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Tracking the Norwegian Regular Market Aggregated Index 2020-2022 – Is There a Case for Passive Bond Fund Management?

An empirical analysis based on Norwegian Bond Pricing´s Regular Market Index for the Norwegian bond market 2020-2022.

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Acknowledgments

With this thesis, we put the final touches on the work of what have been two instructive years on the master´s course in Finance at the Norwegian University of Life Science (NBMU).

We found inspiration to write this thesis from the exciting courses and interesting guest lectures we have experienced, related to work life. We wanted to explore an aspect of the financial markets that was given less attention in our classes, while also incorporating our interest in portfolio management. Ultimately, we decided to explore the connection between portfolio management and the bond market, which was particularly relevant given the current economic climate with frequently increasing interest rates.

The process of working on this thesis has been challenging, but also a great learning experience. In a short period of time, we have gained knowledge about bonds and the Norwegian bond market, building an index-tracking bond portfolio in practice, extensive data processing, and modeling in Excel. Overall, it has been a valuable educational journey that has provided us with knowledge and experience that we will bring with us further into life.

We would like to express our gratitude to several people who have contributed to the creation of this master thesis. First and foremost, we extend a big thank you to our supervisors, Torun Fretheim and Ole Gjølberg, for their valuable feedback and insightful discussions throughout the writing process. Additionally, we would like to acknowledge Pål Prestegård Jonassen from Nordic Bond Pricing for his inspiring guest lecture in the fall of 2022, which sparked our interest in writing a thesis on bonds, and especially for providing us with access to the required dataset. We also thank Øystein Dahl for his guidance and assistance in building the model when our Excel skills fell short. Finally, we appreciate the understanding and support of our loved ones at home, Rasmus and Petter, who have put up with us during the last few months.

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Abstract

The focus of our thesis centers on making the NBP Norwegian Regular Market Aggregated Index investible. This was achieved by constructing an index tracker that seeks to track the index as closely as possible while consisting of a more manageable number of securities. Additionally, the study aims to offer insight into how bond portfolios are affected by an environment characterized by increasing interest rates, through analyzing the performance of the index tracker in such an environment. We find that it is possible to track the portfolio closely with only a few securities, which allows an investor to reasonably presume a level of risk equivalent to that of the index and expect similar returns. Further, we did not find the portfolio to react to the increasing interest rates, as we expected it to, though we find that the return of the portfolio proved to be more volatile in periods of both increasing and decreasing interest rates. Overall, this research provides valuable insights for investors wanting to be exposed to the Norwegian Bond Market in times of rising interest rates.

Sammendrag

Fokuset for denne utredningen har vært å gjøre NBP Norwegian Regular Market Aggregated Index investerbar. Ettersom indeksen er sammensatt og består av over tusen verdipapirer, har vi konstruert en portefølje som skal replikere både risikoen og avkastningen til indeksen, men bestående av et mer håndterbart antall verdipapirer. I tillegg har vi sett nærmere på forholdet mellom avkastningen på et obligasjonsfond i en periode med økende styringsrente. Dette har blitt gjort gjennom å vurder avkastningen til den konstruerte porteføljen over en periode med økende rente. Vi kan konkludere med at det er mulig å replikere både avkastningen og risikoprofilen til indeksen, selv bestående av et betraktelig lavere antall verdipapirer. Dette muliggjør for investorer å være eksponert for det norske obligasjonsmarkedet på lik linje med NORM indeksen, samtidig som man slipper å investere i tusenvis av verdipapirer. Vi kan ikke konkludere med at porteføljen har reagert helt som forventet på økende styringsrente. Derimot kan vi se at porteføljen blir betraktelig mer volatil i perioder med endrende styringsrente. Utredningen vil i sin helhet kunne bidra med verdifull innsikt for investorer som ønsker eksponering i det norske obligasjonsmarkedet, særlig i perioder hvor styringsrenten er på vei oppover.

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1 Introduction

In this thesis, we will construct a portfolio that efficiently tracks the NBP Norwegian Regular Market Aggregate Index (NORM-index). The NORM index is a bond index provided by Nordic Bond Pricing, which is commonly used as a benchmark to measure bond fund performance. We aim to facilitate investment in the NORM index by constructing an index tracker that consists of a relatively small number of securities. The goal is to track the index as closely as possible, leaving minimal tracking error. The period subject to our analysis is the timespan from January 2020 through December 2022.

The first aim of our thesis is to create a portfolio of bonds that tracks the NORM index, while holding a relatively low number of securities. We hope to demonstrate that it is possible to track this index, which consists of more than a thousand individual securities, quite closely by investing in only a small number of bonds. If we consist in creating such an index tracker, it will offer an efficient and low-cost investment alternative to those who wish to be exposed to the broad bond market.

The second topic we will examine is how such an investment vehicle will perform in a market with increasing policy rates. The period covering the fourth quarter of 2021 and throughout 2022 has been characterized by a steady increase in interest rates, which has implications for bond investments. While the yield is expected to rise for fixed-income securities traded in the secondary market because of the inverse relationship between bond yield and their value, this phenomenon is not as prevalent in securities possessing floating rates, as they will adjust to changes in interest rates. As our portfolio will replicate the NORM index, consisting of a combination of fixed-rate securities and floating-rate notes, we will examine how this phenomenon will unfold in our portfolio—providing insight to an investor who seeks to navigate in markets with increasing interest rates.

Overall, our thesis aims to investigate the feasibility of turning a sizeable index into an investible asset by creating an index tracker composed of a small number of securities.

Additionally, we will examine the impact of changing interest rates on our portfolio considering the variety of characteristics among the securities in our portfolio.

2 Understanding Bond Theories, Investment Strategies, and the Bond Market

In this chapter, we will review some basic theoretical aspects of bonds and explain the theoretical impact interest rate has on bonds. Further, we will explain the difference between a passive and active investment strategy before we introduce the bond market and the Norwegian market in specific. By the end, we will introduce Nordic Bond Pricing, which is our main provider of data for this thesis.

2.1 Introduction to Bond Valuation and their Sensitivity Towards Interest Rates

A bond is a fixed-income security that delivers a fixed-income stream over a given period of time. The bond indenture states the commitments that the bond issuer has to the lender, including the par value, annual interest payment, and maturity date, to name some (Bodie et al., 2021, p. 426; Adams & Smith, 2019, p. 10). The value of a fixed-income security is closely related to changes in the interest rates through several of the bond components, hereunder the maturity, duration, credit rating, and the bond´s yield.

The return on a bond investment is given by the bond yield, which is a measure of the rate of return throughout its lifetime. The yield to maturity is the market expectation of the yield if an investor holds the bond until it matures. It can be interpreted as the average rate of return on a bond if it´s held to maturity (Bodie et al., 2021, p. 438). Price and yield are inversely related, meaning that if the price of a bond goes up, its yield goes down, and vice versa (Bodie et al., 2021, p. 497). The return of the bond is thus dependent on the same components that make up the price, such as maturity, coupon payments, and par value.

The following formula demonstrates how the value of a bond is calculated.

$$Bond\ value = \sum_{t=1}^{T} \frac{Coupon}{(1+r)^t} + \frac{Par\ value}{(1+r)^t}$$

Equation 1: Formula for Bond Price Calculations
T= time
r= interest rate

The valuation of a bond can be determined by summarizing the present value of all its cash flows, the coupon payments, and its par value. (Bodie et al., 2021, p. 432). If the coupon rate equals the market interest rate, the bond price equals par value. Though, if the coupon rate is lower or higher than the market interest rate, the bond will sell at a premium or discount.

2.2 Bonds and Their Reaction to Changes in Interest Rates

As mentioned, a bond consists of several components where some are closely related to interest rates. Two types of coupon payment structures are prevalent in the data we will use in our analysis: fixed-rate coupons and floating-rate notes (FRN). Fixed-rate coupons have a fixed coupon rate expressed in the bond indenture, which will not change throughout the lifetime of the bond. In other words, fixed-rate coupons secure a stable payment throughout the bond´s lifetime (Adam & Smith, 2019). Consequently, such coupon payments are not affected by interest rate changes. The value of a bond with a fixed coupon rate will though decline in a rising interest rate environment. FRNs, on the other hand, have a coupon rate that is linked to an external reference rate, which makes these bonds less affected when interest rates increase, as their coupon rates vary along with the market interest rate (Adams & Smith, 2019, p. 121). Thus, they are less exposed to interest rate risk. Because of this characteristic, FRNs are often favored by investors who expect the market interest rate to rise and are willing to accept fluctuations in coupon payments.

Changes in interest rates and the maturity of a bond are also closely related, as the length of the maturity influences its sensitivity to changes in interest rates (Adams & Smith, 2019). Changes in the market interest rate can affect the value of a bond´s future cash flows, which in turn, will affect the value of the bond. If interest rates rise, the present value of a bond's future cash flows declines. As explained in the previous section, such an effect is thus more pronounced for bonds with fixed-rate coupons. The longer the maturity, the higher the risk of experiencing changes

in the interest rate, leaving the effect to be more evident for longer-term bonds (Malkiel, 1962). This is reasoned, as the decline in present value is compounded over a longer period until the bond matures. In a bond portfolio, the investor should thus seek to hold bonds with a variety of maturities as bonds with longer maturity can offer higher potential returns, to compensate for the interest risk exposure.

The duration of a bond is a measure of its sensitivity to changes in interest rates, and the relationship between duration and price sensitivity holds for both individual bonds and bond portfolios (Hayes, 2023a). Duration estimates changes in the bond price, assuming all variables except interest rates are held constant (Adams & Smith, 2019, p. 212). For our analysis, we will use modified duration. Modified duration estimates the percentage change in the bond price given a one percentage change in its yield-to-maturity. It is, therefore, a natural measure of bond exposure to changes in interest rates (Adams & Smith, 2019, p. 217; Bodie et al., 2021, p. 501). As prices of long-term bonds tend to be more sensitive to changes in interest rates than prices of short-term bonds, the modified duration of long-term bonds consequently tends to be higher than that of short-term bonds (Bodie et at., 2021).

Nevertheless, the duration of a bond is an essential consideration for investors, as it can help to assess the risk and potential return of the investment. As bonds with higher modified durations are more sensitive to changes in interest rates, they are more exposed to interest rate risk. By combining long- and short-term bonds with different maturities and duration, investors can mitigate their overall sensitivity to a changing interest rate environment, and by so reducing the interest rate risk.

Understanding a bond's yield is crucial in determining how it is affected by changes in interest rates. The yield represents the return an investor expects from the bond's coupon payments. Higher yields mean that the investor requires higher returns as a premium for taking on the additional risk (Hayes, 2023b). The price and yield of a bond are inversely related (Bodie et al. 2021, p. 435). This is a phenomenon that occurs as the yield on existing bonds becomes less attractive to investors when interest rate increases, as new bonds are issued with a promise of higher returns. As a result, the market price of existing bonds drops, causing an increased yield of the bond portfolio. This effect is more evident for fixed-rate coupon bonds, while FRN´s are less affected as their coupon rate is linked to an external reference rate that varies with the

market interest rate and is reset at short-term intervals (Adams & Smith, 2019, p. 28). Thus, fixed-coupon bonds have a higher exposure to interest rate risk.

2.3 The Impact of Credit Risk on Bond Performance

In addition to interest rate risk, bonds are sensitive to changes in credit risk, which represents the risk of loss resulting from the issuer of the bond failing to make full and timely payments of the coupons and/or principal (Adams & Smith, 2019, p. 262). Credit risk consists of two components; the default risk of the issuer to default on its obligations, and the loss severity, which is the portion of the bond value an investor loses in the event of default.

Since the risk reflects the possibility of the issuer failing to meet its debt obligations, it is highly linked to the financial health of the debt issuer. But it is a compounded risk, and external factors may affect the credit risk, such as changing interest rates.

Floating-rate bonds with a longer maturity will be more sensitive to increased credit risk caused by changes in interest rates. Whenever the interest rate increases, floating-rate bonds will have to pay a higher coupon to their debtholders. That means debt becomes more expensive, and every rise in interest rate will make it harder for the issuer to keep up with debt payments. In other words, the credit risk increases. Bonds with low credit ratings are particularly sensitive to the increased cost of debt as it further weakens their ability to meet their obligations. Consequently, investors in bonds with higher credit ratings may be less affected by changes in interest rates, as these bonds typically have a lower credit risk, to begin with. However, even high-quality bonds are subject to credit risk if the issuer experiences financial difficulties, such as a recession or a decline in revenue.

In addition, changes in interest rates can also affect the yield spread, which is the difference between a bond's yield and its benchmark rate. When interest rates rise, the yield spread typically widens, as investors demand higher compensation for the increased credit risk. To mitigate credit risk in a bond portfolio, investors can employ strategies to diversify across issuers, sectors, and credit ratings.

Credit risk is measured by credit ratings assigned to each bond by independent rating agencies. The major credit rating agencies are Moody´s Investors Service (“Moody´s”), Standard & Poor

("S&P"), and Fitch Ratings ("Fitch"), which issues symbol-based ratings that constitutes an assessment of a bond issuer´s risk of default (Adam & Smith, 2019, p. 271). The ratings are letter-based as we can read from Table 1, ranging from AAA, the highest possible score with extremely low probabilities of default, to D at the bottom for securities that the rating agencies already define as in default. Bonds with ratings in the range from AAA to BBB are called "Investment Grade," while ratings from BB and lower are referred to as "High Yield" or even "Junk Bonds." Generally, issuers of bonds rated investment grade can borrow at a lower interest rate as they are considered less risky investments. Hence the investors do not demand the same level of coupon rates as with high yield-bonds, where they would demand extra compensation for taking on the additional risk.

	Moody´s	S&P	Fitch
Investment Grade	Aaa	AAA	AAA
	Aa1	AA+	AA+
	Aa2	AA	AA
	Aa3	AA-	AA-
	A1	A+	A+
	A2	A	A
	A3	A-	A-
	Baa2	BBB	BBB
	Baa1	BBB+	BBB+
	Baa3	BBB-	BBB-
High Yield	Ba1	BB+	BB+
	...	...	...
	Ca	C	C
	C	D	D

Table 1: Standard credit rating scores from international rating agencies; Moody´s, S&P, and Fitch Ratings.

2.4 Active vs. Passive Investment Strategies

Including fixed-income securities like bonds in investment portfolios can offer both diversification benefits and dampen volatility due to the regular cash flow from coupon payments over the lifetime of the bond (Adams & Smith, 2019, p. 605). The most common distinction in investment strategies is to divide into active and passive management.

While actively invested funds aim to beat an underlying benchmark by handpicking the securities of the portfolios based on either technical or fundamental analysis, a passive investment strategy aims to track a benchmark as closely as possible. As active managers aim to beat the market, there may be significant differences in return between the portfolio and the benchmark, as managers try to exploit changes in the market environment to get higher returns. There may also be a significant turnover of the portfolio in the chase of realizing these higher returns, which again leads to higher management fees and transaction costs. With higher fees and transaction costs, an increase in the rate of return is necessary to achieve positive active returns[1], net of fees and costs (Adams & Smith, 2019, p. 617). However, history has shown that most active managers have underperformed their benchmark when comparing return after fees and transaction costs. The same has applied to bond index funds, but to a lesser extent because of lower turnovers which in turn lowers the total transaction costs and lower management fees for passively managed index funds (Adams & Smith, 2019, p. 617; Malkiel, 2003). As Figure 1 shows, most active managers underperform the market average after accounting for additional expenses from transactions and fees (Malkiel, 2003).

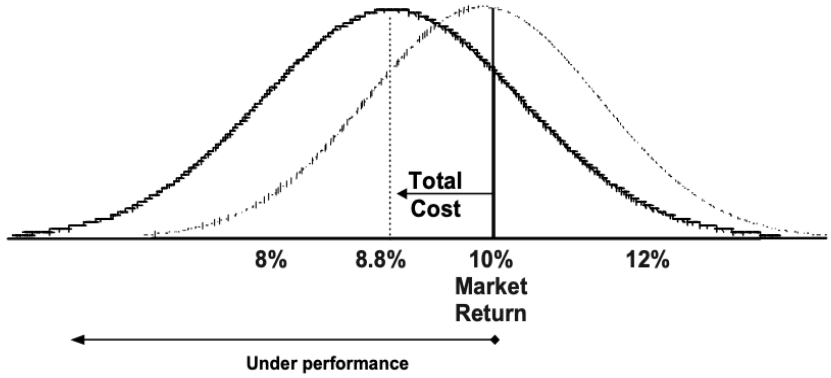

Figure 1: Distribution of Returns After Expenses in Active Portfolio Management.

Source: Malkiel, 2003.

When considering passive management of portfolios, there are two common approaches to tracking a benchmark index; enhanced indexing and pure indexing. An enhanced indexing approach attempts to have a low tracking error[2], while simultaneously generating a modest amount of return above the benchmark (Adams & Smith, 2019, p. 616). The approach allows for some deviations from the index, but the risk factor exposure is tracked closely to maintain

[1] Active return is the portfolio return minus the benchmark return (Adams & Smith, 2019, p. 615).
[2] Tracking error is the annualized standard deviation of the active returns (Adams & Smith, 2019, p. 615).

a low tracking error. However, there is room for some minor mismatches in risk factors under this approach, with the intent of generating higher returns. The management fees are normally a little higher than with the pure indexing approach, due to this "active" element.

The aim of pure indexing is to replicate a bond index as closely as possible, i.e., to have both targeted active return and tracking error to equal zero (Adams & Smith, 2019, p. 616). Portfolio return will in theory be lower than the benchmark returns because of transaction costs and management fees, even though they are lower than that of both the enhanced indexing and active management approaches. The main objective of pure indexing is to create a portfolio that aligns with the risk factors of the benchmark index. This approach allows for some flexibility in holdings to reduce the number of securities and associated costs while making the portfolio easier to manage in practice.

In this thesis, we will focus on the pure indexing approach for our investment strategy. We will provide further details on how this approach will be utilized in constructing our portfolio in the chapter covering the methods used for our index tracker. But before we proceed to that, we´ll examine the Norwegian bond market and our benchmark index in more detail.

2.5 Introduction to the Bond Market

In May 2020, the European Bond Market had a nominal value of EUR 12.2 trillion for SSA Bonds (Sovereign, Supranational, and Agency), whereas only 0.7% of the volume was issued in NOK. European investment-grade corporate bonds volume was EUR 5.65 trillion, whereas 1.7% were in NOK (International Capital Market Association, 2020). In comparison, the three largest stock exchanges in Europe, measured by domestic market capitalization, had a market cap of US 10.05 trillion in October 2020 (Statista, 2023), a period where the value of the US dollar and the Euro remained near parity.

Although the bond market is comparable to the stock market, in terms of volume, it is often overlooked by the media. Some investors find bonds less interesting than stocks and other securities, as they are less volatile. This means that despite the lower risk of significant losses, there is also less potential for high positive returns. Another reason little attention is given to the bond market, is the lack of transparency. Trades may occur over the counter, leaving

information to become public only after the trade has taken place. This makes it to be challenging to stay informed.

2.6 The Norwegian bond market

Nordic Bond pricing has developed a universe of bond indices for the Norwegian bond market. While the branch of Aggregated Government covers the eligible government bond and bills issued by the Norwegian government, the Aggregated Regular Market covers all qualified bonds for the regular market, comprising 1) Covered bonds and bonds issued by municipalities, 2) Senior unsecured bonds, 3) Corporate bonds excluding financials, and 4) Hybrids. The last branch, fronted by the Aggregated High Yield Unhedged, covers the eligible bonds within the High Yield Market. The difference between the Regular and the High Yield market is based on their price levels, measured by their credit spread. The credit spread is set up against a benchmark curve for each classification. Those bonds whose credit spread falls outside the benchmark interval of Regular Markets are categorized as High Yield (Nordic Bond Pricing, 2021).

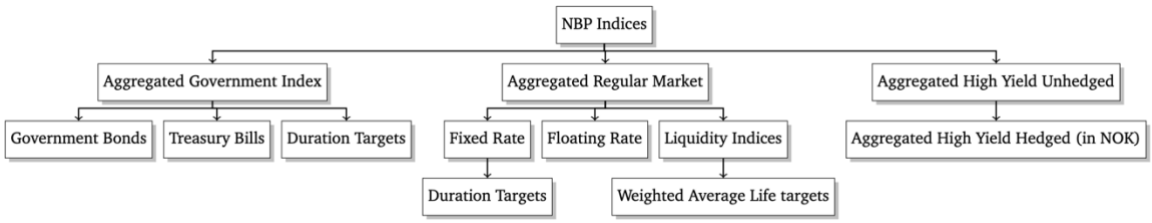

Figure 2: Figure 2 NBP Bond Indices.

Soruce:: Nordic Bond Pricing, 2023.

2.7 Nordic Bond Pricing

Our primary source of data has been Nordic Bond Pricing (NPB), a company that provides pricing services for bonds and has developed several benchmark indices for the Norwegian bond market. NBP was established in 2013 and is still owned by its founders, the Norwegian Fund and Asset Management Association and Nordic Trustee. They are considered an independent provider of pricing services and have agreements with the leading brokerage houses, which grants them access to the information needed to deliver their service. Nordic Bond Pricing is also the administrator of the index series family that our benchmark index is part of. The indices presented by NBP measure the total return performance of bonds registered

in the Norwegian CSD[3] across different maturities, types of interest rate structures and industry segments (Nordic Bond Pricing, 2023).

[3] Central Securities Depositories (Verdipapirsentralen).

3 Introduction to Existing Literature

In the following chapter, we will review existing literature relevant to our thesis. We will present some articles that offer insights into the benefits and challenges of passively managed bond portfolios, the relationship between bond risk and interest rates, and strategies for managing bond portfolios in a low-interest rate environment.

3.1 Passiv forvaltning av obligasjoner i det norske markedet: Malin Brandtun and Alise R. Hornseth (2017).

In 2017, a master thesis by Brandtun and Hornseth (2017) examined if a passive investment strategy was possible to hold in the Norwegian bond market by analyzing the period 2015-2016. This time period was characterized by low and stable interest rates, and liquidity was high in both the stock and bond market (Brantun & Hornseth, 2017). There was also little uncertainty about the expectations of the interest rate curve. Now, nearly a decade later, the underlying economic conditions have changed drastically. In comparison, today´s global economy is still recovering from a global pandemic, which in turn has been challenged by major consequences such as the Russian invasion of Ukraine. More comments on the underlying economic condition will be made in later chapters. However, the essence is that we want to investigate whether the conclusion made by Brantun and Hornseth would be any different, if we performed the same analysis, covering the years 2020-2022.

3.2 Passive Investment Strategies and Efficient Markets: Burton G. Malkiel (2003)

Whether a passive or active managed fund is the best strategy is a heavily debated topic. Sushko & Turner present some of the arguments in favor of a passive invested portfolio. One of the arguments is based on the theoretical idea of the Efficient Market, which implies that prices are not predictable and therefore that it is not possible to consequently beat the market return (Sushko & Turner 2018).

Malkiel (2003) discusses the benefits of passive investment strategies in the context of efficient markets. He also reviews some of the criticism of the strategy and presents evidence that historically indexing has tended to outperform the active strategy in the long run. He concludes that there is strong evidence in favor of passive investment strategy in all markets and that passive management or indexing is in line with the efficient market hypothesis.

The article highlights the benefits of passive bond investment strategies, such as index funds and exchange-traded funds (ETFs), which allow investors to gain exposure to a diversified portfolio of bonds at a low cost. Malkiel notes that passive bond strategies offer several advantages over active strategies, including lower fees, greater transparency, and less turnover. In addition, the article discusses the impact of interest rates on bond prices and highlights the benefits of maintaining a diversified portfolio of bonds to mitigate interest rate risk. Holding a well-diversified bond portfolio consisting of a mix of short-term and long-term bonds can help investors manage interest rate risk and generate a steady income stream.

As Malkiel presents evidence in favor of passive investment strategies, he also touches on and comments upon common criticisms of the technique. He argues that it is difficult for managers of active funds to outperform the market consistently in an efficient market. Even though security markets tend to be relatively efficient in absorbing and adjusting for new information, he acknowledges that researchers have managed to find and isolate anomalies and patterns. Yet, these anomalies seem to disappear shortly after they appear, or they are often of a small magnitude relative to the cost of exploiting them. In other words, he does not discard the idea of an efficient market even though imperfections have been detected. He argues that market anomalies are more easily uncovered after they occur, hence there seems to be no strategies that beat the passive buy-and-hold strategy.

He provides evidence from historical events to support this view. He presents several figures showing that most of the best-performing funds during the 1970s or 1980´ proved to underperform the market in the following years. Most of Malkiel´s article is based on an analysis of the stock market, but he does also include a part on bond performance. His results show that indexing appears to be a winning strategy in both European and US markets, with 69% of funds invested in European securities being outperformed by the Morgan Stanley Capital International Europe Index over a 10-year period. He states that the advantage of indexing is particularly large in the bond markets, where 90% of active global bond managers were outperformed by the Salomon World Government Bond Index over the same 10-year period.

Moreover, Malkiel also states that passive management would still be a winning strategy, even if markets are inefficient, as the winning performance must be a zero-sum game. After accounting for the additional costs of active management, he found that most investors would

underperform the market average. The results show that passive managers will outperform most active managers after costs, where most of these expenses come from the difference in management fees that are typically higher for an actively managed fund than that of an index fund.

Overall, the article argues that passive investment strategies offer a more efficient and cost-effective way to invest in the bond market, particularly in an efficient market environment. Despite some imperfections in a market that is generally quite efficient, they do not give rise to support for any active strategy. Moreover, by providing exposure to a diversified portfolio of bonds at a low cost, passive bond strategies can help investors achieve their investment goals while minimizing risk and maximizing returns. As a result, he argues that passive investment strategies, which seek to replicate the performance of a market index, offer a more efficient way to invest in the bond market**.**

3.3 Bond risk, bond return volatility, and the term structure of interest rates: Luis M. Viceira (2012).

Viceira (2012) explores the relationship between bond risk, bond return volatility, and the term structure of interest rates. The study uses a comprehensive dataset of US government bonds 1962-1970 to investigate the extent to which bond risk, as measured by bond return volatility, is related to changes in the yield curve. He finds that changes in the shape of the yield curve are significantly related to bond risk and that this relationship is robust across different maturities.

The study also finds that longer-term bonds exhibit higher levels of return volatility, which is consistent with the concept of duration risk. In addition, the article demonstrates that the relationship between bond risk and the yield curve is not linear, with the impact of changes in the shape of the yield curve being stronger for bonds with longer maturities.

Viceira´s findings have implications for investors seeking to manage their bond portfolios. The study highlights the importance of considering both bond return volatility and the term structure of interest rates when making investment decisions. This insight into the relationship between bond risk and the yield curve provides a valuable framework for investors seeking to optimize their fixed-income investments in a dynamic interest rate environment.

3.4 Fundamental Economic Variables, Expected Returns, and Bond Fund Performance: Edwin J. Elton, Martin J. Gruber and Christopher R. Blake (1995).

The article investigates the relationship between fundamental economic variables, expected returns, and bond fund performance. The authors examine whether bond funds with better performance are related to macroeconomic variables and whether managers of bond funds can forecast interest rates.

The study uses a sample of 206 bond funds over the period from 1980 to 1991. They construct various macroeconomic variables, such as the term structure of interest rates, industrial production, and inflation, and estimate the expected returns of bond funds using a multifactor asset pricing model.

The results show that macroeconomic variables are important determinants of bond fund performance, with the term structure of interest rates being the most significant variable. They find that bond funds with higher exposure to long-term bonds outperform those with shorter duration, consistent with the theory that longer-term bonds have higher expected returns. They also find evidence that bond fund managers are able to forecast interest rates, and that better-performing bond funds have higher levels of managerial skill.

Finally, they conclude that macroeconomic variables play a crucial role in determining bond fund performance, and that active management can add value to bond funds by forecasting interest rates and exploiting duration risk. The study provides important insights for investors and managers of bond funds, highlighting the importance of considering macroeconomic variables when making investment decisions in the fixed-income market.

4 Data

In the following chapter, the data we have used throughout the analysis will be presented. The processing and analysis of data in this thesis have been both complex and time-consuming, and we have had to make several adjustments to finalize the dataset. These adjustments and other assumptions we have made will be reviewed before we elaborate on the challenges we have met while working with the data.

4.1 The Data Set

The data used in our analysis has primarily been delivered by NBP, with some additional information gathered from Norges Bank and Norges Finansielle Referanse AS (NoRe). The analysis is based on NBP´s NORM Index during the period 01.01.2020-31.12.2022. As the aim of our study is to analyze how an index tracking bond portfolio performs in a market with increasing interest rates, we found this period to be of interest as it both includes a period of low and stable policy rates in most of 2020 and the first half of 2021, before the policy rate was adjusted several times from September 2021 through 2023 (Norges Bank, 2023).

The dataset we received from NBP included all outstanding bonds within the regular market segment in the Norwegian bond market 2020-2022. Further, the data set included monthly information on the constituent bonds of the NORM-index, hereunder information about the individual bond´s sector, duration, maturity, credit rating, constituent weight, and the security's total return reported month to date. The index is rebalanced every month, so the weight of each bond is updated accordingly. In addition to data on the individual bonds, NBP also provided us with monthly data on the total return of the NORM index month to date.

As part of our analysis where to examine how our constructed portfolio performs in a period of increasing interest rates, we downloaded monthly data on the Norwegian policy rate over the same time period. We also downloaded monthly data on the Norwegian 3-month Treasury bill (T-bill) rate, which will be used as a reference for the risk-free rate. The information on both the policy rate and the T-bill is publicly available on Norges Bank´s website. Further, some of the bonds in our dataset are floating rate notes, which are related to the Norwegian Interbank Offered Rate (NIBOR). Data on the 3-month NIBOR rate is publicly available and was downloaded from NoRe´s website.

The *NBP Norwegian Regular Market Aggregated Index* NOK (NORM Index) is one of the benchmark indices constructed by NBP. This index includes all the bonds eligible in the regular market segment (Nordic Bond Pricing, 2022). All securities meet the criteria of being issued in NOK with a minimum issue size of 300 MNOK. They are weighted by their market capitalization and can have fixed or floating rates.

4.2 Adjustments and structuring of the dataset

To construct a portfolio that should hold the same characteristics and risk factors as its benchmark index (NORM), we needed information about the bonds sector, duration, maturity, and credit rating, as well as returns and constituent weights. For most of these variables, the dataset was complete from NBP, but we have had to make some simplifying assumptions regarding credit ratings, especially. In this chapter, we will present the adjustments made to the dataset, and how the data was structured to fit into our model which will be presented later.

The bonds in the NORM index were categorized into more sectors than we were to use in our model. Originally, the index held bonds within eight sectors; Utilities, industry, real estate, senior bank/finance, subordinated debt, covered bonds, hybrid, and local government. To make the amount of data more manageable for the analysis, we made a practical delimitation by merging the original sectors into three more general sectors; Corporate, finance, and municipality. The arrangement of these sectors is presented in Table 2.

Orginal sector	Merged sector
Utilities	Corporate
Industry	
Real Estate	
Senior Bank/Finance	Finance
Subordinated Debt	
Covered Bonds	
Hybrid	
Local Government	Municipality

Table 2: Division of index sectors into more general sector cells.

We received detailed data on maturity, namely the date of issuance, maturity, and expected maturity. For most of the securities, maturity and expected maturity were equal, but for some bonds expected maturity was set at an earlier date than maturity. This applies to bonds with a

call option that hasn´t been called yet, or to bonds that have been redeemed prior to their maturity date. We have made a simplifying assumption and disregarded the possibility of calling a bond, so all bonds have been handled as if they were held to maturity. Time to maturity is calculated by taking the maturity date minus the rebalancing date and dividing by 365, which is consistent with the criteria that will be used in our model.

Further, we received data on the bond´s credit ratings. The credit ratings used by NBP are ratings obtained from international credit rating agencies. They collect ratings from Moody´s, S&P, Fitch Ratings, Scope Ratings, and Nordic Credit Ratings and cover most of the issuers. However, the dataset did not include ratings on all securities included in the NORM index, while other bonds came with ratings from several of the agencies. For the latter, we calculated the average of the ratings on every single bond and gave it a credit score after the standard used by S&P and Fitch Ratings (see Table 1 in Chapter 2.3). For the bonds that did not have ratings from any of these agencies, we found no other source that could supplement our data. Although some of the bonds had the same issuer, we found that they had varying characteristics and risk profiles. Therefore, we could not rely on auto-filling the same credit rating from one bond to another. Moreover, we found that assessing each bond's credit rating would be very time-consuming, and the essence of our thesis does not include evaluating the credit ratings of various bonds. For this reason, we settled on assigning ratings based on a sector average from the securities with credit ratings in the NORM index. We also found these sector averages to be quite consistent through all periods, with small variations in credit score from bond to bond within the same sector. It is also worth mentioning that most of the missing scores were related to bonds issued by Local governments/Municipalities. Even though these securities did not have a credit rating, we believed it was safe to assume that they qualified for a high credit score. Our credit rating assumptions and sector averages are presented in Table 3.

Credit Rating Assumptions	
Sector	***Credit rating***
Utilities	BBB+
Industry	A-
Real Estate	BBB+
Senior Bank/Finance	A
Subordinated Debt	BBB+
Covered Bonds	AAA
Hybrid	BBB
Local Government	AAA

Table 3: Credit rating assumptions calculated from the sector average of the NORM index.

We acknowledge that this might not reflect a fair credit rating on each of the individual bonds. This is partly because it does not consider the individual qualities of each security, nor did we have a sufficient sample size for most of the sectors to make a fair average. However, given the time we had available to perform this analysis, we found it to be a reasonable approach. Further, we recognize that these assumptions are simplifying, and may have contributed to making the distribution of the bonds into subgroups for our model, less precise.

Moreover, the data we received consisted of credit ratings that were updated on different dates. We have used the most recent updated ratings for the bonds and have not considered whether they have differed throughout time.

5 Method

The following chapter is dedicated to explaining the model that forms the basis of our analysis. To start, we will discuss the process of dividing the NORM index into subgroups and selecting securities for our replicating portfolio. Further, we will introduce the model we built to track the NORM index, before elaborating on how we have measured the portfolio´s performance. Additionally, we will review some of our assumptions and challenges associated with the model.

5.1 Stratified Sampling and Dividing the Bonds Into Subgroups

Based on the three years our analysis covers, the NORM index consists of an average of 1171 individual bonds each month. As the high number of securities in the index makes it unfeasible to track it fully, the aim of our thesis is to replicate the risk profile and returns of the index while holding fewer securities in our portfolio. This alternative portfolio, which we name the proxy portfolio, was assembled through stratified sampling. The technique involves categorizing a population into subgroups based on certain criteria before randomly selecting samples from each subgroup (Johannessen et al., 2020, p. 63). Hereafter, we will refer to these subgroups as cells, and the population consists of all the bonds in the NORM index.

Securities with similar characteristics were assumed to have the same risk exposure towards the considered risk factors and are therefore assigned to the same cell. Each cell represents one group of bonds with equal risk exposure defined by their duration, maturity, sector, and credit rating. In Table 4, each of the subcategories for the four criteria is presented. The number of cells sums up to a total of 72 (2*3*3*4). To make our model manageable within the time we had available, we decided to exclude all other variables. Adding any additional categories would have significantly increased the number of cells and made the model more difficult to manage. We acknowledge that this is a simplification of bond characteristics and that these assumptions may have implications for the final results. Nevertheless, we consider the criteria we selected to be appropriate for dividing the bonds into specific subgroups.

Characteristic	Subgroup	Number of cells
Duration	1) Less than 0.5 2) More than 0.5	2
Maturity	1) Less than 5 years 2) 5-15 years 3) More than 15 years	3
Sector	1) Muncipality 2) Finance 3) Corporate	3
Credit Rating	1) AAA 2) AA 3) A 4) BBB	4

Table 4: Criteria for dividing bonds into cells

As Table 4 shows, each of the four characteristics was divided into subgroups which gave the individual bond a "score" within those criteria. With the first criterion, duration, bonds were given a score of 1 if they had a modified duration of less than 0.5, and a score of 2 if the modified duration was more than 0.5. The same applies to the other characteristics as well. Each bond would be assigned scores within each criterion. I.e., a local government bond with a modified duration of 0.65, maturity in 8 years, and a credit rating of AAA would have the following scores; Duration = 2, maturity = 2, sector = 1, and credit rating = 1. The full table of each criterion, their subgroups, and the assigned cell number can be found in Appendix A.

5.2 Portfolio Construction

After assigning each bond to its appropriate cell number between 1 and 72, we could randomly select the desired number of bonds from each cell to construct our proxy portfolio. Our aim is to create a portfolio that tracks the NORM index while holding a relatively low number of securities. The securities within each cell are assigned based on their exposure to the presented risk factors. This allows us to view these bonds as interchangeable substitutes with similar properties.

To have the proxy portfolio follow its benchmark as closely as possible, we needed the weights of each cell in our proxy to have the same weight as in NORM. The NORM index is also rebalanced on the last trading day of each month, implicating that the cell weights may change from month to month as bonds could be assigned to new cells if their criteria change. The proxy

portfolio should always include securities from each of the cells the NORM is invested within. By doing so, we maintain an equal risk exposure for both the proxy and NORM index.

For our proxy to follow the index, the portfolio was rebalanced in accordance with the benchmark. The weights of each cell were calculated for every rebalancing, before the weights were assigned to the security representing that exact cell for a given month. Consequently, we had to calculate the cell weight for each of the 36 months covering the period 2020-2022. The cell weights can be viewed in Appendix B.

With the bonds assigned to its cell and the cell weight calculated, the next step was to select a given number of bonds from each cell to construct the proxy portfolio. From calculating and visualizing the cell weights, we found that not all cells were assigned bonds. Some cells were blank and had a weighing of 0 in the NORM index, which implies that no bonds matched all of the four criteria for that exact cell. As an example, the cells with the criteria of maturity being "above 15 years" had only one cell filled, leaving 11 empty cells. This was also the case for some of the other criteria. We found that each month, between 35 and 39 cells were assigned bonds.

As our aim is to create a tracking portfolio with relatively few securities included, we decided to assign the proxy portfolio only one security from each cell. As a result, our proxy portfolio ended up consisting of between 35 and 39 bonds as shown in Figure 3, depending on the number of cells assigned securities for that exact month. The size of the proxy portfolio therefore changes when rebalanced at the end of the month, in order to hold the same properties as the NORM index.

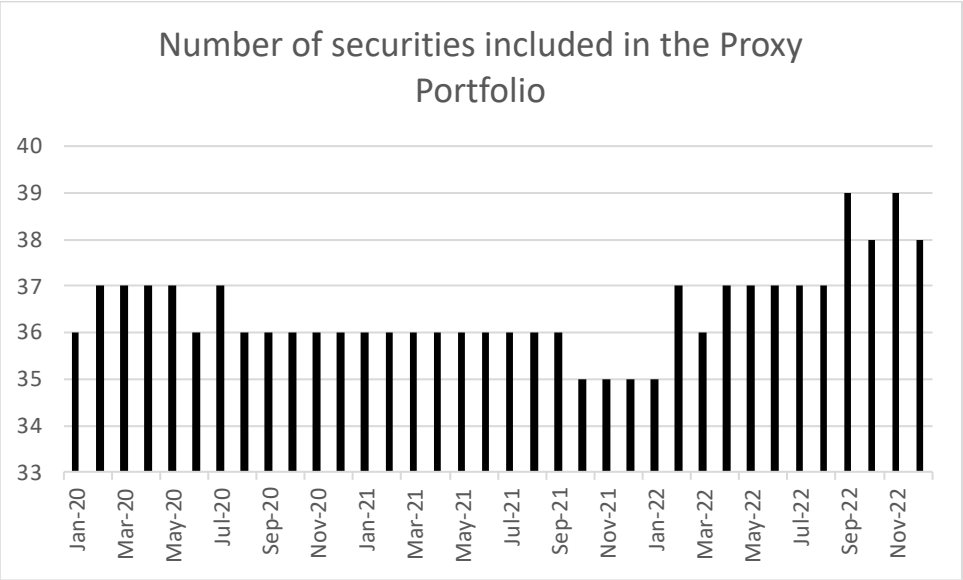

Figure 3: Number of securities held in the proxy portfolio each month, corresponding to the number of cells filled by bonds in the NORM index.

The method of choosing which bonds to include was done by random selection. Our model was built to assign all securities with a random number within each month, before it chose the bond that was randomly assigned the largest number. This exercise was conducted for each cell, in all 36 months, leaving us with 36 proxy portfolios that held a number of securities between 35 and 39 consistent with the NORM index for that same month. The bonds selected for the proxy portfolio were then weighted equally to the corresponding cell weight of the NORM index.

The return of the portfolio was calculated at the rebalancing date. Our model randomly selects a given number of bonds at every rebalancing date, which equals the number of cells that the NORM index is invested in, since all securities within a given cell are assumed to be interchangeable substitutes. Looking back, we realize that our model would have benefited from a constraint that would contribute to a more realistic portfolio when it comes to following a passive investment strategy. The constraint should have made the model include all securities that were selected in the very first portfolio (January 2020) into the following portfolios, as long as the bonds did not change cells during the rebalancing. Without this constraint, our model creates a new portfolio every month. However, with each cell consisting of substitutes and the risk profile and cell weights being equal to that of the benchmark, the proxy portfolios should still manage to provide an adequate result.

Finally, the returns of the proxy bonds were multiplied by the cell weight to find the total return of the proxy portfolio for each month. The return was compared to the return of NORM, and a tracking error was calculated on the difference to determine if the proxy portfolio manages to closely track its benchmark, while holding only approximately 3% of the original securities. This will be further examined in the next chapter.

6 Results

In this chapter, the results from our model will be presented. We will first review the outcomes of the NORM index and our proxy portfolio before we analyze how the proxy portfolio has performed as an index tracker. A discussion of the results will then be presented, and we will comment upon changes in policy rates and how that may have affected our portfolio. Finally, we will comment upon the challenges and limitations of our work, and how they may have had implications for our results.

6.1 Index and Proxy Performance

In the following, we will present the results from the NORM index and the proxy separately. We will review the result for each year, and the three-year period in total. All numbers on returns and standard deviations are annualized. The risk-free rate of 0.40 % is the estimated average rate of the Norwegian 3-month T-bill.

6.1.1 Results for NORM Index.

The NORM index had a total accumulated return of 3.30 % for the whole period of three years. This corresponds to an annual geometric return of 1.10 % as we can read from Table 5. Moreover, NORM had an annual standard deviation of 1.33 % covering all three years.

NORM Index	2020-2022	2020	2021	2022
Accumulated return, annual	3,30%	2,62%	0,38%	0,30%
Geometrical return, annual	1,10%			
Standard deviation, annual	1,33%	1,59%	0,53%	1,58%
Sharpe Ratio	0,53	1,39	-0,03	-0,06

Table 5: Results of the NORM index, 2020-2022.

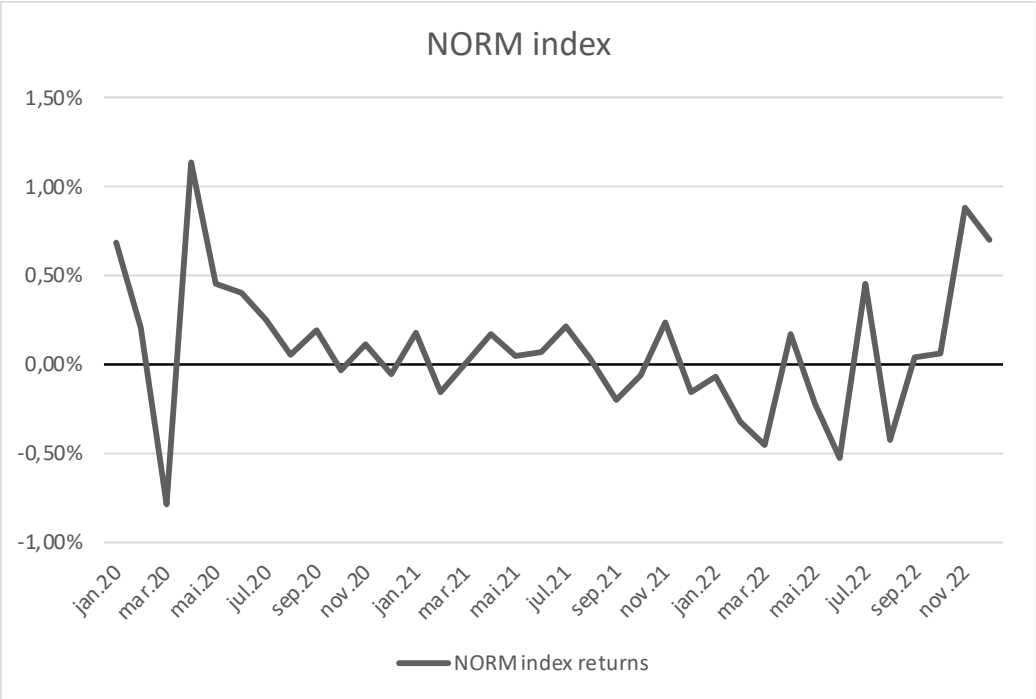

Figure 4: Monthly NORM index returns, 2020-2022.

The index returns are presented in Figure 4. We find that the returns differ from -0.79 % being the lowest return over the three years, found in March 2020, to the highest return at 1.13% in the following month, April 2020. The highest yearly return of 2.62 % was found in 2020 as we see from Table 5, while both 2021 and 2022 had a relatively low return at 0.38 % and 0.30 % respectively. Moreover, we see that the highest standard deviation (SD) was found in 2020 and 2022, which corresponds to the return fluctuations we see in these periods from Figure 4. 2021 appears to be a more stable year with lower volatility, which is also reflected in the SD. 2020 and 2022 had a SD of 1.59 % and 1.58 %, in comparison to 0.53% in 2021. A discussion of these movements will be presented later in this chapter.

Altogether, the returns from 2020 differ considerably from the two other years. This is also illustrated through the Sharpe ratio (SR) in Table 5. With a risk-free rate of 0.40 %, NORM´s risk-adjusted return was calculated to 1.39 in 2020, as the index achieved an excess return above the risk-free free rate. While in 2021 and 2022, the index return was below 0.40 %, resulting in a negative SR of -0.03 and -0.06.

6.1.2 Results of the Proxy Portfolio

Our proxy portfolio did also perform well in total over the period, and the results were quite close to those of the index. Table 6 presents the results. The total accumulated return over all three years was 3.54 %, corresponding to a geometric return of 1.18 % yearly. For the whole period, the portfolio measured a standard deviation of 1.26 %, annualized.

Proxy Portfolio	2020-2022	2020	2021	2022
Accumulated return, annual	3,54%	3,13%	0,42%	-0,01%
Geometrical return, annual	1,18%			
Standard deviation, annual	1,26%	1,39%	0,54%	1,52%
Sharpe Ratio	0,62	1,97	0,04	-0,27

Table 6: Results of the Proxy Portfolio, 2020-2022.

Like the index, 2020 was also the year that achieved the highest annual return at 3.13 %. The portfolio had positive returns also in 2021 before we saw a slightly negative return of -0.01 % in 2022. Unlike the index, 2022 was also the year with the highest annual standard deviation of 1.52 %. The proxy returns are visualized in Figure 5 and the high SD does correspond well with the fluctuations in 2022. As with the index, 2020 was characterized by some extensive movements in returns at the start of the year, while 2021 shows a more stable period with only modest fluctuations. Our proxy achieved its highest return in April 2020 at 1.16 %, beating the index by 0.03 percentage points. On the contrary, the lowest proxy returns were found in March 2022 at -0.52 %, while the index scored its lowest two years before.

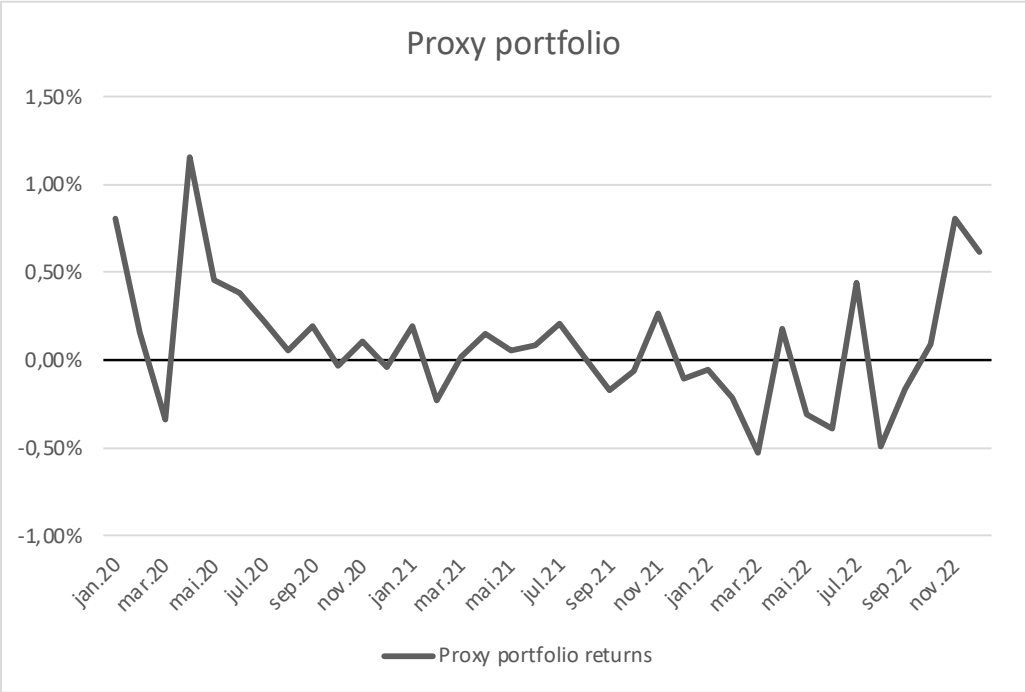

Figure 5: Monthly Proxy index returns, 2020-2022.

The negative annual return is also illustrated in the proxy´s Sharpe ratio for 2022. Both 2020 and 2021 achieved returns above the risk-free rate, resulting in a positive SR of 1.97 and 0.04 respectively. The negative return of the last year led to a negative SR of -0.27.

6.2 The Proxy Portfolio as an Index-tracker

The first aim of our thesis was to create an index-tracking portfolio and to examine to what extent we could track the benchmark index that consists of over a thousand individual bonds by holding relatively few bonds in our portfolio. We have already reviewed the model built to construct the proxy portfolio and presented how bonds were randomly assigned to the proxy according to their risk exposure. In the following, we will deliver results from analyzing the performance of the proxy as an index-tracking portfolio.

While the NORM index consists of on average 1171 securities each month, our proxy portfolio only holds between 35 and 39 securities. On average, the proxy contained 36.5 bonds. Descriptive statistics are presented in Table 7. Each bond is assigned to a cell that they represent, and every bond within that cell shares the same properties and risk exposure related to its duration, maturity, sector, and credit rating. The bond that was randomly selected to represent each cell in our proxy portfolio, holds the same weight as all the bonds combined within that cell in NORM. Since we expect all bonds within a cell to have the same risk

exposure, we would assume that the proxy will be able to follow the movements in NORM relatively close. The results can be read in Table 7, and the proxy portfolio and NORM index are both presented visually in Figure 6.

	NORM	Proxy		
Average number of securities	1171	36,5		
Percentage of NORM		3,1%		
Average return, annual	1,10%	1,18%		
Standard deviation, annual	1,33%	1,26%		
Proxy - NORM	**2020-2022**	**2020**	**2021**	**2022**
Difference in average return, annual	0,08%	0,51%	0,04%	-0,32%
Tracking Error	**0,10%**	**0,14%**	**0,03%**	**0,09%**

Table 7: Descriptive statistics on NORM index and Proxy portfolio performance, 2020-2022.

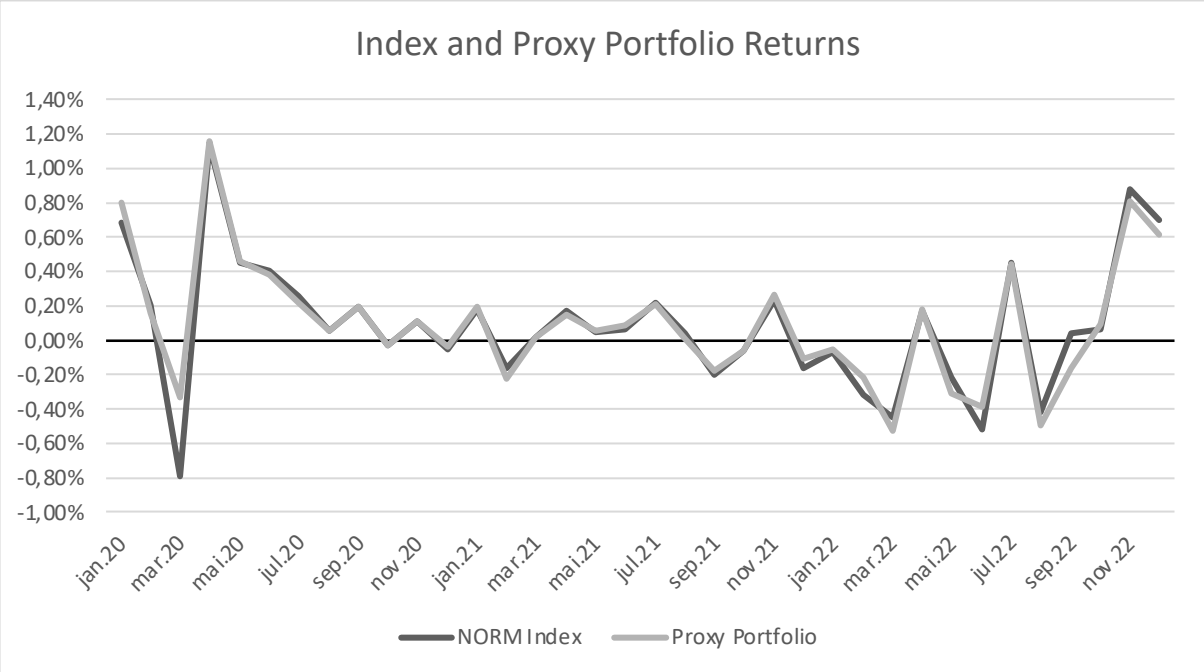

Figure 6: Total returns month to date of the NORM index and Proxy portfolio, 01.01.2020-31.12.2022

The proxy portfolio had an average return of 1.18 % annually, outperforming the NORM index by 0.08 percentage points while only holding 3.1 % of the securities that NORM is invested in. Our proxy also had a lower standard deviation than the index, with an SD of 1.26 % against 1.33 % calculated as an annual average. When examining each year individually, the proxy

performed better than the index in both 2020 and 2021. There was a 0.51% and 0.04% positive difference in returns, compared to the index. However, the proxy underperformed the index by -0.32% in 2022, which is consistent with what we can see from Figure 6. Based on the graph, the proxy portfolio manages to track the movements of NORM quite closely in periods with modest fluctuations between mid-2020 to late 2021, while there are significant discrepancies at the beginning of 2020 and throughout 2022.

These results are also illustrated by the relatively low tracking error of 0.10 % over the period of three years. As the tracking error measures the variability of the return differences between the total return of the proxy portfolio, and the total return of the benchmark index, we get an estimate of how well the proxy performs as an index-tracking portfolio. In comparison, the Norwegian Government Pension Fund Global operates with a tracking error limit of 1.25 percentage points (Norges Bank Investment Management, 2023). Figure 7 graphs the difference in returns between the proxy portfolio and NORM. There are some drastic fluctuations in returns at the beginning of 2020 and through all of 2022. In January and March 2020, the two portfolios had a difference in returns of 0.12 % and 0.45 % respectively. Such differences affect the tracking error measure for that year, leaving us with the highest annual TE of 0.14 %. Both the proxy portfolio and NORM achieved relatively similar returns through 2021, resulting in the lowest TE over the period of 0.03 %. Comparing Figure 7 to the standard deviations of NORM and the proxy from Table 5 and Table 6 (see Chapters 6.1.1 and 6.1.2), 2021 was a year with low volatility for both portfolios. With only modest fluctuations in NORM, our proxy portfolio managed to efficiently track the index.

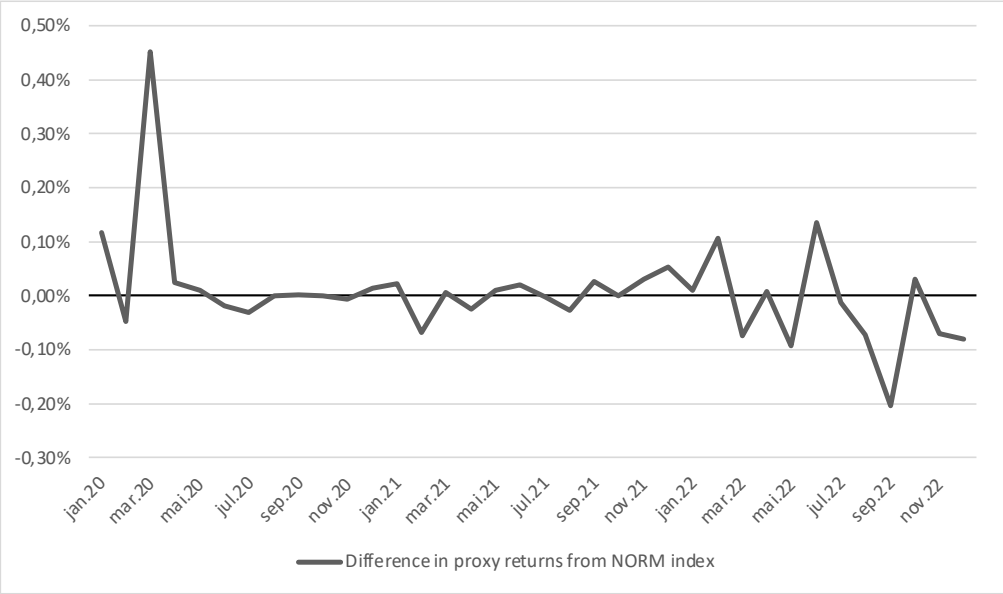

Figure 7: Difference in returns of proxy portfolio minus the returns from NORM index. 01.01.2020-31.12.2022.

2022 turned out to be the most volatile year through our period, reporting annual standard deviations of 1.58 % for NORM and 1.52 % for the proxy. The graph in Figure 7 displays significant fluctuations around zero, indicating high volatility for this period. Graphically, it appears that our proxy had the most difficulty tracking the index this year, with several months showing returns that differed from 0.10 % to -0.20 %. However, the tracking error for 2020 is higher than that of 2022, with 0.14% compared to 0.10 %. In the following, we will comment upon these variations in tracking error, and provide a discussion of which economic variables that could potentially affect the portfolios´ returns.

6.3 Discussion of results

In addition to creating an index-tracking portfolio, our aim was to examine how such an investment vehicle will perform in a market with increasing policy rates. Till now, we have analyzed how the proxy has performed as an index tracker and seen that it is a more efficient tracking instrument in some periods than others. In the following, we will discuss some of the reasons why the performance differs over time, with a focus on the changes in policy rates.

Going into 2020, the policy rate was at 1.5 %. With the outbreak of the covid-19 pandemic, the Norwegian Government and Norges Bank decided to lower the policy rates to damp the fall in activity in the Norwegian economy (Norges Bank, 2020). The first adjustment was

implemented in March 2020, and by June of the same year, the policy rate was set to 0 %. Our proxy portfolio, the NORM index, and the Norwegian policy rate are presented in Figure 11, rebased at 100 for easier comparison. The graphs show that both the index and our proxy portfolio reacted to the pandemic and the subsequent shutdown, resulting in negative returns in March 2020. The rapid fall in returns can be explained by the sudden spike in credit spread (Alfred Berg, 2020). Both portfolios reacted quickly to the adjustments, and already in the month after, they achieved the highest return over the whole three-year period. The drastic increase in returns can be explained by the inverse relationship between interest rates, and bond value. The value of a bond will increase when interest rates fall, given a fixed-rate bond.

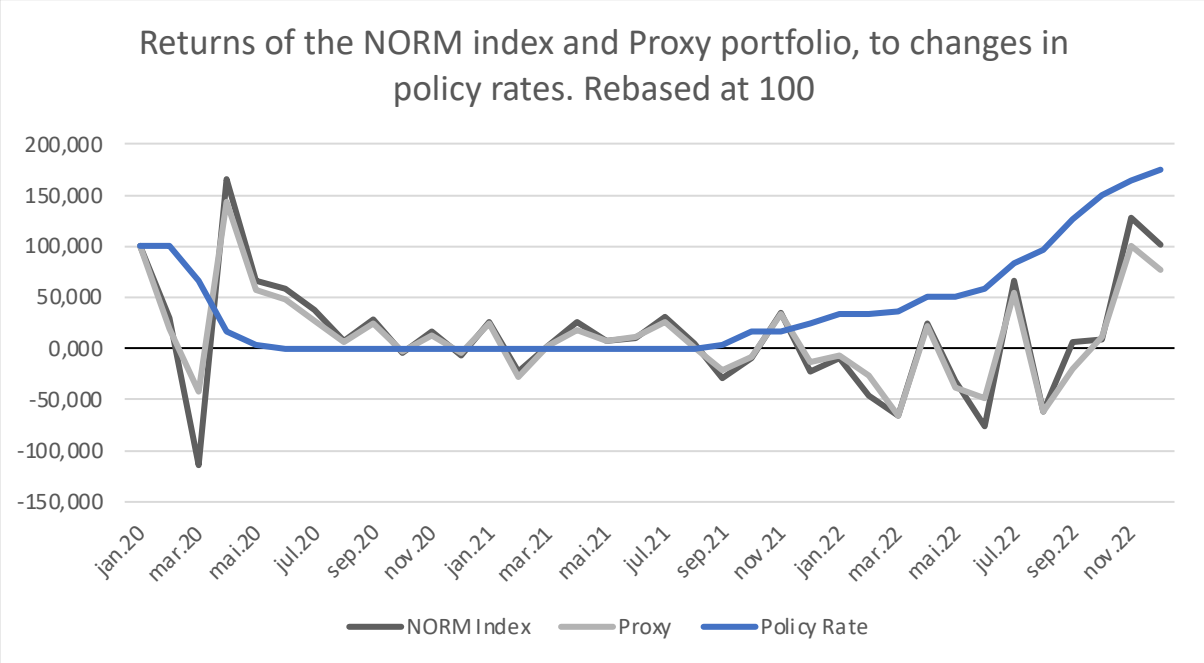

Figure 8: Returns of the NORM index and Proxy portfolio, and changes in policy rates, 2020-2022. Rebased at 100, 01.01.2020.

The NORM index and our proxy portfolio have had a relatively stable distribution of fixed- and floating rates on the constituent bonds as shown in Figure 9, with an average of 40 % of the investments in NORM being fixed-rate bonds. The value of fixed-rate bonds would increase as the policy rate was lowered, and fall when interest rates increase since their coupon rate is held constant, while the discount rate increases. As bonds with floating rates have their interest rate tied to a benchmark rate, their value is less sensitive to changes in market interest rates. In an increasing interest rate environment, FRNs would even appeal to investors, as their coupon rate is adjusted accordingly. As all the bonds in the NORM index are traded in the Norwegian bond market, we have made the assumption that bonds with a floating rate have NIBOR as its

benchmark rate. The 3-month NIBOR rate, the policy rate and the 3-month Norwegian T-bill (risk-free rate estimate) is presented in Figure 10.

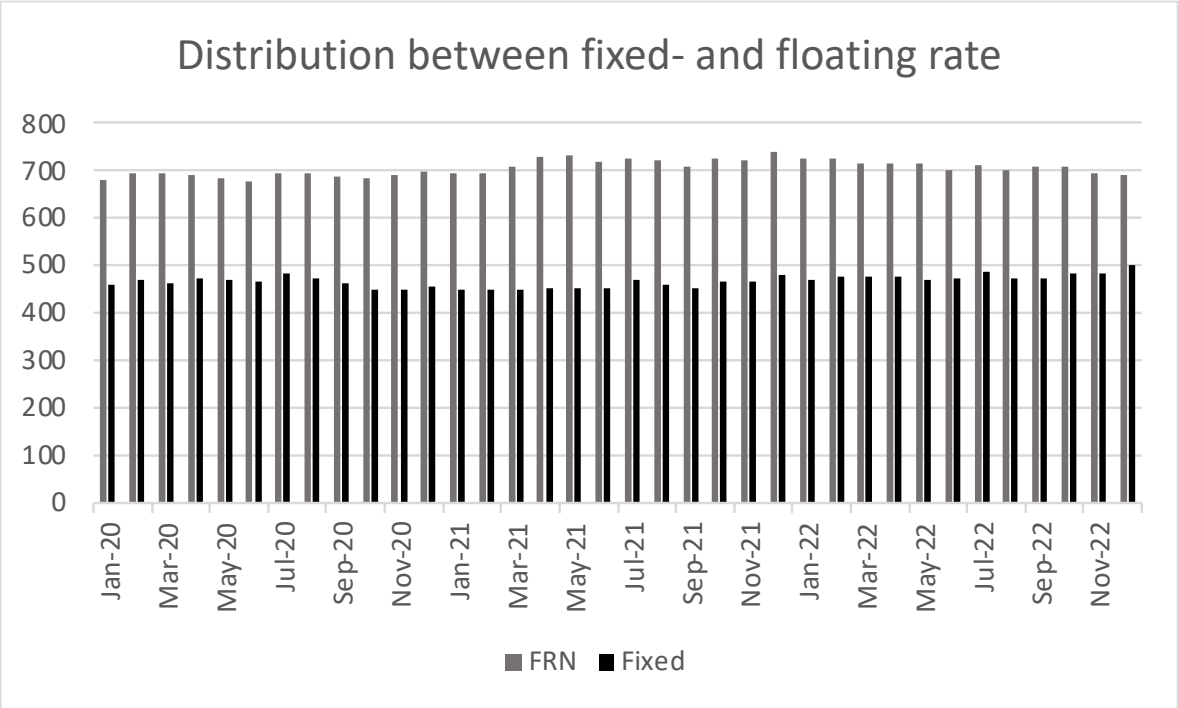

Figure 9: Distribution of bonds with fixed and floating rates in the NORM index.

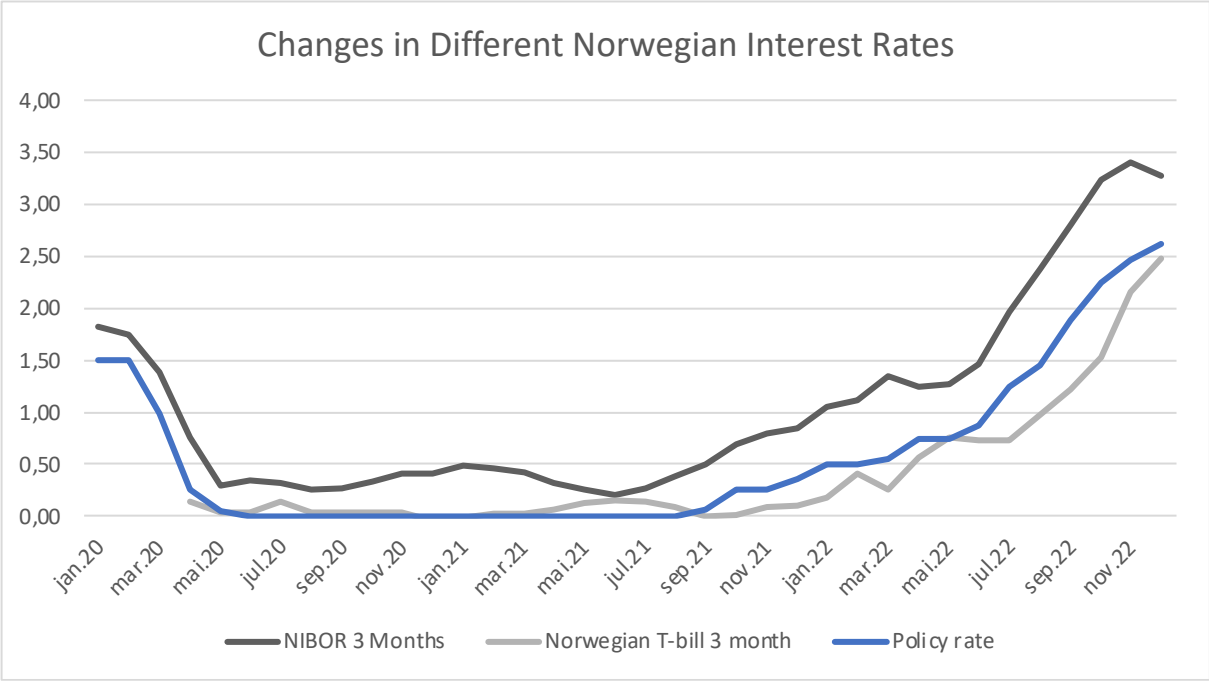

Figure 10: Changes in 3-month NIBOR, 3-month Norwegian T-bill and Policy rate in percentage. 2020-2022.

Fixed or floating rate was not one of our criteria for dividing the NORM index into subgroups before constructing our proxy portfolio. Hence, the difference in returns between NORM and our proxy in March 2020 can be partly explained by what type of interest rate structure the bonds in our portfolio consisted of. Further, 18 of 37 bonds in our proxy were invested in bonds with longer durations, with a total weight of approximately 28 %. As bonds with longer durations are more sensitive to changes in interest rates, this may also explain the differences in returns.

From mid-2020 and into 2021, the policy rate was held constant at 0 % as the pandemic was still affecting the activity in the Norwegian economy. Through this period, our proxy portfolio had the lowest tracking error of the three years, and a modest excess return of 0.04 % compared to the index. With no sudden movements in the overall bonds market, our proxy portfolio manages to efficiently track its benchmark. We can also see from Table 6 (see 6.1.2) that the tracking error is greater during periods when the interest rates are either increasing or decreasing.

The first increase in policy rates after the zero-rate period was put into action on 24. September 2021. Since then, the policy rate was increased several times throughout 2021 and 2022, reaching 2.75 % by the end of 2022. This is consistent with the increasing differences in returns between proxy and the index, and the increase in tracking error that we found over the same period. With each adjustment in the policy rate, both our proxy portfolio and the index experienced movements in their total returns. Bond yields and prices move in the opposite direction, so with increasing interest rates, the yield on current bonds becomes less attractive as investors could sell and reinvest in another bond with higher yields. In addition, inflation stayed higher than expected even after several attempts by Norges Bank to dampen the activity with higher policy rates. The Russian invasion of Ukraine also put a squeeze on both commodities and energy prices, while the labor market was tight and inflation high after the government's attempt to boost the economy after the pandemic. The fluctuations in returns do also represent the uncertainty among investors about whether or not the inflation had peaked, and if rate decisions would flatten out and stabilize (Lynch, 2022).

With such severe and frequent movements in returns as the portfolios experienced in 2022, it was difficult for our proxy to track the NORM index. Among the bonds that are most affected

by changes in interest rates, are bonds with longer maturities and long durations. The NORM index is on average weighted with 24 % of bonds that has a modified duration above 0.5, while bonds with both duration above 0.5 and maturity between 5 and 15 years, are on average weighted with 8.7 %. Bonds with a duration above 0.5 and maturity over 15 years are on average only weighted 0.1 %. In other words, NORM is not heavily weighted with long-term bonds that also have a long duration, which are the bonds that are the most sensitive to interest rate changes. That could also explain why our proxy has managed to track the index so closely for most of the three-year period, as both portfolios are weighted heavily toward shorter-term bonds. Both portfolios are still relatively volatile in 2022, which is a period of consistently increasing interest rates, with standard deviations of 1.52 % and 1.58 % respectively (see Table 5 and Table 6).

It is also worth mentioning that NORM is an index that is invested in the Investment Grade-segment of the bond market, which eliminates some of the credit risks that are related to high-yield bonds. With credit ratings varying from BBB to AAA, the bonds included in both the index and our proxy portfolio are expected to have a lower risk. We also know from previous chapters, that with higher risk, the investor would expect a higher return as a premium. But our portfolio has shown that the period with the highest volatility, measured by the standard deviation, is not consistent with the period that achieves the highest returns. From Table 6 (see 6.1.2) we find that 2022 had the highest annual SD of 1.52 %, while the portfolio achieved a negative return of -0.01 % on average that year.

Before analyzing the performance of the portfolios, we expected to find that the returns on both the NORM index and our proxy portfolio would increase, in accordance with the increasing policy rates. The analysis revealed that the portfolios did achieve some higher returns in 2022 compared to 2021, but these positive returns were offset by approximately equal negative returns. Altogether, 2022 ended with an aggregated average return of -0.01 % for our proxy portfolio. In periods with changing interest rates, we find that both the proxy and NORM index have more fluctuating returns, making it more difficult for the proxy to closely track the index, while we achieve lower tracking errors in periods with more stable interest rates.

6.4 Limitations and Challenges

During the process of working on our thesis, we have acknowledged certain limitations with our model and identified other factors that could have impacted our analysis, if considered earlier. In the following, we will discuss some of these considerations and the implications they could have had on our final results.

The model we built for constructing our proxy portfolio, consisted of four criteria for dividing each bond into its appropriate cell; duration, maturity, sector, and credit rating. A central part of our thesis has been to examine how an index-tracking bond portfolio performs in an environment of increasing interest rates. We acknowledge that including a criterion of whether the bond has a fixed or floating rate, could have provided us with a deeper understanding of the relationship between the change in policy rates, and the corresponding fluctuations we found in returns. We did find that the most severe movements appeared in those periods where the policy rate was adjusted. However, since the securities were not assigned to their cells based on a fixed or floating rate, we could not provide further information about whether the movements were directly related to the bonds rate structure on not. Including another criterion with two options would further double the number of cells, as we would then have 144 individual cells (2*3*3*4*2). This would thus make the model less manageable and make the work of analyzing all the data even more extensive.

Another challenge we had with the dataset, stemmed from the lack of available credit ratings. Although we found a way to apply some more simple assumptions, the solution of assigning credit ratings based on a sector average was not ideal. It is important to acknowledge that these calculations do not consider the specificities of the individual papers. And as our model and cell distribution rely on the unique characteristics of each paper, it is unfortunate that the underlying and individual credit risks were not evaluated on an individual basis.

Lastly, it could also have been interesting to construct another proxy portfolio consisting of several bonds within each cell to examine if that would contribute to a more efficient index-tracking portfolio, by "diversifying" also within a cell. Holding a portfolio that consists of more securities would initially have a greater diversifying effect. But holding more bonds would also imply that more trades would be necessary, which in turn will increase the transaction costs. Then, a trade-off must be made between increasing transaction costs and holding a larger and more robust portfolio. It would be interesting to compare the two proxies and see which

manages to track the index closest. But for now, we are satisfied with the results we got from holding only one portfolio.

7 Conclusion

Holding fixed-income securities as part of an investment portfolio can give the investor valuable diversification effects, and stable and predictable fixed incomes, and serve as a countercyclical investment instrument to the movements in the stock market. Nevertheless, bond funds often receive less attention from investors compared to the stock market, and there are few alternatives if you are looking to hold a passively managed bond portfolio. At least in the Norwegian bond market. The aim of this thesis is to investigate how a constructed passive portfolio manages to track a benchmark index while holding a relatively small number of securities. The purpose is to provide investors with a more affordable alternative to active bond funds, while at the same time being exposed to the broad bond market.

From the construction a proxy portfolio consisting of 36.5 bonds on average, we managed to track the benchmark index (NORM) with a tracking error of 0.10 % over the three-year period of 2020-2023. It is remarkable that our portfolio manages to track the NORM index so closely, despite the fact that we have reduced the number of papers drastically. On average, the proxy portfolio consists of approximately 3 % of all securities invested in the NORM index. The index achieved an average return of 1.10 % annually, compared to 1.18 % from the proxy portfolio. Our proxy portfolio gained an excess return over the benchmark index of 0.08 % over the period, while also having a lower risk measured by standard deviation.

We held a pure indexing approach for our index-tracking portfolio, where the main objective was to achieve a minimal tracking error. In periods with low and stable interest rates, we found the proxy portfolio to achieve tracking errors of only 0.03 %. During these periods, the proxy portfolio was able to deliver almost equivalent results to that of the index, while only holding a small number of papers. However, we found that it was more difficult for the proxy to follow the index in periods characterized by changing interest rates, due to the severe fluctuations in returns and bond value. In both a falling and increasing interest rate environment, we experienced that the proxy portfolio had large movements in the return, although the interest rate changes maintained a consistent trend over a period, with either falling or increasing interest rates.

The period in which we have analyzed with stable and consistent interest rates, has also been a period of very low interest rates. It would be interesting to also examine a period where interest

rates were equally stable but at a high interest rate level. Would we have experienced that the proxy portfolio had managed to closely track the index during this period as well, or have our results been extraordinarily good due to the 0 % policy rate.

Based on the results we have observed, it appears that we have managed to construct a small portfolio that is able to efficiently track an underlying benchmark, even in periods of rising interest rates. The performance of the proxy portfolio was not as good as we had expected for a period of rising interest rates with respect to the return. However, we did achieve a low track, which was the overall objective of the portfolio. Accordingly, we consider our passive bond portfolio to be an example of a good alternative for investors who want to hold a bond portfolio consisting of a small number of securities, but at the same time be exposed to the broad Norwegian bond market. The actual return, after taking into account transaction costs, may have been somewhat lower than the results presented in this thesis. To determine this with certainty, we would need to consider and include several factors into our analysis, which this study does not cover.

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9 Appendix

9.1 Appendix A: Cell Distribution

	Criteria				Score			
Cell	*Duration*	*Maturity*	*Sector*	*Credit rating*	*Duration*	*Maturity*	*Sector*	*Credit rating*
1	Less than 0.5	Less than 5 years	Muncipality	AAA	1	1	1	1
2	Less than 0.5	Less than 5 years	Muncipality	AA	1	1	1	2
3	Less than 0.5	Less than 5 years	Muncipality	A	1	1	1	3
4	Less than 0.5	Less than 5 years	Muncipality	BBB	1	1	1	4
5	Less than 0.5	Less than 5 years	Finance	AAA	1	1	2	1
6	Less than 0.5	Less than 5 years	Finance	AA	1	1	2	2
7	Less than 0.5	Less than 5 years	Finance	A	1	1	2	3
8	Less than 0.5	Less than 5 years	Finance	BBB	1	1	2	4
9	Less than 0.5	Less than 5 years	Corporate	AAA	1	1	3	1
10	Less than 0.5	Less than 5 years	Corporate	AA	1	1	3	2
11	Less than 0.5	Less than 5 years	Corporate	A	1	1	3	3
12	Less than 0.5	Less than 5 years	Corporate	BBB	1	1	3	4
13	Less than 0.5	5-15 years	Muncipality	AAA	1	2	1	1
14	Less than 0.5	5-15 years	Muncipality	AA	1	2	1	2
15	Less than 0.5	5-15 years	Muncipality	A	1	2	1	3
16	Less than 0.5	5-15 years	Muncipality	BBB	1	2	1	4
17	Less than 0.5	5-15 years	Finance	AAA	1	2	2	1
18	Less than 0.5	5-15 years	Finance	AA	1	2	2	2
19	Less than 0.5	5-15 years	Finance	A	1	2	2	3
20	Less than 0.5	5-15 years	Finance	BBB	1	2	2	4
21	Less than 0.5	5-15 years	Corporate	AAA	1	2	3	1
22	Less than 0.5	5-15 years	Corporate	AA	1	2	3	2
23	Less than 0.5	5-15 years	Corporate	A	1	2	3	3
24	Less than 0.5	5-15 years	Corporate	BBB	1	2	3	4
25	Less than 0.5	More than 15 years	Muncipality	AAA	1	3	1	1
26	Less than 0.5	More than 15 years	Muncipality	AA	1	3	1	2
27	Less than 0.5	More than 15 years	Muncipality	A	1	3	1	3
28	Less than 0.5	More than 15 years	Muncipality	BBB	1	3	1	4
29	Less than 0.5	More than 15 years	Finance	AAA	1	3	2	1
30	Less than 0.5	More than 15 years	Finance	AA	1	3	2	2
31	Less than 0.5	More than 15 years	Finance	A	1	3	2	3
32	Less than 0.5	More than 15 years	Finance	BBB	1	3	2	4
33	Less than 0.5	More than 15 years	Corporate	AAA	1	3	3	1
34	Less than 0.5	More than 15 years	Corporate	AA	1	3	3	2
35	Less than 0.5	More than 15 years	Corporate	A	1	3	3	3
36	Less than 0.5	More than 15 years	Corporate	BBB	1	3	3	4
37	More than 0.5	Less than 5 years	Muncipality	AAA	2	1	1	1
38	More than 0.5	Less than 5 years	Muncipality	AA	2	1	1	2
39	More than 0.5	Less than 5 years	Muncipality	A	2	1	1	3
40	More than 0.5	Less than 5 years	Muncipality	BBB	2	1	1	4
41	More than 0.5	Less than 5 years	Finance	AAA	2	1	2	1
42	More than 0.5	Less than 5 years	Finance	AA	2	1	2	2
43	More than 0.5	Less than 5 years	Finance	A	2	1	2	3
44	More than 0.5	Less than 5 years	Finance	BBB	2	1	2	4
45	More than 0.5	Less than 5 years	Corporate	AAA	2	1	3	1
46	More than 0.5	Less than 5 years	Corporate	AA	2	1	3	2
47	More than 0.5	Less than 5 years	Corporate	A	2	1	3	3
48	More than 0.5	Less than 5 years	Corporate	BBB	2	1	3	4
49	More than 0.5	5-15 years	Muncipality	AAA	2	2	1	1
50	More than 0.5	5-15 years	Muncipality	AA	2	2	1	2
51	More than 0.5	5-15 years	Muncipality	A	2	2	1	3
52	More than 0.5	5-15 years	Muncipality	BBB	2	2	1	4
53	More than 0.5	5-15 years	Finance	AAA	2	2	2	1
54	More than 0.5	5-15 years	Finance	AA	2	2	2	2
55	More than 0.5	5-15 years	Finance	A	2	2	2	3
56	More than 0.5	5-15 years	Finance	BBB	2	2	2	4
57	More than 0.5	5-15 years	Corporate	AAA	2	2	3	1
58	More than 0.5	5-15 years	Corporate	AA	2	2	3	2
59	More than 0.5	5-15 years	Corporate	A	2	2	3	3
60	More than 0.5	5-15 years	Corporate	BBB	2	2	3	4
61	More than 0.5	More than 15 years	Muncipality	AAA	2	3	1	1
62	More than 0.5	More than 15 years	Muncipality	AA	2	3	1	2
63	More than 0.5	More than 15 years	Muncipality	A	2	3	1	3
64	More than 0.5	More than 15 years	Muncipality	BBB	2	3	1	4
65	More than 0.5	More than 15 years	Finance	AAA	2	3	2	1
66	More than 0.5	More than 15 years	Finance	AA	2	3	2	2
67	More than 0.5	More than 15 years	Finance	A	2	3	2	3
68	More than 0.5	More than 15 years	Finance	BBB	2	3	2	4
69	More than 0.5	More than 15 years	Corporate	AAA	2	3	3	1
70	More than 0.5	More than 15 years	Corporate	AA	2	3	3	2
71	More than 0.5	More than 15 years	Corporate	A	2	3	3	3
72	More than 0.5	More than 15 years	Corporate	BBB	2	3	3	4

Table 8: Model of how bonds were distributed to cells based on their score on each criteria.

9.2 Appendix B: Cell Weights in NORM-index

Cell Weights per Month in NORM Index

Cell	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21
1	0,033	0,032	0,030	0,031	0,030	0,028	0,030	0,029	0,030	0,029	0,031	0,033	0,032	0,030	0,029	0,031	0,031	0,032
2	0,001	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,003	0,003	0,003	0,003
3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
5	0,415	0,405	0,407	0,439	0,451	0,449	0,463	0,465	0,466	0,474	0,469	0,473	0,480	0,485	0,477	0,470	0,463	0,458
6	0,031	0,031	0,032	0,031	0,030	0,034	0,034	0,034	0,034	0,032	0,032	0,031	0,031	0,030	0,030	0,029	0,032	0,031
7	0,108	0,103	0,102	0,097	0,093	0,091	0,090	0,091	0,088	0,090	0,092	0,090	0,089	0,086	0,089	0,088	0,087	0,086
8	0,011	0,011	0,011	0,010	0,010	0,010	0,010	0,009	0,010	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009
9	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
10	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,001	0,002	0,002	0,001	0,002	0,002	0,001	0,001	0,001	0,001
11	0,027	0,028	0,028	0,025	0,024	0,023	0,025	0,026	0,026	0,025	0,026	0,025	0,026	0,027	0,027	0,029	0,028	0,026
12	0,056	0,054	0,053	0,051	0,047	0,049	0,051	0,050	0,050	0,048	0,051	0,051	0,050	0,051	0,052	0,052	0,056	0,056
13	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,001	0,001	0,001	0,001	0,001	0,001	0,000
14	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
15	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
16	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
17	0,010	0,022	0,020	0,018	0,026	0,023	0,009	0,009	0,009	0,005	0,004	0,006	0,006	0,006	0,017	0,017	0,021	0,024
18	0,000	0,001	0,001	0,001	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
19	0,001	0,003	0,002	0,002	0,001	0,001	0,001	0,001	0,003	0,001	0,001	0,003	0,005	0,004	0,003	0,003	0,003	0,003
20	0,011	0,010	0,011	0,009	0,009	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,012	0,012	0,012
21	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
22	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
23	0,001	0,001	0,003	0,002	0,003	0,002	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,004	0,003	0,004	0,003
24	0,002	0,005	0,006	0,005	0,006	0,007	0,007	0,008	0,008	0,009	0,008	0,009	0,010	0,008	0,006	0,008	0,010	0,010
25	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
26	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
27	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
28	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
29	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
30	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
31	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002
32	0,013	0,011	0,010	0,009	0,009	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,010	0,010	0,009
33	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
34	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
35	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
36	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
37	0,029	0,030	0,031	0,031	0,030	0,030	0,030	0,028	0,027	0,027	0,027	0,027	0,026	0,028	0,028	0,029	0,028	0,028
38	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
39	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
40	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
41	0,046	0,045	0,045	0,044	0,042	0,042	0,040	0,039	0,040	0,039	0,038	0,033	0,026	0,026	0,025	0,024	0,024	0,029
42	0,028	0,026	0,027	0,026	0,025	0,025	0,026	0,026	0,026	0,026	0,026	0,025	0,025	0,025	0,024	0,024	0,021	0,020
43	0,038	0,037	0,038	0,035	0,035	0,034	0,033	0,033	0,034	0,035	0,036	0,036	0,036	0,036	0,036	0,035	0,036	0,035
44	0,003	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002
45	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
46	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
47	0,007	0,007	0,007	0,007	0,007	0,007	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008
48	0,022	0,021	0,021	0,021	0,018	0,019	0,019	0,019	0,020	0,019	0,020	0,019	0,020	0,019	0,019	0,020	0,019	0,022
49	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,016	0,018	0,018	0,018	0,017	0,017	0,017
50	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
51	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
52	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
53	0,032	0,033	0,033	0,032	0,031	0,031	0,029	0,029	0,029	0,030	0,028	0,027	0,026	0,026	0,025	0,026	0,027	0,021
54	0,007	0,007	0,007	0,006	0,006	0,006	0,004	0,004	0,004	0,004	0,004	0,003	0,003	0,003	0,003	0,002	0,002	0,002
55	0,008	0,009	0,009	0,008	0,007	0,007	0,007	0,007	0,005	0,004	0,003	0,005	0,005	0,005	0,004	0,004	0,005	0,005
56	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,000	0,000	0,001	0,001	0,001
57	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
58	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
59	0,020	0,021	0,021	0,019	0,020	0,020	0,019	0,018	0,018	0,019	0,019	0,018	0,018	0,019	0,018	0,019	0,019	0,020
60	0,012	0,012	0,013	0,012	0,010	0,012	0,013	0,013	0,013	0,013	0,014	0,014	0,015	0,015	0,014	0,014	0,015	0,014
61	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
62	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
63	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
64	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
65	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
66	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
67	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
68	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
69	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
70	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
71	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
72	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Cell	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
1	0,034	0,034	0,032	0,035	0,034	0,036	0,036	0,037	0,035	0,039	0,037	0,039	0,044	0,039	0,041	0,042	0,045	0,047
2	0,003	0,003	0,003	0,003	0,003	0,002	0,002	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,002	0,003	0,003
3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
5	0,458	0,453	0,463	0,457	0,456	0,457	0,468	0,446	0,468	0,475	0,474	0,454	0,457	0,462	0,468	0,482	0,480	0,487
6	0,031	0,031	0,031	0,028	0,028	0,027	0,028	0,027	0,026	0,027	0,029	0,029	0,028	0,026	0,025	0,026	0,020	0,019
7	0,086	0,086	0,086	0,086	0,085	0,087	0,087	0,087	0,083	0,082	0,082	0,087	0,086	0,084	0,083	0,080	0,080	0,070
8	0,009	0,010	0,010	0,010	0,010	0,009	0,008	0,009	0,010	0,010	0,009	0,009	0,009	0,009	0,009	0,009	0,010	0,011
9	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
10	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,002	0,002	0,001	0,001	0,002	0,001
11	0,027	0,026	0,024	0,025	0,025	0,024	0,022	0,023	0,022	0,022	0,022	0,024	0,025	0,026	0,026	0,025	0,024	0,026
12	0,056	0,058	0,060	0,060	0,058	0,060	0,060	0,066	0,063	0,061	0,061	0,063	0,062	0,064	0,063	0,061	0,059	0,057
13	0,001	0,001	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,002	0,000	0,000
14	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
15	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
16	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
17	0,019	0,017	0,017	0,017	0,017	0,012	0,010	0,013	0,013	0,015	0,015	0,018	0,013	0,009	0,006	0,001	0,001	0,001
18	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
19	0,003	0,003	0,003	0,003	0,003	0,001	0,001	0,003	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,001	0,001	0,001
20	0,012	0,012	0,012	0,012	0,013	0,014	0,013	0,016	0,015	0,015	0,017	0,017	0,016	0,016	0,016	0,016	0,015	0,015
21	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
22	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
23	0,004	0,004	0,004	0,005	0,005	0,005	0,005	0,005	0,004	0,004	0,004	0,003	0,003	0,003	0,003	0,003	0,003	0,003
24	0,011	0,012	0,013	0,013	0,013	0,012	0,012	0,008	0,007	0,008	0,008	0,008	0,008	0,007	0,008	0,008	0,007	0,007
25	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
26	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
27	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
28	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
29	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
30	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
31	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002
32	0,009	0,009	0,008	0,008	0,008	0,009	0,009	0,010	0,008	0,008	0,008	0,008	0,010	0,010	0,012	0,010	0,010	0,010
33	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
34	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
35	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
36	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
37	0,029	0,028	0,028	0,029	0,029	0,027	0,027	0,029	0,028	0,027	0,027	0,028	0,027	0,027	0,026	0,024	0,024	0,022
38	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
39	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
40	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
41	0,029	0,029	0,024	0,024	0,027	0,030	0,025	0,024	0,024	0,023	0,023	0,025	0,024	0,025	0,024	0,023	0,024	0,024
42	0,020	0,021	0,019	0,019	0,019	0,018	0,019	0,020	0,019	0,018	0,018	0,018	0,018	0,019	0,018	0,017	0,017	0,017
43	0,035	0,036	0,035	0,037	0,037	0,038	0,040	0,042	0,041	0,040	0,041	0,042	0,043	0,044	0,043	0,044	0,045	0,046
44	0,002	0,002	0,002	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,004	0,004	0,004	0,004	0,004	0,006
45	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
46	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002
47	0,009	0,009	0,009	0,010	0,010	0,010	0,011	0,013	0,014	0,013	0,014	0,015	0,015	0,015	0,015	0,015	0,015	0,015
48	0,022	0,022	0,022	0,021	0,022	0,022	0,021	0,022	0,022	0,021	0,020	0,021	0,021	0,021	0,023	0,022	0,021	0,022
49	0,017	0,018	0,018	0,018	0,019	0,021	0,020	0,020	0,019	0,018	0,018	0,019	0,017	0,018	0,017	0,016	0,019	0,019
50	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
51	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
52	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
53	0,021	0,022	0,022	0,021	0,020	0,016	0,016	0,016	0,016	0,016	0,016	0,016	0,017	0,017	0,018	0,019	0,022	0,024
54	0,002	0,003	0,003	0,002	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,002
55	0,005	0,005	0,005	0,005	0,006	0,005	0,006	0,006	0,007	0,005	0,005	0,005	0,004	0,004	0,004	0,005	0,006	0,006
56	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,001	0,001	0,002
57	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
58	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
59	0,022	0,022	0,022	0,022	0,023	0,023	0,022	0,021	0,019	0,018	0,018	0,018	0,019	0,021	0,020	0,018	0,018	0,019
60	0,013	0,014	0,016	0,017	0,016	0,016	0,015	0,016	0,015	0,014	0,014	0,014	0,013	0,013	0,011	0,011	0,011	0,010
61	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
62	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
63	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
64	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
65	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
66	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
67	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
68	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
69	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
70	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
71	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
72	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Table 9: Weight per cell each month in the NORM index. Cells without bonds (weight = 0) in grey.

9.3 Appendix C: List of Tables

9.4 Appendix D: List of Figures

Norges miljø- og biovitenskapelige universitet
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