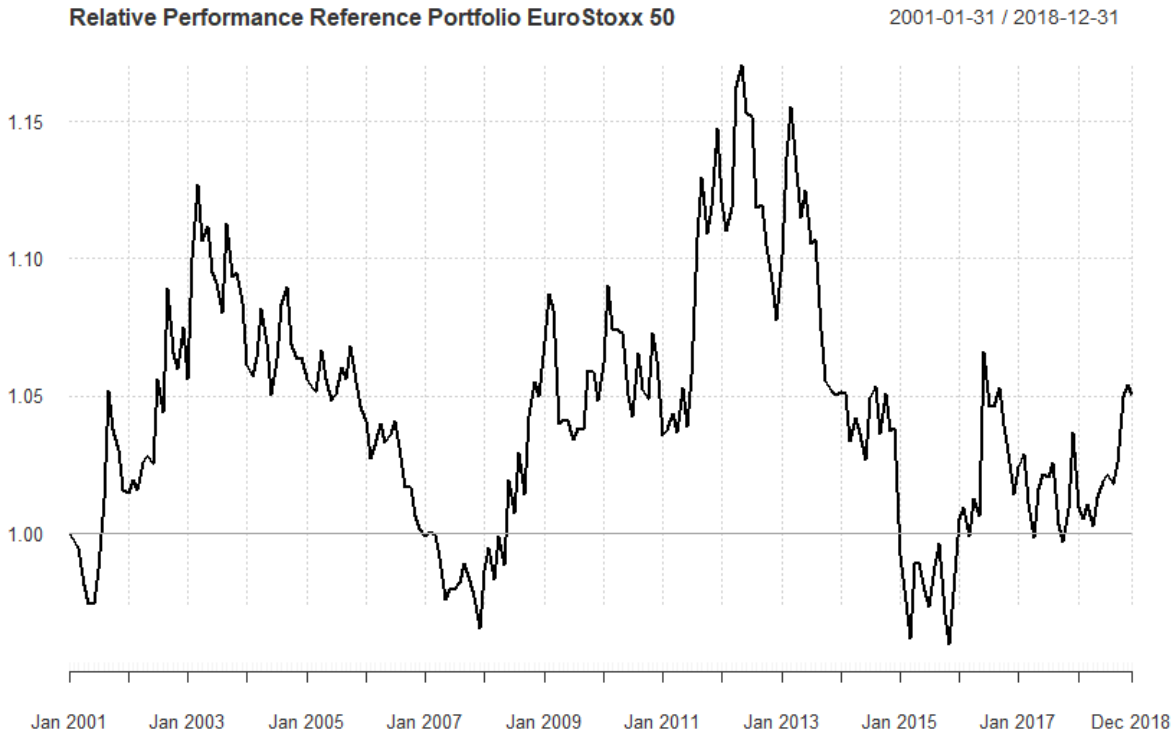
Graph 7: Comparison Cumulative Return EuroStoxx 50 Index and Reference Portfolio EuroStoxx 50

This graph shows the Total Return and the Ending Value of €1 invested in either the EuroStoxx 50 Index or the Reference Portfolio EuroStoxx 50, over the time period 31/01/2001 – 31/12/2018.



Graph 8: Relative Performance Reference Portfolio EuroStoxx 50

This graph shows the relative cumulative performance of the Reference Portfolio EuroStoxx 50 compared to the EuroStoxx 50 Index, over the time period 31/01/2001 – 31/12/2018.



As can be seen from both the table and the graphs, the reference portfolio shows great resemblance compared to the actual index. The reference portfolio appears to perform somewhat better, but with spikes of underperformance during 2008 and 2015. Overall, the reference portfolio has an annual outperformance of 0.27% and a tracking error of 5.41% (see Table 4).

3.1.5 S&P 100

The S&P 100 is a sub-set of the S&P 500, and is designed to measure the performance of large-cap companies in the United States. The index consists of 100 blue chip companies that are active in different industries. In order to be included, the companies should be among the larger and more stable companies in the S&P 500. They must also have listed options. The constituent selection is at the discretion of the Index Committee. So, compared to the previous discussed indices, the S&P 100 is not an entirely rule-based index. The Index Committee takes into account sector balance when selecting the companies for the S&P 100. The index was founded in September 1989. The

S&P 100 represents about 65% of the S&P 500 and more than 50% of the total U.S. equity market. The weight of shares in the index is based on the market capitalization of the shares in free-float. The weight of an individual share is capped at 10%. The index is recomposed on an annual basis.

For the analysis, the time period from 31/01/1990 to 31/12/2018 is used, which covers almost the entire lifespan of the S&P 100 index. In the entire period, 224 companies were, at some point in time, included in the index. The analysis does not cover the entire lifespan as the total return index of the S&P 100 is only available as of 31/01/1990. The reference portfolio is compared to the S&P 100 (Total Return) Index, which tracks the performance of the actual index.

Table 5 shows the descriptive statistics of the S&P 100 and the reference portfolio. In Graph 9, the cumulative return of the S&P 100 and the reference portfolio are displayed. In Graph 10, the relative cumulative performance of the reference portfolio compared to the S&P 100 Index is displayed.

Table 5: Comparison S&P 100 Index and Reference Portfolio S&P 100

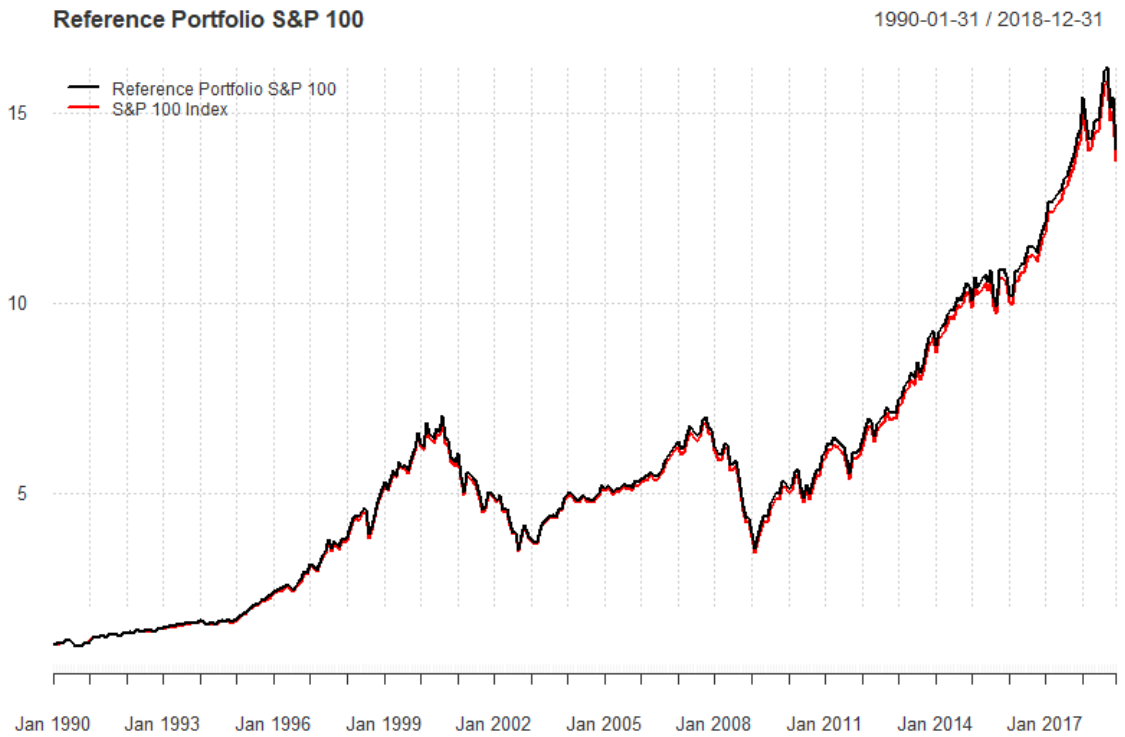
This table includes the Ending Value of €100 invested in either the S&P 100 Index or the Reference S&P 100, over the time period 31/01/1990 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the S&P 100 Index is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
S&P 100 Index	€ 1369.09	0.0947	0.1439					
Reference Portfolio S&P 100	€ 1401.00	0.0956	0.1432	0.0054	0.0008	0.9993	0.9944***	0.9986

***, **, * indicate the significance at the 1%, 5%, and 10% levels.

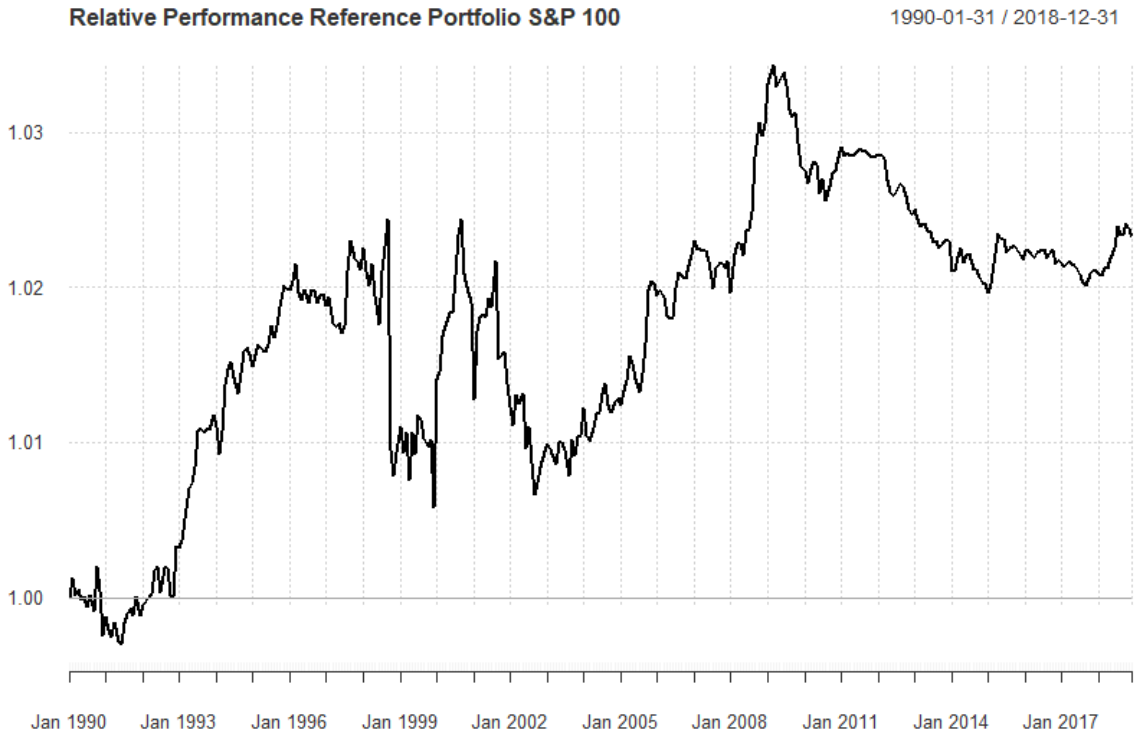
Graph 9: Comparison Cumulative Return S&P 100 Index and Reference Portfolio S&P 100

This graph shows the Total Return and the Ending Value of €1 invested in either the S&P 100 Index or the Reference Portfolio S&P 100, over the time period 31/01/1990 – 31/12/2018.



Graph 10: Relative Performance Reference Portfolio S&P 100

This graph shows the relative cumulative performance of the Reference Portfolio S&P 100 compared to the S&P 100 Index, over the time period 31/01/1990 – 31/12/2018.



As can be seen from both the table and the graphs, the reference portfolio shows great resemblance compared to the actual index. The reference portfolio appears to perform somewhat better in almost the entire sample period. Overall, the reference portfolio has an annual outperformance of 0.08% and a tracking error of 0.54% (see Table 5).

3.2 Fundamental Data

In order to construct the fundamental portfolios, various data is retrieved from Datastream. Similar to Arnott et al. (2005), Stotz et al. (2010) and Walkhausl and Lobe (2010), Book Value of Equity, Cash Flow, Dividend, Revenue, Employees and Income are used. In addition to that, Operating Income is used as new measurement variable. Chen and Dodd (2001) show that operating income significantly explains a portion of stock returns. In addition, Cheng, Cheung, and Gopalakrishnan (1993) find that operating income has a higher association with stock returns than net income. Intuitively, operating income might be a better method compared to the others, as it focuses only

on the operating part of the company. It focuses on the core operations of the company, excluding any income and expenses that are not directly tied to the core business. For instance, taxes and other one-off items that might skew the net income or cash flow are excluded. Therefore, it might be an interesting weighting scheme for a fundamental portfolio.

The following fundamental data is retrieved from Worldscope using Datastream:

- Book Value of Equity (Symbol: WC03501)
- Cash Flow (Symbol: WC04201)
- Dividend (Symbol: WC04551)
- Revenue (Symbol: WC01001)
- Employees (Symbol: WC07011)
- Income (Symbol: WC01751)
- Operating Income (Symbol: WC01250)

3.3 Portfolio Construction

The analysis will compare an equal-weighted portfolio and fundamental weighted portfolios to the capitalization-weighted portfolio. The capitalization-weighted portfolio is the reference portfolio and is constructed as described in section 3.1.

The equal-weighted portfolio will be constructed by assigning the same weight to each stock.

$$w_{s,t} = \frac{1}{N}$$

Where N denotes the number of stocks in the index.

The fundamental portfolios will be constructed by assigning a weight to each stock based on a fundamental metric.

$$w_{i,t} = \frac{F_{i,t-1}}{\sum_{i=1}^{N} F_{i,t-1}}$$

Where $F_{i,t-1}$ is the fundamental metric (i.e. dividend) of stock i at the end of the previous period (i.e. the end of the previous month). This makes sure that the strategy is *ex-ante* investable. In addition, firms with a negative fundamental metric, for instance negative income, will receive

a weight of zero. Hence, firms with a negative fundamental metric will not be shorted in order to keep the strategy easy to implement.

In order to create the Composite portfolio, all seven fundamental metrics are used. The weight of a stock in the Composite portfolio is determined by taking the average of all fundamental weights of that stock. The reason for creating a composite portfolio is that depending on a single fundamental metric could lead to valuation errors. The composite portfolio averages out errors that might occur in single metric portfolios.

In accordance with Arnott et al. (2005), all metrics are trailing five-year averages. Despite the fact that they use single-year metrics for book value and employment, in this analysis the five-year averages will be used for all metrics in order to be consistent with the weighting methodology of the portfolios. When there is less than five years of data for a company, the average of the available data is used.

In order to take into account transaction costs, the monthly turnover will be calculated by subtracting the weight of stock i at time t-1 from the weight of stock i at time t. Then, the outcomes are turned into absolute values to make sure that increases and decreases in weight do not cancel out each other. The absolute values are then summed for all stocks N in the portfolio at time t to arrive at the turnover. Hence, the portfolio turnover is calculated as follows:

$$turnover = \sum_{i=1}^{N} (|w_{i,t} - w_{i,t-1}|)$$

To estimate transaction costs, the turnover is multiplied by the costs of trading. Trading costs are assumed to be 20 basis points.

3.4 Rebalancing

Research on equal-weighted portfolios revealed that rebalancing and the frequency of rebalancing are important contributors to the outperformance of equal-weighted portfolios relative to capitalization-weighted portfolios (see section 2.5.1). In addition, Blitz, Van der Grient, and Van Vliet (2010) show that fundamental indexing with annual rebalancing can be highly sensitive to the subjective rebalancing date. In extreme events, they show that for the year 2009 a fundamental index that is rebalanced in March outperformed the capitalization-weighted index by more than 10%. In contrast, a fundamental index that was rebalanced every September in the same year

underperformed the capitalization-weighted index. They show that fundamental indices that diverge do not tend to mean-revert, meaning that the 'performance-gap' is likely to be permanent.

In order to overcome this problem, the equal- and fundamental weighted portfolios will be rebalanced on a monthly basis. The downside to monthly rebalancing is that turnover and transaction costs are likely to be higher than when the portfolios are less frequently rebalanced, for instance on a quarterly or annual basis.

3.5 Return and Risk Measurement

In order to compare the performance of the indices to each other, several return and risk metrics will be reported. Besides the common annualized return, the Sharpe Ratio and Information Ratio, Jensen's Alpha, Fama & French Three Factor Alpha and Carhart Four Factor Alpha will also be reported.

3.5.1 Sharpe Ratio

The Sharpe Ratio (Sharpe, 1994) displays the return per unit of risk. It adjusts the earned return for the risk that was taken in order to earn this return. The Sharpe Ratio can be calculated as follows:

$$SR = \frac{[R_p - R_f]}{\sigma_p}$$

Where:

SR = Sharpe Ratio
R_p = Return on portfolio p
R_f = Risk-free rate
σ_p = Standard deviation of portfolio p

3.5.2 Information Ratio

The Information Ratio (Sharpe, 1994) displays the degree to which an investment has beaten its benchmark to the consistency with which the investment has beaten its benchmark. Compared to the Sharpe Ratio, it measures the risk-adjusted return compared to a benchmark instead of the risk-free rate. The Information Ratio can be calculated as follows:

$$IR = \frac{[R_p - R_b]}{Tracking\ Error}$$

Where:

IR = Information Ratio
R_p = Return on portfolio p
R_b = Return on benchmark b
$Tracking\ Error$ = Standard deviation of difference between portfolio and benchmark returns

3.5.3 Jensen's Alpha

The Jensen's Alpha (Jensen, 1968) displays the excess return obtained compared to the benchmark. The magnitude of Jensen's Alpha depends on two factors, the return of the benchmark and the CAPM Beta. Hence, Jensen's Alpha corrects the return of a portfolio for market (beta) risk and can be calculated as follows:

$$\alpha_j = [R_p - R_f] - \beta_p [R_M - R_f]$$

Where:

α_j = Jensen's Alpha
R_p = Return on portfolio p
R_f = Risk-free rate
β_p = CAPM Beta of portfolio p
R_M = Return on market portfolio

3.5.4 Fama and French Three Factor Alpha

Building on the work of Jensen (1968), Fama and French (1992) extend this model by adding the risk factors size and value. The size factor is constructed by going long in stocks with a low market capitalization and going short in stocks with a high market capitalization. Hence, this portfolio is called "Small Minus Big" (SMB). The value factor is constructed by going long in stocks with a high book-to-market ratio (value stocks) and going short in stocks with a low book-to-market portfolio (growth stocks). Hence, this portfolio is called "High Minus Low" (HML). The SMB and HML portfolios are constructed as follows:

$$SMB = {}^{1}/_{3}\ (Small\ Value + Small\ Neutral + Small\ Growth) - {}^{1}/_{3}\ (Big\ Value + Big\ Neutral + Big\ Growth)$$

$$HML = {}^{1}/_{2}\ (Small\ Value + Big\ Value) - {}^{1}/_{2}\ (Small\ Growth + Big\ Growth)$$

The Fama & French Three Factor Alpha can be calculated as follows:

$$\alpha_{FF} = \left[R_p - R_f\right] - \beta_p \left[R_M - R_f\right] - s_P[SMB] - v_p\ [HML]$$

Where:

α_{FF} = Fama & French Three Factor Alpha
s_P = Factor coefficient of portfolio p with SMB portfolio
SMB = Excess return of small cap companies over large cap companies
v_p = Factor coefficient of portfolio p with HML portfolio
HML = Excess return of value stocks over growth stocks

The returns of the SMB and HML portfolio are retrieved from Kenneth French's Data Library.

3.5.5 Carhart Four Factor Alpha

Building on the work of Jensen (1968) and Fama and French (1992), Carhart (1997) extended this model by adding the momentum risk factor. The lagged momentum return is the cumulative return of a stock for the month t-12 to month t-2. The momentum factor is constructed by going long in stocks that have positive momentum (stocks that had a positive return) and going short in stocks with negative momentum (stocks that had a negative return). Hence, this portfolio is called "Winners Minus Losers" (WML). The WML Portfolio is constructed as follows:

$$WML = {}^{1}/_{2}\ (Small\ High + Big\ High) - {}^{1}/_{2}\ (Small\ Low + Big\ Low)$$

The Carhart Four Factor Alpha can be calculated as follows:

$$\alpha_C = \left[R_p - R_f\right] - \beta_p \left[R_M - R_f\right] - s_P[SMB] - v_p\ [HML] - m_p\ [WML]$$

Where:

α_C = Carhart Four Factor Alpha
m_p = Factor coefficient of portfolio p with WML portfolio
WML = Excess return of stocks with positive momentum over stocks with negative momentum

The returns of the WML portfolio are retrieved from Kenneth French's Data Library.

4. Results

After some general comments about the procedure to generate the results, the main findings will be discussed.

As described in Chapter 3, the portfolio turnover and transaction costs are an important factor in the performance of the portfolios. For all the portfolios that are simulated, the annual turnover and transaction costs are shown in Appendix I. It should be noted that for the reference portfolio, the turnover is only calculated for informational purposes. In the performance of the reference portfolio, transaction costs are not incurred in order to make the difference compared to the fundamental portfolios more robust.

In addition, general summary statistics of all portfolios can be found in Appendix II. In Appendix III, a graph with the cumulative performance of all portfolios can be found.

For all OLS Regressions used to calculate Jensen's Alpha, Fama & French Three Factor Alpha and Carhart Four Factor Alpha, the Breusch-Pagan Test is used to test for heteroscedasticity. When the p-value for this test is below 0.1, robust standard errors are used. The p-values for all Breusch-Pagan tests can be found in Appendix IV. In order to test for Fama & French Three Factor Alpha, the time period of the DAX, CAC, and S&P 100 had to be decreased as Kenneth French's Data Library only provides three factor data as of July 1990. Hence, the time period for the Three Factor Alpha is from July 1990 to December 2018. The results for the Fama & French Three Factor Alphas are in Appendix VII. In order to test for Carhart Four Factor Alpha, the time period of the DAX, CAC and S&P 100 again had to be decreased as Kenneth French's Data Library only provides Momentum data as of November 1990. Hence, the time period for the Four Factor Alpha is from November 1990 to December 2018.

4.1 DAX

4.1.1 Absolute Performance DAX

As can be seen from the table in Appendix I.1, the annual turnover of the fundamental portfolios of the DAX is roughly two times higher compared to the reference portfolio. The equal-weighted portfolio has the highest turnover, roughly 2.3 times higher compared to the reference portfolio. The annual transaction costs of all portfolios range between 11 and 13 basis points.

In Table 6, the results of the reference portfolio, the equal-weighted portfolio and the fundamental weighted portfolios are shown.

Table 6: Comparison Reference and Capitalization-Indifferent Portfolios DAX

This table includes the Ending Value of €100 invested in either the reference portfolio or any of the capitalization-indifferent-weighted portfolios, over the time period 31/12/1988 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the reference portfolio is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
Reference Portfolio DAX	€ 820.92	0.0727	0.2022					
Equal	€ 1,170.95	0.0855	0.2098	0.0515	0.0119	0.9695	1.0062***	0.9397
Book Value	€ 1,038.52	0.0811	0.2109	0.0448	0.0079	0.9773	1.0195***	0.9551
Cash Flow	€ 1,279.65	0.0887	0.2062	0.0438	0.0149	0.9772	0.9968***	0.9548
Dividend	€ 973.12	0.0788	0.2043	0.0380	0.0057	0.9826	0.9927***	0.9653
Revenue	€ 1,124.80	0.0840	0.2132	0.0476	0.0106	0.9751	1.0280***	0.9506
Employee	€ 1,508.89	0.0947	0.2104	0.0479	0.0205	0.9738	1.0137***	0.9481
Income	€ 1,064.80	0.0820	0.2077	0.0384	0.0087	0.9828	1.0095***	0.9659
Operating Income	€ 1,014.17	0.0803	0.2113	0.0472	0.0071	0.9749	1.0190***	0.9503
Composite	€ 1,141.09	0.0845	0.2074	0.0350	0.0110	0.9857	1.0113***	0.9716

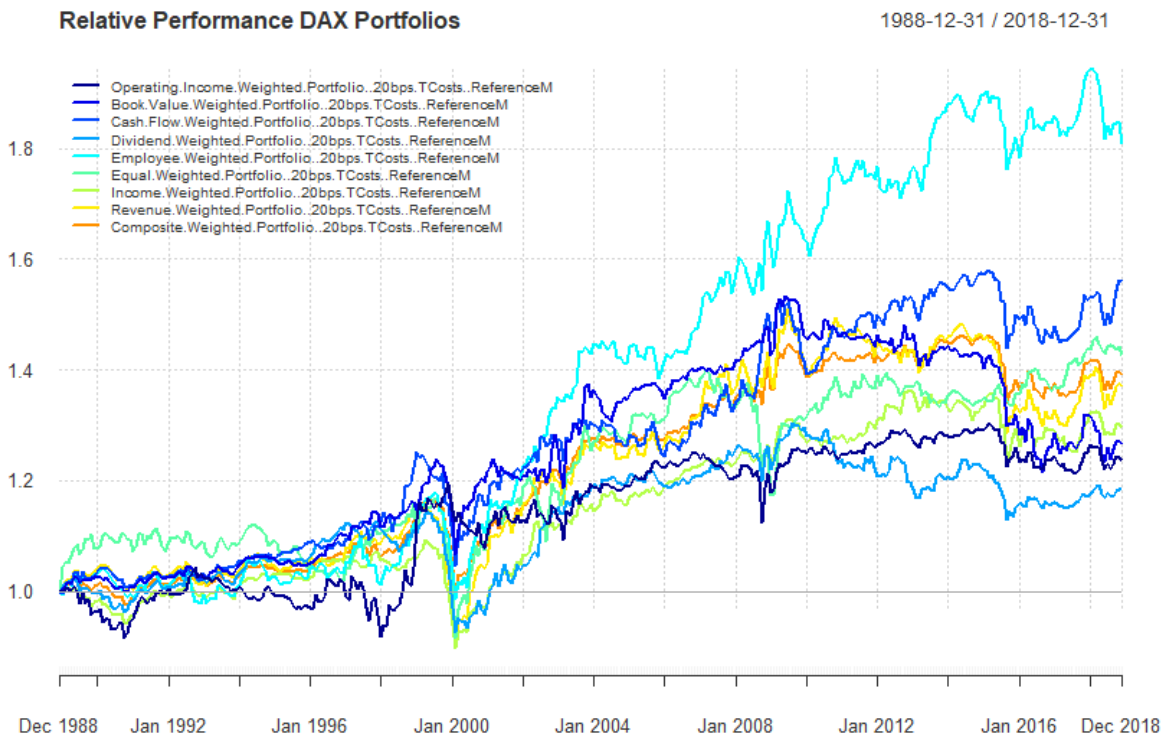
***, **, * indicate the significance at the 1%, 5%, and 10% levels.

As can be seen from Table 6, the equal-weighted portfolio and all fundamental portfolios outperform the reference portfolio in terms of absolute return. In addition, all portfolios have slightly higher annual standard deviations. The equal-weighted portfolio has the highest tracking error (5.15%) and the composite weighted portfolio the lowest (3.5%). The employee weighted portfolio has the highest outperformance compared to the reference portfolio, with an annual excess return of 2.05%. The equal-weighted portfolio has an annual outperformance of 1.19% whilst the composite weighted portfolio earns 1.10% more compared to the reference portfolio. The equal and fundamental portfolios are all highly correlated with the reference portfolio. Furthermore, the equal- and fundamental portfolios all have CAPM Betas around one, with the

reference portfolio as market portfolio. All betas are statistically significant at the 1% level. The Adjusted R-Squared for all linear models are above 0.93. Graph 11 shows the relative cumulative performance of all portfolios compared to the reference portfolio.

Graph 11: Relative Performance DAX Portfolios

This graph shows the relative cumulative performance of the capitalization indifferent weighted portfolios with respect to the Reference portfolio, over the time period 31/12/1988 – 31/12/2018.



Looking at Graph 11, it becomes clear that both the book and cash flow weighted portfolio have a constant higher relative performance compared to the reference portfolio. The equal and revenue weighted portfolio only underperform in the 2000 crisis. The dividend and income weighted portfolio have a small underperformance in the early 1990's and in the 2000 crisis. The employee weighted portfolio has a small underperformance in the early 1990's and in the 2000 crisis, after that the outperformance of the portfolio increases. In 2012-2018 the employee weighted portfolio has a performance that is almost consistently 1.8 times higher compared to the reference portfolio. The operating income weighted portfolio underperforms in the early 1990's and also around 1998. After that, the portfolio recovers and during the 2000 crisis the performance is 1.2 times higher compared to the reference portfolio. The composite portfolio has a small

underperformance in the early 1990's and in the 2000 crisis. After that, the portfolio consistently outperforms the reference portfolio. Another interesting observation is that none of the portfolios seem to be very much affected by the financial crisis in 2008, in terms of relative performance compared to the reference portfolio.

4.1.2 Factor Exposure and Alphas DAX

In order to test for Jensen's Alpha, the risk-free rate is subtracted from the returns of all portfolios, including the reference portfolio. The risk-free rate used for the DAX portfolios is the German 1 Month Deposit Rate, reported by The Financial Times and Thomson Reuters and retrieved via Datastream.

As can be seen in the table in Appendix V.1 the cash flow and employee portfolios have a statistically significant Jensen's Alpha at the 5% level. The composite weighted portfolio has a statistically significant Jensen's Alpha at the 10% level.

For all DAX portfolios, the Sharpe Ratio and the Information Ratio are calculated and reported in Appendix VI.1. The equal- and all fundamental weighted portfolios have higher Sharpe Ratios compared to the reference portfolio. In addition, all portfolios have a positive Information Ratio. The employee weighted portfolio has the highest Sharpe and Information Ratio. The equal-weighted portfolios has a higher Sharpe Ratio compared to the composite weighted portfolio, but the latter one has a higher Information Ratio.

The results of the Fama & French Three Factor model are in Appendix VII.1. The table in Appendix VII.1 shows that only the employee weighted portfolio has three factor alpha, which is only significant at the 10% level. The cash flow weighted portfolio has a negative loading on the size factor, which is significant at the 1% level. This leads to conclude that the portfolio is tilted towards larger companies, which is apparently the case because they have higher cash flows compared to small companies. The dividend weighted portfolio also has a negative factor loading on the size factor, but it is only significant at the 10% level. Furthermore, almost all portfolios have positive loadings on the value factor (that are significant at the 1% level), except for the newly introduced operational income measure.

The results of the Carhart Four Factor model are in Table 7.

Table 7: Carhart Four Factor Alpha DAX Portfolios

This table includes Carhart Four Factor Alpha of all DAX Portfolios over the time period 30/11/1990 – 31/12/2018. Carhart Four Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio DAX. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Carhart 4-Factor Alpha	Market - Rf	SMB	HML	WML	R^2
Reference Portfolio DAX	0.0096***		-0.7502***	-0.0656	-0.4512***	0.1788
	(3.1406)		(-4.5826)	(-0.3728)	(-4.1260)	
Equal	0.0021***	0.9773***	0.0329	0.1040**	-0.1573***	0.9512
	(2.7216)	(49.1011)	(0.6052)	(2.0753)	(-6.1947)	
Book Value	0.0012	0.9889***	-0.0560*	0.1910***	-0.0972***	0.9638
	(1.5627)	(59.9709)	(-1.6684)	(5.1668)	(-3.1153)	
Cash Flow	0.0018**	0.9649***	-0.1116***	0.1183***	-0.0657***	0.9584
	(2.5280)	(76.6900)	(-3.5570)	(4.1550)	(-3.5730)	
Dividend	0.0013**	0.9650***	-0.0842*	0.1054**	-0.0830***	0.9701
	(2.1268)	(66.0931)	(-1.8592)	(2.5401)	(-4.4225)	
Revenue	0.0013*	1.0016***	-0.0183	0.2107***	-0.0935***	0.9601
	(1.7840)	(78.3480)	(-0.5750)	(7.2830)	(-5.0030)	
Employee	0.0022***	0.9973***	0.0351	0.1221***	-0.0720***	0.9501
	(2.8170)	(70.9430)	(1.0010)	(3.8370)	(-3.5050)	
Income	0.0014**	0.9902***	-0.0223	0.1270***	-0.0751***	0.9706
	(2.3228)	(71.9889)	(-0.5674)	(3.1788)	(-4.1965)	
Operating Income	0.0017**	1.0096***	-0.0180	0.0021	-0.0778***	0.9524
	(2.2480)	(72.6350)	(-0.5180)	(0.0680)	(-3.8300)	
Composite	0.0015***	0.9882***	-0.0393*	0.1252***	-0.0806***	0.9769
	(2.9450)	(104.5340)	(-1.6670)	(5.8530)	(-5.8340)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table 7 shows that the equal-, employee and composite weighted portfolios have significant four factor alphas at the 1% level of significance. In addition, the cash flow, dividend, income and operating income weighted portfolios have significant four factor alphas at the 5% level of significance. The alpha of the revenue weighted portfolio is only significant at the 10%

level, and the book value weighted portfolio does not have a significant alpha at all. All portfolios have a negative loading on the momentum factor, which are all significant at the 1% level.

4.2 SMI

4.2.1 Absolute Performance SMI

As can be seen from the table in Appendix I.2, the annual turnover of the fundamental portfolios of the SMI is roughly 2.3 times higher compared to the reference portfolio. The equal-weighted portfolio has the highest turnover, roughly 2.9 times higher compared to the reference portfolio. The annual transaction costs of all portfolios range between 11 and 14 basis points.

In Table 8, the results of the reference portfolio, the equal-weighted portfolio and the fundamental weighted portfolios are shown.

Table 8: Comparison Reference and Capitalization-Indifferent Portfolios SMI

This table includes the Ending Value of €100 invested in either the Reference portfolio or any of the capitalization-indifferent-weighted portfolios, over the time period 31/05/1993 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the reference portfolio is used as the market portfolio.

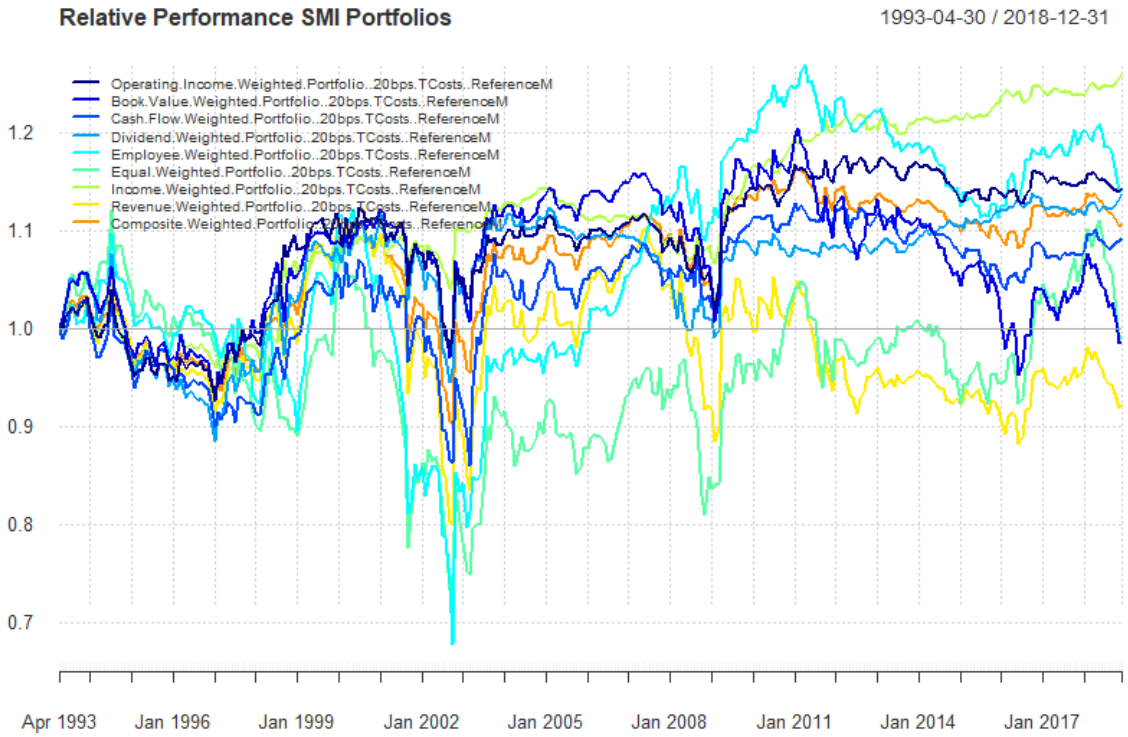
	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
Reference Portfolio SMI	€ 743.43	0.0813	0.1506					
Equal	€ 737.24	0.0809	0.1817	0.0806	-0.0003	0.8990	1.0845***	0.8076
Book Value	€ 731.76	0.0806	0.1787	0.0532	-0.0006	0.9622	1.1416***	0.9255
Cash Flow	€ 812.50	0.0850	0.1731	0.0542	0.0035	0.9534	1.0957***	0.9086
Dividend	€ 845.40	0.0867	0.1738	0.0487	0.0050	0.9649	1.1133***	0.9309
Revenue	€ 685.92	0.0779	0.1914	0.0765	-0.0031	0.9273	1.1784***	0.8595
Employee	€ 847.55	0.0868	0.1788	0.0830	0.0051	0.8870	1.0528***	0.7860
Income	€ 937.03	0.0911	0.1527	0.0287	0.0091	0.9821	0.9956***	0.9645
Operating Income	€ 850.00	0.0870	0.1634	0.0391	0.0052	0.9722	1.0543***	0.9450
Composite	€ 823.35	0.0856	0.1702	0.0468	0.0040	0.9647	1.0900***	0.9304

***, **, * indicate the significance at the 1%, 5%, and 10% levels.

As can be seen from Table 8, the equal-, book value and revenue weighted portfolio have a lower absolute return compared to the reference portfolio. In addition, all portfolios have higher annual standard deviations. The employee weighted portfolio has the highest tracking error (8.3%) and the income weighted portfolio the lowest (2.87%). The income weighted portfolio has the highest outperformance compared to the reference portfolio, with an annual excess return of 0.91%. The equal-weighted portfolio has an annual underperformance of 0.03%, whilst the composite weighted portfolio earns 0.40% more compared to the reference portfolio. The equal- and fundamental portfolios are all highly correlated with the reference portfolio. Furthermore, the equal- and most of the fundamental portfolios have CAPM Betas around one, with the reference portfolio as market portfolio. However, the book value, cash flow and dividend weighted portfolios have betas that are above 1.10. All Betas are statistically significant at the 1% level. The Adjusted R-Squared for all linear models is above 0.93, except for the equal-, revenue and employee weighted portfolio. Graph 12 shows the relative cumulative performance of all portfolios compared to the reference portfolio.

Graph 12: Relative Performance SMI Portfolios

This graph shows the relative cumulative performance of the capitalization indifferent weighted portfolios with respect to the Reference portfolio, over the time period 31/05/1993 – 31/12/2018.



Looking at Graph 12, all portfolios experience some underperformance during the mid-1990's to begin 1999. In addition, almost all portfolios underperform during 2002-2003, except for the income weighted portfolio. After that, the performance widely differs for the portfolios. The equal and revenue weighted portfolio almost consistently underperform, except for some short periods. The other portfolios show almost consistent outperformance after 2003, except for some short periods. In addition, the portfolios maintain their outperformance during the financial crisis in 2008, except for the equal, revenue and dividend weighted portfolios. However, the magnitude of their outperformance decreases.

4.2.2 Factor Exposure and Alphas SMI

In order to test for Jensen's Alpha, the risk-free rate is subtracted from the returns of all portfolios, including the reference portfolio. The risk-free rate used for the SMI portfolios is the Swiss 1

Month Deposit Rate, reported by The Financial Times and Thomson Reuters and retrieved via Datastream.

As can be seen in the table in Appendix V.2, only the income weighted portfolio has a statistically significant Jensen's Alpha, which is only significant at the 10% level.

For all SMI portfolios, Sharpe Ratio and Information Ratio are calculated and reported in Appendix VI.2. Only the income weighted portfolio has a higher Sharpe Ratio compared to the reference portfolio. In addition, all portfolios have a positive a Information Ratio, except for the equal-, book value and revenue weighted portfolios. The income weighted portfolio has the highest Sharpe and Information Ratio. The composite weighted portfolio has a higher Sharpe and Information Ratio compared to the equal-weighted portfolio.

The results of the Fama & French Three Factor model are in Appendix VII.2. The table in Appendix VII.2 shows that only the income weighted portfolio has three factor alpha, which is only significant at the 10% level. The equal- and employee weighted portfolio have a positive loading on the size factor, which is significant at the 1% level. This leads to conclude that the portfolio is tilted towards smaller companies, which makes sense for the equal-weighted portfolio, but it is not what one would expect for the employee weighted portfolio. The positive factor loading indicates that weighting based on the number of employees apparently tilts the portfolio towards smaller companies. Intuitively, this is the opposite of what one would expect. The revenue and composite weighted portfolio also have a positive factor loading on the size factor, which are significant at the 5% level. Again, the positive factor loading on the revenue weighted portfolio is not what one would expect as it makes more sense for this portfolio to be tilted towards larger companies instead of smaller companies. Furthermore, the book value and revenue weighted portfolios have positive loadings on the value factor (that are significant at the 1% level). The composite weighted portfolio also has a positive loading on the value factor, which is significant at the 5% level.

The results of the Carhart Four Factor model are in Table 9.

Table 9: Carhart Four Factor Alpha SMI Portfolios

This table includes Carhart Four Factor Alpha of all SMI Portfolios over the time period 31/05/1993 – 31/12/2018. Carhart Four Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio SMI. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Carhart 4-Factor Alpha	Market - Rf	SMB	HML	WML	R^2
Reference Portfolio SMI	0.0082***		-0.6622***	0.1739*	-0.2011***	0.1780
	(3.4660)		(-6.4180)	(1.8340)	(-3.4270)	
Equal	0.0019	1.0843***	0.2972***	-0.0017	-0.2440***	0.8519
	(1.4530)	(36.1854)	(3.9313)	(-0.0300)	(-6.2653)	
Book Value	0.0006	1.1047***	0.0522	0.1129***	-0.1515***	0.9442
	(0.6825)	(51.1827)	(1.2498)	(3.2972)	(-4.6049)	
Cash Flow	0.0017*	1.0717***	0.0379	-0.0439	-0.1567***	0.9223
	(1.7069)	(39.1591)	(0.7994)	(-1.1119)	(-4.4598)	
Dividend	0.0015*	1.0841***	-0.0118	-0.0279	-0.1320***	0.9404
	(1.6731)	(47.3493)	(-0.3038)	(-1.0311)	(-4.1668)	
Revenue	0.0015	1.1384***	0.1468**	0.0620	-0.2664***	0.8998
	(1.2009)	(38.3611)	(2.5381)	(1.2814)	(-5.6909)	
Employee	0.0023	1.0614***	0.2842***	-0.0451	-0.2137***	0.8215
	(1.7500)	(33.4360)	(4.6690)	(-0.8540)	(-6.4540)	
Income	0.0017***	0.9826***	-0.0048	-0.0359*	-0.0704***	0.9679
	(2.7926)	(53.2113)	(-0.1890)	(-1.9172)	(-3.9600)	
Operating Income	0.0015**	1.0325***	0.0253	-0.0146	-0.1233***	0.9548
	(2.2248)	(47.5810)	(0.7149)	(-0.5210)	(-5.3883)	
Composite	0.0015*	1.0679***	0.0757**	0.0011	-0.1591***	0.9468
	(1.9033)	(54.9686)	(2.0136)	(0.0378)	(-5.6344)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table 9 shows that the income weighted portfolio has a significant four factor alpha at the 1% level of significance. In addition, the operating income weighted portfolio has a significant four factor alpha at the 5% level of significance. The alpha of the cash flow, dividend and composite weighted portfolios are only significant at the 10% level. All portfolios have a negative loading on the momentum factor, and are all significant at the 1% level.

4.3 CAC

4.3.1 Absolute Performance CAC

As can be seen from the table in Appendix I.3, the annual turnover of the fundamental portfolios of the CAC is roughly 2.6 times higher compared to the reference portfolio. The equal-weighted portfolio has the highest turnover, roughly 2.9 times higher compared to the reference portfolio. The annual transaction costs of all portfolios range between 13 and 14 basis points.

In Table 10, the results of the reference portfolio, the equal-weighted portfolio and the fundamental weighted portfolios are shown.

Table 10: Comparison Reference and Capitalization-Indifferent Portfolios CAC

This table includes the Ending Value of €100 invested in either the Reference portfolio or any of the capitalization-indifferent-weighted portfolios, over the time period 31/12/1988 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the reference portfolio is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
Reference Portfolio CAC	€ 868.74	0.0747	0.1812					
Equal	€ 1,083.17	0.0827	0.1981	0.0457	0.0074	0.9749	1.0660***	0.9503
Book Value	€ 1,048.48	0.0815	0.2039	0.0510	0.0063	0.9717	1.0934***	0.9440
Cash Flow	€ 1,114.97	0.0837	0.2080	0.0588	0.0084	0.9637	1.1062***	0.9285
Dividend	€ 1,131.92	0.0842	0.1922	0.0466	0.0089	0.9705	1.0293***	0.9417
Revenue	€ 965.34	0.0785	0.2062	0.0549	0.0035	0.9681	1.1020***	0.9370
Employee	€ 812.55	0.0723	0.2033	0.0536	-0.0022	0.9676	1.0858***	0.9361
Income	€ 1,215.59	0.0868	0.1882	0.0359	0.0113	0.9818	1.0199***	0.9639
Operating Income	€ 1,246.02	0.0877	0.1883	0.0366	0.0121	0.9811	1.0199***	0.9624
Composite	€ 1,078.12	0.0825	0.1970	0.0415	0.0072	0.9794	1.0652***	0.9591

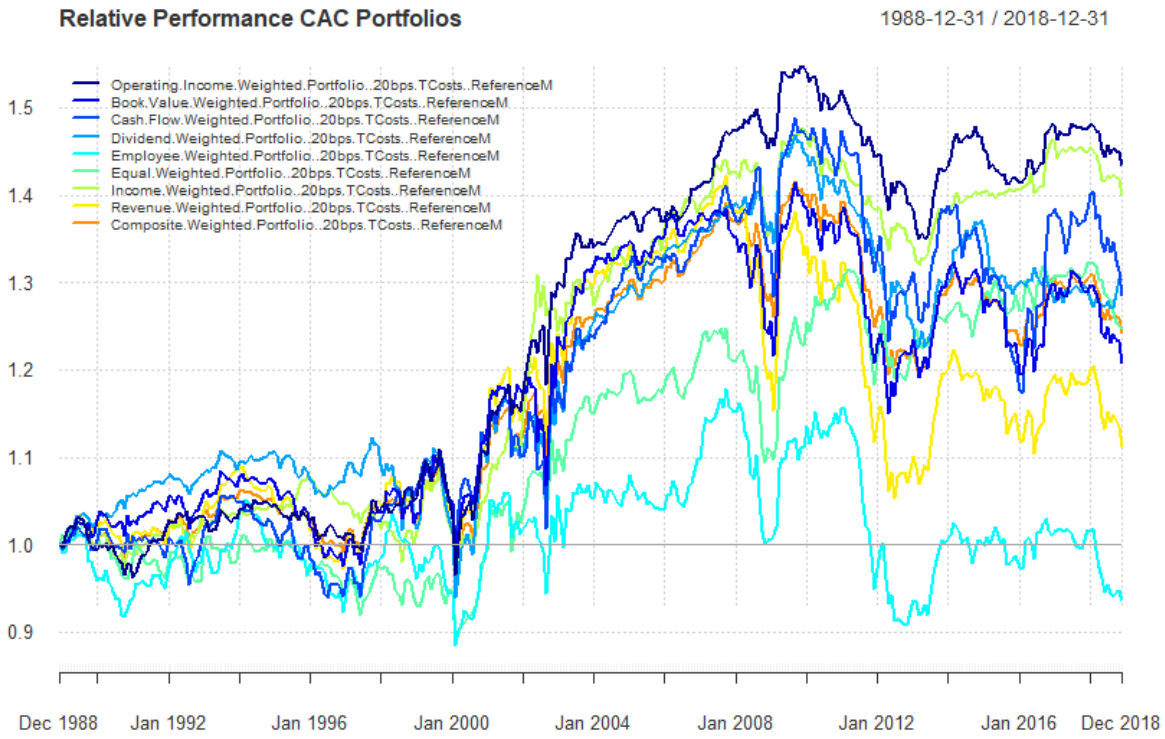
***, **, * indicate the significance at the 1%, 5%, and 10% levels.

As can be seen from Table 10, the equal-weighted portfolio and almost all fundamental portfolios outperform the reference portfolio in terms of absolute return. However, the employee weighted portfolio has an annual underperformance of 0.22% compared to the reference portfolio.

In addition, all portfolios have higher annual standard deviations. The equal-weighted portfolio has the highest tracking error (5.88%) and the income weighted portfolio the lowest (3.59%). The operating income weighted portfolio has the highest outperformance compared to the reference portfolio, with an annual excess return of 1.21%. The equal-weighted portfolio has an annual outperformance of 0.74%, whilst the composite weighted portfolio earns 0.72% more compared to the reference portfolio. The equal- and fundamental portfolios are all highly correlated with the reference portfolio. Furthermore, the equal- and almost all fundamental portfolios have CAPM Betas around one, with the reference portfolio as market portfolio. However, the cash flow and revenue weighted portfolio have betas of around 1.10. All Betas are statistically significant at the 1% level. The Adjusted R-Squared for all linear models are above 0.92. Graph 13 shows the relative cumulative performance of all portfolios compared to the reference portfolio.

Graph 13: Relative Performance CAC Portfolios

This graph shows the relative cumulative performance of the capitalization indifferent weighted portfolios with respect to the Reference portfolio, over the time period 31/12/1988 – 31/12/2018.



Looking at Graph 13, it becomes clear that the equal-weighted portfolio underperforms until 2001, and after that consistently outperforms the reference portfolio. The book value, cash

flow and revenue weighted portfolios consistently outperform the reference portfolio, except for a short and small underperformance during 1996 - 1998 and the 2000 crisis. The dividend, income and operating income consistently outperform the reference portfolio, except during the 2000 crisis. The employee weighted portfolio is quite volatile and not really consistent in its out- or underperformance. The composite portfolio has almost consistent outperformance, except for a short period in the 2000 crisis. In addition, all portfolios maintain their outperformance during the financial crisis in 2008, but there is a decrease in the magnitude of the outperformance during that period.

4.3.2 Factor Exposure and Alphas CAC

In order to test for Jensen's Alpha, the risk-free rate is subtracted from the returns of all portfolios, including the reference portfolio. The risk-free rate used for the CAC portfolios is the French 1 Month Deposit Rate, reported by The Financial Times and Thomson Reuters and retrieved via Datastream.

As can be seen in the table in Appendix V.3, the income and operational income weighted portfolios have a statistically significant Jensen's Alpha at the 10% level.

For all CAC portfolios, the Sharpe Ratio and the Information Ratio are calculated and reported in Appendix VI.3. The equal-weighted portfolio and almost all fundamental weighted portfolios have higher Sharpe Ratios compared to the reference portfolio. In addition, almost all portfolios have a positive Information Ratio. The employee weighted portfolio is the only one with a lower Sharpe Ratio and a negative Information Ratio. The operating income weighted portfolio has the highest Sharpe and Information Ratio. The composite weighted portfolio has a higher Sharpe and Information ratio compared to the equal-weighted portfolio.

The results of the Fama & French Three Factor model are in Appendix VII.3. The table in Appendix VII.3 shows that none of the portfolios have a statistically significant three factor alpha. The equal, revenue and employee weighted portfolios have a positive loading on the size factor, which is significant at the 1% level, indicating that these portfolios are tilted towards smaller companies. This makes sense for the equal-weighted portfolio, but not so for the revenue and employee weighted portfolios. Intuitively, it is the opposite of what one would expect. The book value weighted portfolio also has a positive factor loading on the size factor, which is significant

at the 5% level. Furthermore, all portfolios have positive loadings on the value factor that are all significant at the 1% level.

The results of the Carhart Four Factor model are in Table 11.

Table 11: Carhart Four Factor Alpha CAC Portfolios

This table includes Carhart Four Factor Alpha of all CAC Portfolios over the time period 30/11/1990 – 31/12/2018. Carhart Four Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio CAC. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Carhart 4-Factor Alpha	Market - Rf	SMB	HML	WML	R^2
Reference Portfolio CAC	0.00814***		-0.7826***	0.0267	-0.3657***	0.1956
	(3.0721)		(-5.6750)	(0.1671)	(-4.2233)	
Equal	0.0016**	1.0545***	0.1866***	0.1422***	-0.1377***	0.9661
	(2.5820)	(85.7730)	(6.6860)	(5.7110)	(-8.6350)	
Book Value	0.0011*	1.0654***	0.0540*	0.2685***	-0.1484***	0.9693
	(1.7950)	(87.5720)	(1.957)	(10.8950)	(-9.405)	
Cash Flow	0.0016**	1.0662***	0.0071	0.2464***	-0.1699***	0.9520
	(2.0260)	(60.4508)	(0.1346)	(6.422)	(-6.9994)	
Dividend	0.0015**	0.9863***	-0.0321	0.2023***	-0.1391***	0.9592
	(2.3500)	(75.0340)	(-1.0770)	(7.5970)	(-8.1560)	
Revenue	0.0008	1.0755***	0.1182***	0.3135***	-0.1551***	0.9674
	(1.2540)	(84.9990)	(4.1140)	(12.2290)	(-9.4470)	
Employee	0.0006	1.0738***	0.1886***	0.2097***	-0.1359***	0.9559
	(0.8570)	(74.4300)	(5.7610)	(7.1760)	(-7.2620)	
Income	0.0013**	1.0016***	0.0119	0.1748***	-0.0713***	0.9730
	(2.4740)	(95.6990)	(0.5010)	(8.2450)	(-5.2500)	
Operating Income	0.0017***	0.9855***	-0.0290	0.1775***	-0.0986***	0.9745
	(3.3610)	(97.1470)	(-1.2600)	(8.6340)	(-7.4950)	
Composite	0.0012**	1.0363***	0.0455	0.2275***	-0.1312***	0.9785
	(2.4291)	(80.3272)	(1.4269)	(7.0835)	(-7.5879)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table 11 shows that the operating income weighted portfolio has significant four factor alpha at the 1% level. In addition, the equal, cash flow, dividend, income and composite weighted portfolios have significant four factor alphas at the 5% level. The alpha of the book value weighted portfolio is only significant at the 10% level. All portfolios have a negative loading on the momentum factor, which are all significant at the 1% level.

4.4 EuroStoxx 50

4.4.1 Absolute Performance EuroStoxx 50

As can be seen from the table in Appendix I.4, the annual turnover of the fundamental portfolios of the EuroStoxx 50 is roughly 2.5 times higher compared to the reference portfolio. The equal-weighted portfolio has the highest turnover, roughly 2.7 times higher compared to the reference portfolio. The annual transaction costs of all portfolios range between 12 and 13 basis points.

In Table 12, the results of the reference portfolio, the equal-weighted portfolio and the fundamental weighted portfolios are shown.

Table 12: Comparison Reference and Capitalization-Indifferent Portfolios EuroStoxx 50

This table includes the Ending Value of €100 invested in either the Reference portfolio or any of the capitalization-indifferent-weighted portfolios, over the time period 31/01/2001 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the reference portfolio is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
Reference Portfolio								
EuroStoxx 50	€ 125.42	0.0127	0.1498					
Equal	€ 127.85	0.0138	0.1815	0.0463	0.0011	0.9791	1.1869***	0.9585
Book Value	€ 117.01	0.0088	0.1832	0.0506	-0.0039	0.9736	1.1908***	0.9477
Cash Flow	€ 124.00	0.0121	0.1840	0.0483	-0.0006	0.9789	1.2030***	0.9581
Dividend	€ 146.53	0.0216	0.1647	0.0315	0.0087	0.9844	1.0826***	0.9689
Revenue	€ 121.40	0.0109	0.1901	0.0544	-0.0018	0.9747	1.2373***	0.9498
Employee	€ 118.14	0.0093	0.1864	0.0531	-0.0033	0.9736	1.2122***	0.9477
Income	€ 154.09	0.0244	0.1630	0.0275	0.0116	0.9882	1.0755***	0.9763
Operating Income	€ 139.58	0.0188	0.1684	0.0333	0.0060	0.9849	1.1075***	0.9699
Composite	€ 131.48	0.0154	0.1760	0.0379	0.0026	0.9859	1.1584***	0.9718

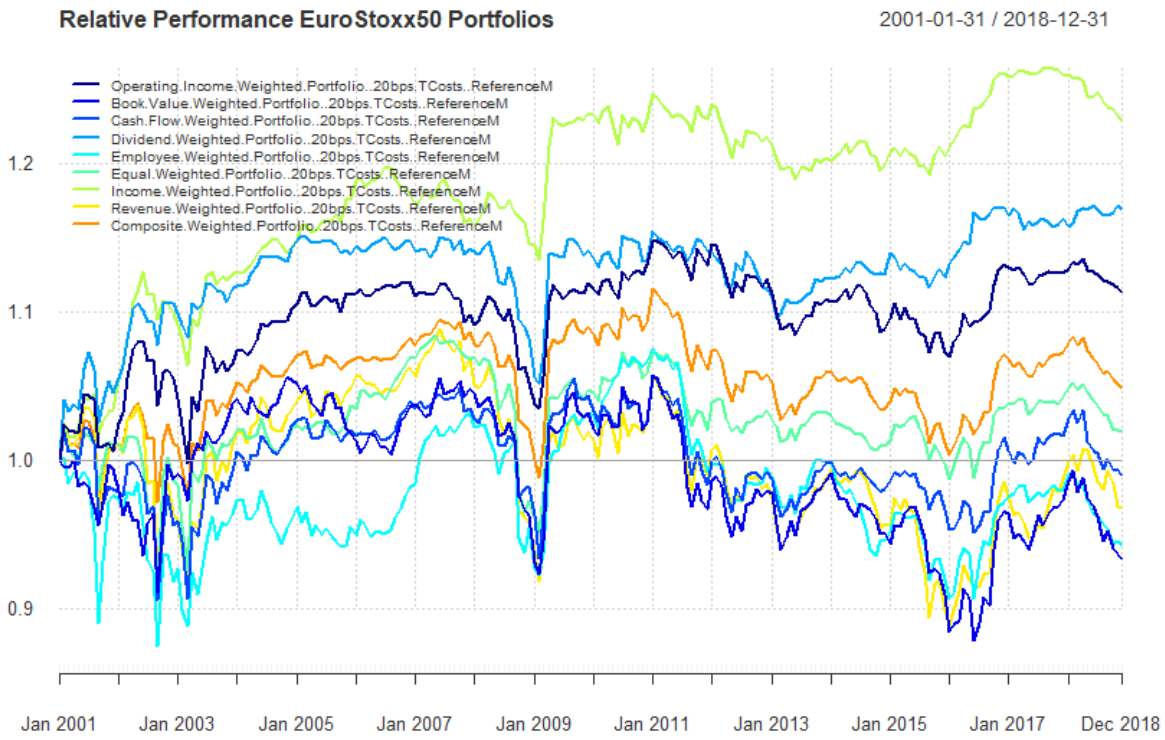
***, **, * indicate the significance at the 1%, 5%, and 10% levels.

As can be seen from Table 12, the equal-weighted portfolio and almost all fundamental portfolios outperform the reference portfolio in terms of absolute return. However, the book value, cash flow, revenue and employee weighted portfolios, have an annual underperformance compared to the reference portfolio. In addition, all portfolios have higher annual standard deviations. The revenue weighted portfolio has the highest tracking error (5.44%) and the income weighted portfolio the lowest (2.75%). The income weighted portfolio has the highest outperformance compared to the reference portfolio, with an annual excess return of 1.16%. The equal-weighted portfolio has an annual outperformance of 0.11%, whilst the composite weighted portfolio earns 0.26% more compared to the reference portfolio. The equal- and fundamental weighted portfolios are all highly correlated with the reference portfolio. It stands out that almost all portfolios have CAPM Betas around 1.20, with the reference portfolio as market portfolio. However, the dividend,

income and operating income weighted portfolio have a beta of around 1.10. All Betas are statistically significant at the 1% level. The Adjusted R-Squared for all linear models are above 0.94. Graph 14 shows the relative cumulative performance of all portfolios compared to the reference portfolio.

Graph 14: Relative Performance EuroStoxx 50 Portfolios

This graph shows the relative cumulative performance of the capitalization indifferent weighted portfolios with respect to the Reference portfolio, over the time period 31/01/2001 – 31/12/2018.



Looking at Graph 14, it becomes clear that the equal-, book value, cash flow, revenue and employee weighted portfolios are quite volatile and show no real consistency in their outperformance. In fact, the graph shows that these portfolios underperform most of the time. However, the dividend, income and operating income show almost consistent outperformance. The composite portfolio is volatile in 2001 – 2003, with spikes of under- and outperformance. After this period, the composite portfolio shows almost consistent outperformance, except for the beginning of 2009. All portfolios show a decrease in relative performance during the 2008 financial crisis, but the dividend, income and operating income weighted portfolios maintain their outperformance whilst the composite portfolio only slightly underperforms.

4.4.2 Factor Exposure and Alphas EuroStoxx 50

In order to test for Jensen's Alpha, the risk-free rate is subtracted from the returns of all portfolios, including the reference portfolio. The risk-free rate used for the EuroStoxx 50 portfolios is the Euro 1 Month Deposit Rate, reported by The Financial Times and Thomson Reuters and retrieved via Datastream.

As can be seen in the table in Appendix V.4, only the income weighted portfolios has a statistically significant Jensen's Alpha at the 5% level.

For all EuroStoxx 50 portfolios, the Sharpe Ratio and the Information Ratio are calculated and reported in Appendix VI.4. Surprisingly, the reference portfolio has a negative Sharpe Ratio. The equal-weighted portfolio and almost all fundamental weighted portfolios have higher Sharpe Ratios compared to the reference portfolio. However, the book value, cash flow, revenue and employee weighted portfolios have a lower Sharpe Ratio. In addition, all portfolios have a positive Information Ratio, except for, again, the book value, cash flow, revenue and employee weighted portfolios. The income weighted portfolio has the highest Sharpe and Information Ratio. The composite weighted portfolio has a higher Sharpe and Information Ratio compared to the equal-weighted portfolio.

The results of the Fama & French Three Factor model are in Appendix VII.4. The table in Appendix VII.4 shows that none of the portfolios have a statistically significant three factor alpha. Additionally, none of the portfolios have statistically significant loadings on the size factor. Furthermore, almost all portfolios have positive loadings on the value factor (that are significant at the 1% level).

The results of the Carhart Four Factor model are in Table 13.

Table 13: Carhart Four Factor Alpha EuroStoxx 50 Portfolios

This table includes Carhart Four Factor Alpha of all EuroStoxx 50 Portfolios over the time period 31/01/2001 – 31/12/2018. Carhart Four Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio EuroStoxx 50. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Carhart 4-Factor Alpha	Market - Rf	SMB	HML	WML	R^2
Reference Portfolio EuroStoxx 50	0.00663***		-0.6121***	0.1862*	-0.5480***	0.3950
	(2.8483)		(-4.0768)	(1.7017)	(-8.2729)	
Equal	0.0014*	1.1007***	0.0239	0.1031***	-0.1442***	0.9700
	(1.7455)	(53.6680)	(0.4065)	(2.6694)	(-5.4143)	
Book Value	0.0010	1.0681***	-0.0364	0.2371***	-0.1731***	0.9718
	(1.3610)	(49.5669)	(-0.8035)	(7.1627)	(-6.7891)	
Cash Flow	0.0011	1.1040***	-0.0039	0.1953***	-0.1447***	0.9747
	(1.6485)	(54.2918)	(-0.0787)	(5.1742)	(-7.3263)	
Dividend	0.0014**	1.0207***	0.0045	0.1142***	-0.0941***	0.9770
	(2.4171)	(64.6324)	(0.1145)	(2.7507)	(-2.9745)	
Revenue	0.0008	1.1522***	0.0737	0.2029***	-0.1379***	0.9665
	(1.0411)	(49.2841)	(1.3063)	(4.5074)	(-5.9253)	
Employee	0.0012	1.1348***	0.0797	0.0584	-0.1495***	0.9587
	(1.3583)	(40.5864)	(1.1461)	(1.4315)	(-5.6101)	
Income	0.0012**	1.0396***	0.0434	0.1032***	-0.0582***	0.9514
	(2.4690)	(74.2457)	(1.4472)	(3.5976)	(-2.6848)	
Operating Income	0.0010*	1.0552***	0.0414	0.1335***	-0.0827***	0.9782
	(1.7181)	(75.5228)	(1.3039)	(4.1061)	(-3.6862)	
Composite	0.0011**	1.0821***	0.0289	0.1492***	-0.1200***	0.9838
	(2.1178)	(74.6993)	(0.7537)	(4.7677)	(-5.8236)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table 13 shows that the dividend, income and composite weighted portfolio have significant four factor alphas at the 5% level. In addition, the equal- and operating income weighted portfolios have significant four factor alphas at the 10% level. All portfolios have a negative loading on the momentum factor, which are all significant at the 1% level.

4.5 S&P 100

4.5.1 Absolute Performance S&P 100

As can be seen from the table in Appendix I.5, the annual turnover of the fundamental portfolios is roughly 3.5 times higher compared to the reference portfolio. The equal-weighted portfolio has the highest turnover, roughly 4.0 times higher compared to the reference portfolio. The annual transaction costs of all portfolios range between 12 and 14 basis points.

In Table 14, the results of the reference portfolio, the equal-weighted portfolio and the fundamental weighted portfolios are shown.

Table 14: Comparison Reference and Capitalization-Indifferent Portfolios S&P 100

This table includes the Ending Value of €100 invested in either the Reference portfolio or any of the capitalization-indifferent-weighted portfolios, over the time period 31/01/1990 – 31/12/2018. Furthermore, the Annualized Return, Annualized Standard Deviation, Annualized Tracking Error, Annualized Excess Return, Correlation, CAPM Beta and R Squared are displayed. In order to calculate the CAPM Beta, the reference portfolio is used as the market portfolio.

	Ending Value of €100	Return	Standard Deviation	Tracking Error	Excess Return	Correlation	Beta	R^2
Reference Portfolio S&P 100	€ 1,401.00	0.0956	0.1432					
Equal	€ 1,759.50	0.1043	0.1489	0.0499	0.0079	0.9425	0.9799***	0.8880
Book Value	€ 1,506.69	0.0983	0.1560	0.0475	0.0025	0.9531	1.0380***	0.9081
Cash Flow	€ 1,781.23	0.1047	0.1517	0.0435	0.0083	0.9582	1.0149***	0.9179
Dividend	€ 1,675.25	0.1024	0.1412	0.0576	0.0062	0.9180	0.9050***	0.8422
Revenue	€ 1,860.90	0.1064	0.1506	0.0492	0.0099	0.9452	0.9936***	0.8931
Employee	€ 2,124.06	0.1115	0.1486	0.0576	0.0145	0.9227	0.9573***	0.8510
Income	€ 2,062.97	0.1103	0.1417	0.0322	0.0135	0.9746	0.9643***	0.9496
Operating Income	€ 1,936.31	0.1079	0.1445	0.0368	0.0113	0.9674	0.9762***	0.9356
Composite	€ 1,851.72	0.1062	0.1432	0.0418	0.0097	0.9585	0.9785***	0.9186

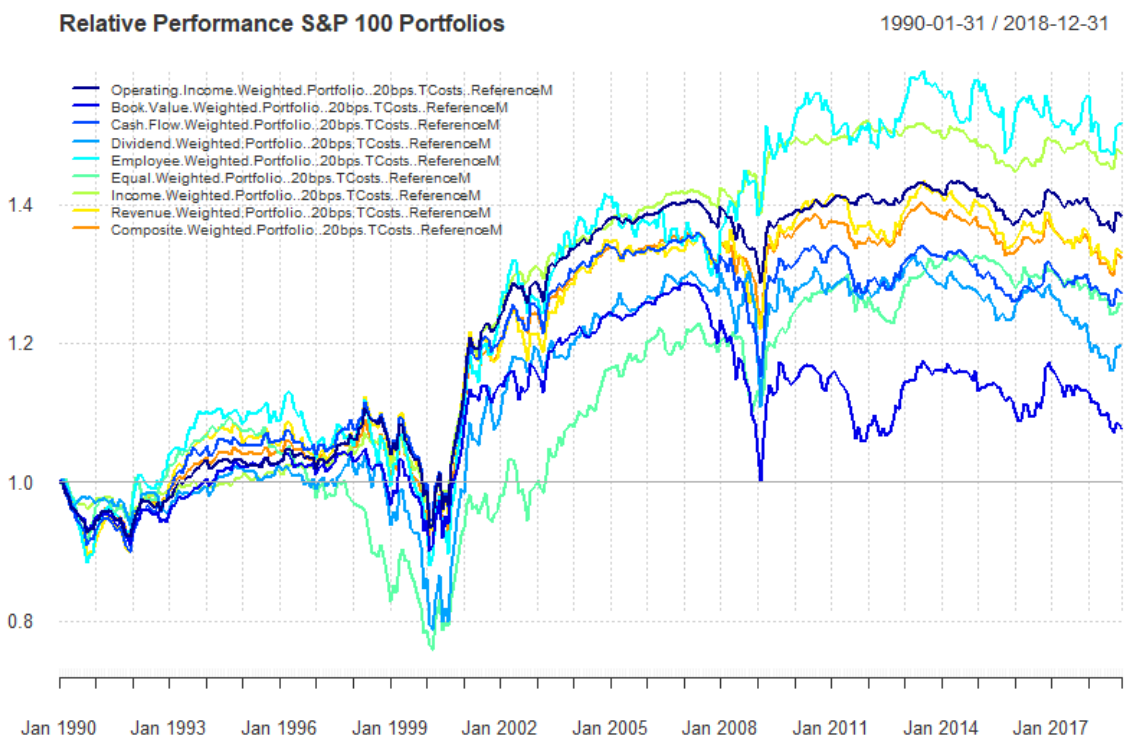
***, **, * indicate the significance at the 1%, 5%, and 10% levels.

As can be seen from Table 14, the equal-weighted portfolio and all fundamental portfolios outperform the value weighted portfolio in terms of absolute return. In addition, almost all

portfolios have slightly higher annual standard deviations, only the dividend weighted portfolio has a lower standard deviation compared to the reference portfolio. The dividend and employee weighted portfolios have the highest tracking error (5.76%) and the income weighted portfolio the lowest (3.22%). The employee weighted portfolio has the highest outperformance compared to the reference portfolio, with an annual excess return of 1.45%. The equal-weighted portfolio has an annual outperformance of 0.79%, whilst the composite weighted portfolio earns 0.97% more compared to the reference portfolio. The equal- and fundamental portfolios are all highly correlated with the reference portfolio. Furthermore, the equal- and almost all fundamental portfolios have CAPM Betas around one, with the reference portfolio as market portfolio. However, the dividend weighted portfolio has a beta of around 0.90. All Betas are statistically significant at the 1% level. The Adjusted R-Squared for all linear models is above 0.85. Graph 15 shows the relative cumulative performance of all portfolios compared to the reference portfolio.

Graph 15: Relative Performance S&P 100 Portfolios

This graph shows the relative cumulative performance of the capitalization indifferent weighted portfolios with respect to the Reference portfolio, over the time period 31/01/1990 – 31/12/2018.



Looking at Graph 15, it becomes clear that all portfolios behave very similarly. They all underperform until 1993 and during the 2000 crisis. After that, they consistently outperform the reference portfolio. Only the equal-weighted portfolio behaves somewhat different as it has a longer period of underperformance, which starts around 1998 and lasts until 2003. During the 2008 financial crisis, the portfolios maintain their outperformance, although lower in magnitude.

4.5.2 Factor Exposure and Alphas S&P 100

In order to test for Jensen's Alpha, the risk-free rate is subtracted from the returns of all portfolios, including the reference portfolio. The risk-free rate used for the S&P 100 portfolios is the Dollar 1 Month Deposit Rate, reported by The Financial Times and Thomson Reuters and retrieved via Datastream.

As can be seen in the table in Appendix V.5, the income weighted portfolio has a statistically significant Jensen's Alpha at the 1% level. The employee and operating income weighted portfolios have statistically significant Jensen's alpha at the 10% level.

For all S&P 100 portfolios, the Sharpe Ratio and the Information Ratio are calculated and reported in Appendix VI.5. The equal-weighted portfolio and almost all fundamental weighted portfolios have higher Sharpe Ratios compared to the reference portfolio. Only the book value weighted portfolio has a lower Sharpe Ratio. In addition, all portfolios have a positive Information Ratio. The income weighted portfolio has the highest Sharpe and Information Ratio. The composite weighted portfolio has a higher Sharpe and Information Ratio compared to the equal-weighted portfolio.

The results of the Fama & French Three Factor model are in Appendix VII.5. The table in Appendix VII.5 shows that only the income weighted portfolio has a statistically significant three factor alpha at the 5%. The equal-, book value revenue and employee weighted portfolios have a positive factor loading on the size factor, which is significant at the 1% level. This leads to conclude that these portfolios are tilted towards smaller companies. This makes sense for the equal-weighted portfolio, but no so for the book value, revenue and employee weighted portfolios. Intuitively, it is the opposite of what one would expect. The cash flow weighted portfolio also has a positive factor loading on the size factor, which is significant at the 5% level. Additionally, the composite weighted portfolio has a positive loading value on the size factor, but is only significant

at the 10% level. Furthermore, all portfolios have positive loadings on the value factor (that are significant at the 1% level).

The results of the Carhart Four Factor model are in Table 15.

Table 15: Carhart Four Factor Alpha S&P 100 Portfolios

This table includes Carhart Four Factor Alpha of all S&P 100 Portfolios over the time period 30/11/1990 – 31/12/2018. Carhart Four Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio S&P 100. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Carhart 4-Factor Alpha	Market - Rf	SMB	HML	WML	R^2
Reference Portfolio S&P 100	0.0084***		0.0339	-0.3778***	-0.2250***	0.1125
	(3.8343)		(0.3499)	(-4.5877)	(-4.1341)	
Equal	0.0012**	0.9850***	0.2113***	0.2274***	-0.1191***	0.9427
	(2.0810)	(68.2820)	(10.7770)	(11.8150)	(-9.4070)	
Book Value	0.0004	1.0545***	0.1164***	0.2487***	-0.1329***	0.9643
	(0.8713)	(66.4109)	(6.0729)	(11.3944)	(-9.3044)	
Cash Flow	0.0011**	1.0301***	0.0865***	0.2298***	-0.1199***	0.9691
	(2.3470)	(75.0908)	(4.3329)	(10.5577)	(-7.4990)	
Dividend	0.0009	0.9450***	0.0022	0.3164***	-0.0987***	0.9289
	(1.3497)	(38.1836)	(0.0715)	(10.3720)	(-5.7070)	
Revenue	0.0013**	1.0083***	0.1202***	0.2468***	-0.1192 ***	0.9488
	(2.3353)	(61.6882)	(4.8504)	(11.7506)	(-6.6366)	
Employee	0.0021***	0.9647***	0.0946***	0.2275***	-0.1195***	0.9018
	(2.7610)	(51.3780)	(3.7080)	(9.0830)	(-7.2570)	
Income	0.0017***	0.9724***	0.0071	0.1454***	-0.0907***	0.9790
	(4.6419)	(80.4749)	(0.4381)	(7.8725)	(-7.7720)	
Operating Income	0.0014***	0.9904***	0.0321*	0.1871***	-0.0948***	0.9737
	(3.5651)	(80.5630)	(1.8253)	(9.5841)	(-7.1237)	
Composite	0.0013***	0.9950***	0.0656***	0.2288***	-0.1108***	0.9702
	(3.0313)	(74.6637)	(3.4772)	(12.0268)	(-8.6456)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table 15 shows that the employee, income, operating income and composite weighted portfolio have significant four factor alphas at the 1% level of significance. In addition, the equal, cash flow, and revenue weighted portfolios have significant four factor alphas at the 5% level of significance. All portfolios have a negative loading on the momentum factor, all significant at the 1% level.

4.6 Discussion

Looking at the annual turnover and transaction costs, it becomes clear that the fundamental indices have about 2 to 2.6 times higher turnover compared to their respective capitalization-weighted indices. An exception in terms of turnover is the S&P 100, of which the fundamental indices have about 3.5 higher turnover, but this is mainly due to the fact that the S&P 100 has a lower turnover itself compared to the other indices. For every index, the equal-weighted index has the highest turnover, ranging from 2.3 times higher for the DAX to 4 times higher for the S&P 100. Overall, trading costs remain quite low at 11 – 14 basis points for all portfolios.

In terms of absolute performance, all composite weighted portfolios perform better than the capitalization-weighted portfolios, with an average annual outperformance of 0.69%. Three out of five composite portfolios perform better compared to their respective equal-weighted counterparts. The average annual outperformance of all composite portfolios compared to the equal-weighted portfolios is 0.13%[3].

The relative cumulative performance of the composite portfolios compared to the capitalization-weighted portfolios appears to be better overall, except for the period around the 2000 crisis. This appears to be the same for the equal-weighted portfolios with respect to the capitalization-weighted portfolios. However, during the 2000 crisis and the financial crisis of 2008, fundamental weighted portfolios appear to perform better compared their equal-weighted counterparts. It is also interesting that both the composite and equal-weighted portfolios maintain their relative cumulative outperformance during the financial crisis of 2008, although lower in magnitude. This does, however, indicate that both fundamental and equal-weighted portfolios are more volatile in times of crisis than the capitalization-weighted portfolio.

[3] This average includes the underperformance of the two composite portfolios that did not manage to outperform their equal-weighted counterparts.

Of all tested portfolios, only one (out of 45) has a statistically significant Jensen's Alpha at the 1% level. Three portfolios were significant at the 5% level and six at the 10% level. The CAPM Betas of the fundamental weighted portfolios were between 0.90 and 1.21, but the composite portfolios have betas that are slightly higher than one. None of the equal-weighted portfolios had a statistically significant Jensen's Alpha at conventional significance levels. The equal-weighted portfolios have betas that are slightly higher than one. These results indicate that in a simple one factor model, both fundamental and equal-weighted indices fail to systematically produce alpha with respect to their capitalization-weighted counterparts. In other words, the fundamental and equal-weighted portfolios only experience a higher absolute return due to their higher exposure to market risk, according to the Jensen One Factor model.

All composite weighted portfolios have higher Sharpe Ratios than their capitalization-weighted counterparts, except for the SMI portfolio. All composite weighted portfolios have a positive Information Ratio ranging from 0.07 for the EuroStoxx 50 to 0.33 for the DAX. All equal-weighted portfolios have higher Sharpe Ratios than their capitalization-weighted counterparts, except for the SMI. All equal-weighted portfolios have a positive Information Ratio, except for the SMI, ranging from -0.005 for the SMI to 0.24 for the DAX. All composite portfolios have higher Sharpe and Information Ratios compared to the equal-weighted portfolios, except for the Sharpe Ratio of the DAX, which is slightly higher for the equal-weighted portfolio compared to the composite weighted portfolio.

Out of 45 tested portfolios, none had a statistically significant Fama & French Three Factor Alpha at the 1% level. Only one portfolio has a statistically significant alpha at the 5% level, and four portfolios at the 10% level. None of the equal-weighted portfolios had a significant three factor alpha at any of the conventional significance levels. Looking at the size factor, two out of five composite weighted portfolios have significant positive factor loadings, namely SMI (positive at the 5% level) and the S&P 100 (positive at the 1% level). However, in both cases the magnitude is quite low, about 0.07 on a monthly basis. All composite weighted portfolios have significant positive loadings on the value factor, and are statistically significant at the 1% level, except for the SMI, which is significant at the 5% level. The magnitude of the factor loading ranges from 0.06 for the SMI to 0.28 for the CAC, on a monthly basis. For the equal-weighted portfolios, three out of five have positive loadings on the size factor and are statistically significant at the 1% level. The magnitude ranges from 0.19 for the S&P 100 to 0.29 for the SMI, on a monthly basis. Four

out of five equal-weighted portfolios have significant positive loadings on the value factor and are significant at the 1% level. The magnitude ranges from 0.12 for the EuroStoxx 50 to 0.28 for the S&P 100. It makes sense for the fundamental portfolios to have a positive loading on the value factor, as the fundamental indexing strategy is based on buying undervalued stocks relative to their fundamentals.

Out of 45 tested capitalization-indifferent portfolios, 32 had a significant Carhart Four Factor Alpha at convenient significant levels, of which 9 at the 1% level, 16 at the 5% level and 7 at the 10% level. All composite weighted portfolios have statistically significant four factor alphas, of which two at the 1% level, two at the 5% level and one at the 10% level. The magnitude of the alpha ranges from 0.11% for the EuroStoxx 50 to 0.15% for the DAX, on a monthly basis. All composite portfolios have negative loadings on the momentum factor and are all statistically significant at the 1% level. The magnitude ranges from -0.08 for the DAX to -0.16 for the SMI. Four out of five equal-weighted portfolios have statistically significant four factor alphas, of which one at the 1% level, two at the 5% level and one at the 10% level. The magnitude ranges from 0.21% for the DAX to 0.12% for the S&P 100. All equal-weighted portfolios have negative loadings on the momentum factor and are all statistically significant at the 1% level. The magnitude ranges from -0.12 for the S&P 100 to -0.24 for the SMI. The rationale behind fundamental portfolios is to buy stocks that are undervalued relative to their fundamentals, and sell stocks that are overvalued relative to their fundamentals. Therefore, it makes sense for the fundamental portfolios to have negative loadings on the momentum factor, as it is a contrarian strategy.

Finally, it becomes clear that some fundamental portfolios perform better than others (in terms of producing Carhart Four Factor Alpha). The book value weighted portfolios perform the worst, only one portfolio is significant at the 10% level. The revenue weighted portfolios perform only slightly better, with one statistically significant at the 5% level and one at the 10% level. The best performer is the income weighted portfolio, with two significant at the 1% level and three at the 5% level. It is closely followed by the newly introduced operating income portfolio, which has two significant at the 1% level, two at the 5% level and one at the 10% level. Looking at the absolute performance of these methods, the average annual outperformance of the book value portfolio is 0.24% and 0.38% for the revenue portfolio. The average annual outperformance of the income portfolio is 1.08% and 0.83% for the operating income portfolio. The average annual outperformance of the equal-weighted portfolio is 0.56% and 0.69% for the composite portfolio.

5. Conclusion

The aim of my research is to investigate whether fundamental weighted indices outperform their capitalization and equal-weighted counterparts in terms of absolute and risk-adjusted performance. Furthermore, I investigate whether fundamental weighted indices produce alpha, after correcting for the Fama & French Three Factor model and the Carhart Four Factor model.

In order to answer these questions, I use data from the DAX, SMI, CAC, EuroStoxx 50 and S&P 100. I create eight fundamental weighted portfolios, using seven fundamental parameters, namely: book value, cash flow, dividend, revenue, employees, income and operating income and one composite portfolio that is the average of all seven fundamental weighted portfolios. I compare these eight weighted portfolios to their capitalization and equal-weighted counterparts.

I find that all composite weighted portfolios outperform their capitalization-weighted counterparts with an average annual outperformance of 0.69%. Additionally, three out of five composite weighted portfolios outperform their equal-weighted counterparts with an average annual outperformance of 0.13%[4]. In terms of relative performance, it becomes clear that both equal- and fundamental weighted portfolios are more volatile during the 2000 and 2008 crisis compared to the capitalization-weighted index. The fundamental weighted portfolios are, however, less volatile compared to the equal-weighted portfolios. Furthermore, four out of five composite weighted portfolios have higher Sharpe Ratios than the equal- and capitalization-weighted portfolios. All composite portfolios have higher Information Ratios compared to their equal-weighted counterparts. Four out of five composite weighted portfolios have statistically significant four factor alphas at the 5% level or higher, with an average monthly alpha of 0.13%. Three out of five equal-weighted portfolios have statistically significant alphas at the 5% level or higher, with an average monthly alpha of 0.16%. Although the average monthly alpha of the equal-weighted portfolios is higher, the results are less significant. In three out of five cases, the alpha of the composite weighted portfolios is more significant than the equal-weighted portfolio and in two out of five cases they are equally significant. So, in terms of producing four factor alpha, there is no hard evidence that fundamental weighted indices outperform equal-weighted indices. Finally, I find that, based on absolute and risk-adjusted performance and producing four factor alpha, the

[4] This average includes the underperformance of the two composite portfolios that did not manage to outperform their equal-weighted counterparts.

book value and revenue weighted portfolios are the worst performers and the income and operating income are the best performers.

The outperformance of the composite portfolios is partly based on factor exposure, and partly based on alpha. Only two out of five composite portfolios have statistically significant positive loadings on the size factor. All composite weighted portfolios have statistically significant loadings on the value factor, which makes sense as the fundamental indexing strategy is based on over- and underweighting stocks that are under- and overvalued relative to their fundamentals. All composite weighted portfolios have statistically significant negative loadings on the momentum factor, which makes sense as fundamental indexing is a contrarian strategy. It is, however, important to note that most composite portfolios only produce significant alpha after adding the momentum risk factor, next to size and value. The composite portfolios have, on average, a three times lower negative momentum exposure compared to the capitalization-weighted indices.

The main takeaway from my thesis is that fundamental indexing is a rewarding strategy that yields higher absolute and risk-adjusted returns compared to equal- and capitalization-weighted indices. Next to that, I find that fundamental weighted indices produce statistically significant four factor alpha. There is no conclusive evidence that fundamental weighted indices produce higher and/or more significant four factor alphas compared to the equal-weighted indices. By sticking to a standard monthly rebalancing frequency, the sensitivity towards the annual rebalancing date is avoided. Finally, I find that the newly introduced operating income parameter is the second best performing parameter (after income) in terms of absolute and risk-adjusted performance and in producing four factor alpha. This is the case for almost all tested indices.

I must, however, note that the evidence is less strong for the SMI, based on producing alphas. This could be the result from the main shortcoming of this thesis, namely the use of European size, value and momentum portfolios that are retrieved from Kenneth French's Data Library. Perhaps, the European factor portfolios are not a good proxy for Swiss factor portfolios and using Swiss factor portfolios would result in more significant results.

Further research may investigate whether dropping the two worst performing fundamental parameters (book value and revenue), would improve the overall results of the composite portfolio without increasing its risk. Furthermore, it may be interesting to check whether the results I find are still valid when using country specific factor portfolios. Subsequently, fundamental portfolios could be compared to pure factor portfolios, revealing which of the two strategies performs better.

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Appendices

Appendix I

Table I.1: Portfolio Turnover and Transaction Costs DAX

This table includes the annual turnover of all DAX portfolios. In addition, the annual transaction costs for all portfolios, except the Reference portfolio, are also included.

	Turnover	Transaction Costs
Reference Portfolio DAX	0.2822	
Equal	0.6536	0.0013
Book Value	0.5907	0.0012
Cash Flow	0.5721	0.0011
Dividend	0.5490	0.0011
Revenue	0.5789	0.0012
Employee	0.5791	0.0012
Income	0.5630	0.0011
Operating Income	0.5915	0.0012
Composite	0.5661	0.0011

Table I.2: Portfolio Turnover and Transaction Costs SMI

This table includes the annual turnover of all SMI portfolios. In addition, the annual transaction costs for all portfolios, except the Reference portfolio, are also included.

	Turnover	Transaction Costs
Reference Portfolio SMI	0.2434	
Equal	0.7153	0.0014
Book Value	0.5803	0.0012
Cash Flow	0.5697	0.0011
Dividend	0.5301	0.0011
Revenue	0.5886	0.0012
Employee	0.6001	0.0012
Income	0.5407	0.0011
Operating Income	0.5549	0.0011
Composite	0.5620	0.0011

Table I.3: Portfolio Turnover and Transaction Costs CAC

This table includes the annual turnover of all CAC portfolios. In addition, the annual transaction costs for all portfolios, except the Reference portfolio, are also included.

	Turnover	Transaction Costs
Reference Portfolio CAC	0.2498	
Equal	0.7200	0.0014
Book Value	0.6653	0.0013
Cash Flow	0.6813	0.0014
Dividend	0.6450	0.0013
Revenue	0.6701	0.0013
Employee	0.6729	0.0013
Income	0.6334	0.0013
Operating Income	0.6396	0.0013
Composite	0.6488	0.0013

Table I.4: Portfolio Turnover and Transaction Costs EuroStoxx 50

This table includes the annual turnover of all EuroStoxx 50 portfolios. In addition, the annual transaction costs for all portfolios, except the Reference portfolio, are also included.

	Turnover	Transaction Costs
Reference Portfolio EuroStoxx 50	0.2433	
Equal	0.6651	0.0013
Book Value	0.6257	0.0013
Cash Flow	0.6135	0.0012
Dividend	0.6066	0.0012
Revenue	0.6243	0.0012
Employee	0.6467	0.0013
Income	0.5916	0.0012
Operating Income	0.5994	0.0012
Composite	0.6085	0.0012

Table I.5: Portfolio Turnover and Transaction Costs S&P 100

This table includes the annual turnover of all S&P 100 portfolios. In addition, the annual transaction costs for all portfolios, except the Reference portfolio, are also included.

	Turnover	Transaction Costs
Reference Portfolio S&P 100	0.1756	
Equal	0.7077	0.0014
Book Value	0.6424	0.0013
Cash Flow	0.6302	0.0013
Dividend	0.5966	0.0012
Revenue	0.6352	0.0013
Employee	0.6302	0.0013
Income	0.6111	0.0012
Operating Income	0.6146	0.0012
Composite	0.6192	0.0012

Appendix II

Table II.1: Summary Statistics DAX Portfolios

	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Reference Portfolio							
DAX	0.0076	0.0114	0.0584	-0.5310	1.9475	-0.2505	0.2037
Equal	0.0087	0.0121	0.0606	-0.5017	2.5948	-0.2781	0.2410
Book Value	0.0084	0.0133	0.0609	-0.3002	2.5867	-0.2647	0.2890
Cash Flow	0.0089	0.0121	0.0595	-0.4597	2.1358	-0.2597	0.2437
Dividend	0.0081	0.0116	0.0590	-0.5014	1.9910	-0.2482	0.2251
Revenue	0.0087	0.0115	0.0615	-0.4158	2.0689	-0.2571	0.2549
Employee	0.0094	0.0124	0.0608	-0.4553	1.6465	-0.2509	0.2159
Income	0.0084	0.0121	0.0599	-0.4996	1.9950	-0.2477	0.2318
Operating Income	0.0083	0.0106	0.0610	-0.4213	2.3271	-0.2583	0.2619
Composite	0.0086	0.0125	0.0599	-0.4544	2.1111	-0.2552	0.2460

Table II.2: Summary Statistics SMI Portfolios

	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Reference Portfolio							
SMI	0.0075	0.0113	0.0435	-0.6218	1.5494	-0.1886	0.1386
Equal	0.0079	0.0155	0.0525	-0.5359	2.0719	-0.2064	0.1941
Book Value	0.0078	0.0137	0.0516	-0.3870	1.8323	-0.2044	0.1816
Cash Flow	0.0081	0.0119	0.0500	-0.3438	2.4607	-0.1978	0.2278
Dividend	0.0082	0.0110	0.0502	-0.4600	2.2297	-0.2094	0.1812
Revenue	0.0078	0.0138	0.0553	-0.2320	2.6341	-0.2106	0.2270
Employee	0.0083	0.0128	0.0516	-0.0670	4.2822	-0.1970	0.2943
Income	0.0083	0.0115	0.0441	-0.4630	0.8545	-0.1631	0.1292
Operating Income	0.0081	0.0121	0.0472	-0.4630	1.2513	-0.1748	0.1537
Composite	0.0081	0.0139	0.0491	-0.4268	1.8417	-0.1939	0.1795

Table II.3: Summary Statistics CAC Portfolios

	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Reference Portfolio							
CAC	0.0074	0.0135	0.0523	-0.3326	0.2678	-0.1684	0.1362
Equal	0.0083	0.0131	0.0572	-0.2773	0.9900	-0.2026	0.2115
Book Value	0.0083	0.0149	0.0588	-0.2292	0.8553	-0.2153	0.2135
Cash Flow	0.0085	0.0145	0.0600	-0.2022	1.3138	-0.2273	0.2569
Dividend	0.0083	0.0149	0.0555	-0.2796	1.2427	-0.2175	0.2116
Revenue	0.0081	0.0134	0.0595	-0.2475	0.9847	-0.2082	0.2273
Employee	0.0076	0.0127	0.0587	-0.2697	0.9409	-0.2090	0.2126
Income	0.0084	0.0140	0.0543	-0.3682	0.7046	-0.1916	0.1832
Operating Income	0.0085	0.0151	0.0544	-0.2946	0.9232	-0.2133	0.1963
Composite	0.0083	0.0145	0.0569	-0.2754	0.9514	-0.2117	0.2012

Table II.4: Summary Statistics EuroStoxx 50 Portfolios

	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Reference Portfolio							
EuroStoxx 50	0.0020	0.0084	0.0432	-0.5249	1.1073	-0.1513	0.1279
Equal	0.0025	0.0088	0.0524	-0.0687	2.9890	-0.1930	0.2087
Book Value	0.0021	0.0108	0.0529	-0.1390	2.0683	-0.1991	0.2051
Cash Flow	0.0024	0.0081	0.0531	-0.2538	2.2135	-0.2068	0.1880
Dividend	0.0029	0.0078	0.0475	-0.2382	1.9243	-0.1631	0.1832
Revenue	0.0024	0.0086	0.0549	-0.2497	2.2063	-0.2076	0.1967
Employee	0.0022	0.0066	0.0538	-0.2729	2.2957	-0.1979	0.1971
Income	0.0031	0.0073	0.0471	-0.2906	1.5667	-0.1651	0.1610
Operating Income	0.0027	0.0076	0.0486	-0.2590	1.9153	-0.1755	0.1780
Composite	0.0026	0.0087	0.0508	-0.2456	2.0159	-0.1879	0.1839

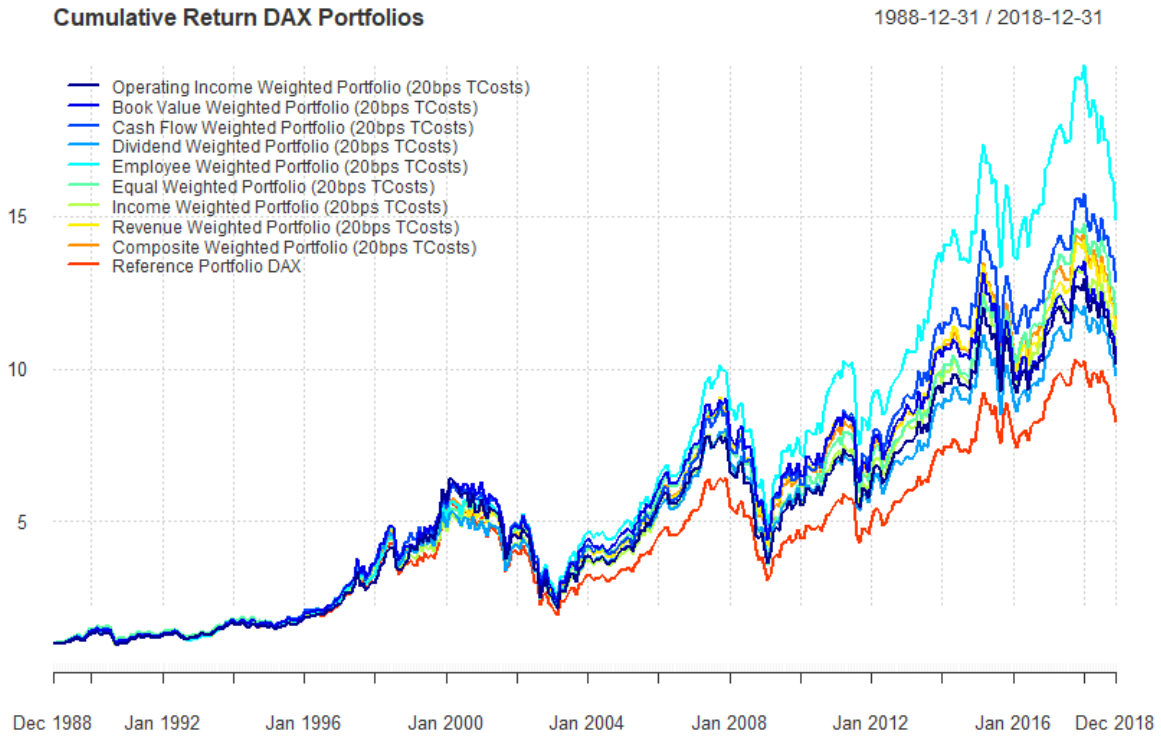
Table II.5: Summary Statistics S&P 100 Portfolios

	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Reference Portfolio							
S&P 100	0.0085	0.0130	0.0413	-0.5403	0.8846	-0.1441	0.1104
Equal	0.0092	0.0133	0.0430	-0.5726	1.5588	-0.1703	0.1326
Book Value	0.0089	0.0143	0.0450	-0.4612	1.2568	-0.1570	0.1530
Cash Flow	0.0093	0.0120	0.0438	-0.4876	1.5307	-0.1750	0.1443
Dividend	0.0090	0.0119	0.0408	-0.5292	2.0623	-0.1544	0.1654
Revenue	0.0094	0.0130	0.0435	-0.4892	1.5816	-0.1755	0.1526
Employee	0.0098	0.0120	0.0429	-0.4841	1.3998	-0.1567	0.1298
Income	0.0096	0.0125	0.0409	-0.5170	1.2043	-0.1412	0.1169
Operating Income	0.0095	0.0134	0.0417	-0.5421	1.2706	-0.1501	0.1135
Composite	0.0093	0.0139	0.0422	-0.5128	1.3944	-0.1545	0.1328

Appendix III

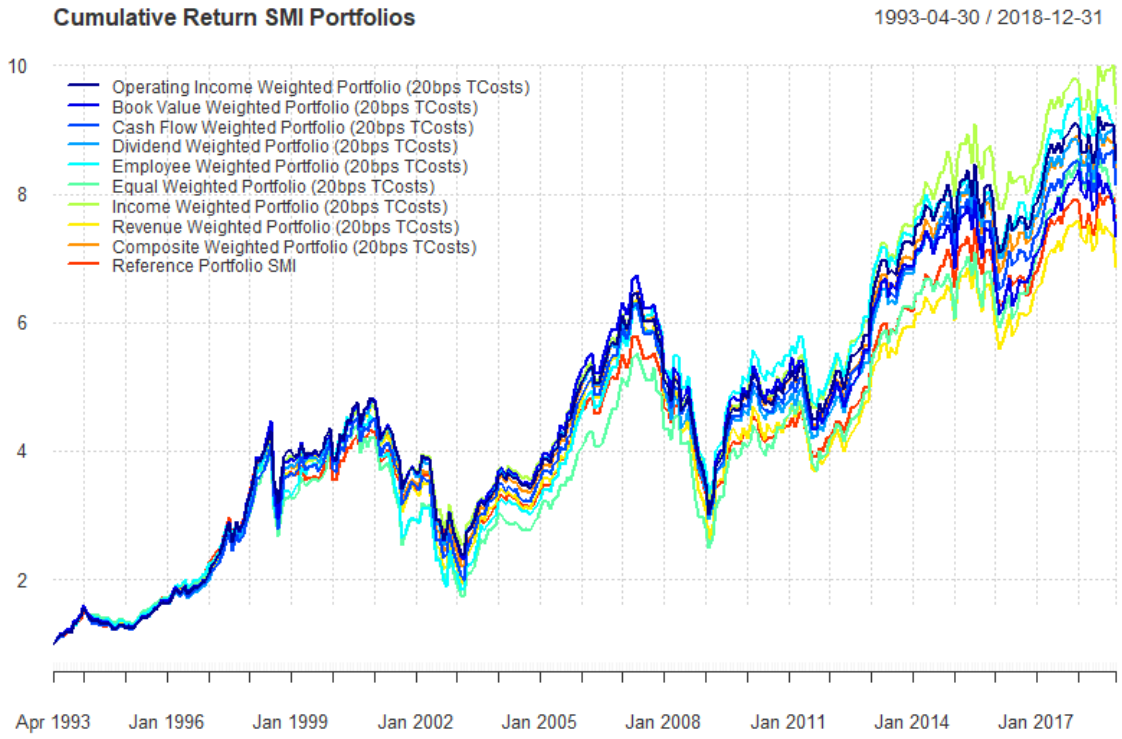
Graph III.1: Cumulative Return DAX Portfolios

This graph shows the Total Return and the Ending Value of €1 invested in either the Reference Portfolio DAX or any of the capitalization indifferent weighted portfolios, over the time period 31/12/1988 – 31/12/2018.



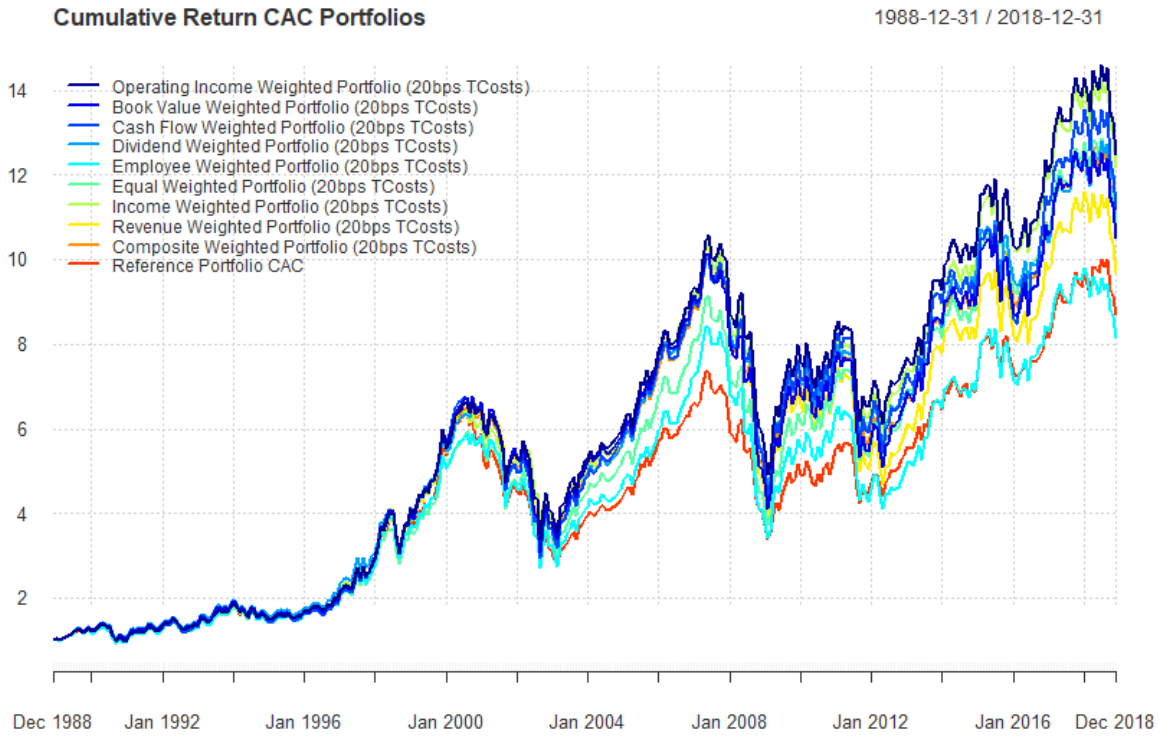
Graph III.2: Cumulative Return SMI Portfolios

This graph shows the Total Return and the Ending Value of €1 invested in either the Reference Portfolio SMI or any of the capitalization indifferent weighted portfolios, over the time period 30/04/1993 – 31/12/2018.



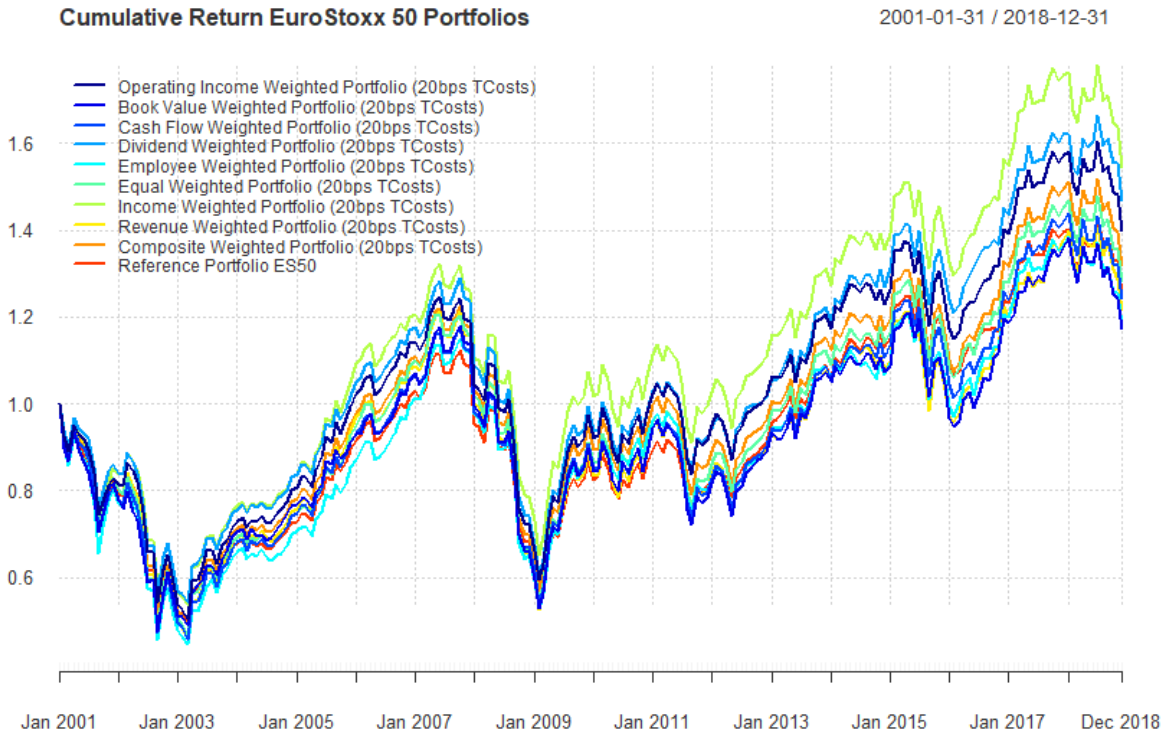
Graph III.3: Cumulative Return CAC Portfolios

This graph shows the Total Return and the Ending Value of €1 invested in either the Reference Portfolio CAC or any of the capitalization indifferent weighted portfolios, over the time period 31/12/1988 – 31/12/2018.



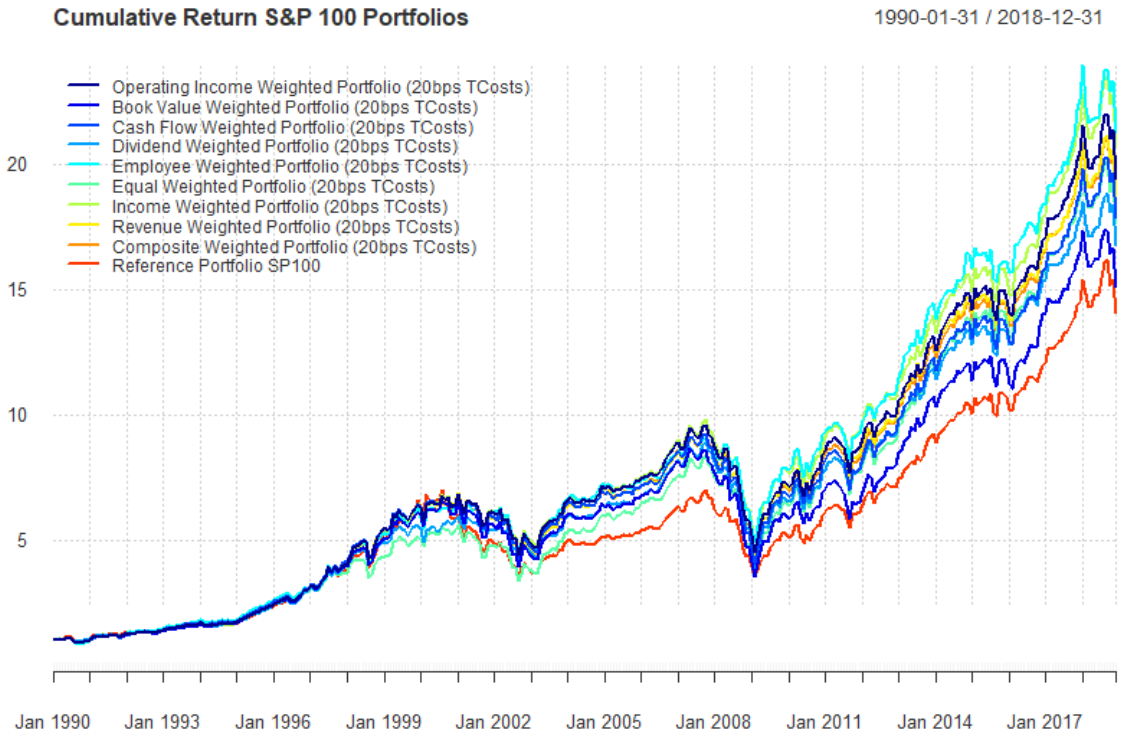
Graph III.4: Cumulative Return EuroStoxx 50 Portfolios

This graph shows the Total Return and the Ending Value of €1 invested in either the Reference Portfolio EuroStoxx 50 or any of the capitalization indifferent weighted portfolios, over the time period 31/01/2001 – 31/12/2018.



Graph III.5: Cumulative Return S&P 100 Portfolios

This graph shows the Total Return and the Ending Value of €1 invested in either the Reference Portfolio S&P 100 or any of the capitalization indifferent weighted portfolios, over the time period 31/01/1990 – 31/12/2018.



Appendix IV

Table IV.1: Breusch-Pagan Tests DAX Portfolios

	Jensen's Alpha p-value	Fama & French Alpha p-value	Carhart Alpha p-value
Reference Portfolio DAX		0.4981	0.0172
Equal	0.0206	0.0049	0.0358
Book Value	0.0016	0.0303	0.0021
Cash Flow	0.3206	0.4117	0.2908
Dividend	0.9072	0.0375	0.0572
Revenue	0.0199	0.0057	0.1712
Employee	0.2472	0.3193	0.8293
Income	0.3802	0.0001	0.0018
Operating Income	0.8200	0.3759	0.6809
Composite	0.1322	0.0079	0.1133

Table IV.2: Breusch-Pagan Tests SMI Portfolios

	Jensen's Alpha p-value	Fama & French Alpha p-value	Carhart Alpha p-value
Reference Portfolio SMI		0.6405	0.7663
Equal	0.9636	0.0702	0.0173
Book Value	0.0317	0.0097	0.0000
Cash Flow	0.1196	0.1681	0.0010
Dividend	0.2248	0.2563	0.0186
Revenue	0.1968	0.1176	0.0072
Employee	0.8562	0.7653	0.1153
Income	0.1478	0.1997	0.0216
Operating Income	0.5505	0.1367	0.0402
Composite	0.4666	0.3941	0.0783

Table IV.3: Breusch-Pagan Tests CAC Portfolios

	Jensen's Alpha p-value	Fama & French Alpha p-value	Carhart Alpha p-value
Reference Portfolio CAC		0.5107	0.0114
Equal	0.2798	0.0659	0.1919
Book Value	0.0301	0.2741	0.2717
Cash Flow	0.0124	0.01712	0.0187
Dividend	0.3238	0.1266	0.6215
Revenue	0.0310	0.0381	0.1128
Employee	0.1830	0.2672	0.7046
Income	0.4429	0.7298	0.1259
Operating Income	0.1173	0.0268	0.1393
Composite	0.0215	0.0212	0.0624

Table IV.4: Breusch-Pagan Tests EuroStoxx 50 Portfolios

	Jensen's Alpha p-value	Fama & French Alpha p-value	Carhart Alpha p-value
Reference Portfolio EuroStoxx 50		0.0447	0.0026
Equal	0.0003	0.0002	0.0004
Book Value	0.0248	0.0060	0.0073
Cash Flow	0.1996	0.0010	0.0017
Dividend	0.2598	0.0004	0.0000
Revenue	0.1228	0.0012	0.0009
Employee	0.2129	0.0277	0.0080
Income	0.2328	0.0001	0.0000
Operating Income	0.0569	0.0006	0.0011
Composite	0.0278	0.0003	0.0001

Table IV.5: Breusch-Pagan Tests S&P 100 Portfolios

	Jensen's Alpha p-value	Fama & French Alpha p-value	Carhart Alpha p-value
Reference Portfolio S&P 100		0.0024	0.0001
Equal	0.9119	0.2588	0.7925
Book Value	0.8051	0.0914	0.0009
Cash Flow	0.9402	0.0059	0.0000
Dividend	0.1406	0.5518	0.0427
Revenue	0.9668	0.0816	0.0017
Employee	0.2868	0.7845	0.2757
Income	0.1480	0.2534	0.0000
Operating Income	0.2268	0.0761	0.0002
Composite	0.4594	0.0405	0.0034

Appendix V

Table V.1: Jensen's Alpha DAX Portfolios

This table includes Jensen's Alpha of all DAX Portfolios over the time period 31/12/1988 – 31/12/2018. Jensen's Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio DAX. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Jensen's Alpha	Reference - Rf	R^2
Reference Portfolio DAX			
Equal	0.0011	1.0063***	0.9400
	(1.4308)	(48.3463)	
Book Value	0.0007	1.0190***	0.9552
	(1.0685)	(55.2824)	
Cash Flow	0.0013**	0.9965***	0.9549
	(1.9760)	(87.2390)	
Dividend	0.0005	0.9924***	0.9655
	(0.9420)	(100.1930)	
Revenue	0.0009	1.0276***	0.9508
	(1.3197)	(62.2884)	
Employee	0.0017**	1.0136***	0.9484
	(2.3540)	(81.1990)	
Income	0.0008	1.0094***	0.9660
	(1.3200)	(101.0100)	
Operating Income	0.0007	1.0190***	0.9505
	(0.9040)	(83.0510)	
Composite	0.0010*	1.0111***	0.9717
	(1.7810)	(110.9990)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table V.2: Jensen's Alpha SMI Portfolios

This table includes Jensen's Alpha of all SMI Portfolios over the time period 31/05/1993 – 31/12/2018. Jensen's Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio SMI. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Jensen's Alpha	Reference - Rf	R^2
Reference Portfolio SMI			
Equal	-0.0002	1.0856***	0.8080
	(-0.117)	(35.958)	
Book Value	-0.0006	1.1416***	0.9255
	(-0.7846)	(50.7152)	
Cash Flow	0.0000	1.096***	0.9088
	(-0.0530)	(55.3220)	
Dividend	0.0000	1.1140***	0.9310
	(-0.0240)	(64.3850)	
Revenue	-0.0009	1.1791***	0.8598
	(-0.7300)	(43.4000)	
Employee	0.0004	1.0536***	0.7863
	(0.3260)	(33.6270)	
Income	0.000804*	0.9960***	0.9645
	91.6790)	(91.3770)	
Operating Income	0.0002	1.0547***	0.9451
	(0.3760)	(72.7110)	
Composite	0.0000	1.0910***	0.9306
	(-0.0080)	(64.1480)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table V.3: Jensen's Alpha CAC Portfolios

This table includes Jensen's Alpha of all CAC Portfolios over the time period 31/12/1988 – 31/12/2018. Jensen's Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio CAC. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Jensen's Alpha	Reference - Rf	R^2
Reference Portfolio CAC			
Equal	0.0006	1.0661***	0.9505
	(0.8690)	(83.042)	
Book Value	0.0005	1.0929***	0.9442
	(0.6483)	(52.4634)	
Cash Flow	0.0007	1.1057***	0.9287
	(0.7892)	(43.4371)	
Dividend	0.0008	1.0288***	0.9418
	(1.1020)	(76.2570)	
Revenue	0.0002	1.1013***	0.9371
	(0.3123)	(48.5522)	
Employee	-0.0002	1.0854***	0.9363
	(-0.2750)	(72.6530)	
Income	0.0009605*	1.0198***	0.9640
	(1.7580)	(98.0780)	
Operating Income	0.0010289*	1.0197***	0.9626
	(1.8460)	(96.0930)	
Composite	0.0006	1.0648***	0.9592
	(0.9458)	(57.0955)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table V.4: Jensen's Alpha EuroStoxx 50 Portfolios

This table includes Jensen's Alpha of all EuroStoxx 50 Portfolios over the time period 31/01/2001 – 31/12/2018. Jensen's Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio EuroStoxx 50. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Jensen's Alpha	Reference - Rf	R^2
Reference Portfolio EuroStoxx 50			
Equal	0.0004	1.1850***	0.9587
	(0.5244)	(34.3517)	
Book Value	-0.0000	1.1888***	0.9479
	(-0.0135)	(37.3566)	
Cash Flow	0.0003	1.2008***	0.9582
	(0.3610)	(70.0570)	
Dividend	0.0009	1.0815***	0.9692
	(1.4880)	(82.0440)	
Revenue	0.0002	1.2348***	0.9499
	(0.2860)	(63.7210)	
Employee	0.0001	1.2100***	0.9479
	(0.0900)	(62.4100)	
Income	0.0011**	1.0743***	0.9765
	(2.1610)	(94.2530)	
Operating Income	0.0007	1.1061***	0.9701
	(1.1498)	(51.0034)	
Composite	0.0005	1.1566***	0.9718
	(0.7793)	(48.5263)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table V.5: Jensen's Alpha S&P 100 Portfolios

This table includes Jensen's Alpha of all S&P 100 Portfolios over the time period 31/01/1990 – 31/12/2018. Jensen's Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio S&P 100. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Jensen's Alpha	Reference - Rf	R^2
Reference Portfolio S&P 100			
Equal	0.0008	0.9815***	0.8882
	(1.081)	(52.443)	
Book Value	0.0001	1.0385***	0.9082
	(0.1900)	(58.52)	
Cash Flow	0.0007	1.0154***	0.9180
	(1.0430)	(62.2270)	
Dividend	0.0011	0.9049***	0.8421
	(1.2120)	(42.9700)	
Revenue	0.0009	0.9942***	0.8931
	(1.2310)	(53.7860)	
Employee	0.0015*	0.9578***	0.8511
	(1.6980)	(44.4740)	
Income	0.0013***	0.9641***	0.9496
	(2.6500)	(80.7500)	
Operating Income	0.0011*	0.9764***	0.9356
	(1.9090)	(70.9010)	
Composite	0.0010	0.9788***	0.9186
	(1.4890)	(62.4860)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Appendix VI

Table VI.1: Sharpe Ratio and Information Ratio DAX Portfolios

This table includes the Sharpe Ratio and Information Ratio for all DAX Portfolios over the time period 31/12/1988 – 31/12/2018. All portfolios are in excess of the risk-free rate. For the Information Ratio, the Reference portfolio is used as the Benchmark.

	Sharpe Ratio	Information Ratio
Reference Portfolio DAX	0.1976	
Equal	0.2494	0.2411
Book Value	0.2285	0.1835
Cash Flow	0.2691	0.3553
Dividend	0.2247	0.1564
Revenue	0.2391	0.2312
Employee	0.2883	0.4331
Income	0.2361	0.2369
Operating Income	0.2239	0.1562
Composite	0.2481	0.3292

Table VI.2: Sharpe Ratio and Information Ratio SMI Portfolios

This table includes the Sharpe Ratio and Information Ratio for all SMI Portfolios over the time period 31/05/1993 – 31/12/2018. All portfolios are in excess of the risk-free rate. For the Information Ratio, the Reference portfolio is used as the Benchmark.

	Sharpe Ratio	Information Ratio
Reference Portfolio SMI	0.4657	
Equal	0.3837	-0.0047
Book Value	0.3888	-0.0125
Cash Flow	0.4264	0.0682
Dividend	0.4343	0.1101
Revenue	0.3487	-0.0442
Employee	0.4226	0.0658
Income	0.5227	0.3373
Operating Income	0.4635	0.1430
Composite	0.4369	0.0908

Table VI.3: Sharpe Ratio and Information Ratio CAC Portfolios

This table includes the Sharpe Ratio and Information Ratio for all CAC Portfolios over the time period 31/12/1988 – 31/12/2018. All portfolios are in excess of the risk-free rate. For the Information Ratio, the Reference portfolio is used as the Benchmark.

	Sharpe Ratio	Information Ratio
Reference Portfolio CAC	0.2117	
Equal	0.2322	0.1676
Book Value	0.2203	0.1283
Cash Flow	0.2262	0.1479
Dividend	0.2477	0.1981
Revenue	0.2038	0.0668
Employee	0.1773	-0.0434
Income	0.2660	0.3266
Operating Income	0.2704	0.3439
Composite	0.2328	0.1812

Table VI.4: Sharpe Ratio and Information Ratio EuroStoxx 50 Portfolios

This table includes the Sharpe Ratio and Information Ratio for all EuroStoxx 50 Portfolios over the time period 31/01/2001 – 31/12/2018. All portfolios are in excess of the risk-free rate. For the Information Ratio, the Reference portfolio is used as the Benchmark.

	Sharpe Ratio	Information Ratio
Reference Portfolio EuroStoxx 50	-0.0146	
Equal	-0.0063	0.0226
Book Value	-0.0331	-0.0767
Cash Flow	-0.0155	-0.0136
Dividend	0.0393	0.2766
Revenue	-0.0212	-0.0333
Employee	-0.0297	-0.0632
Income	0.0571	0.4207
Operating Income	0.0223	0.1794
Composite	0.0024	0.0692

Table VI.5: Sharpe Ratio and Information Ratio S&P 100 Portfolios

This table includes the Sharpe Ratio and Information Ratio for all S&P 100 Portfolios over the time period 31/01/1990 – 31/12/2018. All portfolios are in excess of the risk-free rate. For the Information Ratio, the Reference portfolio is used as the Benchmark.

	Sharpe Ratio	Information Ratio
Reference Portfolio S&P 100	0.4417	
Equal	0.4805	0.1685
Book Value	0.4225	0.0564
Cash Flow	0.4753	0.2043
Dividend	0.4950	0.1149
Revenue	0.4897	0.2136
Employee	0.5293	0.2680
Income	0.5479	0.4467
Operating Income	0.5205	0.3260
Composite	0.5032	0.2473

Appendix VII

Table VII.1: Fama & French Factor Factor Alpha DAX Portfolios

This table includes Fama & French Three Factor Alpha of all DAX Portfolios over the time period 31/07/1990 – 31/12/2018. Fama & French Three Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio DAX. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Fama & French 3-Factor Alpha	Reference - Rf	SMB	HML	R^2
Reference Portfolio DAX	0.0040		-0.8375***	0.1386	0.0968
	(1.3260)		(-6.0290)	(1.0890)	
Equal	0.0003	1.0086***	0.0393	0.1724***	0.9454
	(0.4117)	(46.7219)	(0.6545)	(2.9361)	
Book Value	0.0000	1.0078***	-0.0506	0.2342***	0.9625
	(0.0424)	(53.7926)	(-1.4368)	(6.5040)	
Cash Flow	0.0009	0.9797***	-0.1062***	0.1483***	0.9591
	(1.3420)	(83.0570)	(-3.3440)	(5.3510)	
Dividend	0.0002	0.9818***	-0.0785*	0.1426***	0.9692
	(0.4153)	(66.6113)	(-1.6657)	(3.3356)	
Revenue	0.0001	1.0199***	-0.0126	0.2529***	0.9592
	(0.1822)	(59.5122)	(-0.2807)	(4.8455)	
Employee	0.0012614*	1.0127***	0.0403	0.1550***	0.9510
	(1.7030)	(76.9460)	(1.1370)	(5.0130)	
Income	0.0005	1.0047***	-0.0162	0.1611***	0.9700
	(0.7432)	(72.9460)	(-0.3930)	(3.7392)	
Operating Income	0.0008	1.0216***	-0.0113	0.0388	0.9518
	(1.0530)	(77.5760)	(-0.3180)	(1.2540)	
Composite	0.0005	1.0040***	-0.0336	0.1618***	0.9757
	(1.0089)	(74.9093)	(-0.9102)	(4.3791)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table VII.2: Fama & French Three Factor Alpha SMI Portfolios

This table includes Fama & French Three Factor Alpha of all SMI Portfolios over the time period 31/05/1993 – 31/12/2018. Fama & French Three Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio SMI. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Fama & French 3-Factor Alpha	Reference - Rf	SMB	HML	R^2
Reference Portfolio SMI	0.0061***		-0.6921***	0.2631***	0.1490
	(2.6170)		(-6.6160)	(2.8360)	
Equal	-0.0009	1.1295***	0.2922***	0.0946	0.8215
	(-0.7144)	(27.5382)	(3.3090)	(1.4914)	
Book Value	-0.0012	1.1327***	0.0491	0.17264***	0.9321
	(-1.6390)	(43.7781)	(1.0120)	(4.1726)	
Cash Flow	-0.0002	1.1007***	0.0346	0.0179	0.9085
	(-0.1800)	(50.9840)	(0.8210)	(0.5050)	
Dividend	-0.0001	1.1090***	-0.0146	0.0242	0.9308
	(-0.0810)	(58.8060)	(-0.3950)	(0.7830)	
Revenue	-0.0016	1.1877***	0.1413**	0.1671***	0.8669
	(-1.3610)	(41.2580)	(2.5130)	(3.5360)	
Employee	-0.0002	1.1009***	0.2798***	0.0392	0.7976
	(-0.1130)	(33.1940)	(4.3180)	(0.7210)	
Income	0.0008*	0.9957***	-0.0063	-0.0081	0.9643
	(1.7280)	(83.7500)	(-0.2690)	(-0.4160)	
Operating Income	0.0001	1.0553***	0.0228	0.0341	0.9451
	(0.15800	(66.9210)	(0.7400)	(1.3170)	
Composite	-0.0003	1.0974***	0.0724**	0.0639**	0.9320
	(-0.4240)	(59.9580)	(2.0250)	(2.1260)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table VII.3: Fama & French Three Factor Alpha CAC Portfolios

This table includes Fama & French Three Factor Alpha of all CAC Portfolios over the time period 31/07/1990 – 31/12/2018. Fama & French Three Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio CAC. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Fama & French 3-Factor Alpha	Reference - Rf	SMB	HML	R^2
Reference Portfolio CAC	0.0036		-0.8560***	0.1942*	0.1307
	(1.3420)		(-6.9650)	(1.7240)	
Equal	0.0000	1.0834***	0.1941***	0.1999***	0.9605
	(-0.0226)	(55.9474)	(4.8129)	(4.5612)	
Book Value	-0.0006	1.0905***	0.0618**	0.3327***	0.9619
	(-0.8690)	(84.8690)	(1.9880)	(12.4280)	
Cash Flow	-0.0002	1.0979***	0.0155	0.3190***	0.9438
	(-0.3090)	(48.0630)	(0.2624)	(8.3286)	
Dividend	0.0000	1.0130***	-0.0250	0.2606***	0.9529
	(-0.0210)	(75.4860)	(-0.7710)	(9.3220)	
Revenue	-0.0009	1.1044***	0.1252***	0.3795***	0.9600
	(-1.4475)	(56.4993)	(2.7177)	(9.3934)	
Employee	-0.0009	1.1014***	0.1942***	0.2670***	0.9510
	(-1.3170)	(76.1280)	(5.5480)	(8.8590)	
Income	0.0004	1.0147***	0.0175	0.2067***	0.9719
	(0.8260)	(99.7150)	(0.7090)	(9.7520)	
Operating Income	0.0004	1.0073***	-0.0211	0.2205***	0.9715
	(0.8545)	(63.3775)	(-0.5873)	(6.6646)	
Composite	-0.0003	1.0613***	0.0526	0.2837***	0.9726
	(-0.4954)	(63.1527)	(1.4028)	(8.3769)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table VII.4: Fama & French Three Factor Alpha EuroStoxx 50 Portfolios

This table includes Fama & French Three Factor Alpha of all EuroStoxx 50 Portfolios over the time period 31/01/2001 – 31/12/2018. Fama & French Three Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio EuroStoxx 50. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Fama & French 3-Factor Alpha	Reference - Rf	SMB	HML	R^2
Reference Portfolio EuroStoxx 50	0.0011		-0.7442***	0.3363**	0.1297
	(0.3721)		(-3.5435)	(2.1748)	
Equal	-0.0001	1.1818***	0.0495	0.1154***	0.9613
	(-0.1543)	(36.5439)	(0.7745)	(3.0814)	
Book Value	-0.0009	1.1654***	-0.0057	0.2517***	0.9594
	(-1.2031)	(40.8792)	(-0.1055)	(5.9371)	
Cash Flow	-0.0005	1.1854***	0.0217	0.2076***	0.9661
	(-0.7005)	(40.4411)	(0.3779)	(5.4702)	
Dividend	0.0004	1.0736***	0.0212	0.1222***	0.9726
	(0.7952)	(44.3821)	(0.4617)	(2.8623)	
Revenue	-0.0007	1.2298***	0.0981	0.2146***	0.9593
	(-0.8865)	(40.0341)	(1.5504)	(4.7145)	
Employee	-0.0004	1.2189***	0.1062	0.0711*	0.9499
	(-0.4379)	(35.0928)	(1.3589)	(1.6702)	
Income	0.0006	1.0724***	0.0537	0.1082***	0.9797
	(1.3519)	(58.0792)	(1.6360)	(3.7825)	
Operating Income	0.0001	1.1017***	0.0561	0.1406***	0.9750
	(0.1299)	(51.9098)	(1.5710)	(4.4273)	
Composite	-0.0002	1.1496***	0.0502	0.1594***	0.9774
	(-0.3734)	(49.5897)	(1.0952)	(4.8374)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.

Table VII.5: Fama & French Three Factor Alpha S&P 100 Portfolios

This table includes Fama & French Three Factor Alpha of all S&P 100 Portfolios over the time period 31/07/1990 – 31/12/2018. Fama & French Factor Alpha is found by OLS Regression. The Market Portfolio is the Reference Portfolio S&P 100. All portfolios are in excess of the risk-free rate. Robust standard errors are used when the Breusch-Pagan Test p-value < 0.10.

	Fama & French 3-Factor Alpha	Reference - Rf	SMB	HML	R^2
Reference Portfolio S&P 100	0.0064***		0.0122	-0.2300***	0.0518
	(2.8893)		(0.1090)	(-3.4830)	
Equal	0.0001	1.022***	0.1926***	0.2786***	0.9295
	(0.0144)	(66.2450)	(8.9050)	(13.4580)	
Book Value	-0.0006	1.0920***	0.0917***	0.3032***	0.9485
	(-1.1731)	(61.4573)	(3.7272)	(10.9570)	
Cash Flow	0.0000	1.0662***	0.0677**	0.2813***	0.9553
	(0.0207)	(64.7409)	(2.3853)	(10.3458)	
Dividend	0.0001	0.9739***	-0.0172	0.3562***	0.9194
	(0.1390)	(62.3160)	(-0.7850)	(16.9860)	
Revenue	0.0002	1.0460***	0.1035***	0.2992***	0.9352
	(0.3133)	(53.6733)	(3.1490)	(10.1315)	
Employee	0.0008	1.0067***	0.0820***	0.2828***	0.8884
	(0.9750)	(51.9620)	(3.0190)	(10.8800)	
Income	0.0009**	1.0005***	-0.0083	0.1836***	0.9701
	(2.2060)	(104.7020)	(-0.6210)	(14.3230)	
Operating Income	0.0005	1.0207***	0.0180	0.2282***	0.9643
	(1.2300)	(79.1650)	(0.7455)	(10.3103)	
Composite	0.0003	1.0294***	0.0482*	0.2764***	0.9577
	(0.5582)	(68.8196)	(1.8236)	(11.4761)	

***, **, * indicate the significance at the 1%, 5%, and 10% levels. The T-statistics are reported in parentheses.