Timing the Treasury Bond Market

Indicators predicting the relative evolution of Treasury bonds and Treasury bills

Master of Science Thesis

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Abstract

Since the first financial assets were sold, people have tried to gain information in order to be able to predict the future movements of those assets. There are many ways of doing so including technical and fundamental analysis of the asset. The aim of this thesis is to, by using technical analysis, find indicators, technical, financial or macro economical, that can predict the relative evolution between Treasury bonds and Treasury bills and, by using those indicators, be able to time the market and always hold the asset with the highest return.

Treasury bonds and Treasury bills are government bonds, i.e. a financial instrument in which the investor loans money to government for a fixed interest rate. This asset class is considered very safe in most cases, since the loan is guaranteed by a country's government.

In the theory chapter, the principals of Treasury Bonds are presented together with a description of how markets are correlated and how timing indicators work. Finally, a number of tools for data analysis are introduced. These tools are later used to identify and evaluate possible indicators.

When trying to establish whether an indicator is able to predict the relative evolution between T-Bonds and T-Bills, the indicator value is plotted against the one month return of the price quota $\frac{T-Bond}{T-Bill}$ with different time lags. In this way it is easy to see whether the two entities are dependent in any way. Indicators that are found to have a prediction ability are further evaluated using a test model.

Eventually, 24 different indicators were thoroughly analysed and presented in the result. The ability to predict differs between the indicators, but they all give a better result than random chance. Finally, the indicators were combined and the return of a portfolio based on them was simulated. The resulting indicator portfolio showed to perform considerably better than the benchmark, both in return and risk measures.

Keywords: finance, bond, indicator, market timing

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1 Introduction

This master thesis is being written on behalf of a financial asset management company in Gothenburg. The company has a model, based on a number of indicators, for allocating between stocks and bonds. This model has been developed over the past ten years and is a tool that supports investors in creating high returns whilst limiting the risk. The model for the allocation between different Treasury bonds and Treasury Bills, however, is not very sophisticated and has potential for improvement. This study aims at improving that model by finding indicators that can give an idea of the relative evolution between T-Bonds and T-Bills, hence allowing an better allocation to be made.

Since the model uses indicators to decide in which security to invest, it uses patterns from historic data. Hence, the model performs a technical analysis to time the market. As opposed to fundamental analysis, which involves analyzing the intrinsic value of a company, technical analysis is the study of statistics generated by market activity to identify trends and patterns in financial markets (Lo & Hasanhodzic, 2010, pp. vii-x). Already in the 17^{th} century, during the tulip mania in Holland, some aspects of technical analysis began to appear (Lo & Hasanhodzic, 2010, p. 27). At that time, and through to half way into the 20^{th} century, the technical analysis was done through the analysis of charts. Since the last half of the 20^{th} century, more technical tools and theories have been developed, in which mathematics and computer based analysis takes a major part (Lo & Hasanhodzic, 2010, pp. 81-82). Technical analysts use models and trading rules based on mathematical transformations of e.g. price and volume such as regressions, moving averages, business cycles and so on. In addition to this, market indicators of many kinds are used. These market indicators, which are not necessarily based on financial data, enable more information from other sources to be taken into account when making a decision. The belief is that by studying historic data, conclusions about the future can be drawn. Technical analysts claim that the prices on the financial markets reflect all macro economic factors whereas fundamental analysts study these factors in order to price the financial markets (Lo & Hasanhodzic, 2010, pp. vii-x).

The work with improving the model mentioned above began with a literature study in order to get ideas on indicators that might be able to "predict" the government bond market. This resulted in a list of around 100 potential indicators. Using an application called "Macrobond" around 250 data series, corresponding to different aspects of the indicators, were picked out. These data series were evaluated on an "in sample" period (1996-01-01 to 2010-12-31) and 24 of them were selected to enter the model. The model was tested and optimized for the "in sample" period using four different approaches: maximized return, minimized standard deviation, maximized Sharpe ratio and maximized information ratio. Hence, four different portfolios with different profiles were created. After this, these portfolios were run on an "out of sample" period (2011-01-01 to 2013-01-31) to test the consistency of the indicators. The portfolios, whose allocations were decided by the indicators, were compared to a benchmark portfolio consisting of equal parts of T-Bonds and T-Bills. All four portfolios performed considerably better than the benchmark in this test, creating higher returns with just a little higher risk.

The rest of the essay is organized as follows: Chapter 2 provides a short review of related literature. In chapter 3 the methods for testing, selecting and combining the indicators are described. The results are presented in chapter 4 along with an analysis of the sensitivity to transaction costs. Chapter 5 concludes the thesis with a short discussion on the result.

1.1 Purpose

The purpose of this master thesis is to find and test a number of indicators that anticipate the relative evolution between Treasury bonds and Treasury bills, thus enabling a more optimal allocation between them.

1.2 Delimitations

The thesis comprises finding factors for the market for Swedish Treasury bills and Treasury bonds. However, factors for corporate bonds and other assets as such will not be investigated.

1.3 Research questions

- What factors can potentially anticipate the relative evolution of Treasury bill and Treasury bond prices?
- How can the indicators be evaluated?
- What indicators do actually anticipate the relative evolution of Treasury bill and Treasury bond prices?
- Can the indicators be combined to create a more reliable model?

2 Theory

In this chapter the theoretical framework on which the analysis is based is presented. Initially, the principals behind the bond market are described after which some information on market timing is given. The chapter ends with a description of some tools that are used to analyse numerical data.

2.1 Bonds

A bond is a financial instrument in which the investor loans money to the bond issuer for a fixed interest rate. Interest payments are often made once or twice a year. The issuer, who can be a government, a company or a municipality, is obliged to repay the borrowed money (the face value) at the maturity date of the bond. There is always a risk, however, that the bond issuer will not be able to repay the money at that date. Thus, investors demand a higher interest rate for investing in bonds issued by an entity which has a higher risk of defaulting. Bonds issued by a government are often considered a very safe investment, though of course depending on the country's financials. There are different kinds of government issued bonds of which some are described in this chapter.

2.1.1 Valuing bonds

Bonds can be sold and bought on a secondary market, allowing the ownership of the instrument to be transferred. Hence, it is important to be able to calculate the value of the bond. This is usually done by discounting the expected cash flows of the bond (Brealey, Myers, & Allen, 2008, p. 60). Annual interest payment is assumed:

$$P = \frac{r * F}{1 + r_f} + \frac{r * F}{\left(1 + r_f\right)^2} + \dots + \frac{r * F}{\left(1 + r_f\right)^N} + \frac{F}{\left(1 + r_f\right)^N} =$$

$$= \sum_{n=1}^{N} \frac{r * F}{\left(1 + r_f\right)^n} + \frac{F}{\left(1 + r_f\right)^N}$$

where P is the price of the bond, r is the annual interest rate paid by the bond issuer, F is the face value of the bond, r_f is the annual risk free interest rate and N is the number of years until the bond matures.

Though, this method only gives the theoretical price it shows the principals behind the evolution of the bond price in a simple way. For bonds that pay interest more than once a year or with a term to maturity shorter than a year, the formula looks a bit different (due to compound interest) but the same principals apply.

The formula above shows that the price, or the value, of the bond increases as the market interest rate decreases and vice versa. The logic behind this is that when, for instance, the interest rate is increased, new issued bonds have to offer a higher return in order for investors to choose them before the risk free rate. Since the bond that was issued before the increase of the interest rate now gives a lower return than the new issued ones, their value will fall (Wild, 2007, p. 148). The formula also shows that a long term bond is more sensitive to changes in the market interest rate than is a short term bond (Brealey, Myers, & Allen, 2008, p. 65).

2.1.2 The bond market

Generally, the correlation between governmental bonds and the stock market is negative. When financial markets are unstable, the demand for government bonds is increased due to their low risk (Wild, 2007, p. 30). During most financial crises, the annual return on government bonds has been much higher than their average historic return (Wild, 2007, p. 81). The downside is the governmental bonds moderate return over the long run. Between 1926 and 2007, the average annual real return on government bonds only is a third of the corresponding return for stocks (Wild, 2007, p. 81).

There is an inverse relationship between price and yield in the bond market. A high demand for a certain bond type renders a high price and hence a low yield. In most cases, the longer the time to maturity, the higher the interest rate (Weir, 2006, p. 7). That is because investors demand higher returns for tying up their money for longer since that increases the risk they take (Wild, 2007, pp. 82-83). As mentioned above, increased interest rates mean that the value of a bond decreases. When the economic future looks good, investors expect interest rates to increase. This means that a bond bought today will probably be worth less tomorrow. During such circumstances, investors turn to short term bonds to a higher degree which lowers their return and heightens the return on long term bonds. However, when investors are nervous about the economic future, they expect interest rates to fall, leading to a bond bought today being worth more tomorrow (Wild, 2007, pp. 82-83). In such cases, investors tend to buy long term bonds, hoping to sell them at a higher price in the future. In these cases the relationship between the bond's price and yield is reversed, i.e. the longer the time to maturity, the lower the interest rate (Weir, 2006, p. 7).

2.1.3 Government bonds

There are different kinds of government issued bonds, with the biggest difference being their time to maturity.

A treasury bill is a short term bond that matures in less than a year and is backed by a government. In a country with stable finance, treasury bills are often regarded as the least risky investment available. When issued, treasury bills are sold on actions at a discount of the face value and pay no interest prior to maturity. Instead, the appreciation of the bond provides the return to the investor. The secondary market for treasury bills is very liquid and hence is a good measure of the short term market interest rate. Because of low credit risk and short term to maturity, the price evolution of treasury bills is very stable. As seen in figure 1, the annual return fluctuates mostly between one and five percent. In times of low financial distress, investors demand more return from treasury securities than in times of distress.

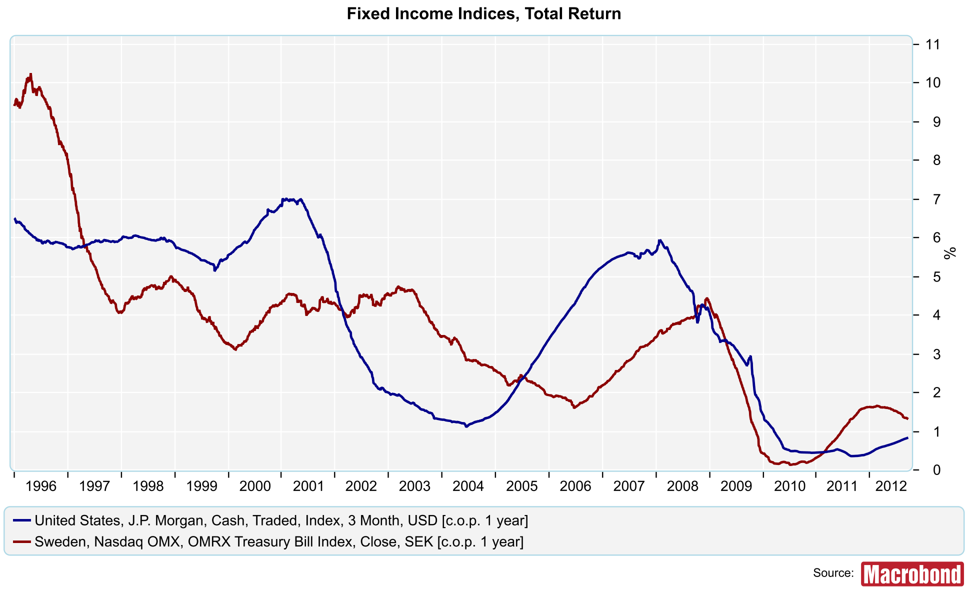


Figure 1 The annual return of Swedish and U.S. treasury bills since 1996.

A treasury bond is a bond with maturity time from one to ten years and is backed by a government. When issued, treasury bonds are sold on actions. They have a fixed interest rate which is paid at certain times during the term to maturity, e.g. annually or semi-annually. The secondary market for treasury bonds is very liquid and the ten-year Treasury bond is often used to get an idea of the market's long term macroeconomic expectations. Because of its longer term to maturity, Treasury bonds are, compared to Treasury bills, more volatile. As seen in figure 2, the annual return mostly fluctuates between -1 and 15 percent.

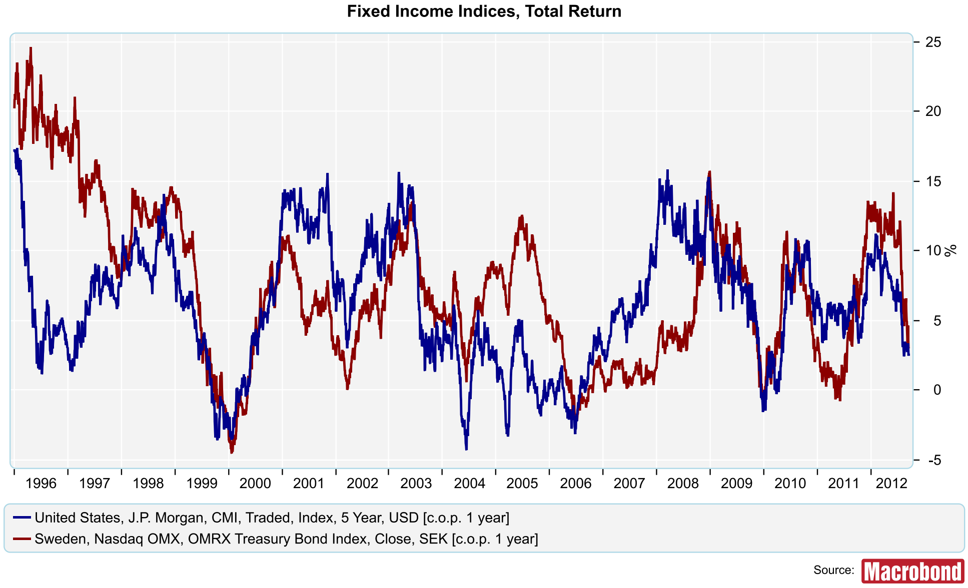


Figure 2 The annual return of Swedish and U.S. treasury bonds since 1996.

Treasury bond returns are more volatile than Treasury bill returns. Hence, the Treasury bond returns are oscillating around the Treasury bill returns as seen in figure 3.

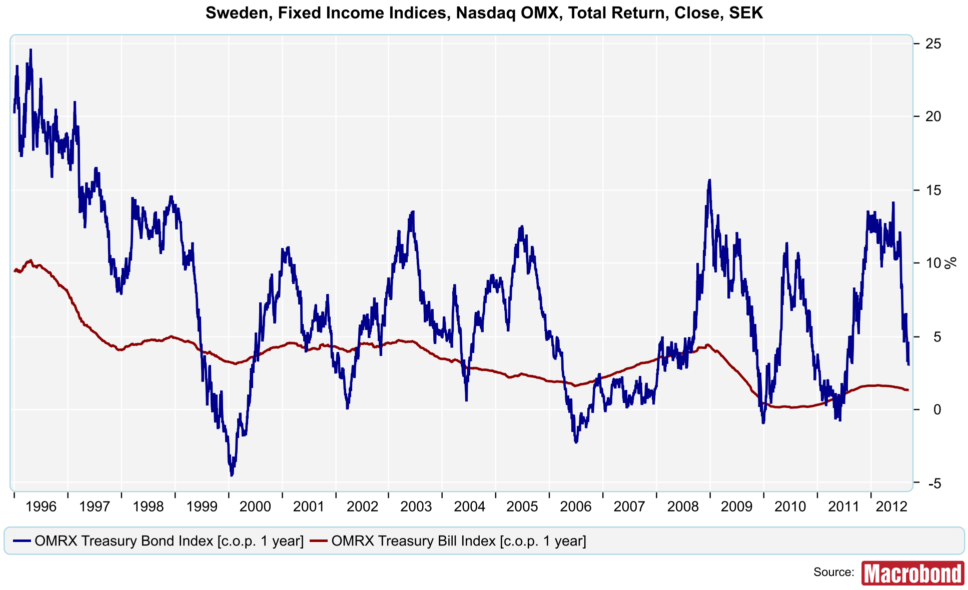


Figure 3 The annual returns of the Swedish treasury bills and treasury bonds.

This means that if a predictor that forecasts the evolution of the Treasury bond relative to the Treasury bill can be found, it is possible for an investor to time the market to always hold the bond type that gives the best return for the moment.

2.2 Market timing

Market timing is the idea of basing investment decisions on a mechanical trading strategy which attempts to predict future market price movements by using specific rules or indicators (Masonson, 2011, p. 5). These rules and indicators can be based on technical or fundamental analysis, such as a momentum strategy or in-depth analysis of companies or markets, or macro-level phenomena along with other "big-picture" data, such as the GDP/Dept ratio of a certain country or the unemployment rate (Crescenzi, 2009, pp. 6-7) (Masonson, 2011, p. 5). The objective of market timing is to have long positions in an asset during an uptrend and to be either in cash or a short position of an asset during a down trend and through that decrease the risk exposure, increase the consistency of the results and diversify the opportunities. (Duarte, 2009, pp. 10-11).

A market timing strategy can be applied to all types of investments, such as stocks, bonds and futures etcetera, and is often based on the outlook for an aggregate market rather than for a certain financial asset (Duarte, 2009, p. 10). Its aim is also to minimize the impact of an investor's emotions on the investments since the majority of the investors, by definition, always are wrong at major market tops and bottoms (Masonson, 2011, p. 5).

2.2.1 Timing indicators

A timing indicator is a data series or a mathematical transformation of one or more data series used by traders to predict the direction of financial assets or indices (Investopedia, Investopedia - Market Indicators). Indicators can be either leading or lagging. A leading indicator precedes events that are yet to happen whereas a lagging indicator is used more as a confirmation tool. This text will focus mainly on leading indicators.

There are many different kinds of indicators, such as economic, financial, technical, tendency surveys, cultural and so on (Weir, 2006). Indicators add additional information to the analysis of securities and, for instance, help to identify momentum and trends for an asset or index. They can also add information about economic and industry conditions in general to provide insight to future potentials. Common technical indicators are moving averages and the relative strength index which both measure momentum. Common macro-level indicators are the unemployment rate, new housing starts and the consumer price index which can be used to predict future economic trends.

The bond market, and the government bond market in particular, is connected to the macroeconomic environment to a much greater extent than is the equity market (Duarte, 2009, pp. 162-164). Bonds, as seen in 2.2.3, often have a negative correlation to the equity market. To put it simple, government bonds depend on the interest rate set by the central bank, which, in turn, set the interest rate according to the economic situation in general and the inflation in particular (Eklund, 2005). Beside the central bank's interest rate, the inflation depends a lot on the commodity prices, particularly the oil price but also agricultural and industrial commodity prices (Duarte, 2009, pp. 164-165). Rising commodity prices often means rising inflation. The inflation also depends on the currency of the country issuing the bonds relative to currencies in other countries (Duarte, 2009, pp. 164-165). Hence, commodity prices and the currency markets also have impact on the government bond market.

Bond prices, and again, government bond prices in particular, are also sensitive to many of the economic reports, since they update the information about the state of the economy and the inflation (Duarte, 2009, p. 165). The employment report and the consumer confidence report are two of the reports with the biggest influence over the bond market (Duarte, 2009, pp. 165-166). Among the most important categories in the employment report are the amount of new jobs created and the trend of wages. High numbers in these indicates a growing economy and hence decreasing bond prices. The consumer confidence report measures what consumers think about the overall state of the economy and their personal financial situation. A high confidence indicates more spending among the consumers and hence economic growth which will lead to sinking bond prices.

2.2.2 Constructing a model based on timing indicators

Naturally, there are numerous ways to construct a model based on timing indicators. Below a description of one way to construct such a model can be found.

Firstly, construct a list with indicators that are thought to be able to predict whatever is to be predicted (Smith & Malin, p. 6). For instance, if the state of the overall economy is to be predicted possible indicators might be: the yield curve, commodity prices, layoffs, interest rates etcetera. The relevance of the different indicators will vary with the market environment. Some factors will give good predictions when the market is in an uptrend and some factors when the market is in a downtrend (Smith & Malin, p. 7).

The next step is to sort out those indicators that actually are able to give a hint on where the market is going. This can be done using different techniques, but Smith & Malin suggest backtesting together with simple plots that show the relationship between different data sets. Then, Smith & Malin (p. 6) suggest a “Rule Book” is created, in which each indicator can take six states: Rising/Falling, High/Low and Post-Peak/Post-Trough. Each indicator is given a score for each state which shows in which direction and how much the market will move when that particular indicator is in that particular state. The scoring is to be completely rule-based. For instance, if the market, in 50 percent of the cases, goes up after an indicator has been rising the score would be lower than if the market goes up every time that indicator has been rising, etcetera.

When this step is finished for all indicators and all states, the indicators should be implemented in a multivariate regression model (SEB, SEB Global Leading Indicator, 2012). All relevant indicators enter the regression with time lags. The lag is set individually for each indicator at an optimal point. After this, the model should be tested using “in sample” and “out of sample” periods (Smith & Malin, p. 15). The rule book should only be based on information available in the “in sample” period to allow for the consistency of the rules and the indicators to be tested during the “out of sample” period.

The model and its indicators should be continuously updated so that indicators that turned out to be bad will be removed and so that new indicators can be added (Smith & Malin, p. 31). However, adding an indicator has to add value, not just noise.

It is important to keep track of the portfolio turnover. Otherwise, the gains from the model will be eaten by the increased brokerage. However, in the case described by Smith & Malin (p. 23), the turnover is quite low due to a relatively slow evolution of many macro series.

2.2.3 Market correlation and macro correlation

Financial markets are, to different degrees, correlated with each other (SEB, SEB Investment Outlook, 2012). This correlation can be used to hedge or as leverage to a portfolio. Financial markets are, in turn, often correlated to macro-level events (SEB, SEB Global Leading Indicator, 2012). If there is a time lag between events on different levels, they can be used to predict future movements in the markets. However, correlations, which are by definition based on historical data, can change over time and hence a strategy should not be based on such data alone. The correlation between fixed income securities and other types of securities for the ten years preceding the specified date can be seen below:

	Equities	Hedge	Real Estate	Private Equity	Commodities	Currencies
2009-07-31	-0.37	-0.37	-0.23	-0.32	-0.41	-0.04
2010-07-30	0.09	0.08	0.00	-0.17	0.12	0.33
2011-10-31	-0.5	-0.3	0.06	-0.38	-0.17	0.19
2012-08-31	-0.44	-0.3	-0.2	-0.35	-0.18	0.17

Table 1 The correlation between fixed income securities and other types of securities.

(SEB, SEB Investment Outlook, 2009) (SEB, SEB Investment Outlook, 2010) (SEB, SEB Investment Outlook, 2011) (SEB, SEB Investment Outlook, 2012)

Banks and institutes have developed models that try to predict future market events using leading macro indicators. SEB have such a model which they claim have a 90 percent correlation with later realized values since the beginning of 2009 (SEB, SEB Global Leading Indicator, 2012). According to Crescenzi and JP Morgan, these kinds of models are increasingly important sources of information when formulating and carrying out an investment strategy (Crescenzi, 2009, pp. 6-9) (Smith & Malin).

2.2.4 Measures of market correlation and risk

When pursuing an investment strategy, it is important to take the risk of the strategy into consideration. To describe the relationship between risk and return the Capital Asset Pricing Model (CAPM) can be used. The model explains what part of an asset’s risk the market will pay a risk premium for (Brealey, Myers, & Allen, 2008, pp. 213-217). CAPM says that, in a competitive market, the theoretical return on an asset depends on the risk free rate, the market return and the asset’s sensitivity to changes in the market, i.e. its sensitivity to market risk, measured by the quantity β through the formula:

$$E[r] = E[r_f + \beta(r_m - r_f)] = r_f + \beta(E[r_m] - r_f)$$

where

$$\beta = \frac{cov(r, r_m)}{var(r_m)}$$

and

r is the theoretical return of the asset, r_f is the risk free rate, r_m is the market return and $(r_m - r_f)$ is the risk premium of the market (Brealey, Myers, & Allen, 2008, pp. 213-217).

Hence, β is a number describing the risk of an asset in relation to a benchmark which, in the case of above, is the stock market. But the benchmark can be chosen to be any portfolio of financial assets, for instance, a portfolio of bonds.

Since $\frac{cov(r_m, r_m)}{var(r_m)} = \frac{var(r_m)}{var(r_m)} = 1$, β of the benchmark itself is always equal to one. If β is smaller than zero, the asset moves in the opposite direction compared to the benchmark; if β is equal to zero, the asset is uncorrelated with the benchmark; if β is larger than zero but smaller than one, the asset moves in the same direction but less than the benchmark; if β is equal to one, the asset moves in the same direction and as much as the benchmark; if β is larger than one, the asset moves in the same direction but more than the benchmark (Brealey, Myers, & Allen, 2008, pp. 213-217).

However, the theoretical return expected by CAPM does, just as any other market model, not always reflect the later realized return. In such cases, when an abnormal return that cannot be explained by CAPM occurs, a measure called Jensen’s alpha can be used:

$$\alpha = r - [r_f + \beta(r_m - r_f)]$$

Jensens’s alpha is one way to help determine if an asset is earning the, according to CAPM, proper return relative to its riskiness. If the value is positive, the asset gives more return relative to its risk than expected by CAPM and vice versa (Investopedia, Jensen's Measure).

A measure of how much of an investment’s movements that can be explained by the movements in the benchmark index through the CAPM is the R^2-value (Newbold, Carlson, & Thorne, 2010, p. 523). This measure is equivalent to the R^2-value described in 2.3.4 and is calculated from the returns on the investment in question compared to the returns on the benchmark. A high R^2-value indicates that the investment’s performance is in line with the benchmark’s and hence a more reliable β-value and vice versa.

A very common risk measure is the standard deviation, or volatility, of an asset. The standard deviation is a statistic that shows how much the return on an investment deviates from the mean return on average (Petruccelli, Nandram, & Chen, 1999, pp. 56-57). A low standard deviation indicates that the data points often are close to the mean and vice versa.

The Sharpe ratio is a measure of return relative to the risk and describes how much additional return an investor will receive for the extra volatility of holding a risky asset (Brealey, Myers, & Allen, 2008, p. 213). It helps to make the performance of one investment comparable with another investment’s through the risk adjustment. The Sharpe ratio is defined as:

$$Sharpe\ ratio = \frac{r - r_f}{\sigma}$$

where r is the annualized return of the investment, r_f is the risk free rate and σ is the annualized standard deviation of the returns of the investment.

One weakness of this measure is that it relies on the returns to be normally distributed (Investopedia, Understanding the Sharpe Ratio, 2010). The normal distribution does not explain big movements in the market and hence often fails to explain the distribution of the returns. The standard deviation does not have the same effect on returns that are not normally distributed and in such cases the Sharpe ratio can be misleading.

Another measure of risk adjusted return, closely related to the Sharpe ratio, is the Information ratio. It measures an investment's excess return relative to a benchmark, i.e. how much the investment pays for the extra risk exposure (AP3, 2009). The information ratio is calculated using the following formula:

$$Information\ ratio = \frac{r - r_b}{\sqrt{var(r - r_b)}}$$

where r is the annualized return of the investment and r_b is the annualized return of the benchmark (Investopedia, Information Ratio - IR).

The higher the information ratio, the higher the active return of the portfolio relative to the amount of risk taken.

Maximum loss is a risk measure that describes the worst case scenario of an investment based on historical data. It is calculated by finding the potentially largest loss that could have been made if the asset was bought on the top and sold on the bottom (Dahlgren, 2012).

Another way to assess the risk of a strategy is to measure the exposure to each asset included in the investment at any given time. A badly diversified portfolio with high exposure to a few assets is riskier than a well diversified portfolio. Hence, the absolute deviation of the portfolio weights from a chosen target value provides a measure of the exposure to each asset (Dahlgren, 2012).

2.2.5 Critique on market timing

Financial markets move in cycles. There are different kinds of indicators that, at least in theory, reflect various market phases. But does this mean that they can be used to decide when to enter and exit a market in an accurate and consistent way?

One of the basic ideas in market timing is that history will repeat itself. Hence, by studying historic data, trading rules can be created which allows conclusions about the future to be drawn. However, this is one of the ideas that critics of market timing is attacking. They claim that before and during periods with much distress in the markets, such as financial crises, trading rules and indicators often fail to deliver accurate predictions of the market movements, i.e. during these periods history tends to stop to repeat itself (Masonson, 2011, p. 2). This is what happened during the 2008 financial crisis after which many of the game rules for the financial markets were changed (Desai, 2011, p. 128) and many "old" trading rules ceased to generate any return (Carlsson, 2012).

Another aspect of market timing and timing indicators that often is criticised is the curve fitting and over optimization. Often, a set of trading rules are optimized to fit a certain data set. However, if trading rules are over optimized they often fail when applied to future data. Investors try to avoid this by testing the rules on "out of sample" data. When doing this, the trading rules are to be based on "in sample data" only.

Timer Digest and Hulbert Financial Digest are two independent organizations that have followed the performance of some market timers for over thirty years. They found that most market timers seldom perform better than chance and sometimes ever worse. However, they also found that some consistently performed better than the general market during that thirty year period. Hence, this study suggests that there is evidence that market timing can be done in an efficient way but most investors fail to do so.

A study made by a research firm called DARBAR showed that the average annual return for investors in equity funds is 4.3 percent during the last 20 years, whereas the S&P500 during the same period averaged 11.8 percent per year (Considine, 2008). However, the study does not say anything about the performance of the individual investors of which some might have performed better than the market. In another study, Murray Z. Frank and Pedram Nezafat claim that investment banks and corporations fail to time the credit market. According to them, investment banks such as Goldman Sachs perform as bad as Ford when trying to time the issuance of their bonds (Frank & Nezafat, 2010, pp. 30-33). In yet another study, Malkiel claims that the best way to tell which fund will perform best is those with low expenses and low turnover (Malkiel, 2004).

2.3 Tools for data analysis

The primary objective of the tools presented here is to extract meaningful data from the sample data. In this section, simple linear regression is described, together with different types of correlation and goodness of fit.

2.3.1 Simple linear regression

Regression analysis is used to understand and quantify statistical relationships between factors that influence a certain phenomenon. The basic idea is to model the dependent variable through a relationship between the independent variables, making it possible to predict the outcome of the dependent variable. Regression analysis can also be used to quantify the strength of the relationship between the dependent and the independent variables. The subclass of regression analysis with most applications is linear regression. Simple linear regression is a linear regression model with only one independent, or explanatory, variable, i.e. the model is a straight line that is fitted to a set of points in a plane. The most common way to fit the model parameters is through the ordinary least-squares method which minimizes the sum of the squared vertical distances between the data points and the fitted line (Petruccelli, Nandram, & Chen, 1999, p. 374). Another method is the least absolute deviation method where the sum of the squared orthogonal distances between the data points and the fitted line is minimized (Petruccelli, Nandram, & Chen, 1999, p. 374).

The simple linear regression model is defined as:

$$y = \beta_0 + \beta_1 x + \epsilon$$

where y is the dependent variable, x is the independent variable, β_0 and β_1 are the model parameters and ϵ is white noise.

Fitting a straight line to a set of data points is a method to aid interpretation of the data. For example, plotting two time series, depicting data from different phenomena but for the same time interval, in the same scatter plot, with one series on the x-axis and the other on the y-axis, can reveal correlations or patterns between the two phenomena. Beneath, such a plot with monthly returns on OMXS30 and Swedish T-Bond is shown as an example. A 140 day lag is applied on the OMXS30 returns:

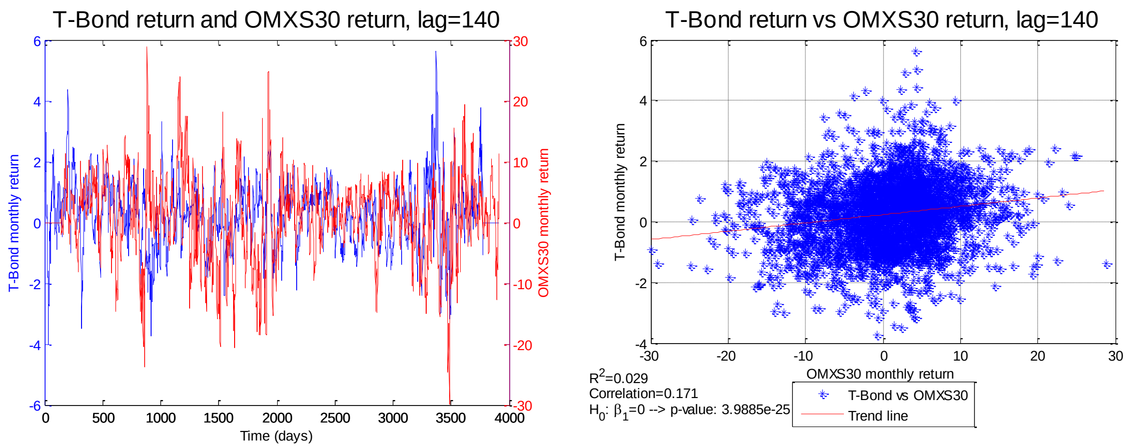


Figure 4 The graphs to the left depict monthly returns on Swedish T-Bond and monthly returns on the OMXS30 index. In the scatter plot on the right, T-Bond monthly returns are plotted on the y-axis and OMXS30 monthly returns are plotted on the x-axis.

The positive correlation between the two data sets is difficult to see in the graph to the left, but in the graph to the right it is quite obvious. The trend line shows the average value of the T-Bond returns for a given return on OMXS30 and hence can be used as a rough estimator. Lagging one of the series relative to the other is a useful method when analyzing financial time series and might reveal patterns that were hidden when no lag was used (Newbold, Carlson, & Thorne, 2010, p. 602). This is necessary when constructing timing indicators.

2.3.2 Cross correlation

Cross correlation is a measure of the linear predictability of a series, y_t, at time t using another series, x_s, at time s. If y_t and x_s are correlated when $s > t$, y_t is lagging, if $s < t$, y_t is leading and if $s = t$, the correlation appears without any time shift. If stationarity is assumed, conclusions drawn from a sample can be used as estimations for the whole population (Shumway & Stoffer, 2011, p. 28). Moreover, the stationarity gives that the cross correlation only depends on the difference between s and t and not on their location in time. The cross correlation function for a sample is given by

$$\hat{\rho}_{xy}(\tau) = \frac{\sum_{t=1}^{n-\tau}(x_{t+\tau} - \bar{x})(y_t - \bar{y})}{\hat{\sigma}_x\hat{\sigma}_y}$$

where $\tau = s - t$, $\hat{\sigma}$ is the sample standard deviation and $\bar{x}$ and $\bar{y}$ are the sample mean of the respective series.

This is a measure of the ability to decide the value of one series at time t from the value of another series at time s. The certainty of such models depends on the cross correlation, i.e. the stronger the correlation, the higher the certainty of the model. The reliability of the correlation can be assessed using statistical inference. To do this, a confidence interval which, at a given level of confidence, contains the true correlation can be constructed around the sample correlation. The width of the interval at a certain confidence level mostly depends on the amount of data points and their variance. However, inference for the correlation coefficient is sensitive to the data distribution. Exact tests may be misleading if the data is not approximately normally distributed.

Cross correlation can be used to make predictions of future movements if the correlation appears with a time shift. Consider the model

$$y_t = ax_{t-l} + \epsilon_t$$

where a is a constant, ϵ_t is white noise and l is the time shift.

If $l > 0$, x_t is leading y_t, and can be used to predict the future movements of y_t. The stronger the cross correlation between y_t and x_s, the better the model's predictions will be.

2.3.3 Autocorrelation

Autocorrelation is the cross correlation of a time series with itself. It is a measure of the linear predictability of a series at time t using a value from the same series at time s. It is a mathematical tool for finding repeating patterns in a series, such as the presence of a periodic signal which has been buried under noise.

The assumption of stationarity is used which gives the following formula for the autocorrelation of sample data

$$\hat{\rho}_x(\tau) = \frac{\sum_{t=1}^{n-\tau}(x_{t+\tau} - \bar{x})(x_t - \bar{x})}{\hat{\sigma}^2}$$

where $\tau = |s - t|$, $\hat{\sigma}$ is the sample standard deviation and $\bar{x}$ is the sample mean of the series.

The autocorrelation coefficient has the same properties as the cross correlation coefficient. Predictions about the future values of the series can be done in the same manner as with cross correlation. The only difference is that the forecast is based on earlier values from the series itself, not on values from another series.

2.3.4 Fit of a simple linear regression

The correlation coefficient is a measure of the correlation, or linear dependence between two variables. For a sample, it is defined in the same way as the cross correlation but without the time shift.

Hence, the correlation coefficient is the mean of the product of standardized data values and thus has no unit (Petruccelli, Nandram, & Chen, 1999, pp. 362-363). It takes values between -1, which means perfect negative correlation, and $+1$, which means perfect positive correlation. The correlation coefficient being equal to 0 means that there is no linear correlation between the two variables. The interpretation of the correlation coefficient depends on the context and the purpose. One value of the coefficient can in one context be considered very high and in another very low. This measure is not very robust if outliers are present and, in those cases, needs to be complemented with an inspection of the scatterplot of x and y.

The coefficient of determination, R^2, is a measure of how well a linear regression model fits the data. It is defined as:

$$R^2 = 1 - \frac{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

In the simple linear regression case, R^2 can also be written as the square of the correlation coefficient.

The term in the numerator can be interpreted as the variance of the model's errors and the term in the denominator can be interpreted as the sample variance. Hence, this quota is the fraction of the variance that is not explained by the model and thus R^2 is the fraction of the variance that is explained by the model. In other words, R^2 measures how well future outcomes are likely to be predicted by the model (Petruccelli, Nandram, & Chen, 1999, pp. 386-387). From this follows that R^2 ranges from 0 to 1, where 1 means that the model perfectly predicts the outcomes and 0 means that the model does not predict the outcomes at all.

When applying simple linear regression to produce a trend line, the R^2-value says how much of the variance in the data that is explained by the fitted line, however it does not say anything about the statistical significance of the trend line. A scattered data set can have a low R^2-value but a high significance in a test for the presence of a trend. A test for a trend in the data, i.e. a test to reject the null-hypothesis that the slope, $\hat{\beta}_1$, is equal to zero, can be conducted using t-statistics. To conduct such a test, the error terms are assumed to be normally distributed.

The t-statistic equals:

$$t^*_{\hat{\beta}_1} = \frac{\hat{\beta}_1 - H_0}{\hat{\sigma}(\hat{\beta}_1)} \sim t_{k-2}$$

where

$$\hat{\sigma}(\hat{\beta}_1) = \frac{\hat{\sigma}}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}} = \frac{\sqrt{\frac{1}{n-2}\sum_{i=1}^{n} e_i^2}}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}}$$

and H_0 is the value of $\hat{\beta}_1$ under the null-hypothesis, k is the degrees of freedom and $\sigma(\hat{\beta}_1)$ is the standard error of the estimator $\hat{\beta}_1$.

Since the aim of the test is to test whether the trend line is significant or not, the null-hypothesis, H_0, is set to zero:

$$H_0\colon\ \hat{\beta}_1 = 0$$

$$H_a\colon\ \hat{\beta}_1 \neq 0$$

If H_0 can be rejected in favour of the alternative hypothesis H_a, the slope, $\hat{\beta}_1$, is statistically significant and hence so is the trend. The t-statistic produces a number, the *p*-value, which is the probability of getting a t-statistic as large as the observed value by random chance when the null-hypothesis actually is true, i.e. the probability of the trend being present by chance (Rice, 2007, p. 335). The smaller the *p*-value, the stronger the evidence against the null-hypothesis.

There are different ways to assess the fit, both graphical and quantitative. Quantitative methods for testing the f fit are useful but often focus on a particular aspect of the relationship between the model and the data, compressing that information into one single number. However, there are other methods that address the same problem. Graphical analysis have an advantage over numerical methods since graphs can illustrate more complex aspects between the model and the data. Different graphical analysis of the residuals can be conducted in order to confirm that the residuals are uncorrelated (perform an autocorrelation test) with each other, normally distributed (create a normal Q-Q-plot) and have constant variance which are properties that are needed for the model to have a high goodness of fit (Rice, 2007, pp. 550-556).

Ideally, the residuals should show no relation to the independent variables when plotted together. This is why the linear regression models have a white noise term added to it. If the errors are uncorrelated and normally distributed, they correspond to the white noise term in the model and hence the model fit to the data is correct.

3 Methods

In this chapter, the methods used to generate, analyse and combine the indicators are presented. How important indices and models are constructed is also covered here.

3.1 Generation of potential indicators

The first step in the idea generation was to get an overview of the financial markets in general and the bond market in particular. This was done by reading articles on the subject on the internet, by reading basic literature in corporate finance and macroeconomics and literature on investing and market timing and through interviews with people working in the industry. The interviews were structured more like a general conversation about the subject than a traditional interview. During and after this step, ideas on different possible indicators were continuously generated.

In the next step, more specialized texts were studied such as analysis and business and investment outlooks from JP Morgan and Morgan Stanley together with similar texts from SEB, Swedbank and Handelsbanken. These sources gave, throughout the process, ideas on indicators that were less general than those produced in the previous step.

When these steps were carried out, a list with around 100 potential indicators had been produced. The next step was to find data series corresponding to the potential indicators using an application called Macrobond which is a global database containing millions of economic time series. It turned out that some of the indicators, such as consumer confidence and unemployment, were represented by many different data series which measured different aspects of the same phenomenon. Also, since some events might first be visible on other markets than the Swedish, the same data series, when available, for the German and the U.S. market were used. Eventually, a list of 500 data series, corresponding to the original 100 indicators, was produced. However, in order for the analysis to be relevant, some requirements were put on the data series: They have to contain data from at latest 1996-01-01, since otherwise the time period in which trends and patterns are to be searched for will be too short to draw any conclusion from. The data also had to be updated at least once a month, since it would be impossible to spot trends or patterns in data with a lower updating frequency. This resulted in that around half of the original 500 data series were removed from the list.

3.2 Analysis of the indicators

In this section, the procedure of analyzing and selecting indicators is described. The result from this procedure can be found in Appendix 4.

The test period has been partitioned into an “in sample” and an “out of sample” period. The “in sample” period ranges from 1996-01-01 to 2010-12-31 and the “out of sample” period ranges from 2011-01-01 to 2013-01-31 and is used to establish whether the indicators that were found continue to have an ability to make predictions. The indicators have been tested on the whole time period, however since the “out of sample” period is short compared to the “in sample” period, this has a very limited effect on the result.

The measure T-Bond/T-Bill return is used to decide whether T-Bonds perform better than T-Bills or vice versa during a given time period. The T-Bond/T-Bill return is, simply, the monthly change in percent of this quota. The reason to why the T-Bond/T-Bill return is used is that it is how the T-Bonds and the T-Bills evolve relative to each other that is interesting. If the return of this quota is positive T-Bonds have performed better than T-Bills and vice versa. A thorough description of the T-Bond and T-Bill indices can be found in Appendix 2.

To analyse the indicators, the indicator values were plotted against T-Bond/T-Bill monthly return with different time lags. In this way, the relationship between the indicator and the T-Bond/T-Bill return at different time lags can easily be examined. The plot is made for 20, 40, 60 and 80 (business) days lag which corresponds to 1, 2, 3 and 4 months. A trend line was also added to further simplify the search for trends. When looking for trends and patterns between the indicators and the T-Bond/T-Bill return three aspects were regarded: Is there a linear relation? How does the T-Bond/T-Bill return respond to the indicator's extreme values? How does the T-Bond/T-Bill return respond to large changes of the indicator?

The Return vs. Indicator plots (which can be found in Appendix 4) contain the correlation between the T-Bond/T-Bill return and the indicator, the statistical significance of the slope of the trend line and the R^2-value describing the fit of the trend line to data. However, these measures do not capture all possible relationships between the two entities. For instance, there could be dependence between the variables that only occur during extreme values of the indicator. Such relationships will probably not be visible through the statistical measures presented above. Hence, all plots for all lags and all indicators are examined manually. If the correlation between the T-Bond/T-Bill return and the indicator is stronger than 0.2 and the Return vs. Indicator plot is clearly tilted along the trend line, the indicator will be tested for linear dependence in the test model described below. In many cases, relations in the extreme values are not captured by the measures provided in the graph. If no general relation between the data series can be seen when examined, but it is found that, for instance, indicator values below a certain number often imply low T-Bond/T-Bill return, the indicator will be tested for relations in the extreme values in the test model described below. The relation between the T-Bond/T-Bill return and changes in the indicator value is examined in the same way as for the two cases described above. The indicator value changes are plotted against the T-Bond/T-Bill return and linear dependence and dependence in the extreme values are looked for.

Another thing that has been taken into consideration when looking for relations between the T-Bond/T-Bill return and the indicators is that the relation has to look about the same when increasing or decreasing the lag by a small number of days. If the relation disappears or changes a lot for small changes in the lag, the relation has most likely occurred by random chance. In such cases the indicator will be rejected.

The procedure described above, aims at finding a quantitative relation between the indicator and the T-Bond/T-Bill return to define limits for when the indicator is to be activated. For instance, if values below -20 for a certain indicator implies low T-Bond/T-Bill return and values above 30 for the same indicator implies high T-Bond/T-Bill return, limits will be set to -20 and 30 and a signal will be sent from that indicator when it deceeds -20 or exceeds 30 (i.e. when the indicator is activated). Inevitably, there is an element of judgment and experience when performing this analysis and the analysis described in the paragraph above since it is difficult to adopt an entirely quantitative approach in each step. However, the methodology has been consistent throughout the process.

If a relation between the indicator and the T-Bond/T-Bill return is found according to the description above, the relation is evaluated in a "test model". The test model utilizes one indicator at a time to test whether or not it has an ability to predict the relative evolution of T-Bonds and T-Bills by simulating a portfolio whose allocation between the two assets is decided by the value of the specific indicator. This simulation takes a transaction cost of 0.1 percent into account and is done for the time period 1996-01-01 to 2013-01-31. When the indicator exceeds or deceeds the limit which is individually set for each indicator according to the quantitative relation found in the procedure described above, this signals that the allocation between T-Bonds and T-Bills should be changed according to the following principle:

$$TBond\ ratio_t = \frac{Value(TBond)_t}{Value(TBond + TBill)_t} = 0.5 + c * g(indicator\ value_t - indicator\ average)$$

where

$$g(x) = \begin{cases} 0, & if\ no\ signal\ is\ sent \\ x, & if\ a\ signal\ i\ sent \end{cases}$$

and t is the day on which a value occurs.

Thus, if the indicator value does not exceed or deceed that limit, there will be equal parts of T-Bonds and T-Bills. If the T-Bond ratio calculated by the formula is above 1, the ratio will be set to 1 and if the T-Bond ratio is below 0, it will be set to 0. Then, the T-Bill allocation is set as:

$$TBill\ ratio_t = 1 - TBond\ ratio_t$$

The effect on the allocation is decided by a coefficient (c) which depends on the standard deviation of the indicator values according to:

$$c = \pm \frac{1}{std(indicator\ data\ serie)}$$

The indicators are very different in which values they take. Some indicators can take very large values whereas some just makes small oscillations around zero. The model has to be able to handle all kinds. With c set in this way, the model demands larger deviations from the indicator average, for a given effect on the T-Bond ratio, from an indicator with high standard deviation compared to an indicator with low standard deviation. In this way the T-Bond ratios for different indicators will be comparable. The sign of the coefficient depends on if the correlation between the indicator and the return of T-Bond/T-Bill is positive or negative.

If an indicator sends a signal, the model takes that allocation and holds it for one month before another allocation can be taken. During that month, no new signal can be received from that indicator. When one month has passed, a new position will be taken depending on the value of the indicator, following the same procedure as described above. Hence, a new position can be taken maximally once a month. The test model also simulates a benchmark portfolio which consist of 50 percent T-Bonds and 50 percent T-Bills. When the indicator does not deviate from its “normal value”, the indicator portfolio is identical to this benchmark portfolio.

Using the test model, the performance of the indicator portfolio can be compared to the performance of the benchmark portfolio. This is done using a number of risk and return measures (see 2.2.4). These measures have been chosen together with Magnus Dahlgren and are in accordance with prevailing industry standards. For an indicator to be considered to have an ability to make forecasts, the indicator portfolio has to have a higher return than the benchmark at the end of the period. It also should have about the same or lower standard deviation and maximum loss and a higher Sharpe ratio along with an average allocation not exceeding 70 percent for any of the bond types. Additionally, it has to be activated continuously during the time period so that it shows consistency and the excess return, compared to the benchmark, should also be spread out during the whole time period and not just occur at a few single occasions. It is difficult to construct quantitative measures for the last two conditions. When evaluating whether those conditions were fulfilled or not, what “looked good” according to my own judgment was a big part of the evaluation.

The measures used to compare the indicator portfolio to the benchmark portfolio are calculated using methods in accordance with industry praxis. The β-value is calculated against the benchmark portfolio described above and is based on weekly returns of the indicator portfolio and the benchmark portfolio. Thus, Jensen’s alpha is also based on weekly returns. The standard deviation, Sharpe ratio and information ratio are also calculated using weekly returns which are scaled up to annual returns.

When going through hundreds of potential indicators, at some point an indicator, which by random chance seems to have the ability to predict the relative returns of T-Bonds and T-Bills, will occur. However, if many indicators with an ability to predict are found, it is very unlikely that most of them will have got the predictive ability by random chance. Hence, the effect of such indicators on the final portfolio will most likely be extremely small and they will also, during a future revise of the indicators, be removed.

Below, a normal probability plot of the T-Bond/T-Bill one month returns can be seen. This plot measures how well the data is modelled by the normal distribution.

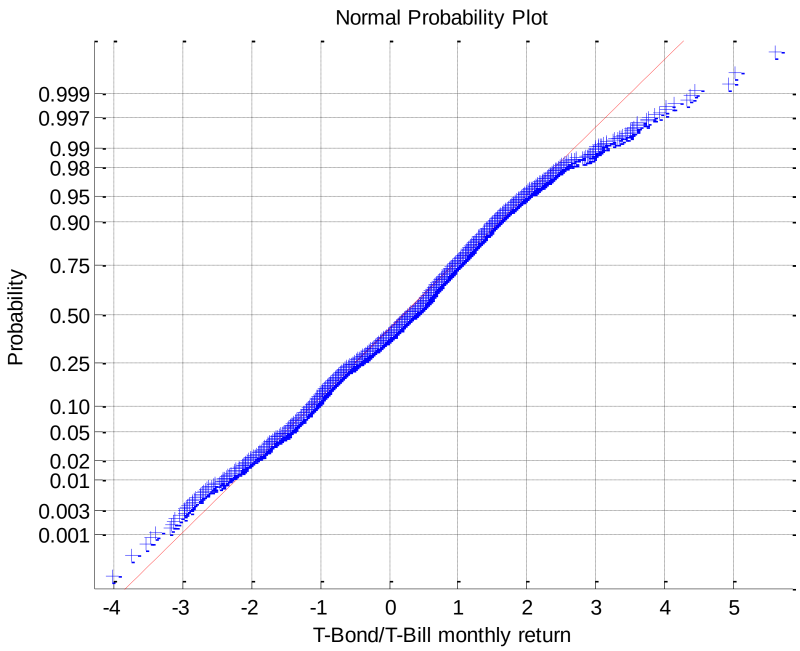


Figure 5 A normal probability plot of the T-Bond/T-Bill monthly return.

The monthly return of T-Bond/T-Bill does not follow the normal distribution for extreme values. The graph shows that the tails of the data are fatter than the normal distribution's which means that extreme values are more likely to occur in reality than predicted by the normal distribution. However, for values that are not extreme, i.e. for around 98 percent of the data, the T-Bond/T-Bill monthly returns follow the normal distribution quite well.

The residuals from a simple linear regression, modelling the T-Bond/T-Bill one month return using the OMXS30 one month return can be seen below, along with the autocorrelation of the residuals.

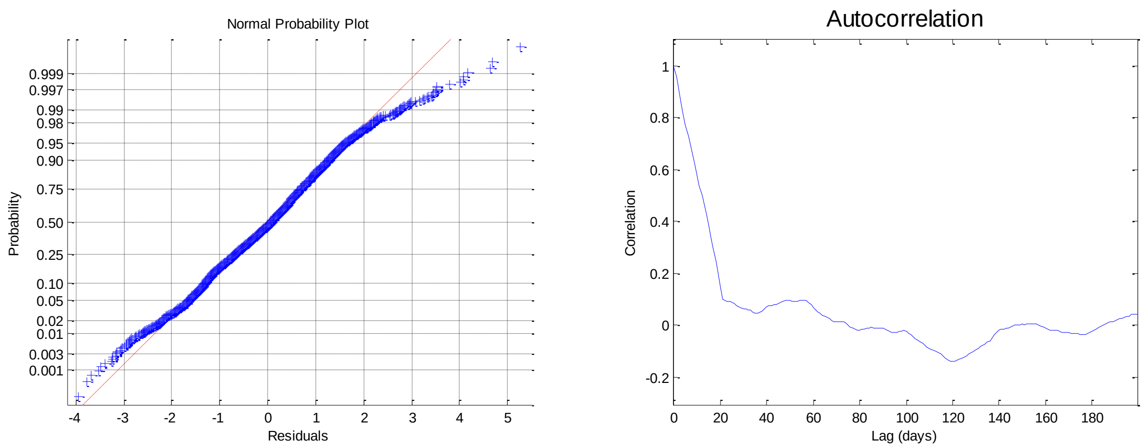


Figure 6 The graph to the left is a normal probability plot of the residuals from using OMXS30 one month returns to model the T-Bond/T-Bill one month return via simple linear regression. The graph to the right shows the autocorrelation of the residuals.

The residuals follows the normal distribution quite well, except for in the tails which are fat. This means, again, that extreme values occur more often in reality than if the residuals had been normally distributed. Since the residuals are based on returns over one month (20 days), the autocorrelation for the first 20 days is calculated partly on the same data which is gradually shifted. This is what causes the linearly decreasing slope during those 20 first days. After the first 20 days, the autocorrelation of the residuals is around zero which indicates that they are uncorrelated to each other.

3.3 Combining the indicators

In order to create a model that takes in information from all the indicators simultaneously, the indicators have to be combined in some way. This is done on the following form:

$$TBond\ ratio_t = \frac{Value(TBond)_t}{Value(TBond + TBill)_t} = \beta_1 f_1(x_{1t}) + \beta_2 f_2(x_{2t}) + \cdots + \beta_q f_q(x_{qt})$$

where q is the number of different indicators, $TBond\ ratio_t$ is the optimized allocation for T-Bonds at time t (adjusted so that it lies between 0 and 1), f_i is a function, x_{it} is the value of a specific indicator at time t and β_i is the model weights.

The function f_i transforms the indicator values in the exact same way as the test model described in 3.2. It uses the quantitative relations between the indicators and the T-Bond/T-Bill return found in the analysis of each individual indicator to calculate a suggested T-Bond ratio. If a signal is not given by the indicator, the function returns a T-Bond ratio of 0.5. If a signal is given, the indicator values are standardized. Then, depending on the sign of the correlation between the indicator and the T-Bond/T-Bill return, the standardized values are given a positive or negative sign. After this, the value 0.5 is added.

$$f_i(x_{it}) = 0.5 + c * g_i(indicator\ value_t - indicator\ average)$$

where

$$g_i(x) = \begin{cases} 0, & if\ no\ signal\ is\ sent \\ x, & if\ a\ signal\ i\ sent \end{cases}$$

and c is defined as in 3.2.

If the result deceeds 0, $f_i(x_{it})$ is set to 0 and if it exceeds 1, $f_i(x_{it})$ is set to 1. If an indicator sends a signal, this suggests a certain T-Bond ratio is to be held. That suggested T-Bond ratio is held for one month. During that month, no new signal can be received from that indicator. For a more thorough description of the procedure of converting each indicator value into a T-Bond ratio, see 3.2.

Hence, the function f_i converts the values of the indicators into numbers between 0 and 1 that describe the suggested allocation of T-Bonds for each indicator. These suggested allocations are combined, using the formula above, to create a model that, given the values of all the indicators, returns a suggested T-Bond allocation. The model is first run for the “in sample” period and then for the “out of sample” period. The values of the indicators are checked every day and if an indicator sends a signal, that signal is saved but the allocation is not changed before the current week has finished. This means that during the first week of the simulation, the indicator portfolio consists of 50 percent T-Bonds and 50 percent T-Bills. During the weekend, all signals from the week are used to create the new allocation for the portfolio. That allocation is held during the following week while collecting new signals from other indicators each day. Those new signals are, during the following weekend, used to create a new allocation which is held during the following week and so on. When an indicator has sent a signal, that signal is held the same for one month. If no new signal is received during one week and all signals from the previous week are still present, the allocation will be the same for the next week as for the previous one. If all signals have been deactivated, i.e. one month has passed since there last was a new signal, the allocation will be 50 percent T-Bonds and 50 percent T-Bills.

Hence, the allocation can be changed once a week in accordance with that week’s new signals. This means that the combination of the indicators, i.e. the T-Bond ratio, can change values maximally once a week whereas each function, f_i, can change values maximally once a month. The reason to this is that should the allocation be changed every day, the transaction costs would be too high. As an example let’s say that during the first week, only indicator 1 sends a signal. During this week, the allocation is 50 percent T-Bonds and 50 percent T-Bills. When the first week is over, the T-Bond allocation will be changed according to indicator 1’s value. That allocation is kept during the second week. In the second week, indicator 3 also sends a signal. Hence, the allocation will be changed after the second week. Since the signal from indicator 1 is held for one month, the allocation for the third week will depend on the values from both indicator 1 and 3. Each indicator can change maximally once a month so indicator 1 cannot send a new signal before week 5 has passed and indicator 3 cannot send a new signal before week 6 has passed.

The T-Bond ratio takes values between 0 and 1 and describes the allocation that the combination of the indicators suggests. Consequently, the T-Bill ratio is given by:

$$TBill\ ratio_t = 1 - TBond\ ratio_t$$

The T-Bond ratio and the T-Bill ratio are then used to create an indicator portfolio whose allocation is decided by all the indicators together. Also in this case, a transaction cost of 0.1 % is used. The weights, β_i, are found through optimization of that indicator portfolio on the “in sample” period using the Matlab function fmincon. Depending on the desired profile of the portfolio, the optimization is done with respect to different performance measures of the portfolio. In total, four different portfolios are constructed:

- Portfolio 1: Maximized return at the end of the period.
- Portfolio 2: Minimized standard deviation during the period.
- Portfolio 3: Maximized Sharpe ratio during the period.
- Portfolio 4: Maximized information ratio during the period.

Naturally, the weights will be different for the different portfolios since, for instance, the characteristics for a portfolio with maximized return differs a lot from a portfolio with minimized standard deviation.

The optimization is conducted using a number of constraints. Firstly, no indicator should be allowed to be too dominant, i.e. an upper bound for the weights has to be set. The upper bound will depend on the number of indicators included in the model. The more indicators included, the lower the upper bound will be. As the result later will show, 24 indicators were selected to be included in the model. Hence, $\frac{1}{24} \approx 0.042$ would be the upper bound (and the lower bound) if all indicators were to have the same influence over the model. However, some indicators might suit some portfolio profiles better than others. This means that the indicators should be able to get different weights depending on the portfolio profile so that the indicators suitable for that portfolio get more influence over it. Hence, the upper bound should be set above 0.042 to allow for some indicators to influence the model more than others. On the basis of this discussion, the upper bound was set to 0.07 since this allows the indicators to have different influence over the model without getting too dominant. To control the relative influence of each indicator on the whole model, the sum of the weights has to equal one. Otherwise, all weights are allowed to equal to the upper bound. Since all indicators included in the model have been selected on the basis of their positive performance, no indicator is to have a negative weight and all selected indicators are to be included in the model, i.e. a lower bound, for the weights, larger than zero has to be set. The lower bound also depends on the number of indicators in the model and the more indicators the lower the lower bound will be. Based on the discussion in this paragraph, the lower bound was set to 0.01.

The constraints can be summarized as:

$$\beta_i \leq 0.07 \qquad i = 1, 2, \ldots, 24$$

$$\beta_i \geq 0.01 \qquad i = 1, 2, \ldots, 24$$

$$\sum_{i=1}^{24} \beta_i = 1$$

Two examples of how the model works is given below:

Let’s say that, during week 1, no indicator sends a signal. This means that all f_i return the value 0.5. Since the sum of the weights, β_i, equal 1, the model will suggest a T-Bond ratio of 0.5 for week 2.

Let’s say that, during week 1, indicator 1 and 3 send signals and all other indicators do not. Both indicator 1 and 3 want to increase the T-Bond ratio. When this happens, the values of f_1 and f_3 will be higher than 0.5 while all other f_i will equal 0.5. Hence, the model will suggest a T-Bond ratio higher than 0.5 for week 2. How much above 0.5 the ratio will be is decided by the value of β_1 and β_3 and by how much the indicator values deviate from their mean. Large β give a higher ratio and vice versa and large deviations give a higher ratio and vice versa.

4 Results

In this chapter, the different categories of indicators that have been tested are presented. Those indicators that show an ability to forecast the relative return of T-Bonds and T-Bills are then thoroughly analysed. Eventually, the indicators are combined in a model and tested “out of sample”.

4.1 Indicators

Many different types of potential indicators were generated during the initial work phase. The categories to which they belong are presented below. In total, around 250 potential indicators have been tested. All tested indicators can be found in Appendix 1.

Business surveys: Business confidence is a measure of the degree of optimism on the state of the economy that business owners are expressing through their activities of investing and spending. Decreasing business confidence often implies slowing economic growth which often means that government bonds will perform better, especially T-Bonds.

Consumer surveys: Consumer confidence is an economic indicator updated every month which measures the optimism the consumer feel about the overall state of the economy and their personal financial situation. A lower value of the consumer confidence often implies a weaker economy which, in theory, should be good for government bonds.

Currencies: The evolution of the relative value between different currencies can reveal information about what investors think about a certain country’s financials which, in turn, affects the price of bonds issued by that state.

Cash flows: The flow of money between different assets can give a hint on how investors think the economy will develop during the near future. This, of course, also affects the value of government bonds.

Reference interest rates: Interest rates have a very large impact on the value of bonds and hence have to be tested.

Equity indices: Returns on bond markets and equity markets often have a negative correlation since money flowing from one of them often means that money flows to the other. Hence, high indicator values should imply low T-Bond/T-Bill returns and vice versa.

Volatility indices: Volatility indices measure the market volatility. High market volatility indicates high distress among investors which often is positive for bond markets.

Industries and sectors: How different industries perform, in absolute and relative figures, can give a hint on in which direction the economy is moving. For instance, high activity in the construction industry often indicates an upwards trend in the economy.

Government bonds: The yield spread between government bonds issued by different countries can give a clue on the reliability of a country’s financials. Increasing yield spread between, for instance, Swedish and German government bonds indicates that investors have higher confidence in Germany’s financials than in Sweden’s.

Corporate bonds: The yield spread between government bonds and corporate bonds indicates in which direction the economy is moving. Increasing spreads means that the economy is slowing and hence investors demand higher return on corporate bonds to cover the increased risk.

Public debt: The higher the debt of the government, the lower confidence in that government’s ability to pay its liabilities. Hence, the public debt affects the government bond prices in a very direct way.

Household debt: The higher the debt of the households, the lower the long run consumption of the households. Decreasing consumption means slower economy which often is good for the government bond market.

Bankruptcies: Many bankruptcies often indicate a slower economy which increases the demand, and hence the value, of government bonds.

Inflation: The value of a bond is directly connected to the inflation. High inflation means low bond values and vice versa.

Housing Affordability Index: The housing affordability index measures that which is deemed affordable to those with a median household income. A high value of this index often means that the economic outlook is good which is often bad for the government bond market.

Real estate and buildings: The amount of new buildings and buildings under construction indicates in which direction the economy is moving. Many new building often means that the economy is strong which often implies a weak bond market.

Retail: Retail indices measure the sale of goods and services from individuals or businesses to the end user. High values of this indicator imply high spending among consumers which suggest a strong economy which often is negative for the government bond market

Monetary aggregates: This indicator class measures the total amount of monetary assets in an economy at a specific time. In general, high money supply indicates inflation and vice versa.

Commodities: Commodities and bonds often have a negative correlation since high commodity prices suggest high inflation which is bad for the bond markets.

Unemployment: The unemployment rate is one measure of the general state of the economy. High unemployment often means a bad economic outlook which, in turn, often means that government bond markets are doing well.

4.2 Analysis

Around 250 different data series were tested in order to find indicators that were able to predict the relative evolution of T-Bonds and T-Bills. Of these data series, 24 showed to give indications on how these securities were moving relative to each other. Of the 24 selected indicators, most showed a correlation between the indicator's extreme values and the T-Bond/T-Bill return but some indicators had a linear relationship with the return and in some cases large value changes of the indicator could suggest in which direction the quota was moving. The selected indicators, and a thorough description of them, can be found in Appendix 4.

During the 2008 financial crisis, many extreme values occur in the data series. However, for an indicator to be interesting, it is important that it, over time, continuously delivers new, valid predictions. To establish this, a test model, described in section 3.2, was used whose result can be seen in Appendix 4.

Using the test model, the performance of each indicator could be evaluated. This was done using a number of risk and return measures (see 2.2.4). For an indicator to be considered to have an ability to make forecasts, the indicator portfolio had to have a higher return than the benchmark. It also had to have about the same standard deviation and maximum loss and a higher Sharpe ratio along with an average allocation not exceeding 70 percent for any of the bond types. Additionally, it has to be activated continuously during the time period so that it shows consistency and the excess return, compared to the benchmark, should also be spread out during the whole time period and not just occur at a few single occasions.

Below, a summary of the performance of the 24 indicators can be seen along with the performance of the benchmark portfolio and portfolios consisting of T-Bonds and T-Bills solely:

Indicator/Portfolio	Lag	Annual return	Standard deviation	Sharpe ratio	Information ratio	Jensen's alpha	Beta	R^2	Maximum loss	Avg. T-Bond part	T-Bond abs. dev.
T-Bill	-	1.4 %	0.1 %	0	-	-	-	-	0.1 %	0 %	-
T-Bond	-	6.3 %	5.0 %	0.97	-	-	-	-	3.0 %	100%	-
Benchmark	-	3.8 %	2.5 %	0.38	-	-	1	-	1.5 %	50%	0
US, Manufacturing Price Index	80	4.7 %	2.3 %	0.56	0.58	0.4 %	1.08	0.86	2.4 %	53.1 %	0.07
US, Manufacturing Price Index	20	4.8 %	2.4 %	0.56	0.58	0.3 %	1.12	0.92	2.7 %	54.1 %	0.04
US, Manufacturing Backlog of Orders	80	4.5 %	2.2 %	0.45	0.49	0.2 %	1.05	0.96	2.7 %	53.5 %	0.04
OMXS30 One Month Return	40	4.6 %	2.5 %	0.44	0.14	0.3 %	0.95	0.62	1.9 %	45.6 %	0.37
OMXS30 One Month Return	40	4.6 %	2.2 %	0.52	0.56	0.2 %	1.05	0.96	2.7 %	51.4 %	0.01
OMXS30 One Month Return	140	5.2 %	2.6 %	0.67	0.71	1.0 %	1.04	0.66	3.2 %	54.3 %	0.37
Volatility Index (VIX)	20	4.7 %	2.4 %	0.52	0.41	0.2 %	1.06	0.92	3.2 %	52.4 %	0.02
Swe, Consumer Confidence Price Trends	80	4.6 %	2.2 %	0.50	0.28	0.4 %	0.92	0.73	3.6 %	46.4 %	0.12
US, - Swe Government Bonds 5 Year, Yield	60	4.4 %	1.9 %	0.51	0.14	0.2 %	0.85	0.86	2.7 %	39.8 %	0.10
US, Net New Flow of Mutual Funds, Stocks	40	4.6 %	2.3 %	0.49	0.44	0.2 %	1.07	0.95	2.7 %	51.4 %	0.01
US, Net New Flow of Mutual Funds, Stocks	60	4.5 %	2.2 %	0.48	0.43	0.2 %	1.05	0.96	2.7 %	51.4 %	0.01
Swe, Unemployment over next 12 months	60	4.7 %	2.1 %	0.59	0.33	0.1 %	1.02	0.98	2.9 %	51.2 %	0.01
Ger, Labour Costs & Turnover in Construction	60	4.5 %	2.1 %	0.47	0.54	0.1 %	1.01	0.99	2.7 %	51.4 %	0.01
US, Labour Turnover	80	4.4 %	2.0 %	0.47	0.48	0.2 %	0.97	0.97	2.2 %	48.7 %	0.01
Swe, Total Retail Trade (Volume), Change	60	4.5 %	2.1 %	0.48	0.46	0.1 %	1.03	0.98	2.9 %	51.7 %	0.02
Swe, Total Retail Trade (Volume), Change	80	4.5 %	2.1 %	0.46	0.61	0.2 %	1.03	0.98	2.7 %	52.0 %	0.02
Ger, Retail Sale of Hardware, Change	40	4.5 %	2.1 %	0.50	0.47	0.2 %	0.10	0.97	2.2 %	50.0 %	0.03
S&P 500 Retailing, Monthly Return	40	4.6 %	2.1 %	0.52	0.32	0.3 %	0.97	0.89	2.2 %	49.5%	0.04
Emerging Markets, Equity Indices, Monthly Ret.	40	5.3 %	2.6 %	0.69	0.57	0.9 %	0.99	0.62	2.3 %	46.1 %	0.37
Emerging Markets, Equity Indices, Monthly Ret.	40	4.7 %	2.2 %	0.56	0.52	0.3 %	1.02	0.91	2.2 %	50.0 %	0.03
S&P 500 Return - Emerging Markets, Return	40	5.5 %	2.6 %	0.78	0.72	1.1 %	0.99	0.63	2.8 %	47.2 %	0.36
Ger, Construction Index, Monthly Return	40	5.0 %	2.6 %	0.60	0.45	0.6 %	1.04	0.67	3.6 %	47.9 %	0.34
Copper, Monthly Return	40	4.6 %	1.9 %	0.56	0.35	0.3 %	0.90	0.91	2.2 %	46.1 %	0.04
Silver, Monthly Return	40	4.6 %	2.3 %	0.50	0.44	0.2 %	1.09	0.94	2.7 %	52.6 %	0.03

Table 2 Indicator performances in short.

4.3 Combining the indicators by optimizing their weights

The indicators that were found to have an ability to predict are combined to form a model that can be used to decide the allocation between T-Bonds and T-Bills. Combining the indicators is done by optimization of the weights during the "in sample" period with respect to a number of criterions, depending on the desired profile of the portfolio. The different portfolios are: Maximized return, minimized standard deviation, maximized Sharpe ratio and maximized information ratio. Depending on the criteria of the optimization, the weights will be different. For more information on how the indicators are combined, see section 3.3.

The indicators that are selected to be a part of the model are based on the result in section 4.2 and Appendix 4. Hopefully, the indicators will provide a better prediction when combined compared to being used one by one. The indicator weights sum up to 1 and all indicators constitute between 1 and 7 percent of the model so that all are included and none of them is allowed to be too dominant. The selected indicators are those who performed best in the test conducted using the test model (see Appendix 4). For more information on how the optimization is done, see chapter 3.3.

A brokerage of 0.1 percent of the transaction is also taken into account in the model. This percentage corresponds to the bid/ask spread of the securities which leads to that, at each transaction a fraction of the value of the T-Bonds and T-Bills that are sold and bought will be lost. Since Swedish government bonds are highly liquid, the spread is quite small.

How the selected indicators are used in the model is presented in the table below. The table shows under which conditions the indicators send signals to the model. For instance, the volatility index (VIX) sends a signal to the model when a value change smaller than -7 or larger than 6 occurs.

Indicator	Lag	Val. <	Val. >	Chg. <	Chg. >	Cont.
US, Manufacturing Price Index	80	36	75			
US, Manufacturing Price Index	20			-6.5		
US, Manufacturing Backlog of Orders	80		60			
OMXS30 One Month Return	40					X
OMXS30 One Month Return	40	-20				
OMXS30 One Month Return	140					X
Volatility Index (VIX)	20			-7	6	
Swe, Consumer Confidence Price Trends	80	-1	35			
US, – Swe Government Bonds 5 Year, Yield	60		1			
US, Net New Flow of Mutual Funds, Stocks	40	-1300				
US, Net New Flow of Mutual Funds, Stocks	60	-1300				
Swe, Unemployment over next 12 months	60			-20	20	
Ger, Labour Costs & Turnover in Construction	60	5800				
US, Labour Turnover	80				39	
Swe, Total Retail Trade (Volume), Change	60		3			
Swe, Total Retail Trade (Volume), Change	80	-2.2	3			
Ger, Retail Sale of Hardware, Change	40	-1.2	1.3			
S&P 500 Retailing, Monthly Return	40	-20	20			
Emerging Markets, Equity Indices, Monthly Ret.	40					X
Emerging Markets, Equity Indices, Monthly Ret.	40	-19	20			
S&P 500 Return – Emerging Markets, Return	40					X
Ger, Construction Index, Monthly Return	40					X
Copper, Monthly Return	40		20			
Silver, Monthly Return	40	-20				

Table 3 The indicators included in the model. Val. </> means value smaller/larger than, Chg.</> means change smaller/larger than and Cont. means continuous.

The indicator numbers presented in the tables below refer to the sections in Appendix 4.

When optimizing to maximize the return of the indicator portfolio, the weights below are obtained. This portfolio is called "Portfolio 1".

Indicator	Weight (β)	Indicator	Weight (β)	Indicator	Weight (β)
7.4.1.a	0,01	7.4.6	0,07	7.4.12	0,07
7.4.1.b	0,06	7.4.7.a	0,01	7.4.13	0,01
7.4.2	0,07	7.4.7.b	0,01	7.4.14.a	0,06
7.4.3.a	0,01	7.4.8	0,07	7.4.14.b	0,01
7.4.3.b	0,01	7.4.9	0,07	7.4.15	0,07
7.4.3.c	0,05	7.4.10	0,03	7.4.16	0,07
7.4.4	0,06	7.4.11.a	0,01	7.4.17	0,03
7.4.5	0,07	7.4.11.b	0,06	7.4.18	0,01

Table 4 Indicator weights for Portfolio 1.

When optimizing to minimize the standard deviation of the indicator portfolio, the weights below are obtained. This portfolio is called "Portfolio 2".

Indicator	Weight (β)	Indicator	Weight (β)	Indicator	Weight (β)
7.4.1.a	0,06	7.4.6	0,07	7.4.12	0,06
7.4.1.b	0,01	7.4.7.a	0,03	7.4.13	0,07
7.4.2	0,01	7.4.7.b	0,02	7.4.14.a	0,06
7.4.3.a	0,05	7.4.8	0,02	7.4.14.b	0,01
7.4.3.b	0,01	7.4.9	0,07	7.4.15	0,07
7.4.3.c	0,01	7.4.10	0,07	7.4.16	0,04
7.4.4	0,02	7.4.11.a	0,05	7.4.17	0,07
7.4.5	0,06	7.4.11.b	0,02	7.4.18	0,04

Table 5 Indicator weights for Portfolio 2.

When optimizing to maximize the Sharpe ratio of the indicator portfolio, the weights below are obtained. This portfolio is called “Portfolio 3”.

Indicator	Weight (β)	Indicator	Weight (β)	Indicator	Weight (β)
7.4.1.a	0,06	**7.4.6**	0,07	**7.4.12**	0,06
7.4.1.b	0,01	**7.4.7.a**	0,01	**7.4.13**	0,05
7.4.2	0,07	**7.4.7.b**	0,01	**7.4.14.a**	0,06
7.4.3.a	0,01	**7.4.8**	0,04	**7.4.14.b**	0,01
7.4.3.b	0,01	**7.4.9**	0,07	**7.4.15**	0,07
7.4.3.c	0,05	**7.4.10**	0,03	**7.4.16**	0,07
7.4.4	0,02	**7.4.11.a**	0,01	**7.4.17**	0,07
7.4.5	0,07	**7.4.11.b**	0,06	**7.4.18**	0,01

Table 6 Indicator weights for Portfolio 3.

When optimizing to maximize the information ratio of the indicator portfolio, the weights below are obtained. This portfolio is called “Portfolio 4”.

Indicator	Weight (β)	Indicator	Weight (β)	Indicator	Weight (β)
7.4.1.a	0,06	**7.4.6**	0,03	**7.4.12**	0,06
7.4.1.b	0,01	**7.4.7.a**	0,01	**7.4.13**	0,04
7.4.2	0,07	**7.4.7.b**	0,06	**7.4.14.a**	0,05
7.4.3.a	0,01	**7.4.8**	0,07	**7.4.14.b**	0,01
7.4.3.b	0,01	**7.4.9**	0,07	**7.4.15**	0,07
7.4.3.c	0,05	**7.4.10**	0,07	**7.4.16**	0,07
7.4.4	0,02	**7.4.11.a**	0,01	**7.4.17**	0,01
7.4.5	0,01	**7.4.11.b**	0,06	**7.4.18**	0,07

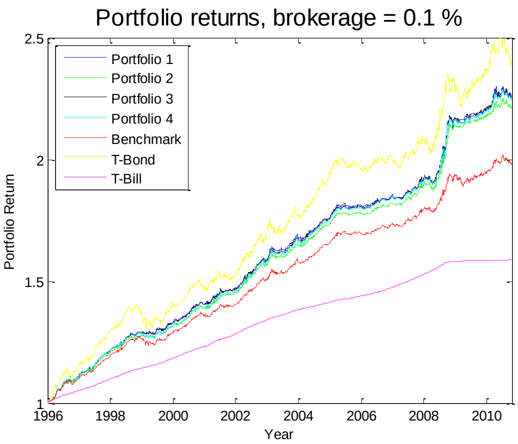
Table 7 Indicator weights for Portfolio 4.

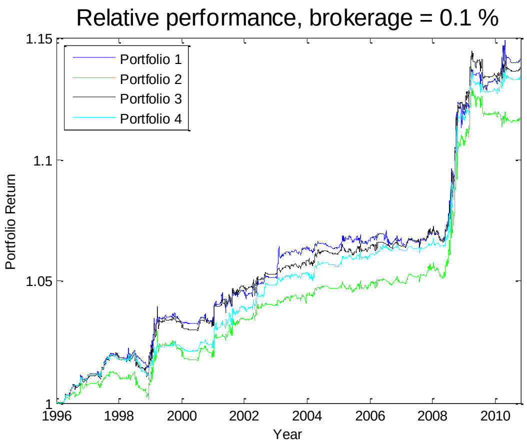
All weights fulfil the specified conditions. Running the test model using the different models yields the following “in sample” result:

	Benchmark	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	T-Bill	T-Bond
Annual return	4.8 %	5.8 %	5.6 %	5.7 %	5.7 %	3.3 %	6.3 %
Standard deviation	1.9 %	2.3 %	2.1 %	2.1 %	2.2 %	0.3 %	3.8 %
Sharpe ratio	0.74	1.05	1.06	1.11	1.06	0	0.78
Information ratio	-	1.04	0.96	1.11	1.19	-	-
Jensen’s alpha	-	0.8 %	0.8 %	0.9 %	0.8 %	-	-
Beta	1	1.09	1.00	1.02	1.07	-	-
R^2	-	0.84	0.84	0.85	0.88	-	-
Maximum loss	2.7 %	2.4 %	2.0 %	2.1 %	2.1 %	0.1 %	5.6 %
Avg. T-Bond part	50 %	53.7 %	48.7 %	49.6 %	52.9 %	0 %	100 %
T-Bond abs. dev.	0	0.16	0.14	0.14	0.13	-	-

Table 8 Summary of indicator portfolios.

All indicator portfolios perform better than the benchmark in all measures except for the standard deviation even though they all have almost the same average allocation as the benchmark. However, the indicator portfolios time the market better and hence perform better. The return is almost as high as the return for a portfolio with 100 percent T-Bonds. Additionally, the indicator portfolios have a much lower standard deviation, a much higher Sharpe ratio and a much lower maximum loss. Overall, the performance of the different indicator portfolios is quite similar to each other





The plots show that all indicator portfolios evolve similarly. The relative performance curves are constantly increasing which means that the indicator portfolios are performing better than the benchmark throughout the whole period.

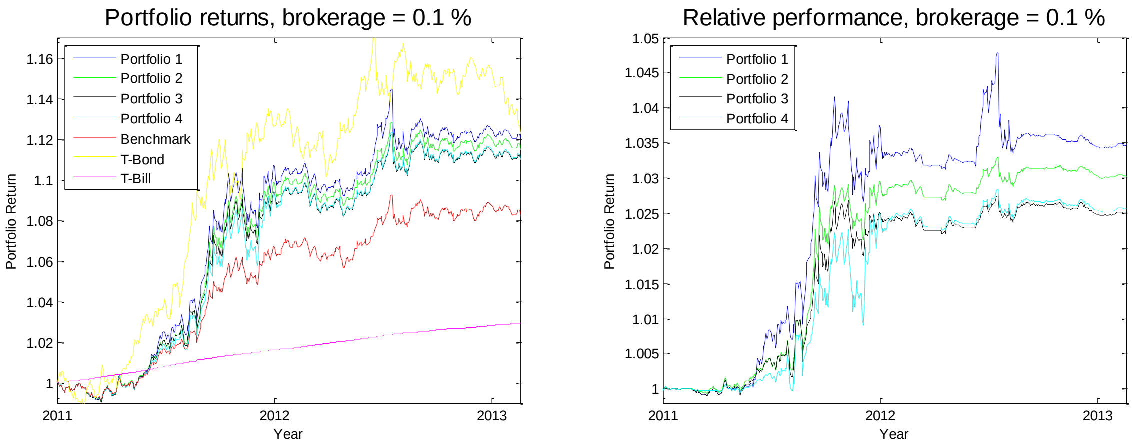
4.4 “Out of sample” testing

For the two years and one month following the time period the indicators were evaluated on (i.e. 2011-01-01 to 2013-01-31) an “out of sample” test was run on the same portfolios as seen above. During this test, the indicator weights were held constant and the indicators were used in the same way as during the initial time period to evaluate whether the indicators keep on predicting the relative evolution of T-Bonds and T-Bills and hence can be used in a model that sets the best allocation. The result from the “out of sample” test can be seen below.

	Benchmark	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	T-Bill	T-Bond
Annual return	3.8 %	5.5 %	5.3 %	5.1 %	5.1 %	1.4 %	6.3 %
Standard deviation	2.5 %	3.8 %	3.3 %	3.3 %	3.5 %	0.1 %	5.0 %
Sharpe ratio	0.96	1.09	1.18	1.12	1.06	0	0.97
Information ratio	-	1.10	1.44	1.24	1.00	-	-
Jensen’s alpha	-	0.6 %	0.8 %	0.6 %	0.5 %	-	-
Beta	1	1.45	1.28	1.26	1.33	-	-
R^2	-	0.92	0.95	0.95	0.92	-	-
Maximum loss	1.5 %	2.8 %	2.0 %	2.0 %	2.6 %	0.1 %	3.0 %
Avg. T-Bond part	50 %	67.2 %	61.0 %	60.4 %	61.2 %	0 %	100 %
T-Bond abs. dev.	0	0.20	0.14	0.14	0.14	-	-

Table 9 Summary of indicator portfolios.

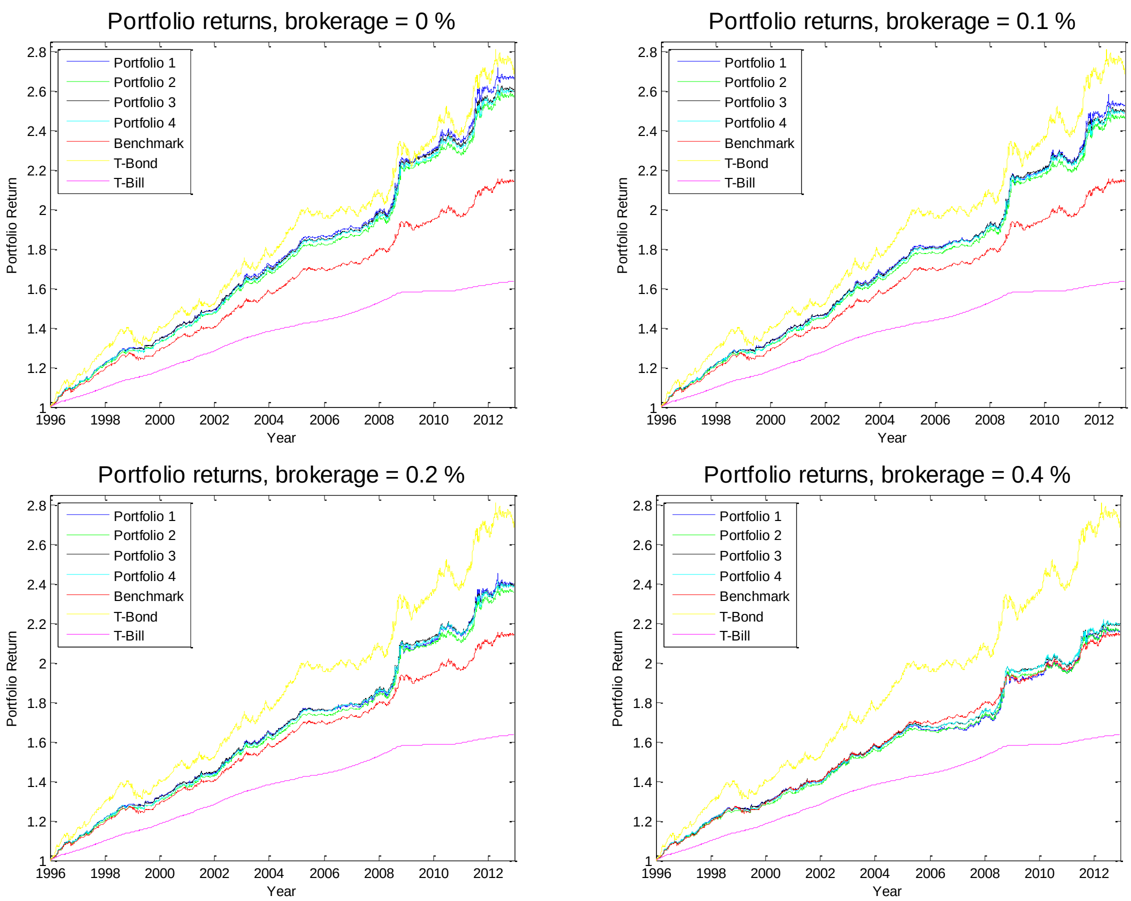
The indicator portfolios perform a lot better than the benchmark also during the “out of sample” period. All risk and return measures are better for the indicator portfolios than for the benchmark except for, again, the standard deviation. This means that the indicators still produce predictions about the relative performance between T-Bonds and T-Bills. Comparing the indicator portfolios shows that Portfolio 1 to 3 are still getting the best numbers in what they are programmed to do (i.e. the minimized standard deviation portfolio still has the lowest standard deviation and so on) even though the indicators and their weights were optimized with respect to another time period. However, Portfolio 4, which was programmed to maximize the information ratio, now has the lowest information ratio value of them all. During this time period, the T-Bond part is a bit higher for the indicator portfolios than during the “in sample” period, but not notably high.



Also in this time period, the evolutions of the indicator portfolios are similar. The relative performance curves are non-decreasing during the whole time period and hence the indicator portfolios perform as good as or better than the benchmark.

4.5 Sensitivity to transaction costs

Since the brokerage can vary over time, it is important to test the model's sensitivity to different levels of transaction costs. However, the market for this kind of securities is very liquid so the brokerage will most likely be between 0.1 and 0.2 percent of the transaction. Below, the portfolios are presented with 0, 0.1, 0.2 and 0.4 percent brokerage:



The portfolios are turned over around 3 times per year which is, according to Dahlgren, not a high number. The pictures show that even though the brokerage is low, the returns of the indicator portfolios are very affected by it. At a brokerage of 0.4 percent, the excess return, compared to the benchmark portfolio, is almost gone.

5 Conclusions

It is possible to find indicators that seem to be able to predict the relative evolution between T-Bonds and T-Bills. Some indicators included in the result are better than others but they all give a better result than random chance.

Even though a lot has changed in the financial markets after the 2008 financial crisis, many of the discovered indicators show a good result also after this time period. Many extreme values occurred during that crisis and basing a trading strategy on these extreme values solely might be very risky since the circumstances were extraordinary.

Some factors that, according to the theory, should be able to be used as indicators did not show any ability to predict the relative performance between T-Bonds and T-Bills. One example is Business confidence which is represented by many different data series of which none showed a very good prediction ability. The reason to this is probably that the market takes these reports into consideration so quickly that the time lag between the report and the assets' response is too short to be used in this case.

When the indicators are combined in the model, the resulting indicator portfolio performs a lot better than when the indicators are used one by one. When compared to a benchmark portfolio, the return is a lot higher for the indicator portfolio, even though the average allocation between T-Bonds and T-Bills is close to fifty-fifty. In addition, almost all risk measures show better values than the benchmark.

When tested "out of sample" the indicators still produce predictions that lead to better performance of the indicator portfolio than the benchmark even though the indicators were optimized for the "in sample" period. This fact indicates that it is possible to time the market in an efficient way using timing indicators.

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7 Appendices

7.1 Appendix 1 – More on simple linear regression

Suppose there are n data points $\{y_i, x_i\}$ to which a straight line is to be fitted:

$$\hat{y}_i = \hat{\beta}_0 + \hat{\beta}_1 x_i$$

where $\hat{y}_i$ is the estimated value of y using the i:th value of x and $\hat{\beta}_0$ and $\hat{\beta}_1$ are the estimated model parameters.

Next, define the residuals $e_i = y_i - \hat{y}_i$. The $\hat{\beta}_0$ and $\hat{\beta}_1$ that minimizes the following function is the ordinary least-squares estimation of this problem:

$$S = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 = \sum_{i=1}^{n} \left[y_i - \left(\hat{\beta}_0 + \hat{\beta}_1 x_i\right)\right]^2$$

Differentiating with regard to $\hat{\beta}_0$ and $\hat{\beta}_1$ yields:

$$\frac{\partial S}{\partial \hat{\beta}_0} = -2 \sum_{i=1}^{n} \left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right) = 0$$

$$\frac{\partial S}{\partial \hat{\beta}_1} = -2 \sum_{i=1}^{n} x_i \left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right) = 0$$

After manipulation of the above expressions the result is obtained:

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} = \hat{\rho}_{xy} \frac{\hat{\sigma}_y}{\hat{\sigma}_x}$$

$$\hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}$$

where $\bar{x}$ and $\bar{y}$ are the average of the x and y variables respectively, $\hat{\rho}_{xy}$ is the sample correlation coefficient between x and y and $\hat{\sigma}_x$ and $\hat{\sigma}_y$ are the sample standard deviation of x and y respectively.

7.2 Appendix 2 – Bond indices

The T-Bind/T-Bill quota consists of two indices; a T-Bond index and a T-Bill index which both are total return indices. A total return index is different from a price index in that it assumes that all cash distributions are reinvested which, in this case, means that all interest payments during the time period are included in the index (Investorwords). A price index, on the other hand, only tracks the price movements of the securities that the index consists of. A total return index displays a more accurate representation of the index's performance (Investopedia, Investopedia).

The T-Bond and T-Bill indices are called OMRXTBOND and OMRXTBILL, respectively and are calculated continuously during every Swedish banking day and are based on official statistics from Swedish National Debt Office on their issues (Nasdaq, Trading - Fixed Income - Sweden - Fixed Income Products). OMRXTBILL is an index related to Treasury bills and OMRXTBOND is an index related to nominal Treasury bonds (Nasdaq, Trading - Fixed Income - Sweden - Fixed Income Products). The purpose of the indices is to illustrate the changes in value for portfolios consisting of the respective bond type (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010). The formula for calculating these indices is:

$$I_t = \frac{\sum_{j=1}^{n_t} \left(mv_{j,t} + coup_{j,t} \right) \times issvol_{j,t}}{\sum_{j=1}^{n_t} \left(mv_{j,t-1} \right) \times issvol_{j,t-1}} \times I_{t-1}$$

where I_t is the value of the index at time t, n_t is the number of securities included at time t, $issvol_{j,t}$ is the issued volume in nominal terms for loan j at time t, $mv_{j,t}$ is the market value for security j at time t and $coup_{j,t}$ is the coupon for $bond_j$ with day of coupon at time t. (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 4) (Nasdaq, Trading - Fixed Income - Sweden - Fixed Income Products)

The market value refers to settled amounts (Nasdaq, Trading - Fixed Income - Sweden - Fixed Income Products). For bonds this is calculated as the price plus accrued interest in accordance with calculation principles for the Swedish Money- and Bond Market, i.e. the following is taken into account:

- The number of banking days between the expiration day and the settlement day according to practices applicable to the respective securities at any given time, i.e. currently three banking days for bonds and two banking days for treasury bills (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 4).
- For bonds with coupons, the price is rounded off to three decimal places before accrued coupon interest is added, where the number five is rounded upwards (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 4).
- Bonds are listed at yield to maturity while treasury bills are listed at the simple interest rate (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 4).
- The market value, mv, is calculated on the morning immediately preceding that day's calculation by using the latest interest rate (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, pp. 4-5).

When a coupon is paid out, the market value of the bond decreases. However, since the coupon payment is assumed to be reinvested in the formula above, the index value is not affected by the coupon payment (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 6).

When a new bond is issued, which does not replace an existing security, the issued volume is adjusted after the closing of the trading on the seventh banking day each month (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 5). When a new bond is exchanged for an old one, to maintain the index's duration, the issued volume is adjusted on the morning before the start of the trading on the banking day following the day of the exchange (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 6). Bonds are generally excluded from the index when the time to maturity is shorter than one year (Nasdaq, Rules for the Construction and Maintenance of the OMRX Indexes, 2010, p. 6).

7.3 Appendix 3 – Tested data series

In Appendix 1, all indicators that have been tested are presented. The indicators are divided into different subgroups where each group contains indicators of the same kind.

Business surveys:
Assessment of Order-Book Levels, Balance
Employment Expectations for the Months Ahead
Assessment of Stocks of Finished Products
Construction, Confidence Indicator, Production Expectations for the Months Ahead
Assessment of Export Order-Book Levels, Employment Expectations over the Next 3 Months
Evolution of Your Current Overall Order Books
Durable Consumer Goods, Selling Price Expectations for the Months Ahead
Non-Durable Consumer Goods, Production Expectations for the Months Ahead
The Consumer Confidence Indicator (CCI)
The Macro Index (KI)
The Micro Index (KI)
Manufacturing, Inflow of New Orders on The Export Market
Manufacturing, Volume of Production, Expectations
Manufacturing, Overall Order Books, Present Situation Assessment
Industrial Confidence Indicator
Costs & Hours Worked, Number of Working Days, Per Month
USA, Business confidence, ISM, Report on Business, Manufacturing, Purchasing Managers' Index

These indicators are very similar to Germany Business confidence IFO, Business Survey, Trade & Industry, Business Climate.

Leading indicators:
OECD MEI, Sweden, CLI Finished Goods Stocks Level, SA
OECD MEI, Sweden, CLI Order Books Level, SA
OECD MEI, Sweden, CLI Yield 5-year Government Bonds (Normalised), SA, Index
OECD MEI, Sweden, CLI - Amplitude Adjusted, SA, Index
OECD MEI, Sweden, CLI - Reference Series GDP (normalised), SA, Index
United States, Citi, Commodity Terms of Trade Index
OECD MEI, United States, CLI - Amplitude Adjusted, SA, Index
United States, ECRI, Weekly Leading Index, WLI
United States, Conference Board, Business Cycle Indicators, Leading Economic Index (LEI), Composite Index, SA
United States, Conference Board, Business Cycle Indicators, Leading Economic Index (LEI), Diffusion (1-Month Span), SA
United States, Federal Reserve Bank of San Francisco, Tech Pulse Index
United States, Conference Board, Business Cycle Indicators, Leading Economic Index (LEI), Composite Index (Change over 6-Month Span), SA, AR
United States, Conference Board, Business Cycle Indicators, Leading Economic Index (LEI), Manufacturers' New Orders, Consumer Goods & Materials, SA, USD
United States, Conference Board, Business Cycle Indicators, Contribution to LEI, Avg. Consumer Expectations for Business & Economic Conditions, SA
United States, Conference Board, Business Cycle Indicators, Sales, Orders & Deliveries, Change in Mfrs' Unfilled Orders, SA
United States, Conference Board, Business Cycle Indicators, Fixed Capital Investment, Industrial Production Business Equipment, SA
United States, Conference Board, Business Cycle Indicators, Inventories & Inventory Investment, Manufacturing & Trade Inventories, SA, USD
United States, Domestic Trade, Retail Trade, ICSC Indexes, Leading Indicator of Shopping Center Sales, Index

OECD MEI, Germany, CLI Orders Inflow, SA, Index
OECD MEI, Germany, CLI Finished Goods Stocks Level, SA
OECD MEI, Germany, CLI Business Climate Indicator(Normalised), SA, Index
OECD MEI, Germany, CLI Total New Orders Manufacturing, SA, Index
OECD MEI, Germany, CLI Spread Of Interest Rates, AR
OECD MEI, Germany, CLI - Amplitude Adjusted, SA, Index
OECD MEI, Germany, CLI - Trend Restored, SA, Index
OECD MEI, Germany, CLI - Reference Series GDP (normalised), SA, Index
United States, Conference Board, Business Cycle Indicators, International Comparisons-Industrial Production & Consumer Prices, Germany 6-Month Change in Consumer Prices, SA, AR
United States, Conference Board, Business Cycle Indicators, International Comparisons-Stock Price Indexes & Exchange Rates, Federal Republic of Germany Stock Prices
Macrobond Leading Indicator

Currencies:
Switzerland, FX Spot Rates, Macrobond, CHF per USD
Germany, FX Spot Rates, Macrobond, DEM per USD
Denmark, FX Spot Rates, Macrobond, DKK per USD
Euro Area, FX Spot Rates, Macrobond, EUR per USD
United Kingdom, FX Spot Rates, Macrobond, GBP per USD
Norway, FX Spot Rates, Macrobond, NOK per USD
Sweden, FX Spot Rates, Macrobond, SEK per USD
Switzerland, FX Spot Rates, ECB, CHF per EUR, Fixing
Denmark, FX Spot Rates, ECB, DKK per EUR, Fixing
United Kingdom, FX Spot Rates, ECB, GBP per EUR, Fixing
Norway, FX Spot Rates, ECB, NOK per EUR, Fixing
Sweden, FX Spot Rates, Central Bank of Sweden, SEK per NOK, Fixing
Sweden, FX Spot Rates, Central Bank of Sweden, SEK per DKK, Fixing
Sweden, FX Spot Rates, Central Bank of Sweden, SEK per CHF, Fixing

These are relatively similar to SEK/EUR.

Consumer surveys:
General Economic Situation over Next 12 Months
Statement on Financial Situation of Household, Balance
Financial Situation over Next 12 Months
Unemployment Expectations over Next 12 Months
Major Purchases over Next 12 Months
Konjunkturinstitutet (KI), Economic Tendency Survey, Economic Tendency Indicator
Konjunkturinstitutet (KI), Swedish Economy, General Economic Situation Compared with 12 Months Ago
Konjunkturinstitutet (KI), Swedish Economy, General Economic Situation over the next 12 Months
Konjunkturinstitutet (KI), Prices in General, The Rate in which Prices will Change in the next 12 Months
Sweden, Consumer Surveys, Konjunkturinstitutet (KI), Unemployment, Over the next 12 Months
Sweden, Consumer Surveys, DG ECFIN, Consumer Confidence, Unemployment Expectations over Next 12 Months, Balance, SA
Sweden, Unemployment, Rate, Males & Females, By Age, Unemployed or in Labour Market Programs, Total 16-64 Years (PES)
Sweden, Unemployment, Unemployed Persons, Males & Females, By Age, Unemployed & Applicants in Labour Market Programs, Total (PES)
Sweden, Unemployment, Rate, Males & Females, By Age, Total 16-64 Years, SA
Sweden, Unemployment, Unemployed Persons, Males & Females, By Age, Total 16-64 Years
Sweden, Labour Turnover, Layoffs, Total
Bundesbank, Germany, Business Statistics, Economic Indicators, Employment, Labour Costs & Turnover in the

Construction Sector, Germany, Employees, SA
Bundesbank, Germany, Business Statistics, Economic Indicators, Employment, Labour Costs & Turnover in the Construction Sector, Germany, Man-Hours Worked, SA
Bundesbank, Germany, Business Statistics, Economic Indicators, Employment, Labour Costs & Turnover in the Construction Sector, Germany, Wages & Salaries, SA, EUR
Bundesbank, Germany, Business Statistics, Economic Indicators, Employment, Labour Costs & Turnover in the Construction Sector, Germany, Turnover, Total, SA, EUR
Bundesbank, Germany, Business Statistics, Economic Indicators, Employment, Labour Costs & Turnover in the Construction Sector, Germany, Turnover, Housing Construction, SA, EUR
United States, Labour Turnover, Mass Layoffs, Layoff Events, All Industries, SA
United States, Labour Turnover, Mass Layoffs, Total Initial Claimants, All Industries, SA
Sweden, Labour Turnover, New Vacancies, Total (PES)
Sweden, Labour Turnover, Remaining Vacancies, Total (PES)
Sweden, Labour Turnover, Layoffs, Total
Sweden, Labour Turnover, New Vacancies, Total (PES), Trend Adjusted, SA
Sweden, Labour Turnover, Remaining Vacancies, Total (PES), Trend Adjusted, SA
United States, Labour Turnover, Layoffs & Discharges, Nonfarm, Announced Job Layoffs
United States, Labour Turnover, Mass Layoffs, Layoff Events, All Industries
United States, Labour Turnover, Mass Layoffs, Layoff Events, Private Nonfarm, SA
Bundesbank, Germany, Business Statistics, Economic Indicators, Productivity & Labour Costs in Industry, Gross Wages & Salaries per Unit of Turnover, Germany, Mining, Quarrying & Manufacturing Sector (B + C), Data on Specialist Sections of Local Units, Calendar Adjusted, SA, Index
United States, Unemployment, Jobless Claims, Initial, Total, SA
United States, Unemployment, Jobless Claims, Continuing, Total, SA
United States, Unemployment, Jobless Claims, Insured Unemployment Rate

Fixed income indices:
Sweden, Fixed Income Indices, Nasdaq OMX, OMRX Total Bond Index-OMRX Real Return Bond Index, Total Return, Close, SEK
Sweden, Fixed Income Indices, Nasdaq OMX, OMRX Total Bond Index-OMRX Real Return Bond Index, Total Return, Close, SEK
United States, Government Benchmarks, Macrobond, 10 Yield-"Constant Maturity, Inflation Indexed, Yield", 10 Year, Yield

Cash flows:
United States, Net New Cash Flow of Long-Term, Stock Mutual Funds, Redemptions, USD
United States, Net New Cash Flow of Long-Term, Stock Mutual Funds, USD
United States, Net New Cash Flow of Long-Term, Municipal Bond Mutual Funds, New Sales, USD
United States, Net New Flow of Mutual Funds, Bond, Total, USD
United States, Net New Flow of Mutual Funds, Money Market, USD

Reference interest rates:
Sweden, Interbank Rates, STIBOR, 3 Month, Fixing
Germany, Interbank Rates, EURIBOR, 3 Month, Fixing

Equity indices:
United States, Equity Indices, S&P, 500, Index, Price Return, USD

The indicators beneath have also been tested and are very similar to S&P 500 minus emerging markets large, mid and small cap returns.

1.0000	0.9339	1.0000	0.9335
0.9339	1.0000	0.9341	0.9999
1.0000	0.9341	1.0000	0.9339
0.9335	0.9999	0.9339	1.0000

United States, Equity Indices, S&P, 500, Index, Price Return, USD- Emerging Markets, Equity Indices, MSCI, IMI (Large, Mid & Small Cap), Index, Total Return, USD
United States, Equity Indices, S&P, 500, Index, Price Return, USD- Emerging Markets, Equity Indices, MSCI, Mid & Large Cap, Index, Price Return
United States, Equity Indices, S&P, 500, Index, Total Return, USD- Emerging Markets, Equity Indices, MSCI, IMI (Large, Mid & Small Cap), Index, Total Return, USD
United States, Equity Indices, S&P, 500, Index, Total Return, USD- Emerging Markets, Equity Indices, MSCI, Mid & Large Cap, Index, Price Return

Industries and sectors:
OECD MEI, Sweden, Construction - Confidence Indicator, SA
Sweden, Business Surveys, DG ECFIN, Construction Confidence Indicator, Evolution of Your Current Overall Order Books, Balance, SA
Sweden, Business Surveys, DG ECFIN, Construction Confidence Indicator, Balance
Eurostat, Sweden, Construction, Building & Civil Engineering, Construction & Production Index, Construction, SA, Index
OECD MEI, United States, Production Of Total Industry, SA, Index
OECD MEI, Germany, Production Of Total Industry, SA, Index
OECD MEI, Sweden, Production Of Total Industry, SA, Index
Eurostat, Sweden, Industry Turnover Index, Total Market, Manufacturing, SA, Index
Sweden, Equity Statistics, Nasdaq OMX, All Sections, Total, Turnover, SEK
Sweden, Equity Statistics, Nasdaq OMX, All Sections, Total, Turnover, SEK
United States, Equity Indices, S&P, 500, Construction Materials, Index, Total Return, USD
United States, Equity Indices, S&P, 500, Construction & Engineering, Index, Total Return, USD

Government bonds:
Sweden government bond 5 years minus 3 months se5ygov- se3mgov
Germany government bond 5 years minus 3 months se5ygov- se3mgov
US government bond 5 years minus 3 months se5ygov- se3mgov

Corporate bonds:
derate0023-de5ygov
djcorp05cp-us05ygov

Public debt:
Sweden, Public Debt, Central Government, Inflation-Linked Bonds
Sweden, Government Benchmarks, Swedish National Debt Office, Government Borrowing Rate, Fixing
Sweden, Public Debt, Central Government, Total, SEK
Sweden, Public Debt, Central Government, Net Borrowing Requirement, SEK
Sweden, Public Debt, Central Government, Treasury Bonds, SEK
Sweden, Public Debt, Central Government, Inflation-Linked Bonds, SEK
Sweden, Public Debt, Central Government, Treasury Bills, SEK
Sweden, Public Debt, Central Government, Primary Borrowing Requirement, SEK
Sweden, Public Debt, Central Government, Change in Central Government Debt, SEK

Household debt:
segpfi0024
sebank0304

Bankruptcies:
Sweden, Bankruptcies, 1-4 Employees, Incorporated Companies (Aktiebolag)
Sweden, Bankruptcies, 1-4 Employees, Sole Proprietorships (Enskilda Firmor)
Sweden, Bankruptcies, 1-4 Employees, Partnerships (Handelsbolag)
Sweden, Bankruptcies, 5-9 Employees, Incorporated Companies (Aktiebolag)
Sweden, Bankruptcies, 5-9 Employees, Sole Proprietorships (Enskilda Firmor)
Sweden, Bankruptcies, 5-9 Employees, Partnerships (Handelsbolag)
Sweden, Bankruptcies, 10-19 Employees, Incorporated Companies (Aktiebolag)
Sweden, Bankruptcies, 10-19 Employees, Sole Proprietorships (Enskilda Firmor)
Sweden, Bankruptcies, 10-19 Employees, Partnerships (Handelsbolag)
Sweden, Bankruptcies, 20-49 Employees, Incorporated Companies (Aktiebolag)
Sweden, Bankruptcies, 20-49 Employees, Sole Proprietorships (Enskilda Firmor)
Sweden, Bankruptcies, 20-49 Employees, Partnerships (Handelsbolag)
Sweden, Bankruptcies, Above 50 Employees, Incorporated Companies (Aktiebolag)
Sweden, Bankruptcies, Above 50 Employees, Sole Proprietorships (Enskilda Firmor)
Sweden, Bankruptcies, Above 50 Employees, Partnerships (Handelsbolag)
Sweden, Bankruptcies, No Employees, Incorporated Companies (Aktiebolag)
Sweden, Bankruptcies, No Employees, Sole Proprietorships (Enskilda Firmor)
Sweden, Bankruptcies, No Employees, Partnerships (Handelsbolag)
Sweden, Bankruptcies, No Employees, Private Individuals

Inflation:
Sweden, Consumer Price Index, Total, Index
Sweden, Inflation, Underlying Inflation KPIF, Index
United States, Consumer Price Index, All Items, Total, SA, Index
United States, Core Inflation Index, OECD Economic Outlook, Estimate, Calendar Adjusted, SA, Index
Germany, Consumer Price Index, Total, SA, Index
Germany, Consumer Price Index, Total, Excl. Energy & Seasonal Food, Index

Central bank interest rates:
Sweden, Policy Rates, Repo Rate (Effective Dates)
United States, Deposit Rates, Federal Reserve, Eurodollar (London), 1 Month
United States, Deposit Rates, Federal Reserve, Eurodollar (London), 3 Month
United States, Deposit Rates, Federal Reserve, Eurodollar (London), 6 Month

Producer price index:
United States, Producer Price Index, Finished Goods, Total, SA, Index
Germany, Producer Price Index, Industrial Products, Total, SA, Index
Sweden, Producer Price Index, Total, Index

Housing Affordability Index:
United States, National, National Association of Realtors, Housing Affordability Index, Monthly Mortgage Rate
United States, National, National Association of Realtors, Housing Affordability Index, Principle & Interest Payment, USD
United States, National, National Association of Realtors, Housing Affordability Index, Payment as a Percentage of Income
United States, National, National Association of Realtors, Housing Affordability Index, Qualifying Income, USD
United States, National, National Association of Realtors, Housing Affordability Index, Composite, Index
United States, National, National Association of Realtors, Housing Affordability Index, Fixed, Index

Real estate and buildings:
Sweden, House Price Barometer, One- & Two-Dwelling Buildings, National, Average Price, SEK
Eurostat, Sweden, Construction, Building & Civil Engineering, Construction & Production Index, Buildings, Index
Eurostat, Sweden, Construction, Building & Civil Engineering, Building Permits Index, Building Permits (1000m2), Residences for Communities, Index
Eurostat, Sweden, Construction, Building & Civil Engineering, Building Permits Index, Building Permits (1000m2), Office Buildings, Index
Eurostat, Sweden, Construction, Building & Civil Engineering, Building Permits Index, Building Permits (1000m2), Non-Residential Buildings, Index
Eurostat, Sweden, Construction, Building & Civil Engineering, Building Permits Index, Building Permits (1000m2), Non-Residential Buildings, Except Office
United States, Construction by Status, Construction Started, Residential, New Privately Owned, Total, SA, AR
Sweden, House Price Barometer, One- & Two-Dwelling Buildings, National, Number of Purchases

Retail:
OECD MEI, Sweden, Passenger Car Registrations, SA, Change P/P
OECD MEI, Sweden, Total Retail Trade (Volume), SA, Change P/P
Sweden, Domestic Trade, Retail Trade, Total except Fuel, SA, Index
Sweden, Domestic Trade, Retail Trade, Total except Fuel, Constant Prices, Index
Sweden, Domestic Trade, Retail Trade, Mostly Durables, Total, Constant Prices, Index
Sweden, Domestic Trade, Retail Trade, Total except Fuel, Calendar Adjusted, Constant Prices, Index
Sweden, Domestic Trade, Retail Trade, Mostly Durables, Total, Calendar Adjusted, Constant Prices, Index
Sweden, Domestic Trade, Retail Trade, Clothes & Footwear, Total, Calendar Adjusted, Constant Prices, Index
Sweden, Domestic Trade, Retail Trade, Clothes & Footwear, Total, Trend Adjusted, Index
Sweden, Domestic Trade, Retail Trade, Household Equipment by EU, Total, PY=100, Index
OECD MEI, United States, Passenger Car Registrations, SA, Change P/P
OECD MEI, United States, Total Retail Trade (Volume), SA, Change P/P
United States, Domestic Trade, Retail Trade, Retail Sales, Total, Trend Adjusted, Calendar Adjusted, SA, USD
United States, Domestic Trade, Retail Trade, ICSC Indexes, Leading Indicator of Shopping Center Sales, Index
United States, Gasoline, All Grades, All Formulations, Retail Prices, USD
United States, Domestic Trade, Retail Trade, Retail & Food Services Sales, Total, Trend Adjusted, Calendar Adjusted, SA, USD
United States, Domestic Trade, Retail Trade, Retail Sales & Food Services, Excluding Motor Vehicle & Parts, Trend Adjusted, Calendar Adjusted, SA, USD
United States, Domestic Trade, Retail Trade, Total, Constant Prices, SA, USD
OECD MEI, United States, Passenger Car Registrations, SA
Germany, Domestic Trade, Retail Trade, Turnover, Total, Excl. Vehicle Trade, Calendar Adjusted (X-12 ARIMA), Constant Prices, SA (X-12 ARIMA), Index
OECD MEI, Germany, Total Retail Trade (Volume), SA, Change P/P
Germany, Business Surveys, DG ECFIN, Retail Trade Confidence Indicator, Business Activity (Sales) Development over the Past 3 Months, Balance, SA
Germany, Business Surveys, DG ECFIN, Retail Trade Confidence Indicator, Business Activity Expectations over the Next 3 Months, Balance, SA
Germany, Business Surveys, DG ECFIN, Retail Trade Confidence Indicator, Prices Expectations over the Next 3 Months, Balance, SA
Germany, Business Surveys, DG ECFIN, Retail Trade Confidence Indicator, Orders Expectations over the Next 3 Months, Balance
Germany, Economic Sentiment Surveys, ZEW, Financial Market Report, Retail / Consumer Goods, Balance
Germany, Domestic Trade, Retail Trade, Turnover, Total, Excl. Vehicle Trade, Constant Prices, Index
Germany, Domestic Trade, Retail Trade, Turnover, Total, Excl. Vehicle Trade, Trend Adjusted (BV4.1), Constant Prices, Index
Eurostat, Germany, Retail Trade & Services, Employment, Retail Sale of Audio & Video Equipment; Hardware,

Paints & Glass; Electrical Household Appliances, Etc. in Specialised Stores, SA, Change P/P
Eurostat, Germany, Retail Trade & Services, Total Market (Deflated), Retail Trade, Except of Motor Vehicles, Motorcyles & Fuel, Constant Prices, Index
United States, Equity Indices, S&P, 500, Retailing, Index, Total Return, USD

Monetary aggregates:
Sweden, Monetary Aggregates, M1, All Forms of Ownership, Total, SEK
Sweden, Monetary Aggregates, M2, All Forms of Ownership, Total, SEK
Sweden, Monetary Aggregates, M3, Total, SEK
United States, Monetary Aggregates, M1, Total, SA, USD
United States, Monetary Aggregates, M2, Total, SA, USD
Germany, Monetary Aggregates, M1, Total, EUR
Germany, Monetary Aggregates, M2, Total, SA (X-12 ARIMA), EUR
Germany, Monetary Aggregates, M3, Total, SA (X-12 ARIMA), EUR

Commodities (index and monthly returns):
Crude Oil, WTI, Global Spot, Close, USD
Gold, LBMA, P.M., Fixing, USD
Aluminium, LME Official Prices, Cash Buyer, USD
Copper, LME Official Prices, Cash Seller & Settlement, USD
United States, Crude Oil & Petroleum Products, Crude Oil, Europe Brent, USD
Wheat, No. 2 Hard Winter, Kansas City, Close, USD
Cattle, Feeder, Average, Oklahoma City, Close, USD
Propane, New York, Close, USD
Natural Gas, Henry Hub, Close, USD
Silver, LBMA, Fixing, USD

T-Bond and T-Bill
OMRX Treasury Bond Index
OMRX Treasury Bill Index

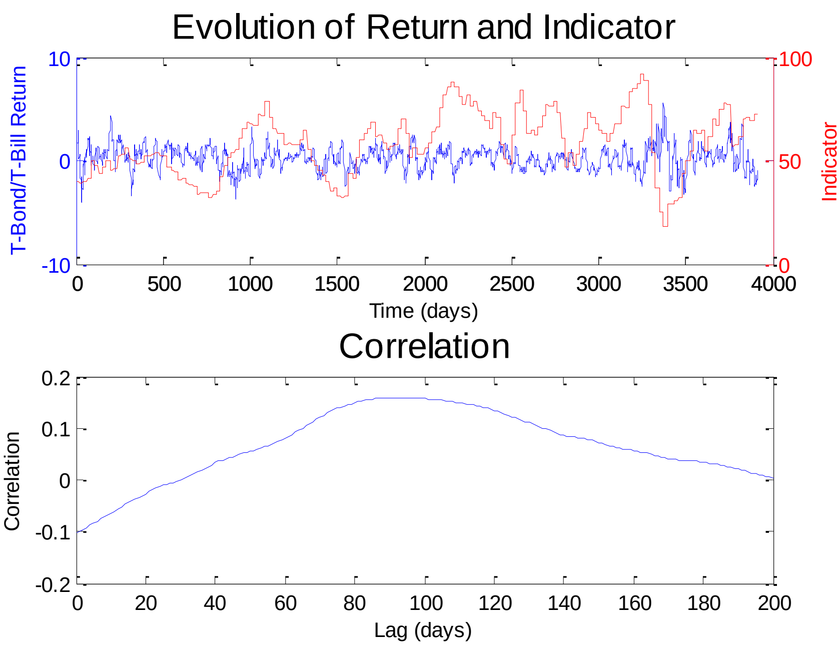
7.4 Appendix 4 – Evaluated indicators

The indicators presented below are those who showed an ability to predict the relative evolution of T-Bonds and T-Bills. The different measures included in the graphs are described in the 'Theory' chapter under 2.1.2 and 2.3.3.

In this chapter, business days are referred to when mentioning a certain number of days, i.e. five days equals a week, 20 days equals a month and so on. In the "Return vs. Indicator"-plots, the measure on the y-axis is the one month return of the quota $\frac{T-Bond}{T-Bill}$ and the measure on the x-axis depends on the indicator. The correlation graphs refer to the correlation between the T-Bond/T-Bill return and the indicator at different lags. The lag describes how many days the T-Bond/T-Bill return has been lagged with respect to the indicator, i.e. how many days the indicator curve has been shifted forward in time.

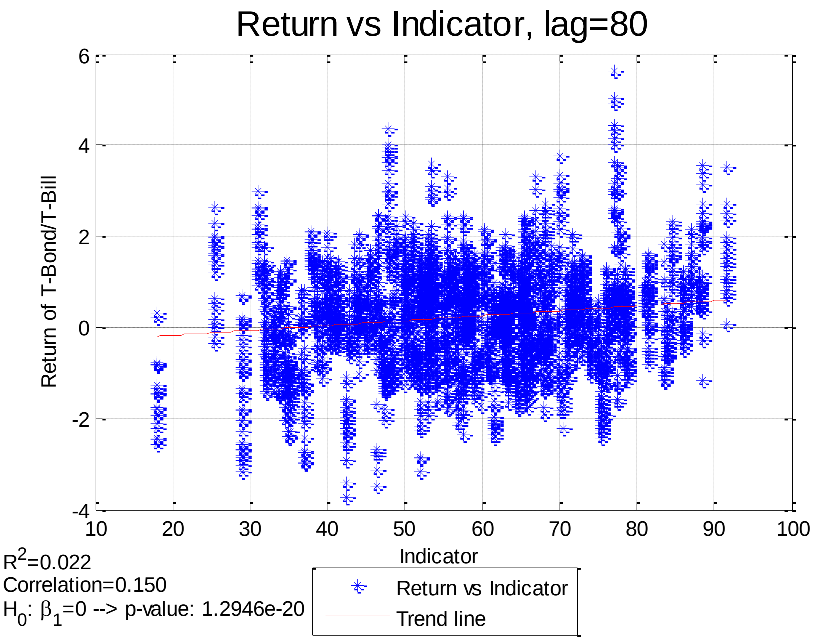
7.4.1 United States, Report on Business, Manufacturing, Prices Index

The Manufacturing ISM gather data on a monthly basis through surveys of supply management professionals. The surveys are a measure of the degree of optimism on the state of the economy that business owners are expressing through their activities of investing and spending. Decreasing values of the index often implies slowing economic growth which often means that government bonds will perform better, especially T-Bonds.



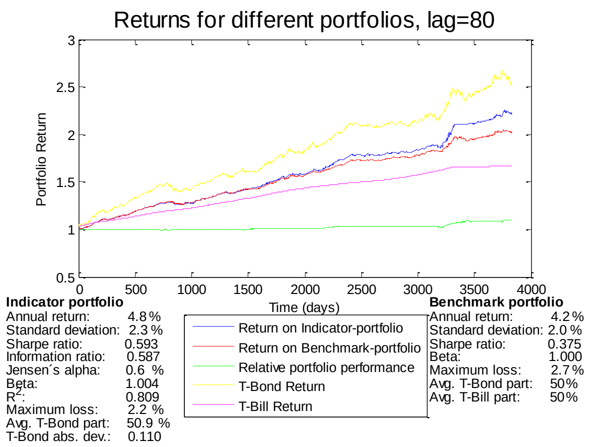
The indicator fluctuates pretty slowly, mostly between 50 and 80. The correlation is rising steadily until the lag between the T-Bond/T-Bill return and the indicator is 100 days, then it is decreasing.

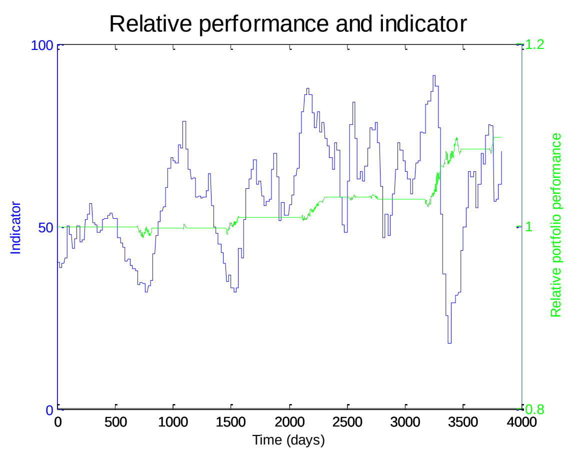
Beneath the Return vs Indicator plot can be seen:

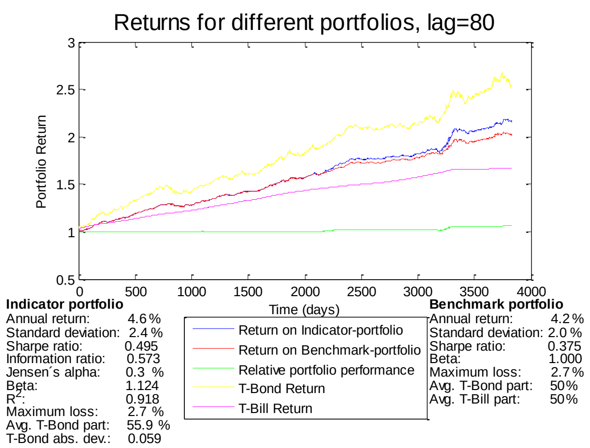


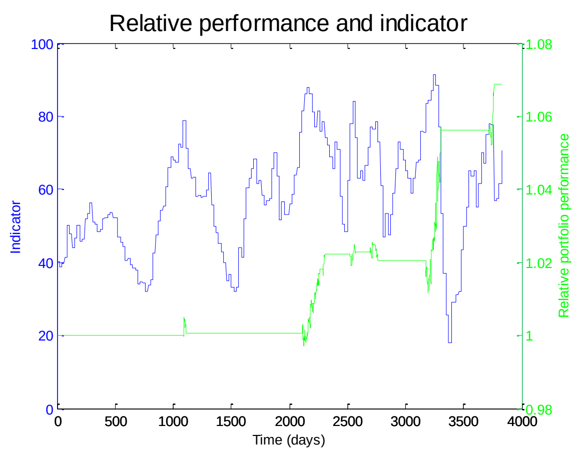
As the correlation graph suggests, the plots with a 20, 40 and 60 day lag have a flatter trend line, apart from that they look very similar to the 80 day lag plot. For indicator values lower than 37 the T-Bond/T-Bill return seems to be negative and for indicator values higher than 77 the opposite seems to be the case.

Running the test model using these settings yields:



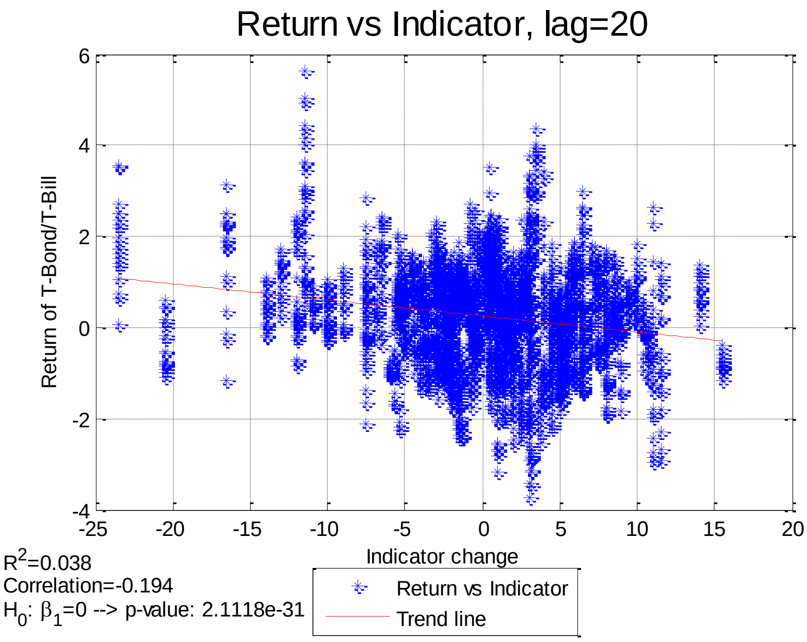






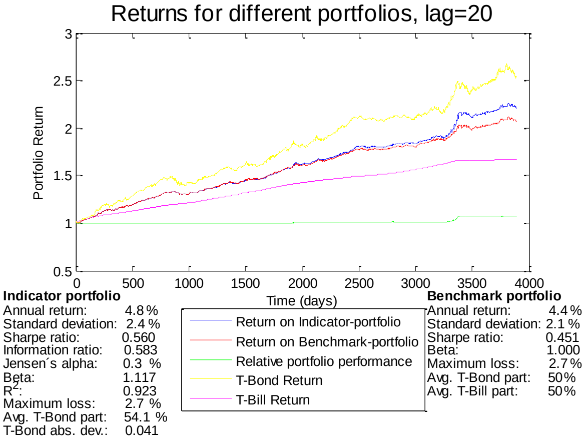
In the two graphs on the top, the model is set to only act on indicator values smaller than 37 and values higher than 77. The indicator portfolio has a higher annual return and has a much higher Sharpe ratio compared to the benchmark together with the information ratio. The relative portfolio performance curve shows that the indicator portfolio performs better than the benchmark during many periods. However, most of the indicator portfolio's excess return is gained around day 3500 which is the time for the 2008 financial crisis and, hence, also the time for most of the extreme values of the indicator. Many of the high extreme values, though, occur every now and then and could be used as more reliable signals than the low extremes values occurring around 2008. In the two graphs on the bottom, the model is set to only act on indicator values larger than 77. Also in this case, the indicator portfolio has a higher annual return and a higher Sharpe than the benchmark. The R^2-value shows that a lot of the indicator portfolio's excess return can be explained by its β. In both scenarios, the maximum loss is the same and also equal to the maximum loss of the benchmark portfolio. Jensen's alpha is a little higher for the indicator portfolio on the top whereas the opposite is true for the beta value. The relative performance curve shows that the indicator portfolio performs better than the benchmark after around day 2000 and that most of its excess return is, again, gained during the 2008 financial crisis.

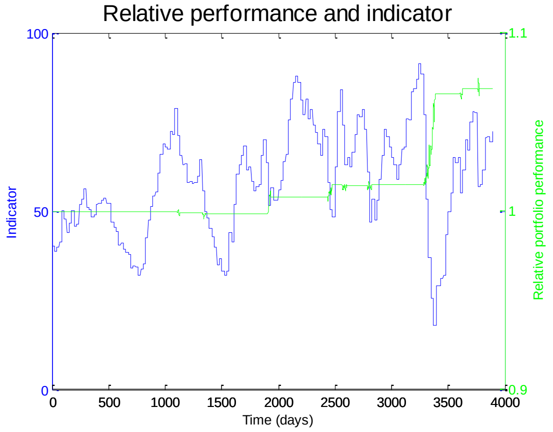
Plotting what happens with the T-Bond/T-Bill return succeeding a change of the indicator yields the following graph:



The trend line flattens as the lag is increased, and at a lag of 80 days, the trend line has a zero slope. For drops of the indicator value larger than 7, the T-Bond/T-Bill return is almost always positive. Such large drops occur quite a few times during the time period.

Running the test model calibrated to act only if the indicator value drops by 7 or more yields the following graphs:



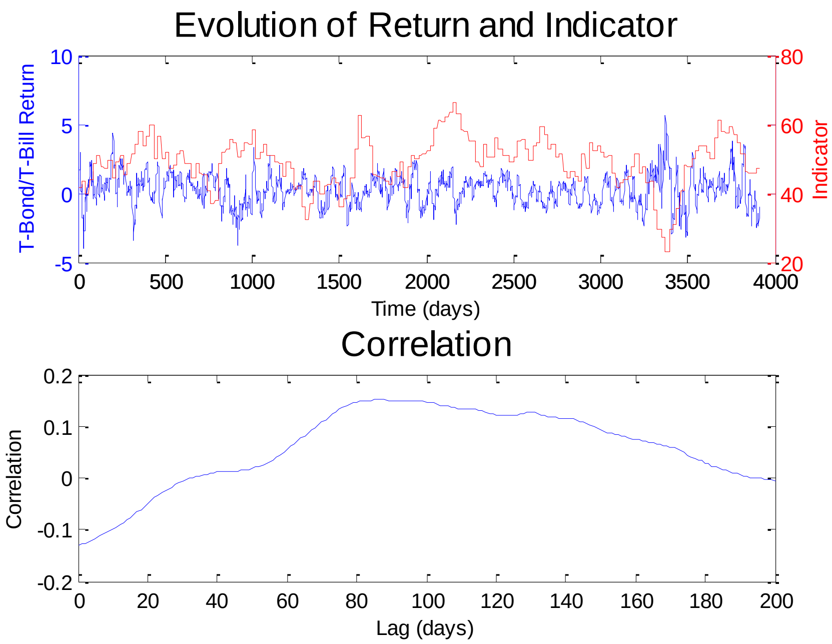


The indicator portfolio's annual return is higher than the benchmark. The Sharpe ratio is also higher for the indicator portfolio but the maximum loss is the same. Studying the magnified relative performance curve to the right shows that almost all of the excess return is gained during the 2008 financial crisis.

The result obtained from this indicator points in the opposite direction as what is theoretically expected since the return vs indicator plot has a positive correlation. However, the return vs indicator plot for changes in the indicator has a negative correlation which is in line with the theory.

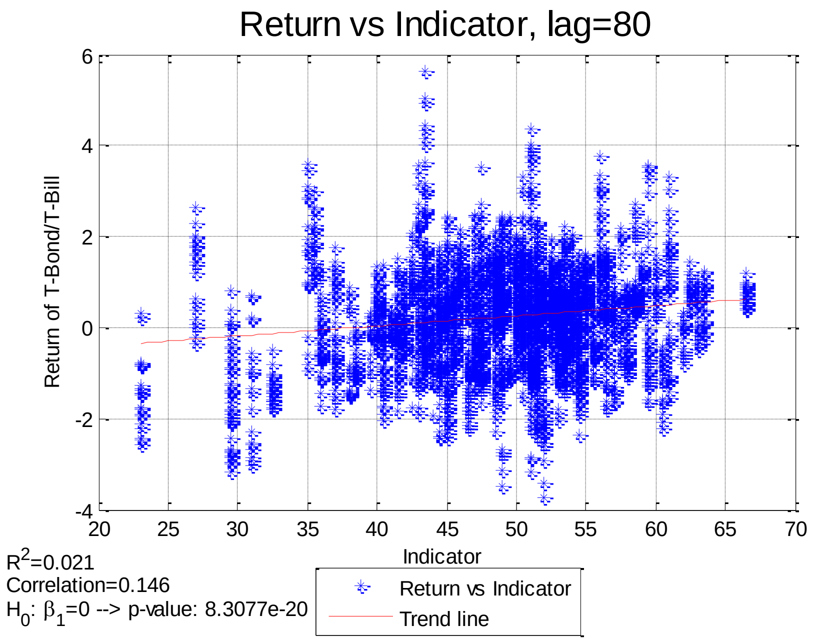
7.4.2 United States, Report on Business, Manufacturing, Backlog of Orders Index

The Manufacturing ISM gather data on a monthly basis through surveys of supply management professionals. The surveys are a measure of the degree of optimism on the state of the economy that business owners are expressing through their activities of investing and spending. Decreasing values of the index often implies slowing economic growth which often means that government bonds will perform better, especially T-Bonds.



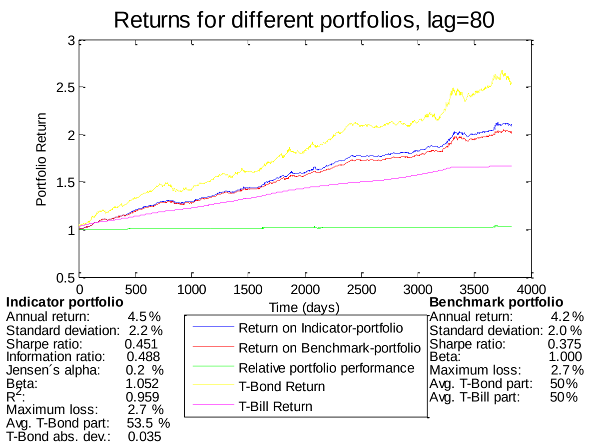
This indicator oscillates mostly between values of 40 and 60. The correlation between the T-Bond/T-Bill return and the indicator is increasing as the lag is increased and peaks at a lag around 80 days.

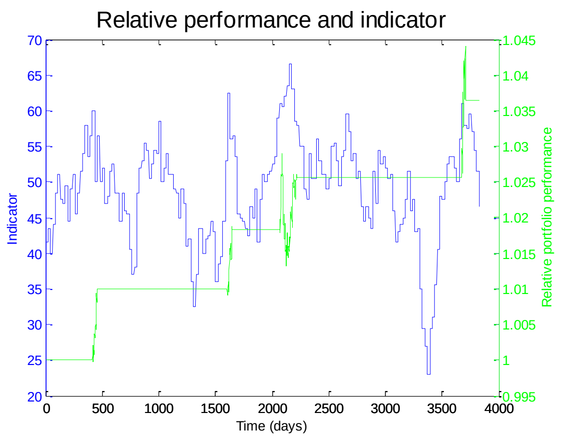
The Return vs Indicator plot with an 80 day lag can be seen below:



The trend line has a very high statistical significance and is upwards sloping. For indicator values below 35 T-Bills have a higher return than T-Bonds, however such low indicator values have only occurred once in history. For indicator values above 60 T-Bonds often perform better than T-Bills. Indicator values above 60 have occurred at a few different occasions in the past.

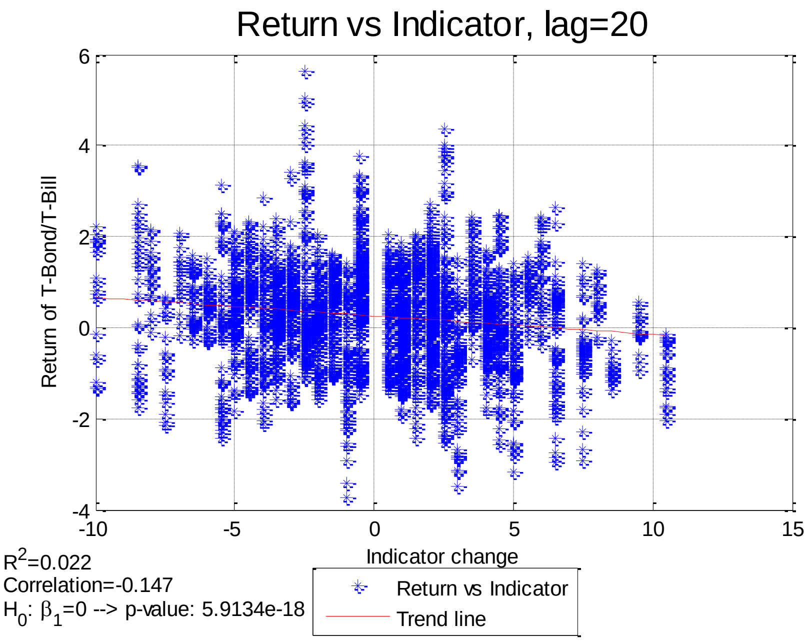
Running the test model calibrated to act only on indicator values larger than 60 gives the following graphs:





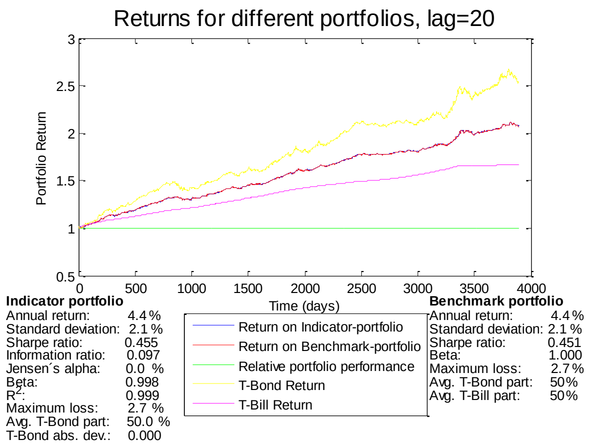
The annual return for the indicator portfolio is a little higher than the benchmark, and so is the Sharpe ratio. The value of Jensen’s alpha is low and the beta value is close to one and the R^2-value is quite high. The relative performance curve is only decreasing on a few occasions; else it is constant or increasing.

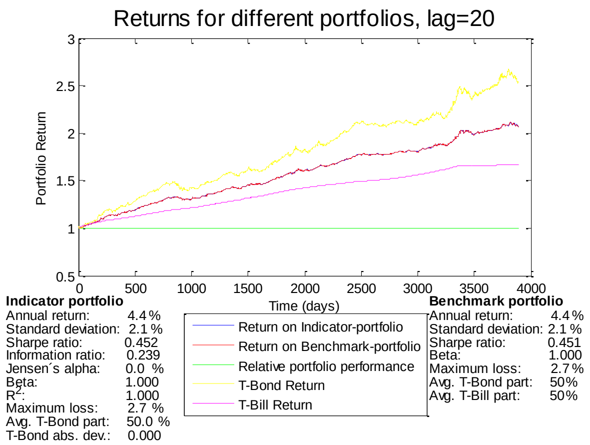
Plotting what happens with the T-Bond/T-Bill return following a change in the indicator gives the following:



For very large drops, T-Bonds seem to perform better than T-Bills and vice versa. Such large jumps do not occur very often, though. The same tendency can be seen when increasing the lag, but this makes the slope of the trend line decrease and at a lag of 80 days, the slope is zero.

Setting the test model to act only if the indicator goes up or down by at least ten yields the following:



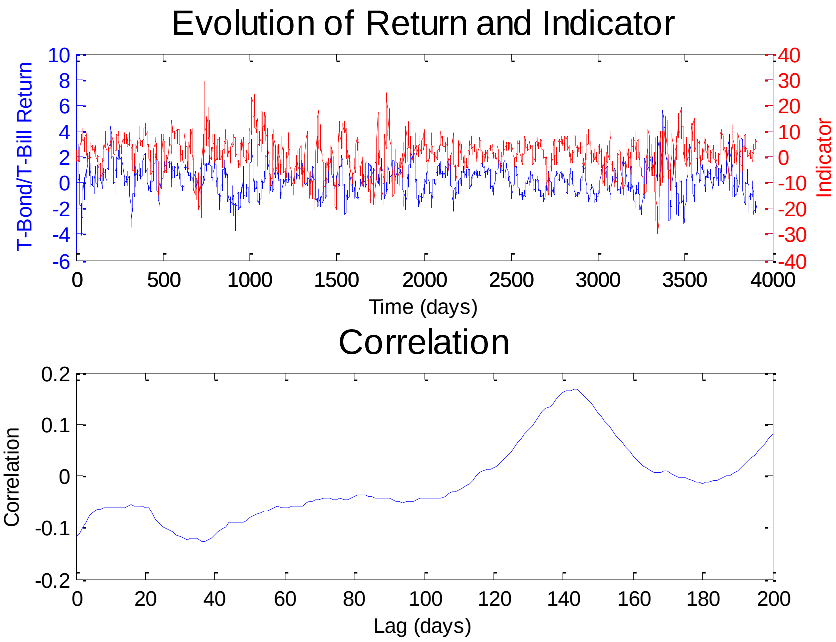


In the picture to the left the model acts on indicator changes larger than ten and in the picture to the right the model acts on indicator changes smaller than minus ten. The annual excess return for the indicator portfolio is small in both cases and the Sharpe ratio is slightly higher than the benchmark. The maximum loss in the left hand side case is a little lower than the benchmark’s and in the right hand side case the maximum losses are equal. The average absolute deviation of the T-Bond part from 50 percent is very low, indicating that the portfolio keeps a good mix of T-Bond and T-Bills most of the time.

The result obtained from this indicator points in the opposite direction of what is theoretically expected since the return vs indicator plot has a positive correlation. However, the return vs indicator plot for changes in the indicator has a negative correlation which is in line with the theory.

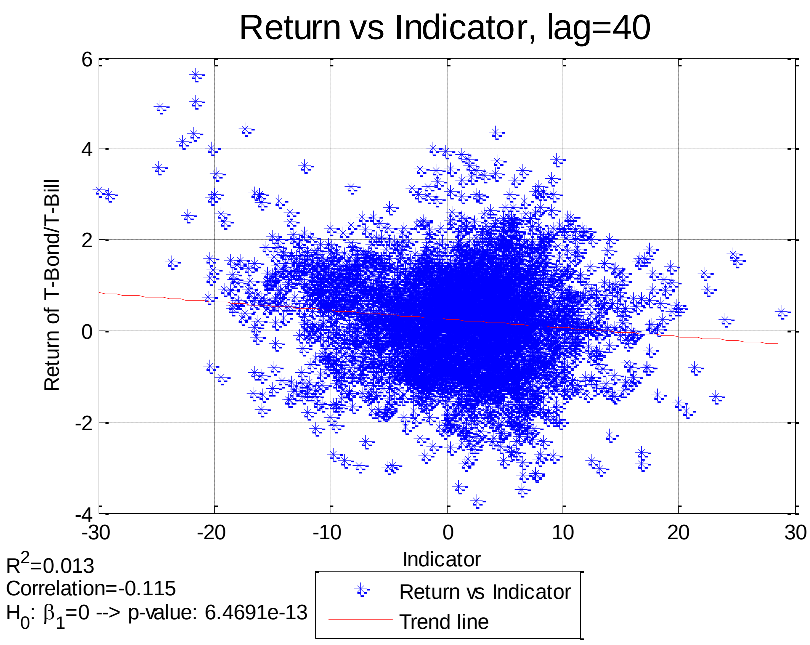
7.4.3 OMXS30 one month return

This indicator is calculated as the monthly return of the OMXS30 index and is updated on a daily basis. Returns on bond markets and equity markets often have a negative correlation and hence, high indicator values should imply low T-Bond/T-Bill returns and vice versa.



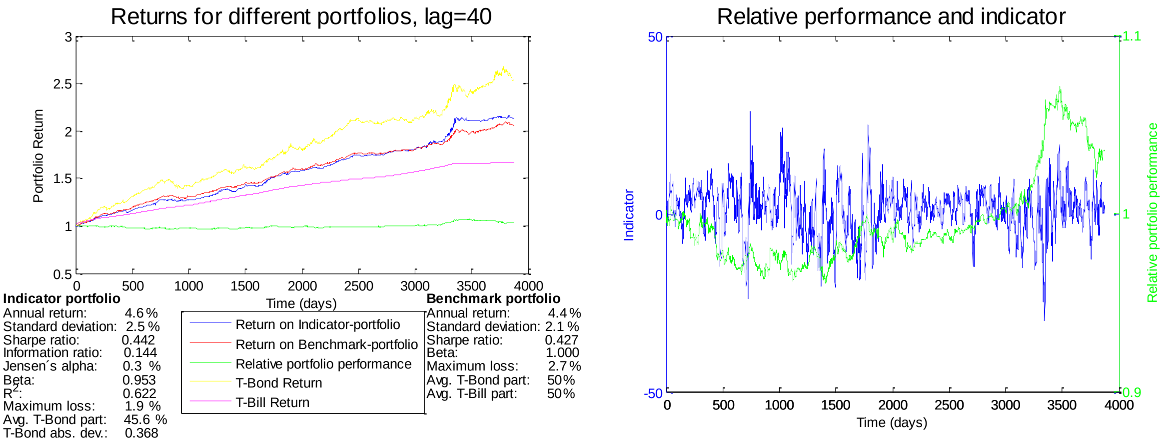
The indicator is mostly oscillating between -10 and 10. Inspecting the upper graph, there is no obvious relation between the indicator and the return of T-Bond/T-Bill. The correlation graph is a bit “jumpy” with the best negative correlation for between 20 and 40 days lag and the best positive correlation for a 140 day lag.

The plots for a 20, 40 and 60 day lag are pretty similar. The biggest difference is the slope of the trend line which, for all lags, has a very high *p*-value suggesting that the correlation has a high statistical significance. The plot for a lag of 40 days is shown below:



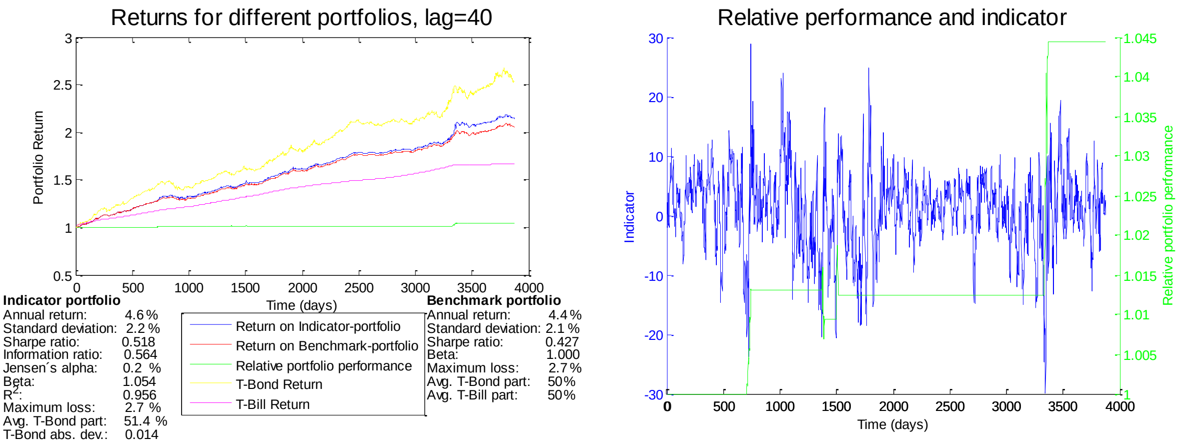
The correlation is negative which means that for high indicator values, the proportion of T-Bills should be increased and vice versa. For very low indicator values, the return on T-Bond/T-Bills is high. However, such low values on the indicator have only occurred during the 2008 financial crisis. The statistical significance of the trend line is very high. The result obtained from this indicator points in the same direction as what is theoretically expected since, at least for relatively small lags, the return vs indicator plot has a negative correlation.

Running the test model, using each value of the indicator to decide the allocation between T-Bills and T-Bonds gives the following result:



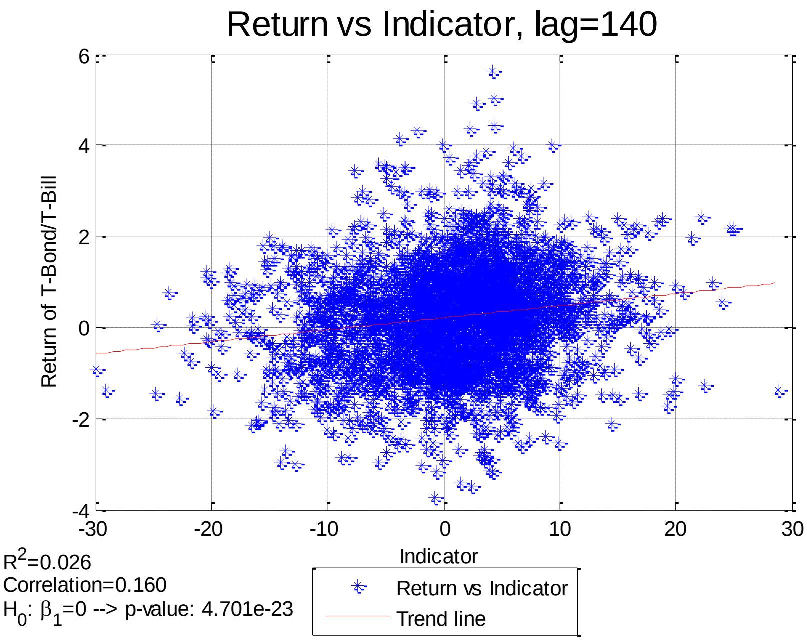
As always, each position is held for one month. The indicator portfolio and the benchmark portfolio perform pretty equally until the crisis in 2008. During the crisis the return on the indicator portfolio is higher than the benchmark. The Sharpe ratio is almost the same for the indicator portfolio and the benchmark and the information ratio is low. The indicator portfolio has a higher return but is a bit more volatile but still has a lower maximum loss and a β-value below one. In the graph to the right, the relative performance is plotted together with the indicator. It is difficult to see any pattern other than that during the financial crisis in 2008 the indicator portfolio performs better.

Running the test model, calibrated only to act when the indicator value is lower than or equal to -20 gives the following returns:



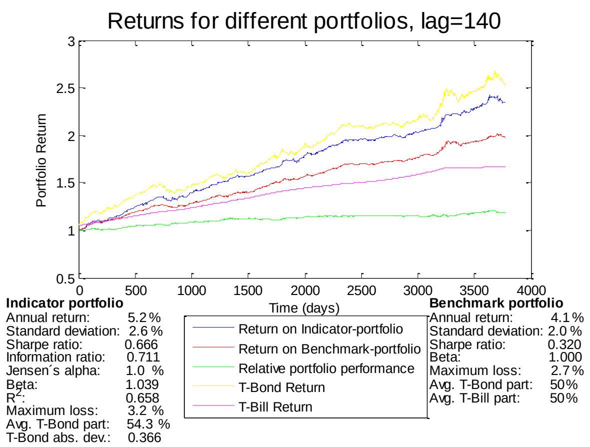
The Sharpe ratio for the indicator portfolio is higher than the benchmark due to higher annual return and almost equal volatility. Also the information ratio for the indicator portfolio is high. The relative performance curve shows that the indicator portfolio's excess return is only gained during the financial crises 2000 and 2008.

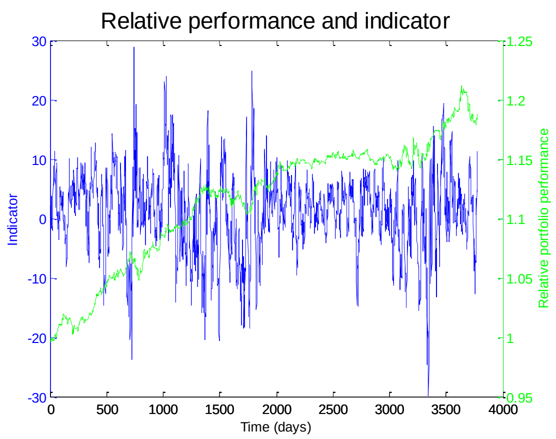
For a lag of 140 there is a positive correlation between the indicator and the T-Bond/T-Bill return as shown in the plot below:



Now, the correlation between the indicator and the T-Bond/T-Bill return is positive. No other trend or pattern is easy to discern from this graph. The statistical significance of the trend line is very high, although R^2 indicates that the fit to the data is poor.

Running the test model, set to decide the proportion of T-Bonds and T-Bills based on the value of the indicator and, as usual and set to hold each position for one month, yields:

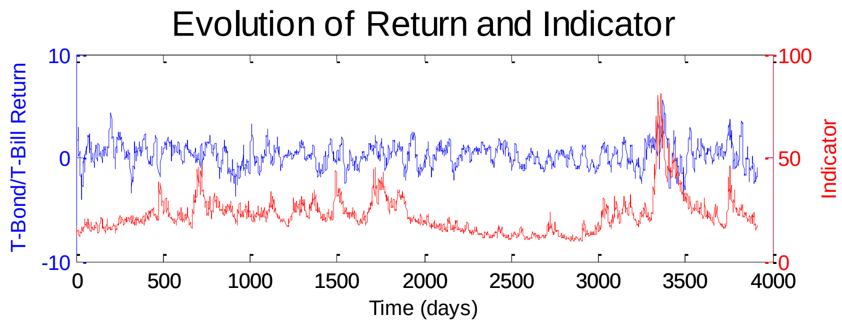


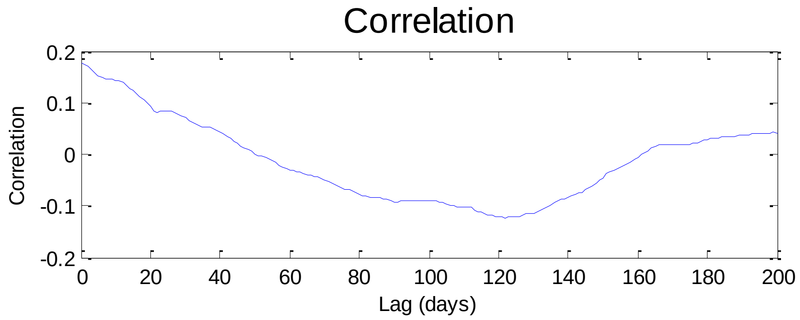


This strategy gives a lot higher return than the benchmark portfolio. It is difficult to explain why the indicator portfolio performs so much better in this case with a lag of 140 compared to the case where the lag is 40. Partly due to a very low R^2-value, the value of Jensen's alpha is quite high. The indicator portfolio has a higher maximum loss than the benchmark. The relative performance plot in the graph to the right shows an increase during the whole time period except for the last bit. Also, the Sharpe ratio is a lot better for the indicator portfolio than for the benchmark but the maximum loss is higher.

7.4.4 VIX

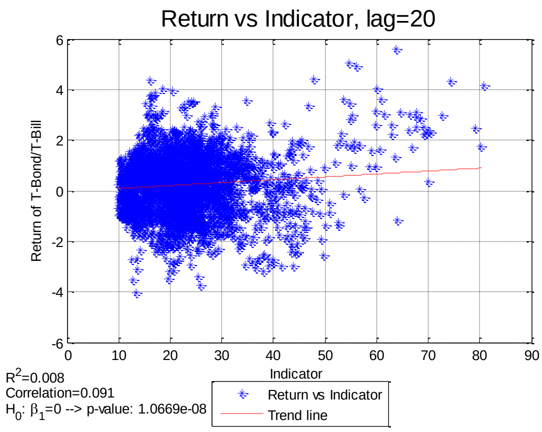
The VIX-index is a measure of the implied volatility of S&P 500 index options. The index is updated every day and a high value indicates distress on the equity market which, in theory, should be positive for the bond market.

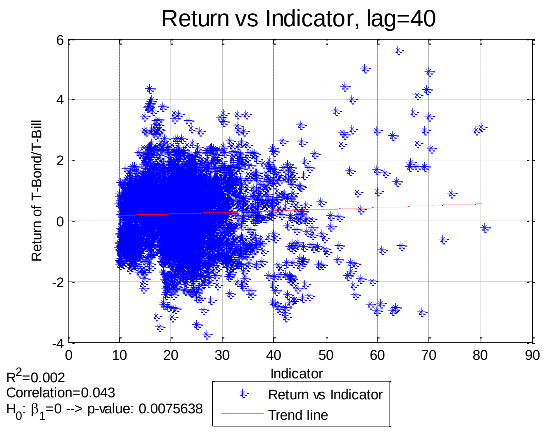


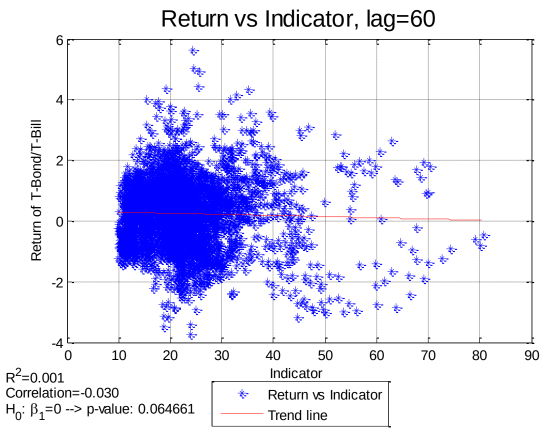


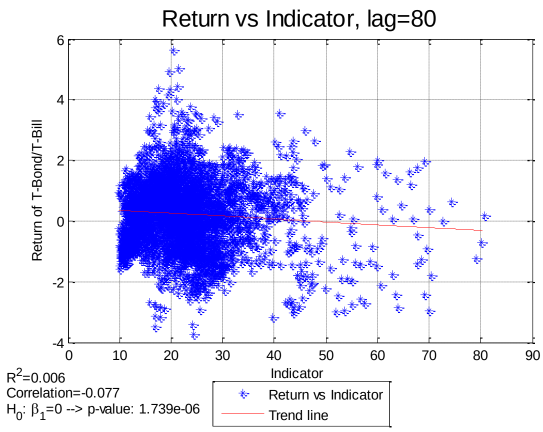
From the top graph it can be seen that when the indicator exhibits extreme values, the T-Bond/T-Bill return goes up as well indicating that T-Bonds are to be preferred before T-Bills. The indicator's normal value is around 20 and with peaks around 40 and sometimes as high as 80.

Plots with lags of 20, 40, 60 and 80 days can be seen below:



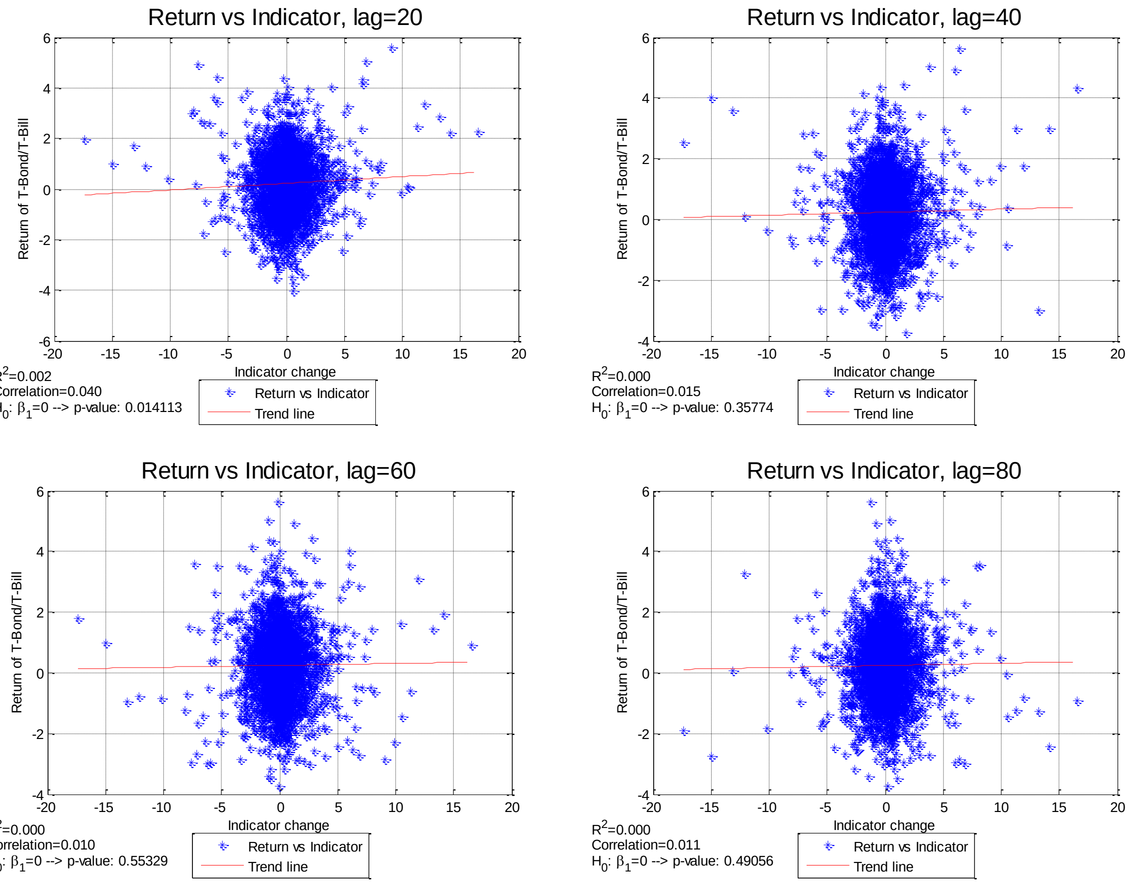






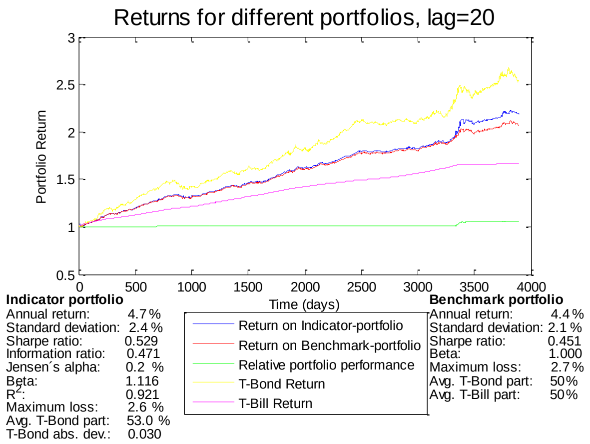
As seen in the indicator- and T-Bond/T-Bill graph on the top, the 20 days lag plot shows positive correlation for indicator values higher than 50 but such high values have only occurred during 2008. However, the correlation gets lower as the time lag grows and after 40 days it is almost gone and after 60 days the correlation has become negative. It seems like this indicator affects the bond market so quickly that, when lag is applied on it, its effect diminishes. The result obtained from this indicator points in the same direction as what is theoretically expected since the return vs indicator plot has a positive correlation.

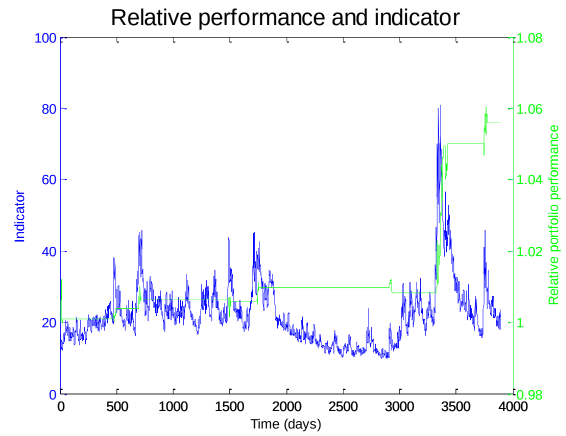
The plot below shows what happens with the T-Bond/T-Bill return after changes in the indicator.

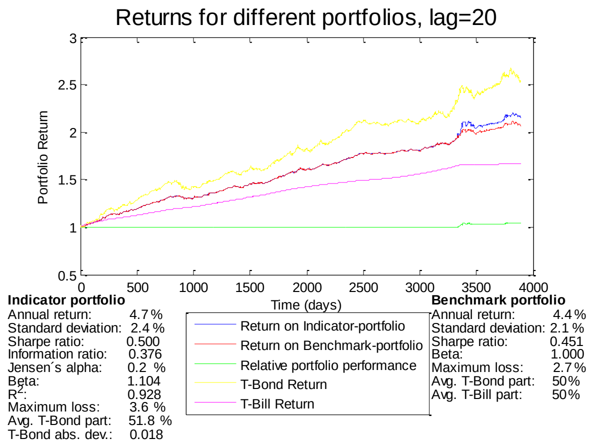


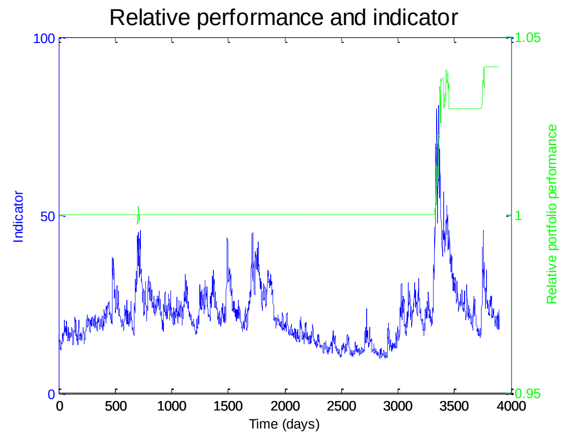
With a lag of 20 days, the T-Bond/T-Bill return following a big change of the indicator is positive. This tendency diminishes as the lag is increased and when the lag is 60 days, the tendency is almost inverted. As usual, the most extreme changes of the indicator have only appeared during the financial crisis in 2008 and hence are difficult to draw conclusions from.

Running the test model with a 20 day lag and under the condition only to act on value-changes larger than seven and smaller than minus seven yields the following result:





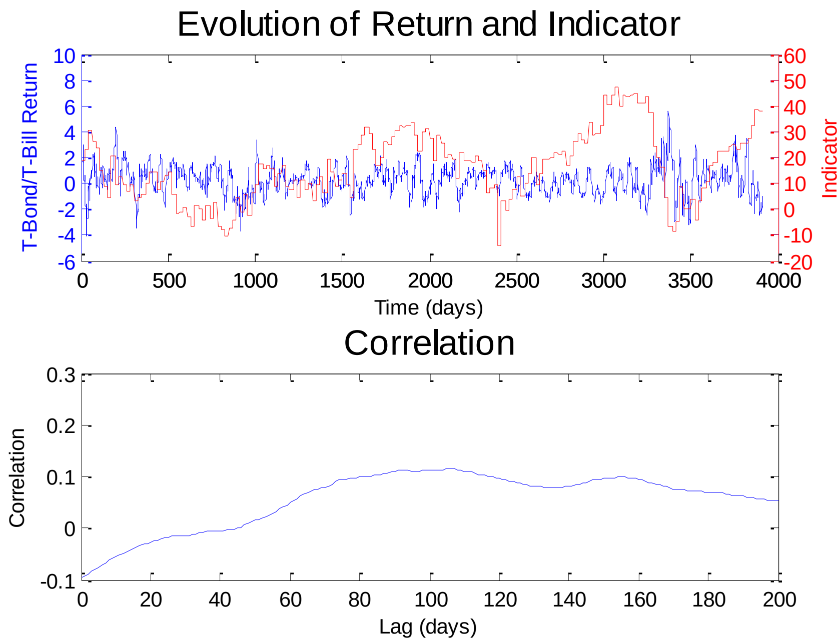




In the pictures on the top, the model acts on value-changes larger than seven and in the pictures on the bottom the model acts on value-changes smaller than -7. In both cases, the indicator portfolio performs better than the benchmark but with a little higher volatility and in the bottom case, with a little higher maximum loss. The Sharpe ratio is also higher for the indicator portfolio in both cases and the relative performance curve is moving upwards steadily without many dips. Indicator value-changes smaller than -7 only occur during the 2008 financial crisis and thus might be difficult to draw any conclusions from. Value-changes larger than seven, however, have occurred at several occasions during the test period but most of the excess return of the indicator portfolio is, again, gained during the financial crisis. The lag is also quite short which requires a quick response to the indicator values.

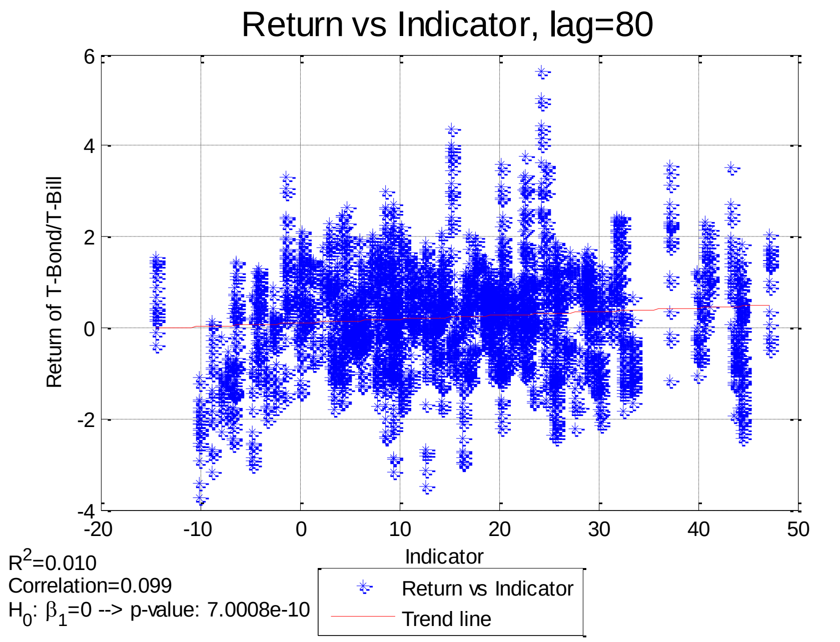
7.4.5 Sweden, consumer confidence, price trends over next 12 months

Consumer confidence is an economic indicator updated every month which measures the optimism the consumer feel about the overall state of the economy and their personal financial situation. A lower value of the consumer confidence often implies a weaker economy which, in theory, should be good for government bonds.



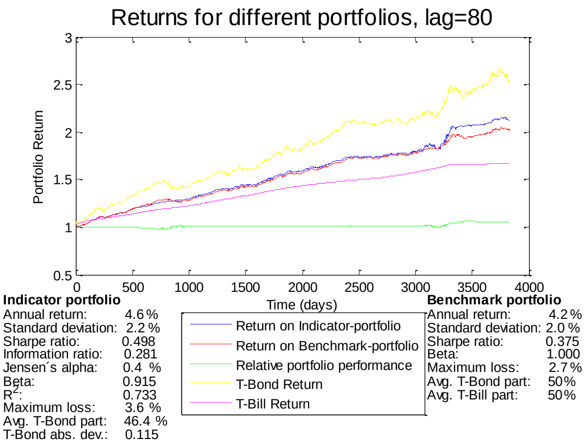
It is difficult to see any patterns between the indicator and the T-Bond/T-Bill return from the top graph. The correlation the two entities is increasing as the lag is increased up to a lag around 80 days.

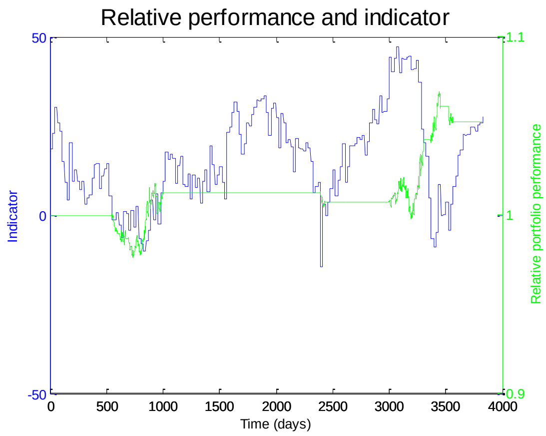
Plotting for a lag of 80 days gives the following:



The R^2-value is very low and shows a bad fit of the data to the trend line. The correlation is also quite low. However, for extreme values of the indicator, there seems to be a pattern, albeit weak. For values lower than -1 of the indicator, the T-Bond/T-Bill return often is low and for values higher than 36 the same return often is high. The high extreme values only occur during the 2008 financial crisis, however the low extreme values occurs every now and then. The result obtained from this indicator points in the opposite direction of what is theoretically expected since the return vs indicator plot has a positive correlation.

Testing this pattern in the test model yields the following:

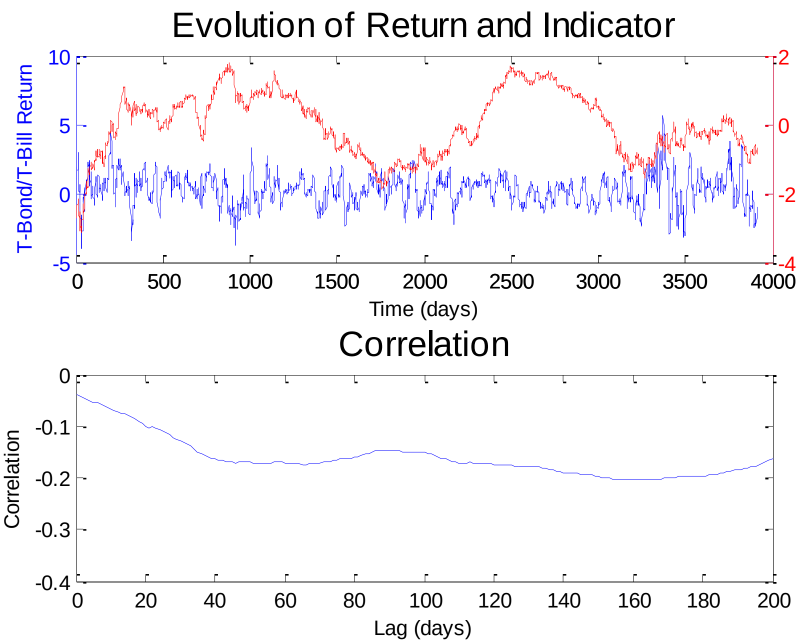




As seen in the graph to the left, the indicator portfolio gives a 5.4 percent annual return whereas the benchmark portfolio gives a 4.7 percent annual return but is less volatile. The Sharpe ratio for the indicator portfolio is also a lot higher than the benchmark and the information ratio is relatively high. In the graph to the right, the relative performance is depicted together with the evolution of the indicator and it shows that the indicator portfolio is performing equally well or better than the benchmark for almost the whole time period.

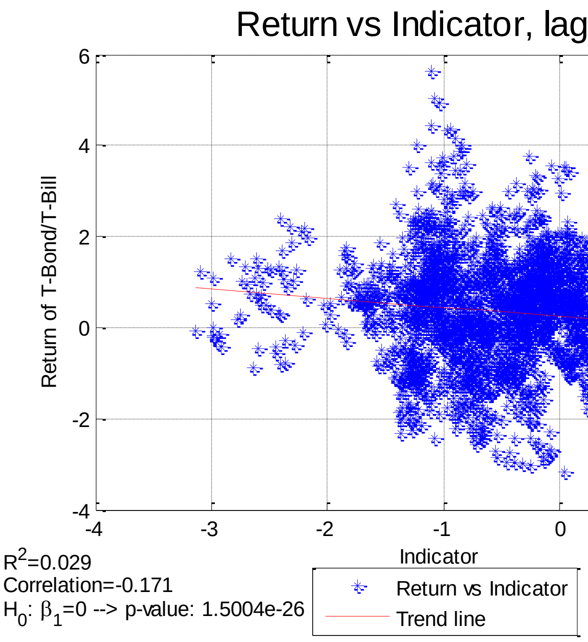
7.4.6 United States-Sweden Government Bonds, 5 Year, Yield

A high positive value of the interest gap between the US and Sweden implies that the economic state of the Swedish government is better than that of the US which should be positive for the Swedish government bond market.



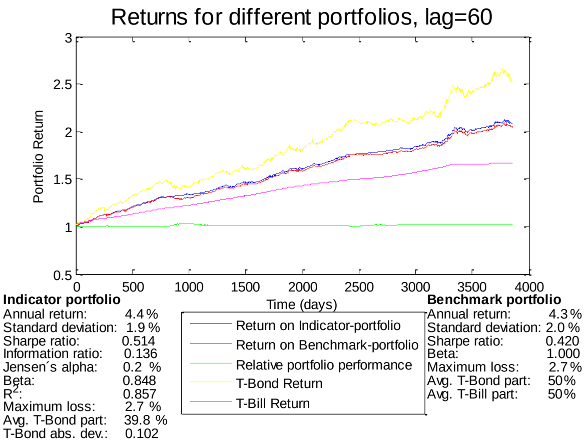
Again, it is difficult to discern any patterns or trends just by looking at the graph on the top which also is confirmed by the fact that the correlation between the T-Bond/T-Bill return and the indicator at a lag of zero days is very close to zero. The indicator values are mostly moving between -1 and 1. However, the indicator changes slowly over time. When applying a lag of 40 days or more the correlation is around minus 0.2.

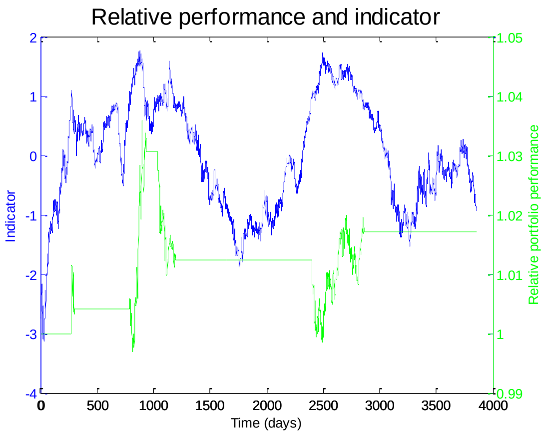
The return vs indicator plots with a lag of 40, 60 and 80 days look similar. The 60 days lag plot looks like:



The R^2 value is low but the statistical significance of the slope of the trend line is high. For indicator values larger than one, there is a slight tendency of negative returns which would suggest that T-Bills are to be preferred to T-Bonds. Indicator values larger than one occurs at several occasions during the studied time period which implies that this tendency is repeating itself. The result obtained from this indicator points in the opposite direction of what is theoretically expected since the return vs indicator plot has a negative correlation.

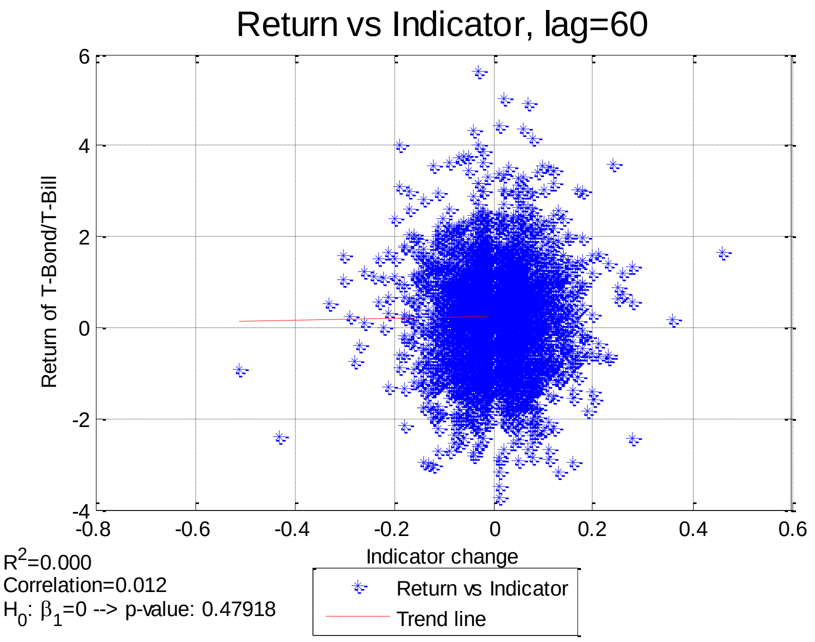
Running the test model calibrated to act only on indicator values larger than one gives the following:





The indicator portfolio has an annual return slightly higher than the benchmark. It also has lower volatility and a higher Sharpe ratio together with a relatively low information ratio. Jensen's alpha is 0.3 percent for the indicator portfolio and the maximum loss is the same for both portfolios. In the graph to the right, the relative performance curve is magnified and shown together with the evolution of the indicator. Even though this strategy does not give a constantly increasing relative performance curve, the indicator portfolio performs better than the benchmark during every period that contains indicator values above one.

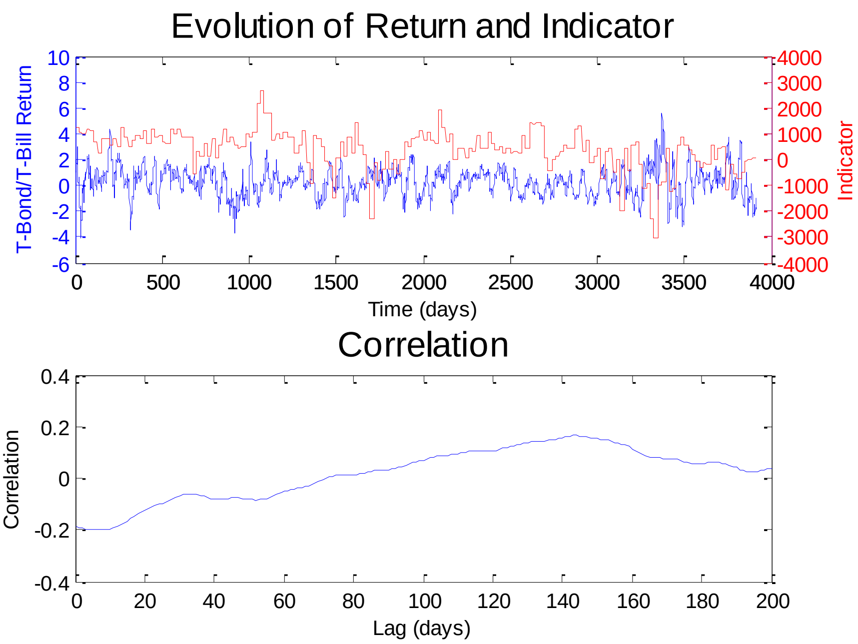
When plotting the T-Bond/T-Bill return together with changes of the indicator no interesting tendency or pattern is found for any time lag:



The values form a blob around the origin which is impossible to draw any conclusions from.

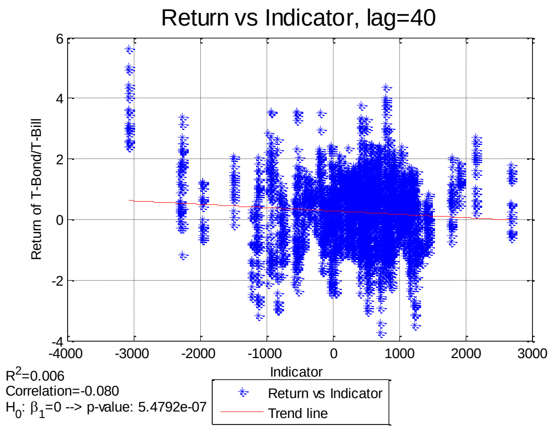
7.4.7 United States, Net New Flow of Mutual Funds, Stock, Total, USD

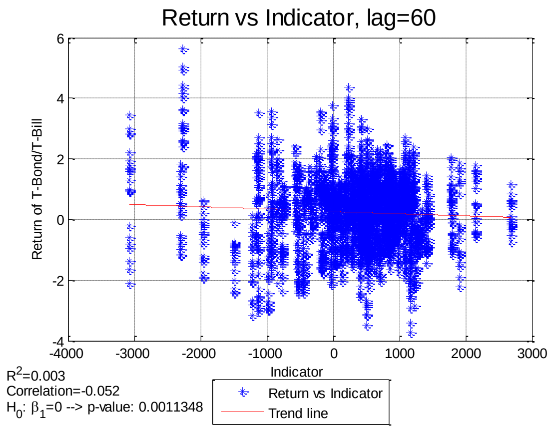
This indicator is updated once every month and measures the flow of money to stocks in mutual funds. A high indicator value hence should imply a low T-Bond/T-Bill return.



In the top graph, some inverse dependence can be seen between the indicator and the T-Bond/T-Bill return. This is also confirmed by the correlation graph which shows a negative correlation for a zero day lag.

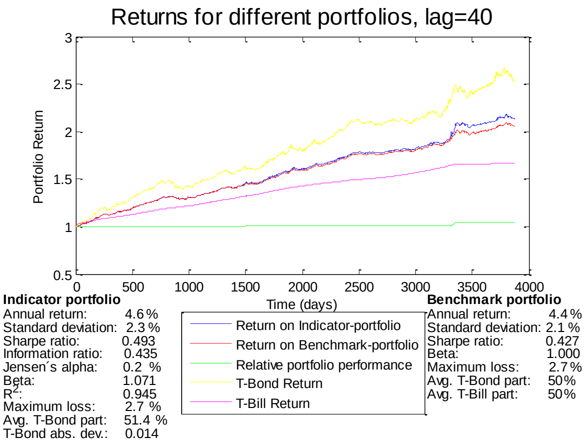
Plotting the indicator against the T-Bond/T-Bill return with a 40 and 60 day lag gives the following graphs:

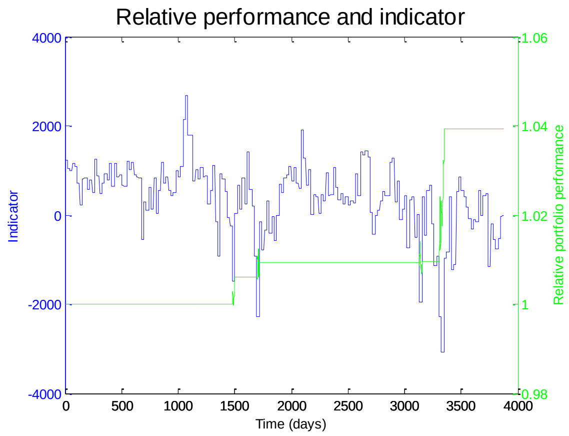




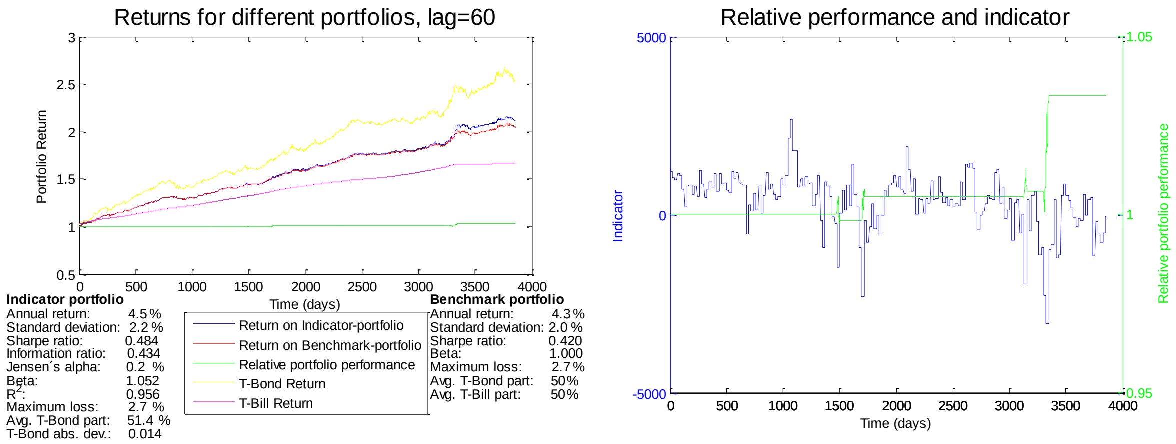
Since the indicator is only updated once every month, there are around 20 returns for every indicator value. As seen in the plot to the right and especially in the one to the left, for low indicator values the return is often positive. Indicator values lower than -1400 occurs at different occasions a few times during the studied time period and for many of these occasions, the T-Bond/T-Bill return is positive. The result obtained from this indicator points in the same direction of what is theoretically expected since the return vs indicator plot has a negative correlation.

Running the test model under these conditions for a 40 and 60 day lag yield:



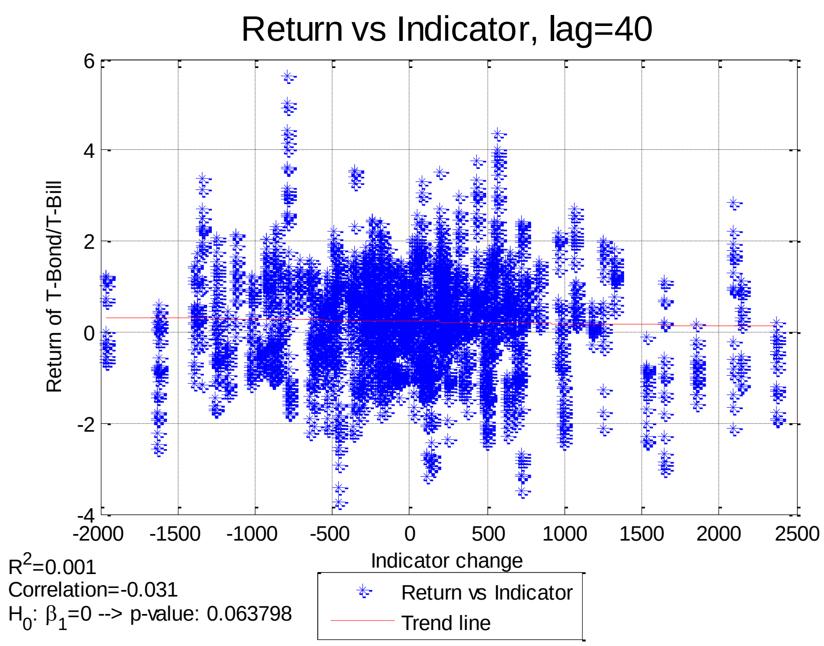


In the 40 day lag case, the annual return and standard deviation is slightly higher for the indicator portfolio compared to the benchmark portfolio. The Sharpe ratio is higher for the indicator portfolio together with the information ratio which shows that it has higher return relative to its risk. The maximum loss is the same for both portfolios. The relative performance curve to the right shows that the indicator only reaches -1400 or below a few times but the fact that the strategy works at different occasions separated by relatively long time makes the result more reliable since this indicates that the pattern is repeating itself.



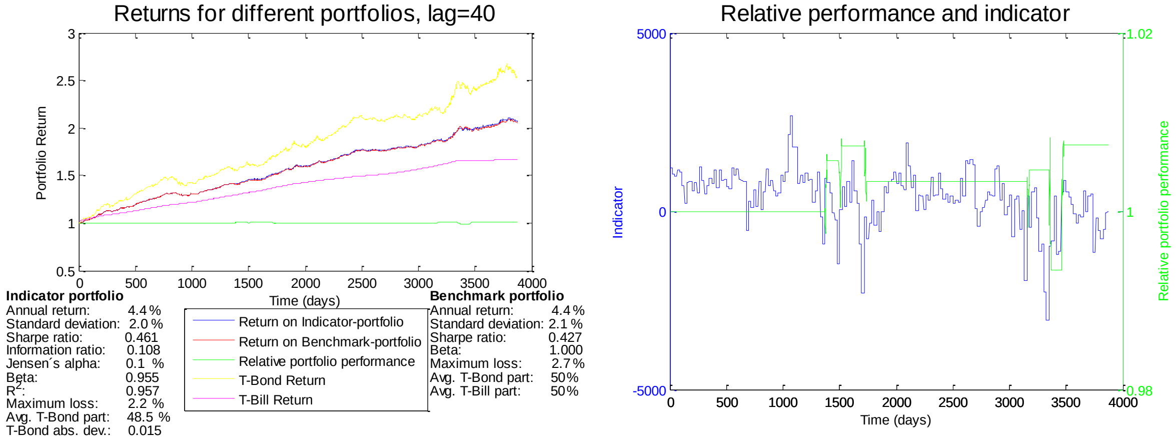
The result in the 60 day lag case is very similar to the previous case. The biggest difference is that in this case, a very large proportion of the excess return of the indicator portfolio is gained during one time period, which lowers the reliability of this strategy with this time lag compared to with a time lag of 40 days.

Plotting what happens after a large change in the indicator with a 40 day lag gives the following graph:



For changes in the indicator larger than 1500 the return is mostly negative which suggests that T-Bills are to be preferred to T-Bonds. For smaller and negative value changes, no interesting pattern or trend is distinguishable.

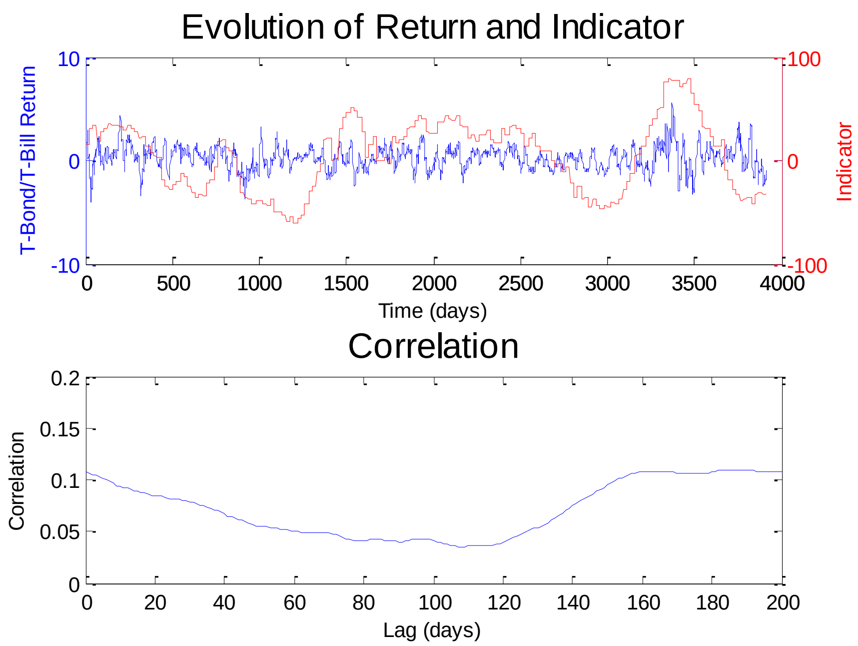
Running the test model set only to act on value changes larger than 1500 yields the following:



The indicator performs almost equally well as the benchmark, with only a little higher return and a little lower volatility. The relative performance curve is jumping up and down which indicates that this strategy is not very reliable.

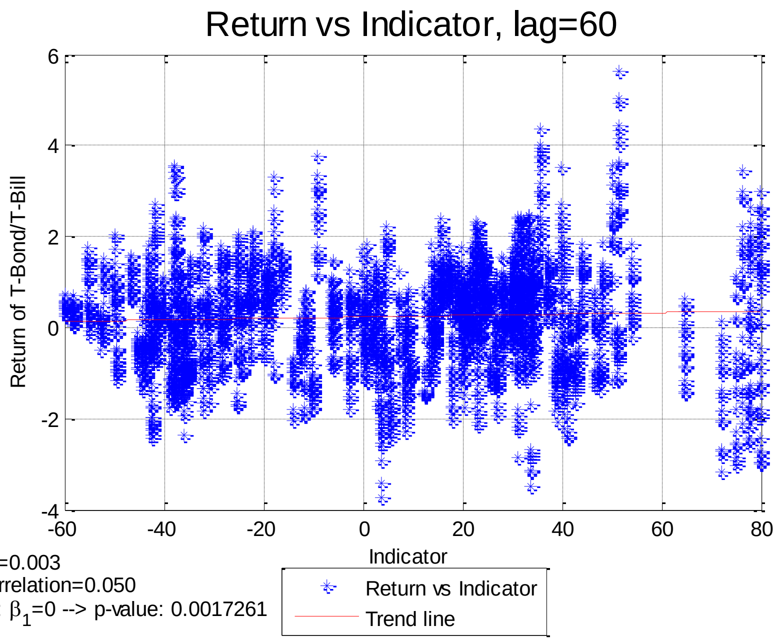
7.4.8 Sweden, Unemployment over the next 12 months

The Konjunkturinstitutet gather data on a monthly basis through surveys of consumers. The surveys are a measure of the degree of optimism on the state of the economy that consumers are experiencing. Decreasing values of the index often implies slowing economic growth which often means that government bonds will perform better, especially T-Bonds.



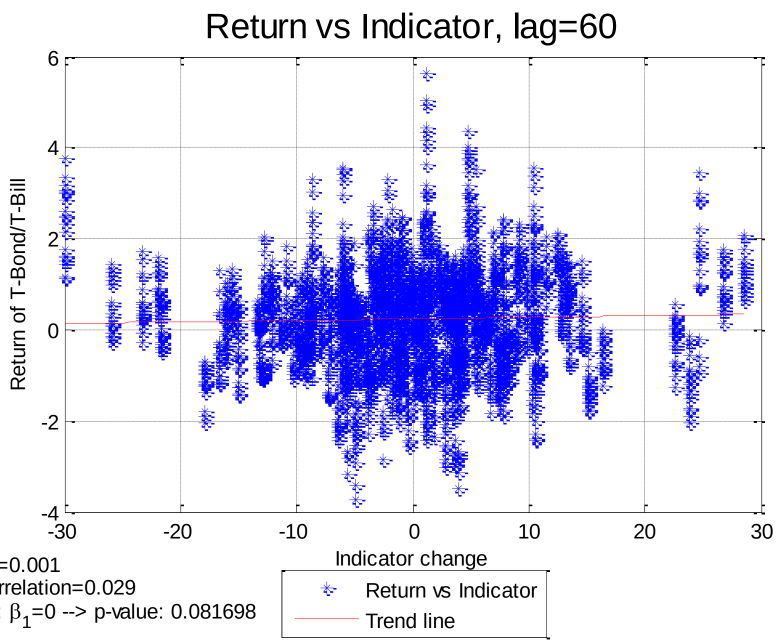
The indicator seem to have some correlation with the T-Bond/T-Bill return graph, at least after 3000 days, however in the first half of the studied time period no obvious pattern is present. The correlation plot is close to zero for all lags larger than 20 days.

The typical return vs indicator plot for different lags of this indicator looks as follows:



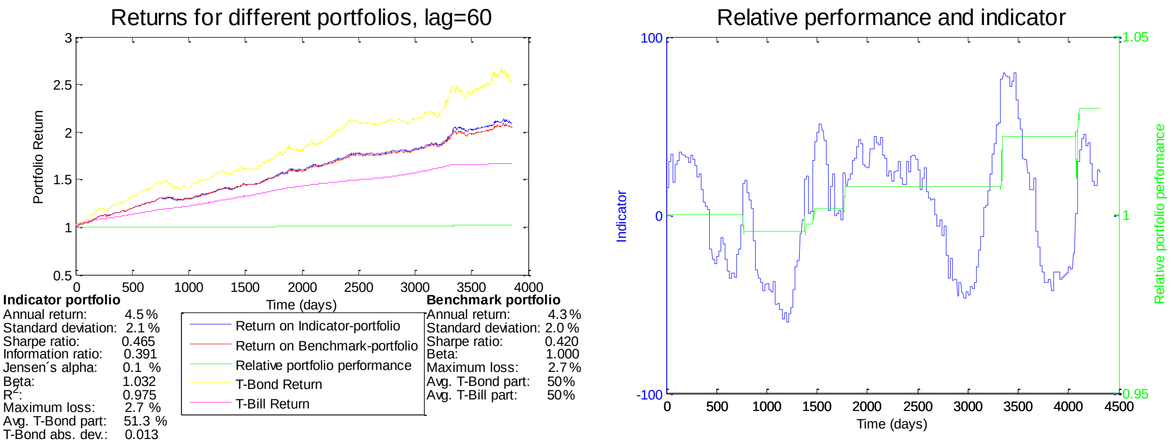
The plot shows no resemblance of a pattern whatsoever which is confirmed by the R^2 value, which equals zero, and the low significance of the slope of the trend line. The result obtained from this indicator does not point in the same direction as what is theoretically expected since the return vs indicator plot has almost zero correlation.

Plotting what happens with the T-Bond/T-Bill return following a change in the indicator gives:



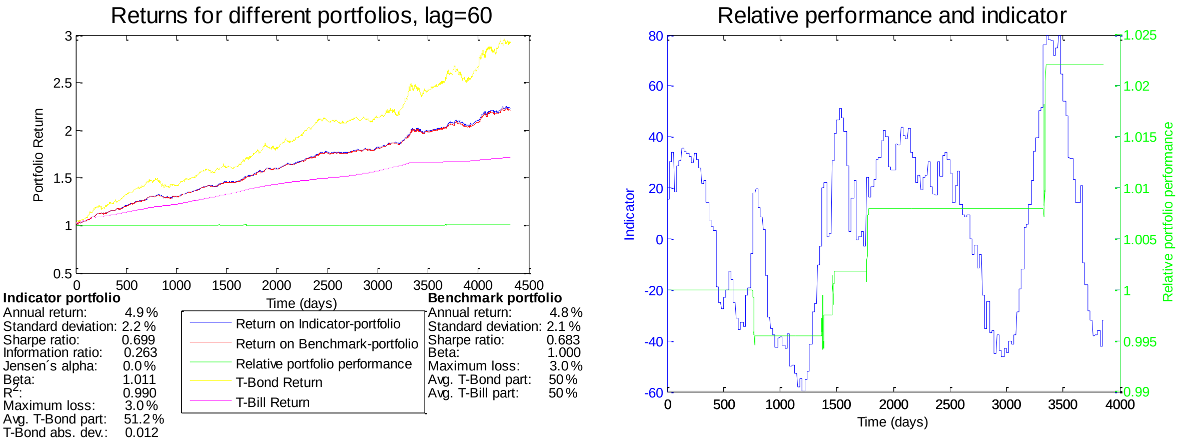
Again, the statistical measures show no indication of a pattern, but looking at extreme changes of the indicator values, with a 60 day lag, the return often is positive for both positive and negative changes. Such large jumps of the indicator have occurred every now and then throughout the time period studied which can be seen in the relative performance curves below.

Running the test model, set to act on value changes larger than 20 yields the following graphs:



The annual return, together with the volatility and the Sharpe ratio, is a little higher for the indicator portfolio than for the benchmark portfolio. The maximum loss is the same for the two portfolios and the beta value is close to one. The high R^2-value gives a low value on Jensen's alpha. The relative performance curve is increasing almost every time a value change larger than 20 occurs. However, most of the indicator portfolio's excess return is gained around the time of the latest financial crisis.

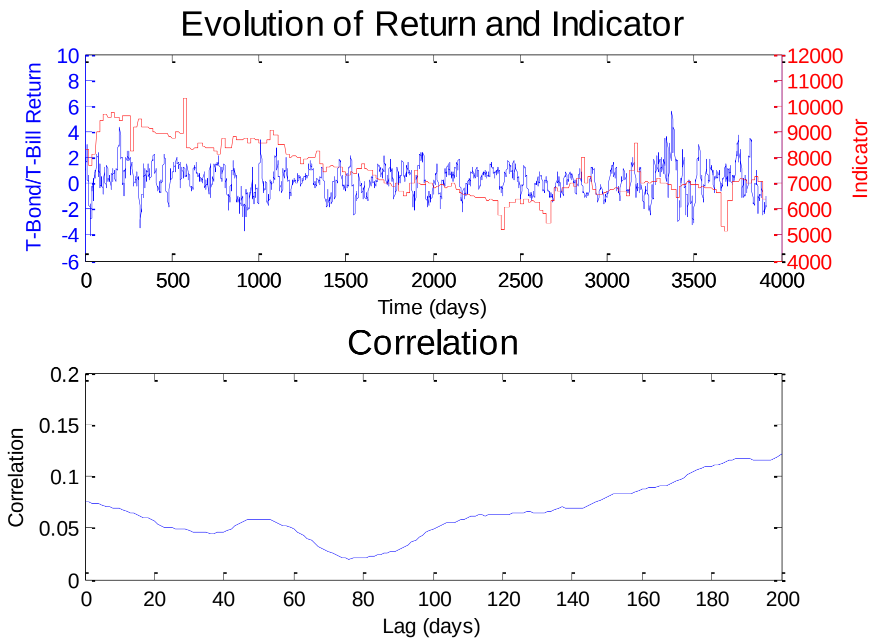
Acting on value changes of -20 and smaller the corresponding result is:



The indicator portfolio performs only marginally better than the benchmark and the relative performance curve shows that more than half of its excess return is gained during the 2008 financial crisis which lowers the reliability of this strategy.

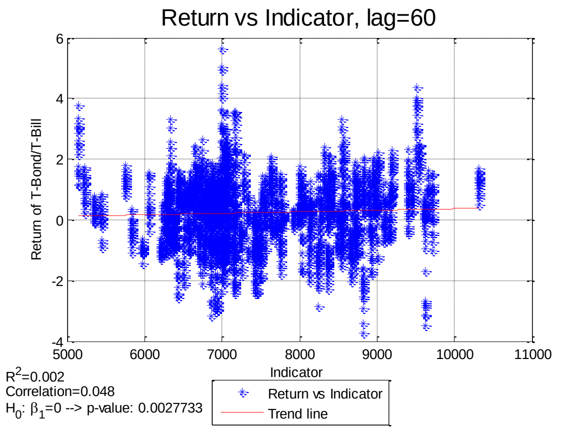
7.4.9 Germany, Labour Costs & Turnover in the Construction Sector

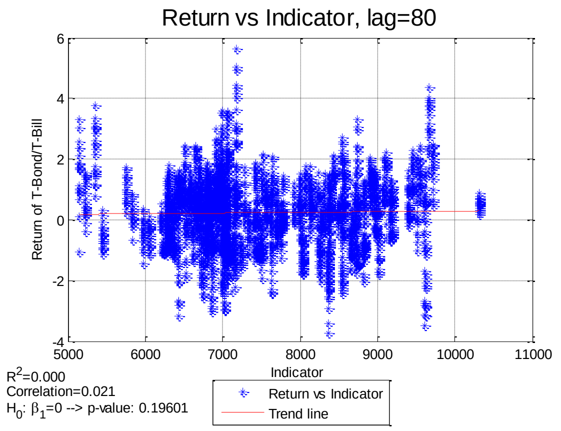
This indicator is updated on a monthly basis and measures the activity on the German construction companies. A high indicator value should imply a strong overall economy and hence a weak government bond market.



The indicator is evolving relatively slowly over time and has, for more than half of the studied time period, been around values of 7000. The correlation curve is a bit jumpy and very low for any lag.

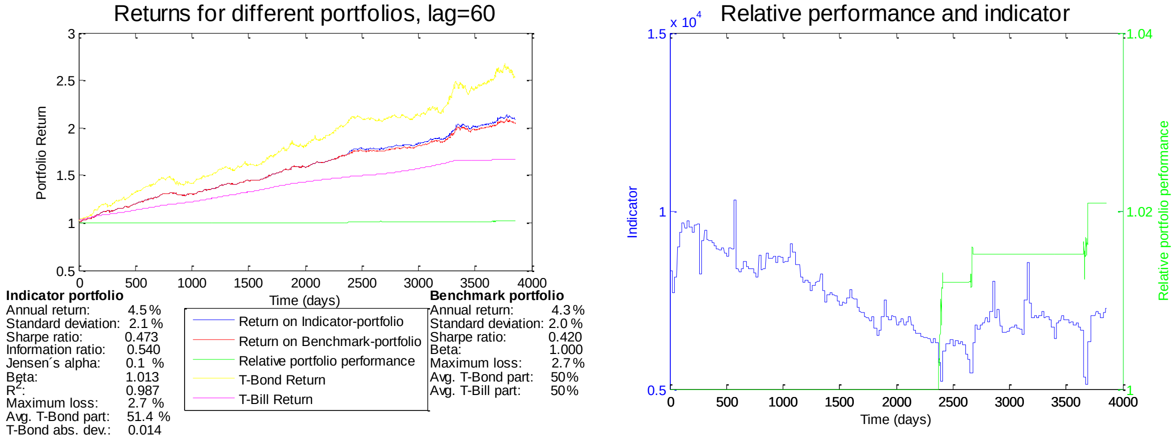
Plotting the T-Bond/T-Bill return against the indicator with lags of 60 and 80 days gives the following:





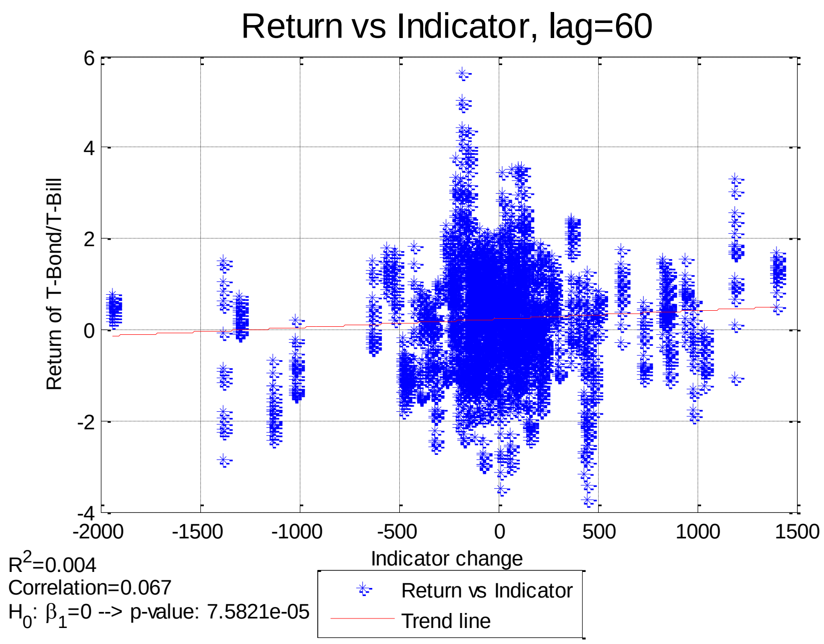
The two plots are very similar and their statistical measures show a very low correlation between the returns and the indicator, although the statistical significance of the trend line in the 60 day lag case is high. Again, it is in the extreme values the existence of some kind of tendency is found: For very low indicator values, high returns on the T-Bond/T-Bill quota are common. As seen in the first graph in the paragraph such low values do only occur on a few occasions and only during the second half of the studied time period. The result obtained from this indicator does not point in the same direction as what is theoretically expected since the return vs indicator plot has almost zero correlation.

Running the test model for the 60 day lag case, since the two plots above are so similar, set to act on values lower than 5800 yields:



The indicator portfolio performs only a little better than the benchmark using this strategy with only small differences between the performance measures of the two portfolios. The relative performance curve is almost non-decreasing but since such low values only occur on few occasions the strategy might not be very reliable.

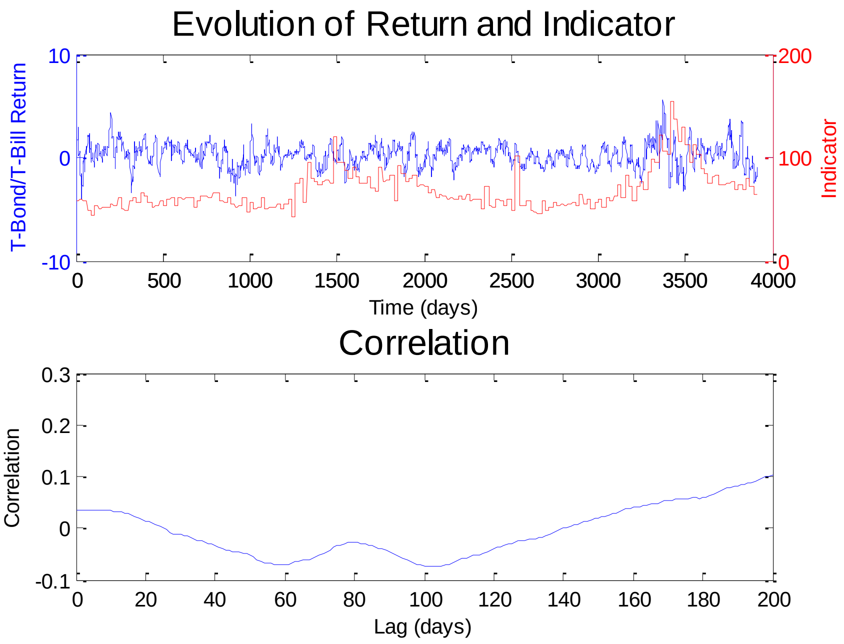
Plotting the T-Bond/T-Bill return against changes in the indicator yields the following graph:



The plots with other lags are similar to this one and show no interesting tendencies that are worth mentioning.

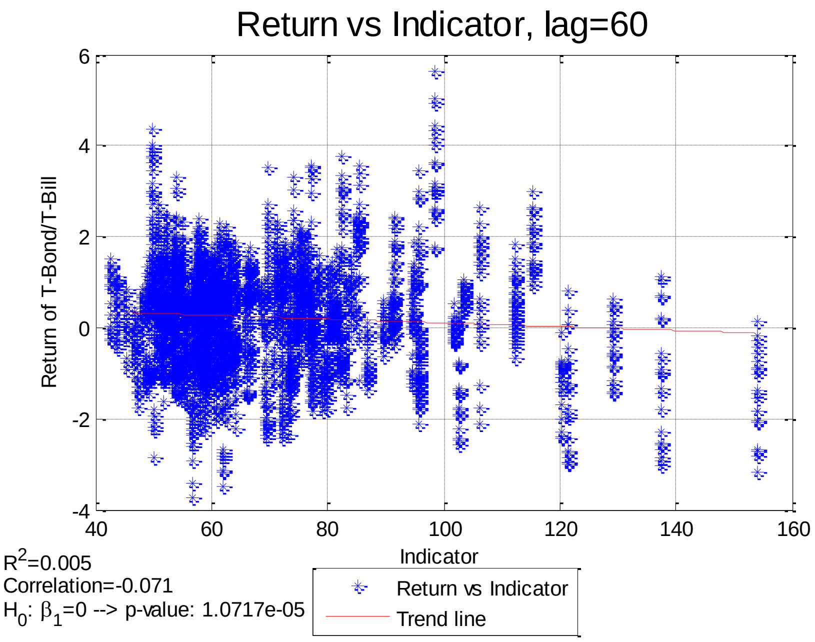
7.4.10 United States, Labour Turnover

This indicator is updated once every month and measures the US labour market. A high indicator value suggests high unemployment and hence a weak overall economy which should be positive for the government bond market.



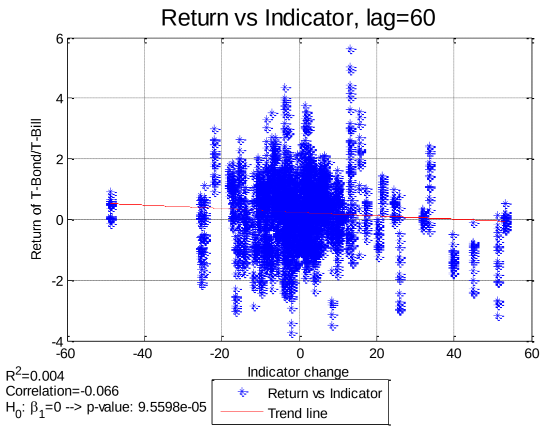
The indicator is relatively stable over time, with a few peaks along the way. The correlation plot shows that the correlation between the T-Bond/T-Bill return and the indicator is low regardless of the lag.

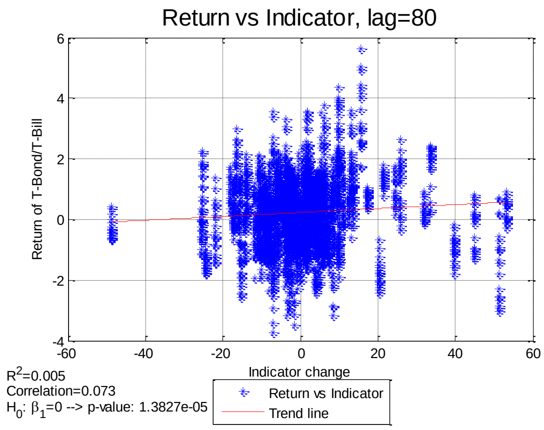
The typical return vs indicator plot for this indicator looks as follows:



Even though indicator values above 120 seem to co-occur with negative returns, this observation is not very usable since such low values only occur during one time period which is the 2008 financial crisis. The result obtained from this indicator does not point in the same direction as what is theoretically expected since the return vs indicator plot has almost zero correlation.

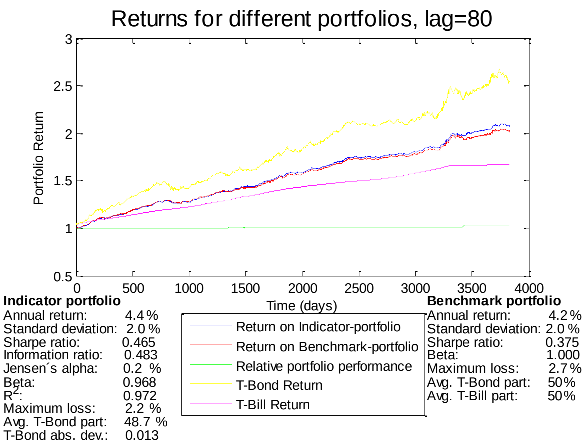
Plotting T-Bond/T-Bill return against changes of the indicator values gives:

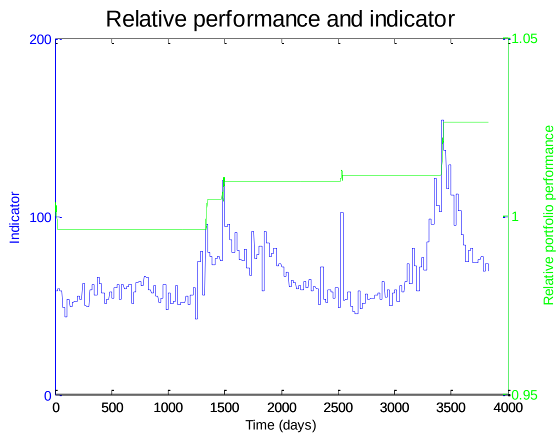




Overall, the two plots does not show any trend, which also is the conclusion drawn from looking at the statistics for the plots. However for positive extreme values, returns are often negative for both 60 day and 80 day lag.

Running the test model for an 80 day lag, since the two plots are similar, set to act only on indicator value changes equal to or higher than 40 gives:

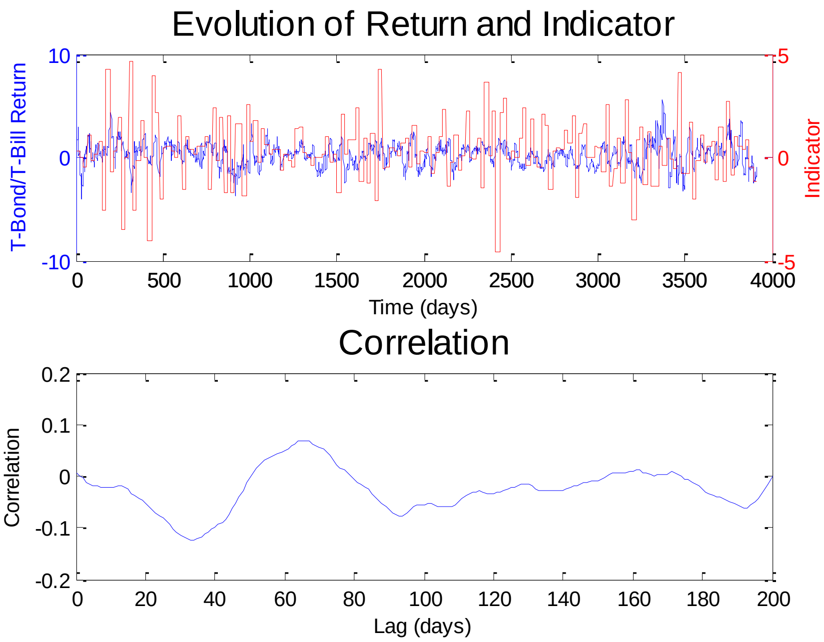




The annual return is a little higher for the indicator portfolio than for the benchmark and their volatility is equal. The Sharpe ratio is higher for the indicator portfolio and the maximum loss is the same as the benchmark's. The relative performance curve is almost non-decreasing and shows that changes in the indicator as high as 40 are not very common but are spread out over the whole time period.

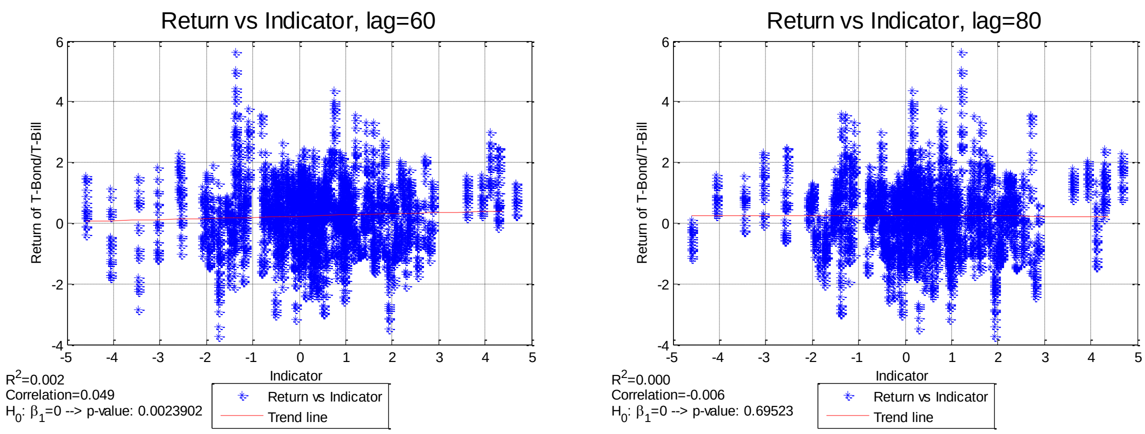
7.4.11 Sweden, Total Retail Trade (Volume), Change

This indicator is updated once every month and measures the sale of goods and services from individuals or businesses to the end user. High values of this indicator imply high spending among consumers which suggest a strong economy. This is often negative for the government bond market and should result in negative T-Bond/T-Bills returns.



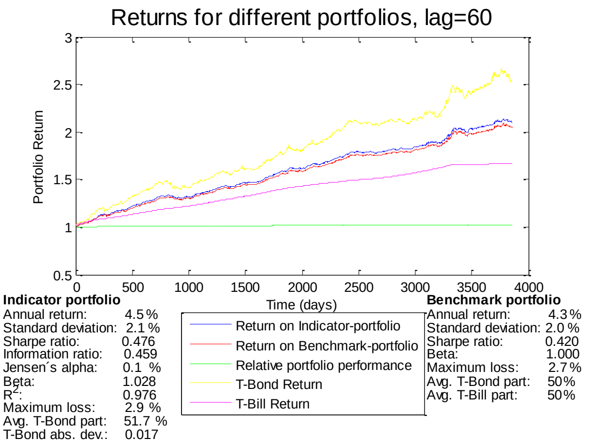
The indicator is oscillating around zero, and mostly takes values between -2 and 2. The correlation curve is very irregular but stays around zero for every lag.

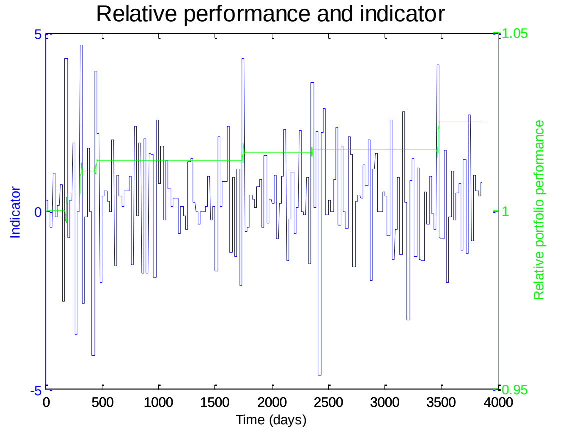
Plotting the T-Bond/T-Bill return against the value of the indicator yields interesting cases when the lag is 60 and 80 days:



For both cases, the statistical measures show no indication of trends in the data. The R^2 values are zero or very close to zero and the statistical significance of the slope of the trend line is low. However, high extreme values of the indicator correspond, for both cases, to a positive return of T-Bond/T-Bill. In the 80 day lag case, low extreme values also often give a positive T-Bond/T-Bill return. Looking at the first plot in this paragraph shows that such extreme indicator values occur every now and then during the studied time period which gives more credibility to a strategy based on it. The result obtained from this indicator does not point in the same direction as what is theoretically expected since the return vs indicator plot has almost zero correlation.

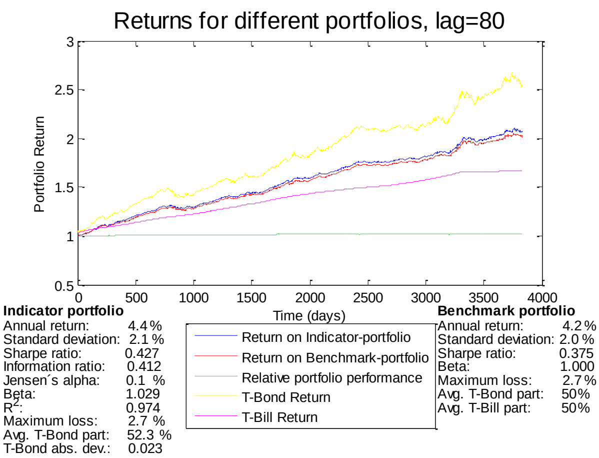
Running the test model set to act only on indicator values above 3 with a 60 day lag on the indicator gives:

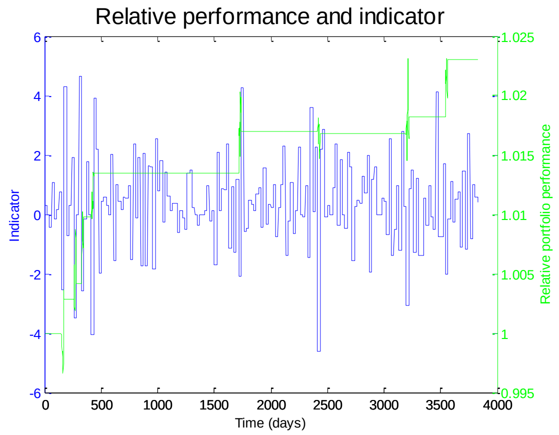


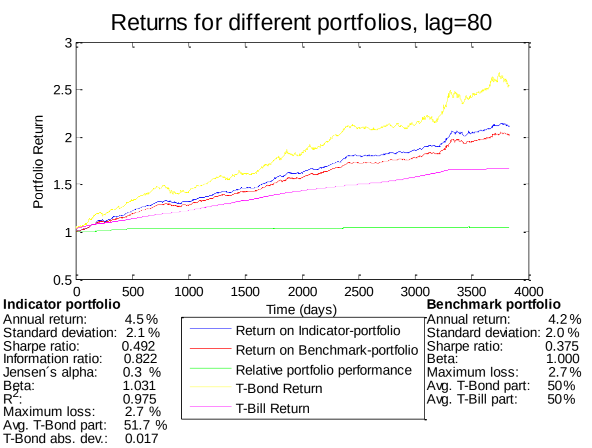


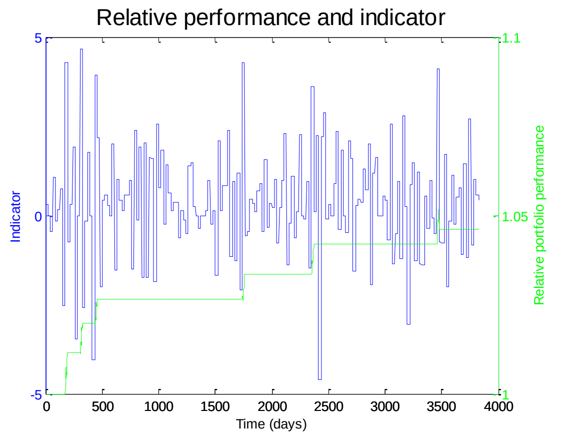
The annual return is higher for the indicator portfolio than for the benchmark together with the volatility and the Sharpe ratio whereas the maximum loss is equal for both portfolios. The information ratio is relatively high and Jensen's alpha is low due to the high value of R^2. The relative performance curve is steadily increasing throughout the time period.

Running the test model with an 80 day lag and set to act only on indicator values below -2 and above 3 yields the following result:





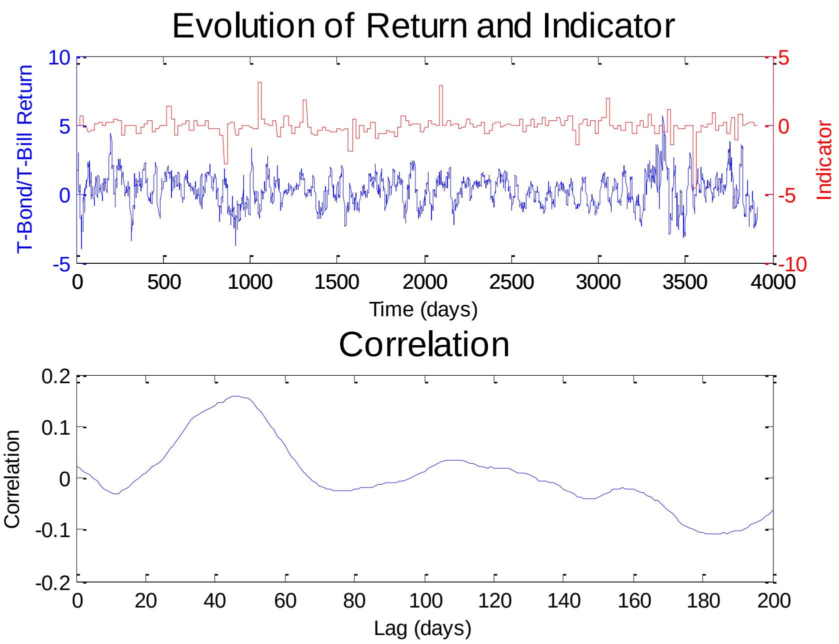




The top two graphs are the result of the model acting on values below -2. The indicator portfolio has a slightly higher annual return, volatility and Sharpe ratio, but has the same maximum loss as the indicator portfolio. The information ratio is high and the average absolute deviation of the T-Bond part from 50 percent is low. The relative performance curve reveals that most of the indicator portfolio's excess return is created at two distinct occasions: between day 250 and day 500 day and at day 4000. Between those dates, the indicator portfolio performs equally well as the benchmark portfolio. The bottom two graphs are the result of the model acting on values above 3. The indicator portfolio performs better or equally well as the benchmark in every measure except for the volatility where the benchmark is slightly lower. The relative performance curve is increasing throughout the whole time period and almost never decreases which means that the indicator portfolio performs better or equally well as the benchmark portfolio all the time.

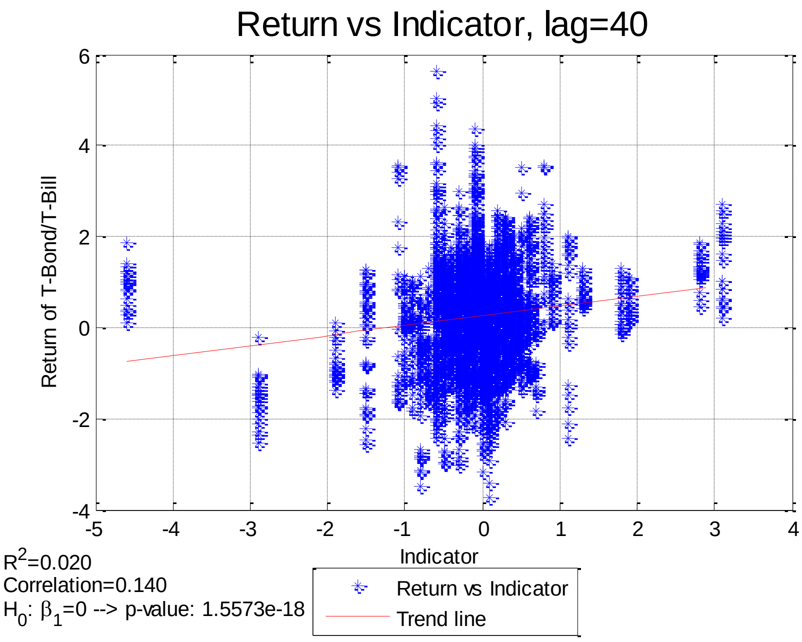
7.4.12 Germany, Retail Sale of Hardware, Change

This indicator is updated once every month and measures the sale of goods and services from individuals or businesses to the end user. High values of this indicator imply high spending among consumers which suggest a strong economy. This is often negative for the government bond market and should result in negative T-Bond/T-Bills returns.



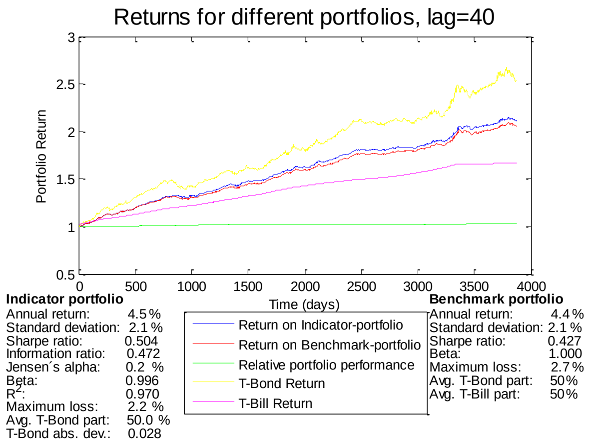
The indicator is mostly doing small oscillations around zero. At lag zero, the correlation with the T-Bond/T-Bill return is almost zero and at a lag around 40, the correlation between the T-Bond/T-Bill return and the indicator peaks at just above 0.1. For larger lags, the correlation stays around zero.

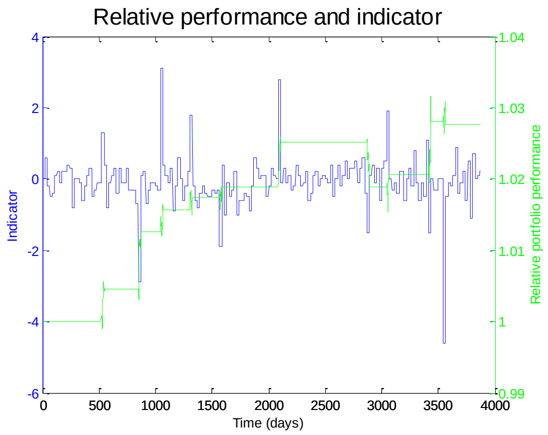
The return vs indicator plot with a 40 day lag looks like:



Around the origin, the data points form a cloud without a clear tendency in any direction. But as the indicator values gets further away from the origin, some kind of trend forms. For indicator values smaller than -1.2, the T-Bond/T-Bill return is negative and for indicator values larger than 1.2, the opposite is true. This is also shown by the trend line which has an upwards slope with very high statistical significance. This result points in the opposite direction of what is expected from the theory since it shows that a high activity on the retail yields positive returns on T-Bond/T-Bill.

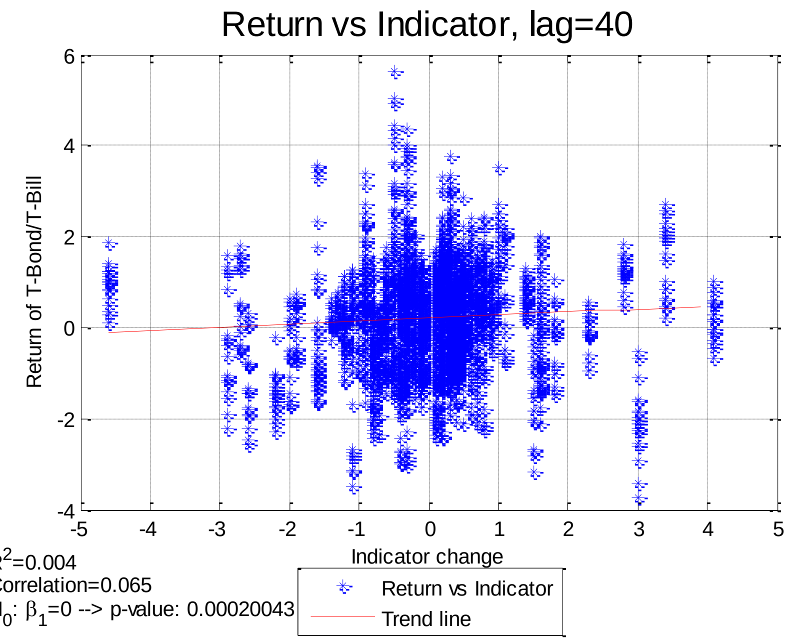
Running the test model under the above conditions yields the following result:





The indicator portfolio is as volatile as the benchmark but has higher annual return and hence a higher Sharpe ratio. The beta value is very close to one and Jensen's alpha is quite low due to the high R^2-value. Both portfolios have the same average proportion of T-Bonds and T-Bills but the indicator portfolio times the market better than the benchmark and hence has a higher return. According to the relative performance curve, the indicator portfolio is steadily increasing until around day 2000. After that, this strategy does not work as well as it worked before day 2000.

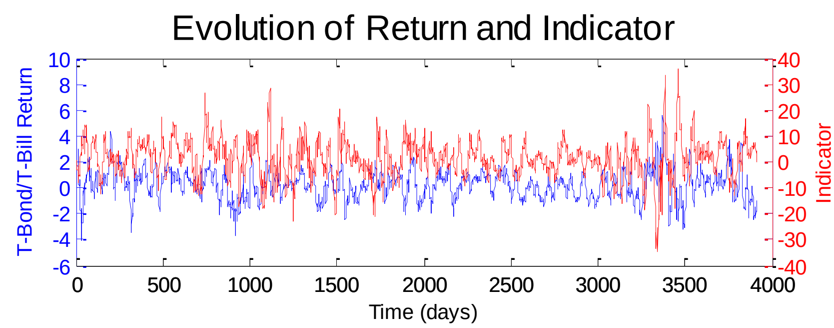
Plotting the indicator changes against the T-Bond/T-Bill return gives the following:

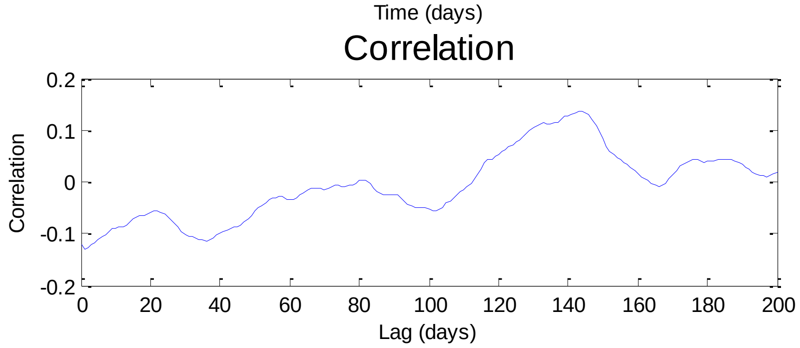


Plots for other lags are similar to this one and shows no trace of anything an investment strategy could be based on.

7.4.13 United States, Equity Indices, S&P, 500, Retailing, Monthly Return

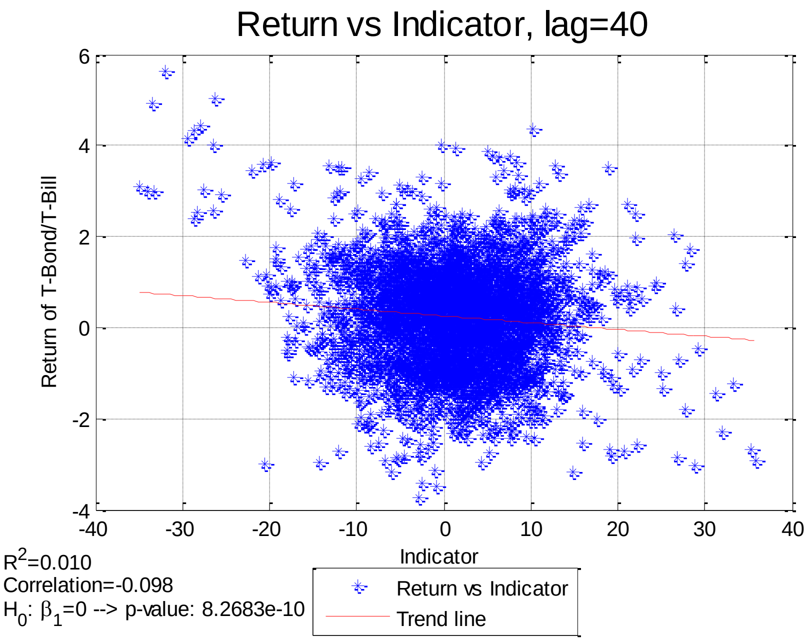
This indicator measures the sale of goods and services from individuals or businesses to the end user. High values of this indicator imply high spending among consumers which suggest a strong economy. This is often negative for the government bond market and should result in negative T-Bond/T-Bills returns.





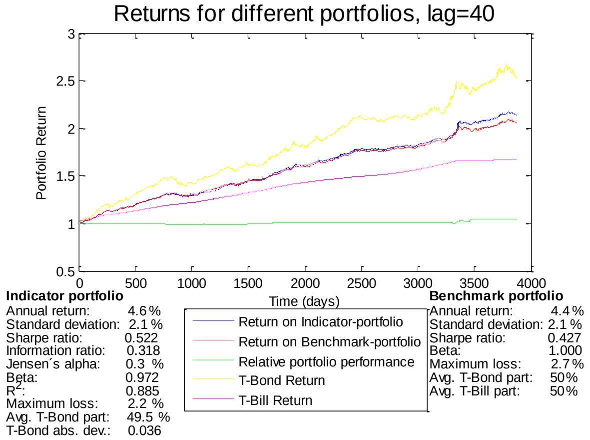
In the graph on the top, some negative correlation can be distinguished which is confirmed by the correlation graph at a zero day lag. Overall, the correlation graph is rather irregular and jumps up and down for the different lags but stays around zero for most of the time.

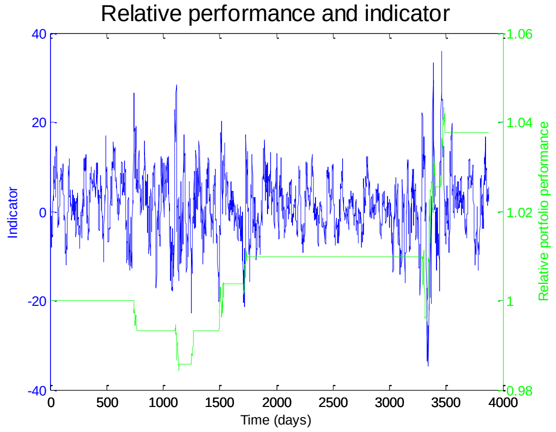
Plotting the T-Bond/T-Bill return against the indicator with a lag of 40 days gives the following:



Around the origin, the data points almost form a circle suggesting that the outcome is random. But looking at the extreme values of the indicator, a pattern can be seen. For low indicator values, the T-Bond/T-Bill return is positive and for high indicator values the same return is negative. This result points in the same direction as what is expected from the theory since it shows that a high activity on the retail yields negative returns on T-Bond/T-Bill.

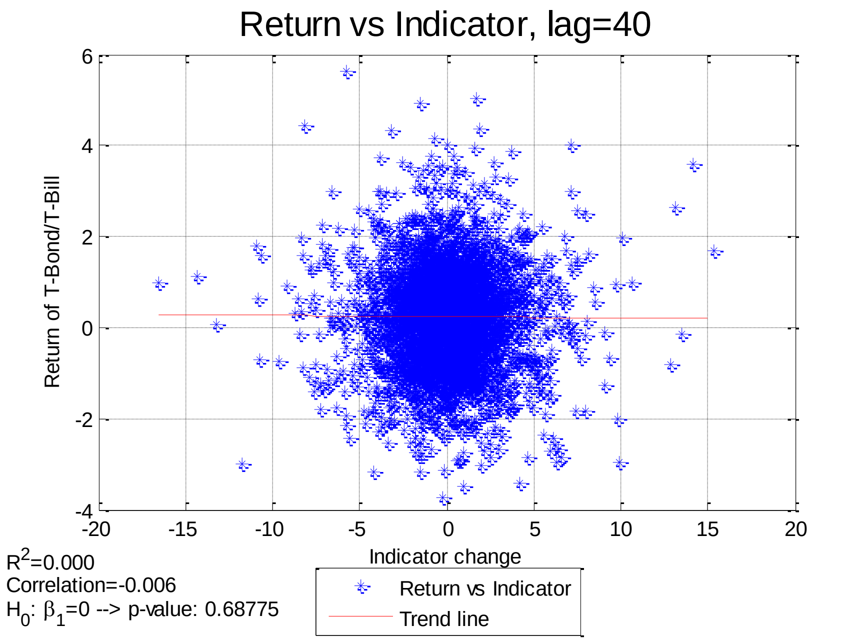
Running the test model to evaluate this tendency, set to act on values lower than -20 and higher than 20 gives the following:





The indicator portfolio has a higher annual return than the benchmark, and has the same volatility and thus a higher Sharpe ratio. The maximum loss is equal for the two portfolios as well as the average allocation between T-Bonds and T-Bills. The relative performance curve shows that indicator as extreme as -20 and 20 does not occur very often during the studied time period. This strategy does not make the indicator portfolio perform better than the benchmark at all times and most of the indicator portfolio’s excess return is gained during the latest financial crisis. That fact lowers the credibility of this strategy.

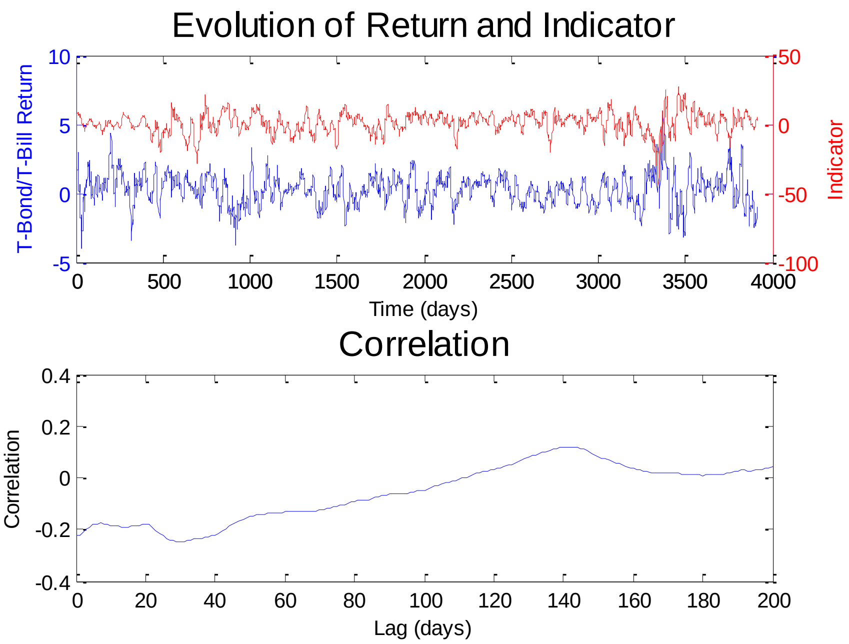
Plotting what happens with the T-Bond/T-Bill return after changes in the indicator gives the following:



Plots for other lags are similar. The data points form a cloud around the origin and look as if they are randomly spread out. The statistical measures say the same: The R^2 value shows the fit of the trend line to the data is zero and the significance of the slope if the trend line is very low.

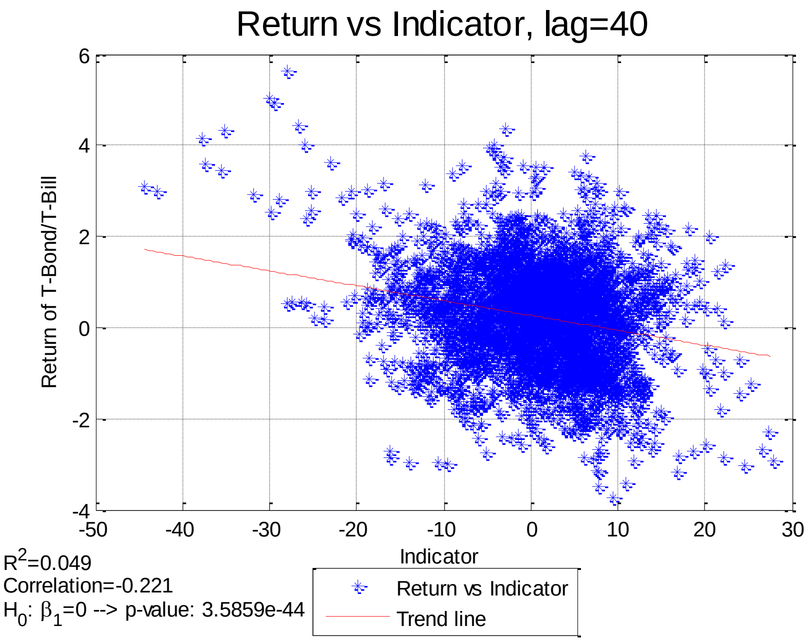
7.4.14 Emerging Markets, Equity Indices (Large, Mid & Small Cap), Monthly Return

A high value of this indicator should imply that investors are willing to invest in companies on markets that are in growth and in the process of industrialization. This means that money flows from developed markets such as the Swedish which would suggest that the T-Bond/T-Bill return is negative.



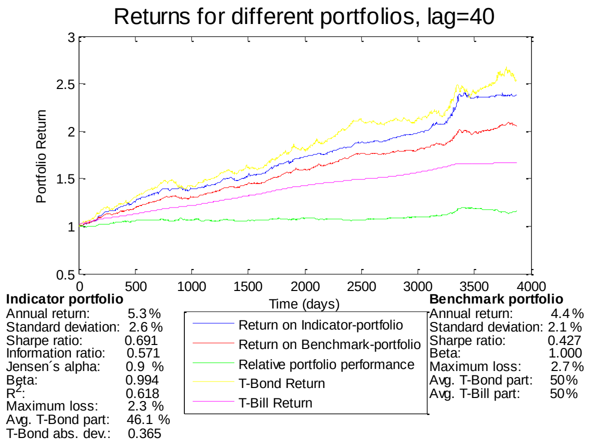
The small inverse relation between the indicator and the T-Bond/T-Bill return is difficult to see in the top graph but is, according to the correlation curve, a bit smaller than -0.2. The correlation between the T-Bond/T-Bill return and the indicator is slowly tending toward zero as the lag is increased and at a lag of 120 days, the correlation reaches zero.

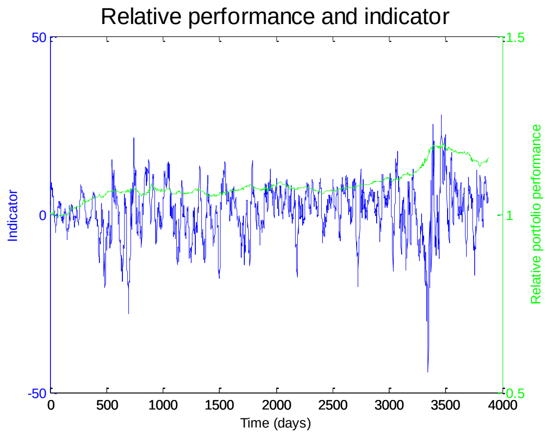
The negative slope of the trend line also decreases as the lag is increased. With a lag of around 40 days, the negative slope reaches its maximum. The return vs correlation plot with a 40 day lag looks like:



Around the origin, the data points form an ellipse that is tilted in the same direction as the trend line. The angle of the tilt is not very large and might be too small to use as an indicator. However, for indicator values smaller than -20 and larger than 20 there is a clear tendency. For negative extreme values, the T-Bond/T-Bill return is positive and for positive extreme values, the same return often is negative. This result points in the same direction as what is expected from the theory.

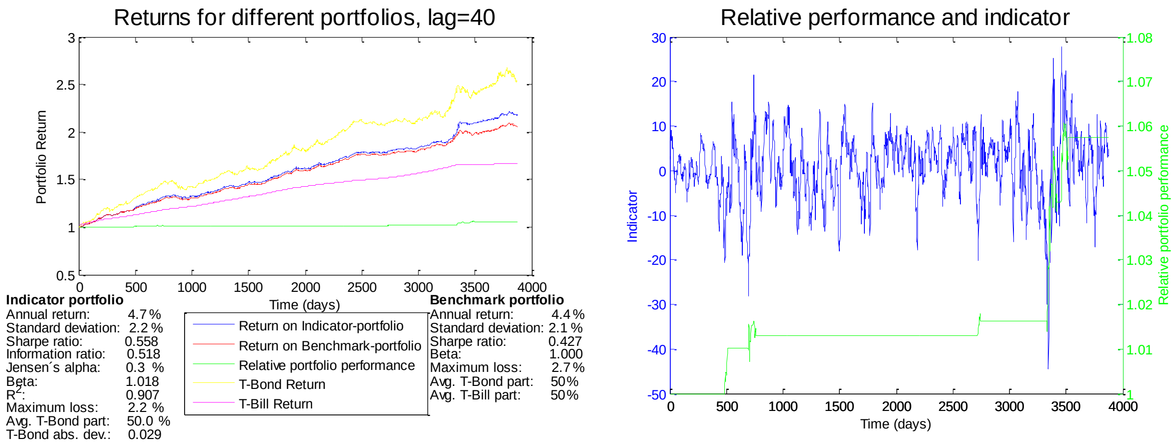
Running the test model, using each value of the indicator to decide the allocation between T-Bills and T-Bonds gives the following result:





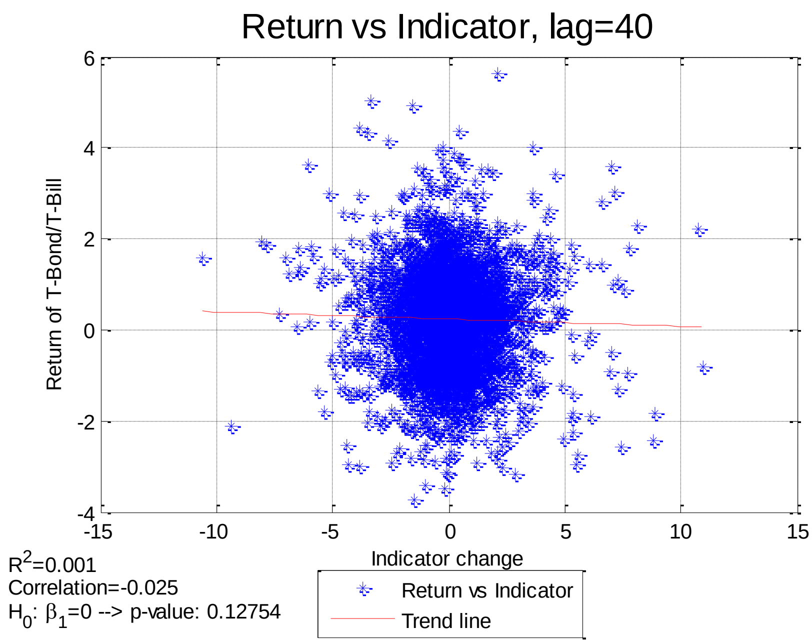
The relative risk return, as measured by the Sharpe ratio and the information ratio, is high for the indicator portfolio. The annual return of the indicator portfolio is a lot higher but it has a higher volatility than the benchmark and it also has a smaller maximum loss. Jensen's alpha is high due to the beta-value being close to one and the R^2-value being very low. The relative performance curve is increasing quite steadily which shows that the indicator portfolio performs better than the benchmark for most of the time.

Running the test model, utilizing only the pattern for the extreme values yields the following:



This strategy is a little less volatile than the one simulated above, but gives a lot smaller annual return and also has a lower Sharpe ratio and information ratio. The relative performance curve reveals that these extreme values only occur during two timer periods. It also reveals that the major part of the indicator portfolio's excess return is gained during the 2008 financial crisis.

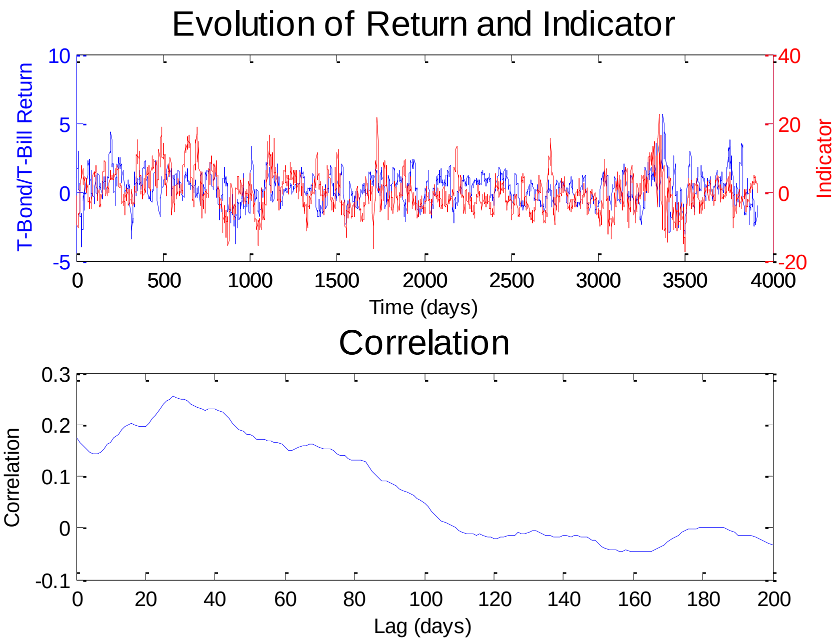
The return vs indicator plots for changes in the indicator value are quite similar for different lags. The plot for a 40 day lag can be seen below:



The data points are scattered around the origin and no clear patterns or trends can be seen in this plot, even though the trend line has a high statistical significance. The value of R^2 indicates the fit of the trend line is poor.

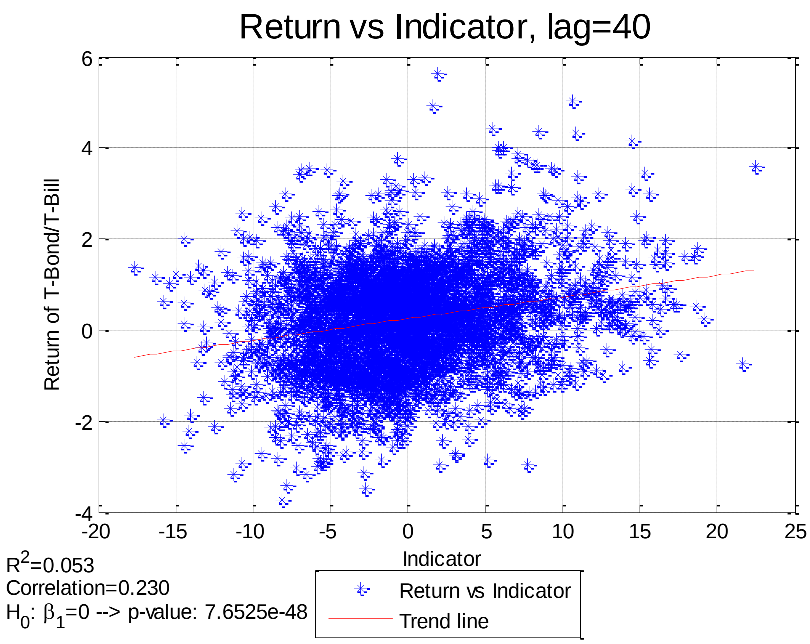
7.4.15 S&P 500 one month return minus Emerging Markets one month return

This indicator measures the difference in returns between developed and emerging markets. A high value of the indicator suggests that money is flowing from emerging markets to developed markets and vice versa. This implies that investors are not willing to take on very high risks which is positive for the government bond market.



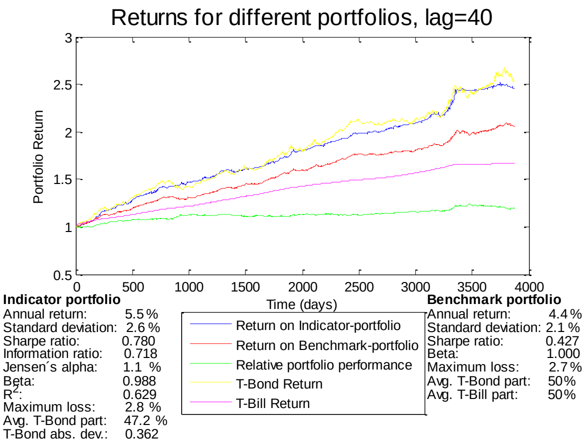
From the top graph, it is possible to see that the indicator is related to the T-Bond/T-Bill return. This is confirmed by the correlation graph which shows that at a zero day lag, the correlation is a little below 0.2. The correlation is then increasing as the lag is increased until a lag at about 30 days. After that, the correlation decreases as the lag is increased, tending towards zero.

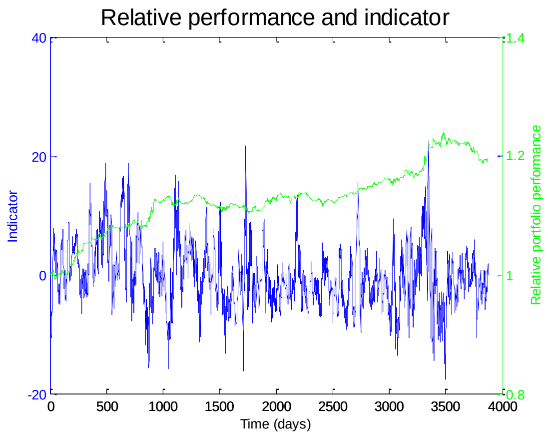
With a 40 day lag, the return vs indicator plot looks as follows:



The slope of the trend line has a very high statistical significance and the data points are gathered in an upwards-tending cloud around the trend line. There does not seem to be any special trend for the indicator's extreme values. This result points in the same direction as what is expected from the theory.

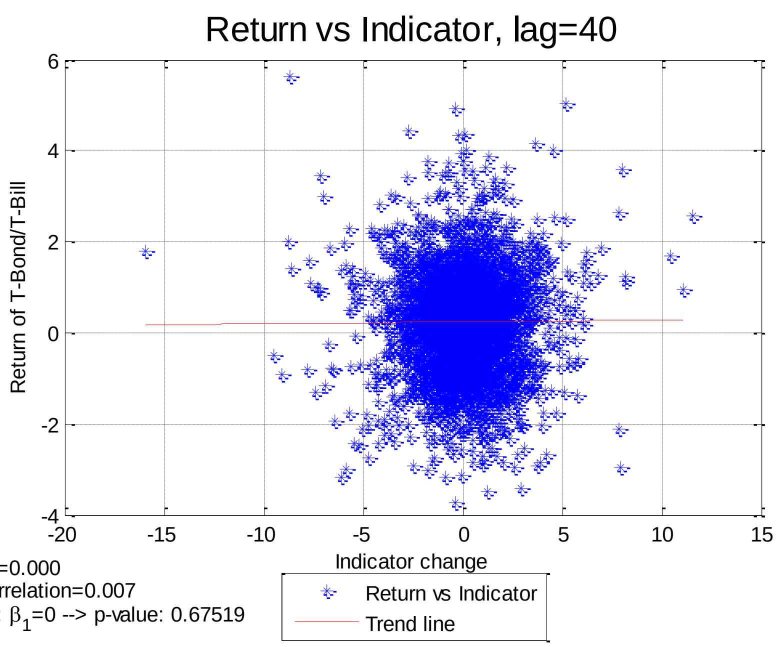
Running the test model, set to decide the proportion of T-Bonds and T-Bills based on the value of the indicator and, as usual, set to hold each position for one month, yields:





The indicator portfolio performs a lot better than the benchmark but with a higher volatility. The Sharpe ratio is a lot higher for the indicator portfolio which also has a relatively high information ratio. Due to the low R^2-value, Jensen's alpha is quite high. The indicator portfolio has a higher maximum loss than the benchmark. The relative performance curve shows that the indicator portfolio is performing better than the benchmark during almost the whole time period. The curve is almost constantly increasing until the 2008 financial crisis, after which the strategy does not perform as well as it did before.

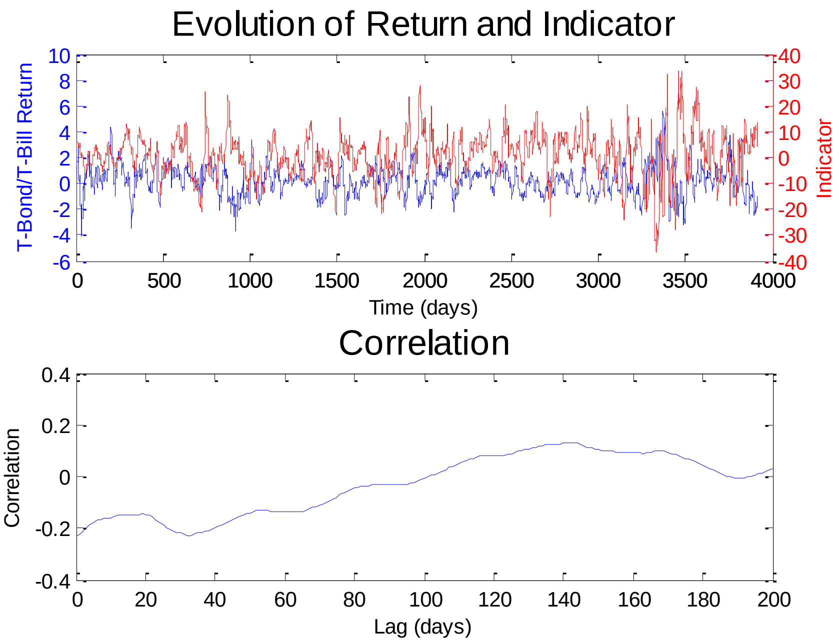
Plotting the T-Bond/T-Bill return against changes in the indicator yields similar plots regardless of what lag is used. The plot with a 40 day lag is seen below:



The data points look randomly spread around the origin, forming a cloud without any pattern to base a strategy on. The fit of the trend line to the data is very low since the R^2 value is zero and the correlation is close to zero. Also, the statistical significance of the slope of the trend line is very low.

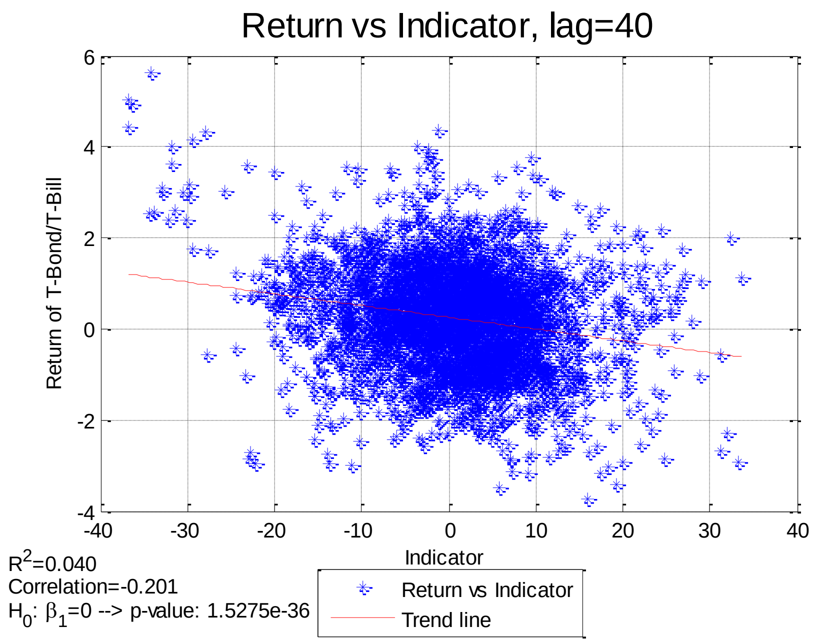
7.4.16 Germany, Prime All-Share Construction Index, Monthly Return

This indicator is calculated as the monthly return of the DAX index and is updated on a daily basis. Bond markets and equity markets often have a negative correlation and hence, high indicator values should imply low T-Bond/T-Bill returns and vice versa.



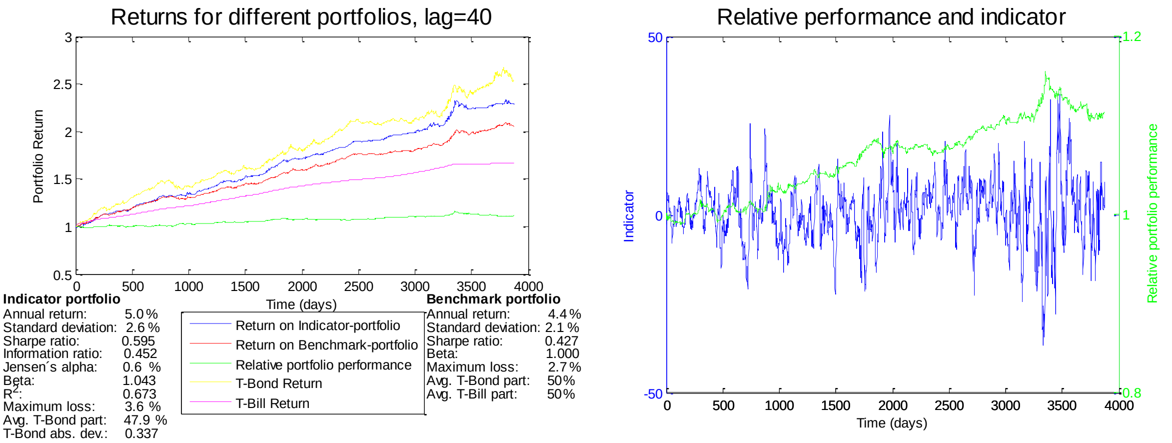
This indicator is quite volatile and mostly takes values between -10 and 10. The correlation between the T-Bond/T-Bill return and the indicator is tending toward zero as the lag is increased but still has a correlation of around -0.2 when the lag is 40 days.

The return vs indicator plot with a lag of 40 days looks like:



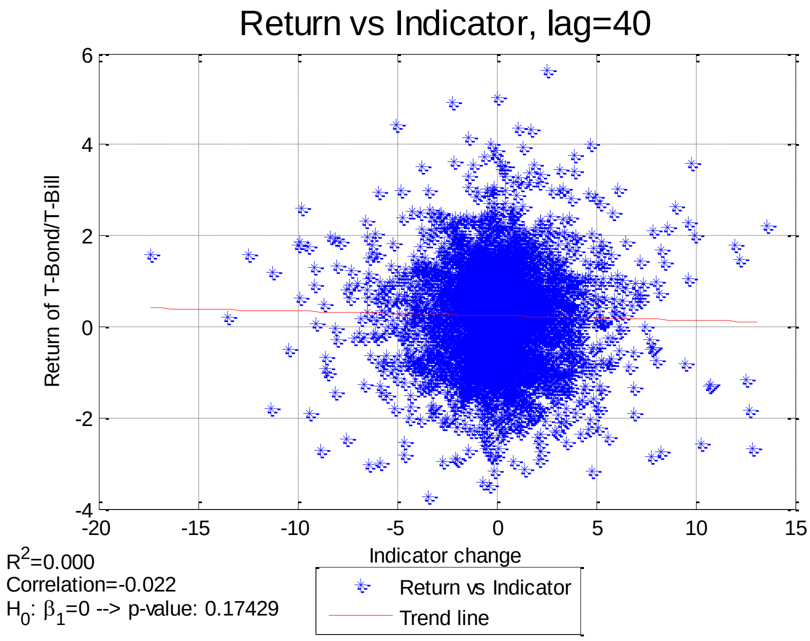
The data points form an ellipse around the origin which is tilted along the trend line. For positive indicator extreme values, no clear tendency can be seen but for negative extreme values T-Bond/T-Bill returns are often positive. However, such low indicator values have only occurred during one time period and hence are not very reliable as indications on future returns. This result points in the same direction as what is expected from the theory.

Running the test model, set to decide the proportion of T-Bonds and T-Bills based on the value of the indicator gives the following result:



The indicator portfolio's annual return is higher than the benchmark's but also is more volatile. Yet, the Sharpe ratio is higher for the indicator portfolio but also the maximum loss. The R^2-value is low giving a relatively high Jensen's alpha. The indicator portfolio performs better than the benchmark during almost the whole time period, but after around day 3500, the relative performance is not as strong as it was before. This strategy seems to have worked well before the 2008 financial crisis but it is uncertain if it still is as successful.

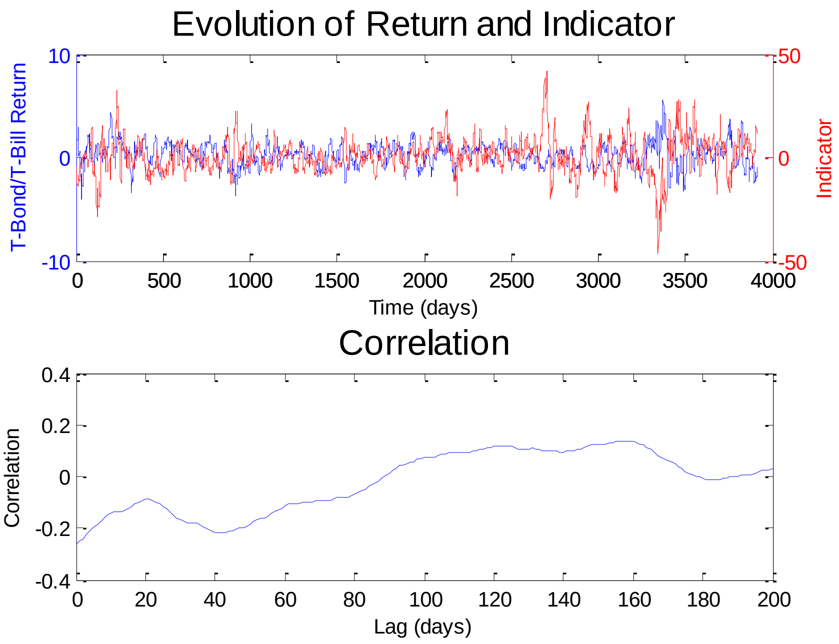
Plotting the changes of the indicator against the T-Bond/T-Bill return yields similar plots for different lags. Below, the plot with a 40 day lag can be seen:



As seen, there are no trends to be seen in this plot, which also is confirmed by the statistical measures.

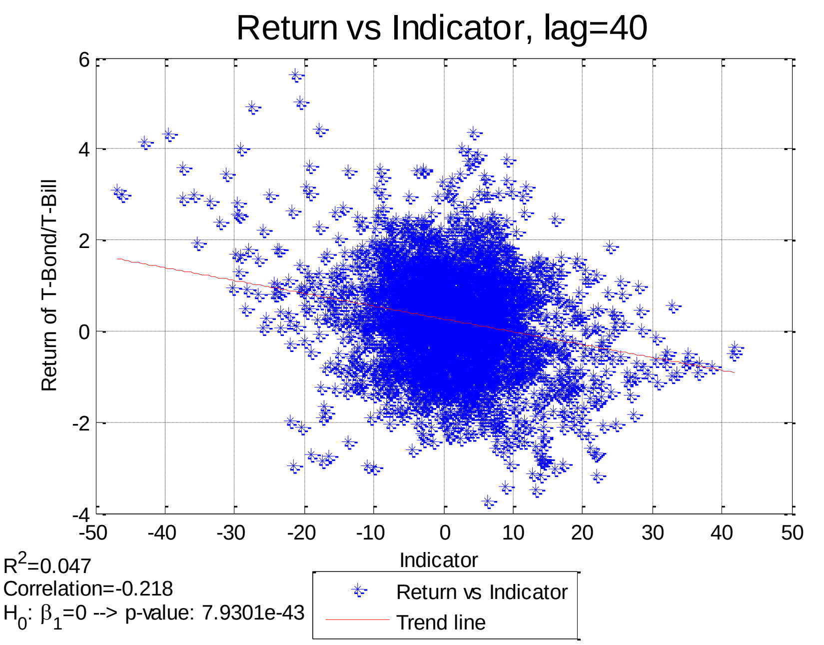
7.4.17 Copper, Monthly Return

Commodities and bonds often have a negative correlation since high commodity prices suggest high inflation which is bad for the bond markets. Hence, high values of this indicator should suggest low returns on T-Bond/T-Bill.



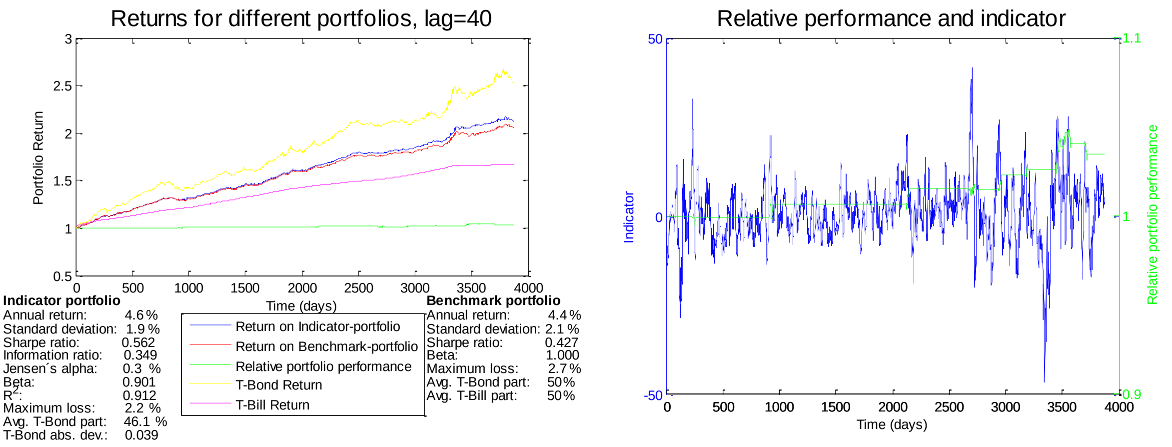
It is possible to discern that the T-Bond/T-Bill return has a negative correlation with the indicator by looking at the graph on the top. This is confirmed by the correlation plot which shows that the correlation at a zero day lag is close to -0.3. At a 40 day lag, the correlation between the T-Bond/T-Bill return and the indicator is around -0.2 and as the lag is increased, the correlation tends to zero.

The return vs indicator plots with lags between 30 and 50 days are similar. Beneath, the plot with a 40 day lag can be seen:



Around the origin, the data points almost form a circle from which nothing can be seen of how the value of the indicator affects the T-Bond/T-Bill return. Negative extreme values tend to give a positive return on T-Bond/T-Bill, however almost all indicator values lower than -20 occur during the same time period. Although the tendency is not as clear for the positive extreme values as for the negative ones, they occur more often during the time period and often together with negative returns on T-Bond/T-Bill. This result points in the same direction as what is expected from the theory.

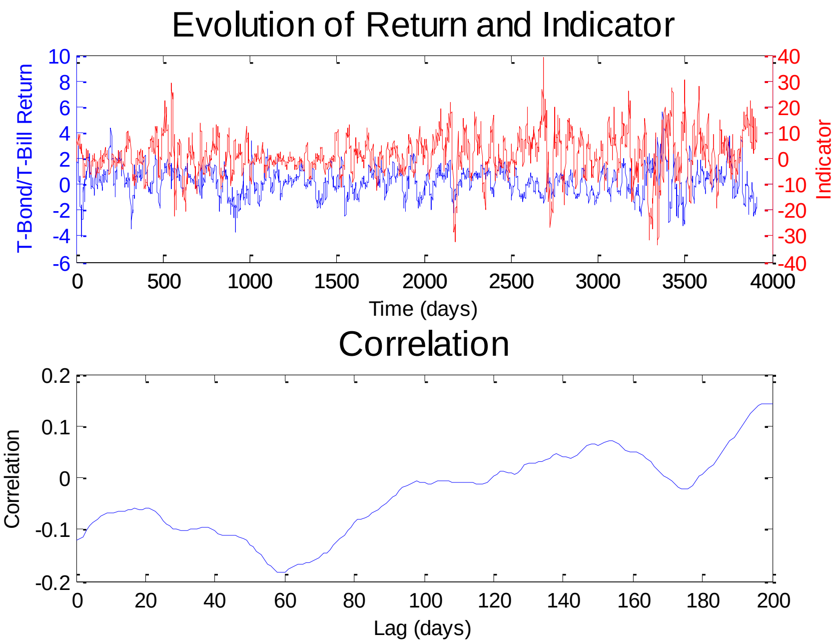
Running the test model calibrated to act on indicator values higher than 20 gives the following result:



The volatility of the indicator portfolio is a little smaller than the benchmark's which, together with the indicator portfolio's slightly higher annual return, gives a higher Sharpe ratio. The information ratio is quite low and the beta value is smaller than one. The relative performance curve shows that extreme values this high occur every now and then during the time period and that this strategy makes the indicator portfolio perform continuously better than the benchmark for the whole time, except for the last few years where the two portfolios perform almost equally well.

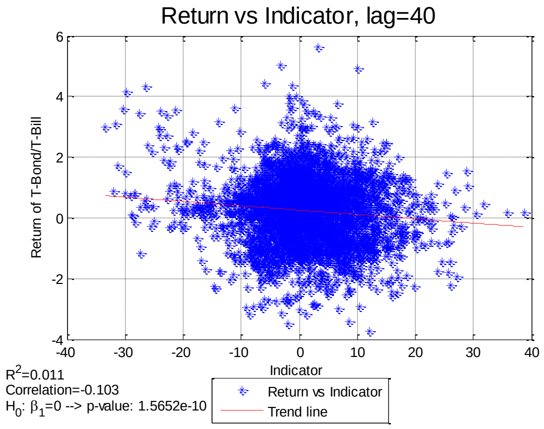
7.4.18 Silver, Monthly Return

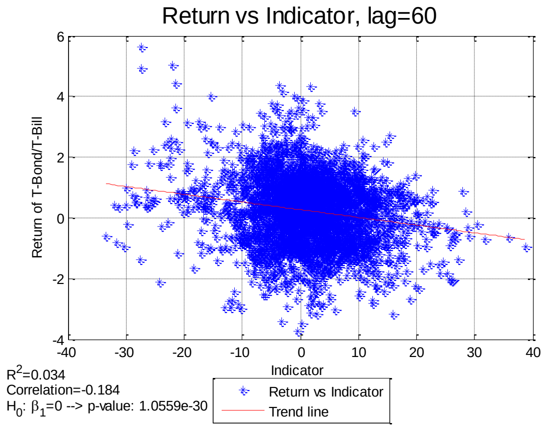
Commodities and bonds often have a negative correlation since high commodity prices suggest high inflation which is bad for the bond markets. Hence, high values of this indicator should suggest low returns on T-Bond/T-Bill.



The indicator fluctuates around zero, mostly between values of -15 and 15. It is difficult to distinguish any dependence between the indicator and the T-Bond/T-Bill return just by looking at the top graph. The correlation curve is quite irregular but is stable between a 40 and 60 day lag after which it tends to zero with a little jump in the end.

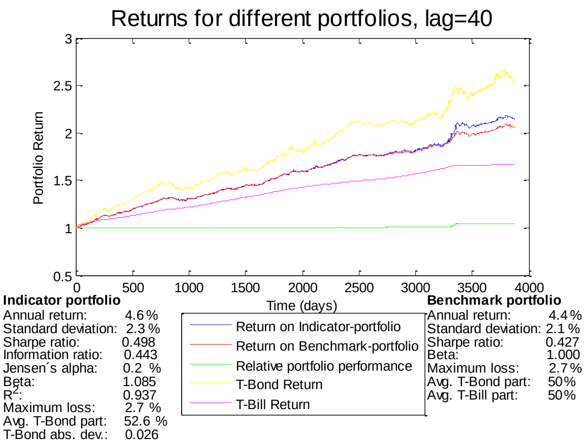
For a 40 and 60 day lag, the return vs indicator plot looks like:

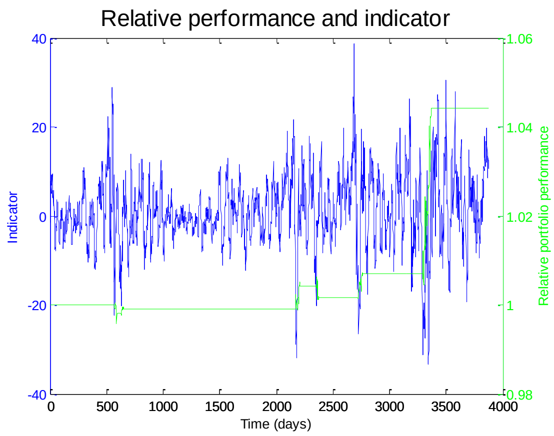




Most of the data points are gathered around the origin, forming an ellipse with the y-axis as its major axis. However, for negative extreme values, many data points indicate a positive return on the T-Bond/T-Bill quota which means that T-Bonds are to be preferred to T-Bills. The tendency is clearer in the 40 day lag case than in the 60 day lag case. The first graph in this paragraph shows that indicator values lower than -20 occurs every now and then after day 2000 on the studied time period. This result points in the same direction as what is expected from the theory.

Running the test model for the 40 day lag case, set to act on indicator values smaller than -20 gives the following result:



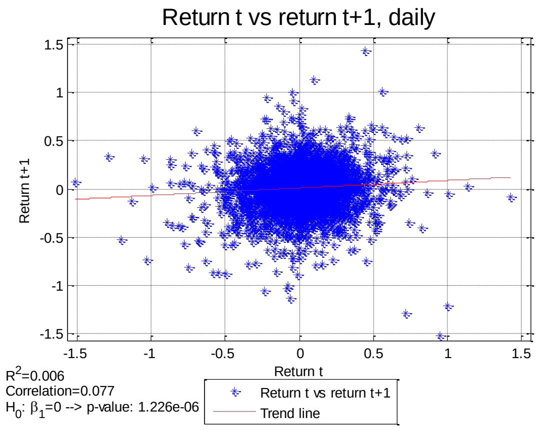


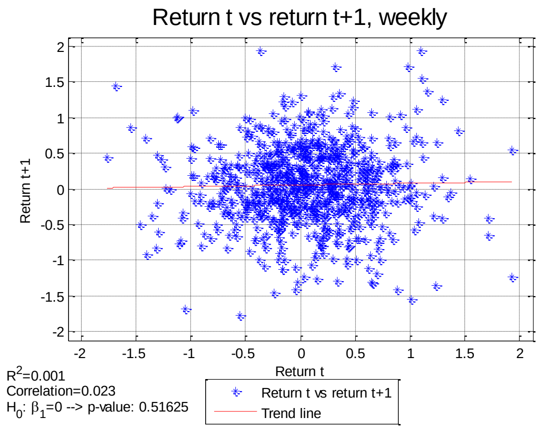
The annual return, together with the volatility, is a little higher for the indicator portfolio than for the benchmark portfolio. The indicator portfolio's Sharpe ratio is also a little higher than the benchmark's and their maximum losses are equal. The relative performance curve shows that the indicator portfolio performs better than the benchmark most of the time when the indicator takes values below -20. Most of the indicator portfolio's excess return is gained during the latest financial crisis, but some is also gained after it. The corresponding result for the 60 day lag case is similar to this.

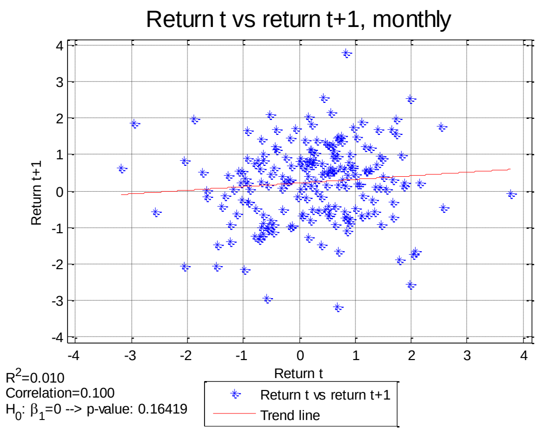
7.4.19 T-Bond/T-Bill

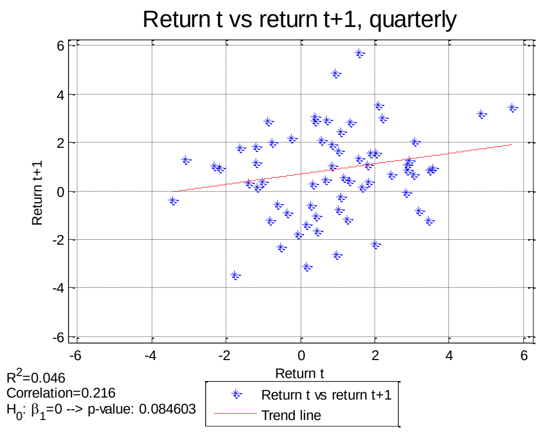
Plotting the return for time period t on the x-axis and the return for time period $t+1$ on the y-axis produces a picture that gives an indication on whether a momentum strategy would work or not. If the data points forms some kind of linear trend with a positive slope, this would indicate that a high return for time period t often is followed by a high return for time period $t+1$ and vice versa, which is the principle of a momentum strategy.

Using this technique for the daily, weekly, monthly and quarterly returns on T-Bond/T-Bill produces the following graphs:



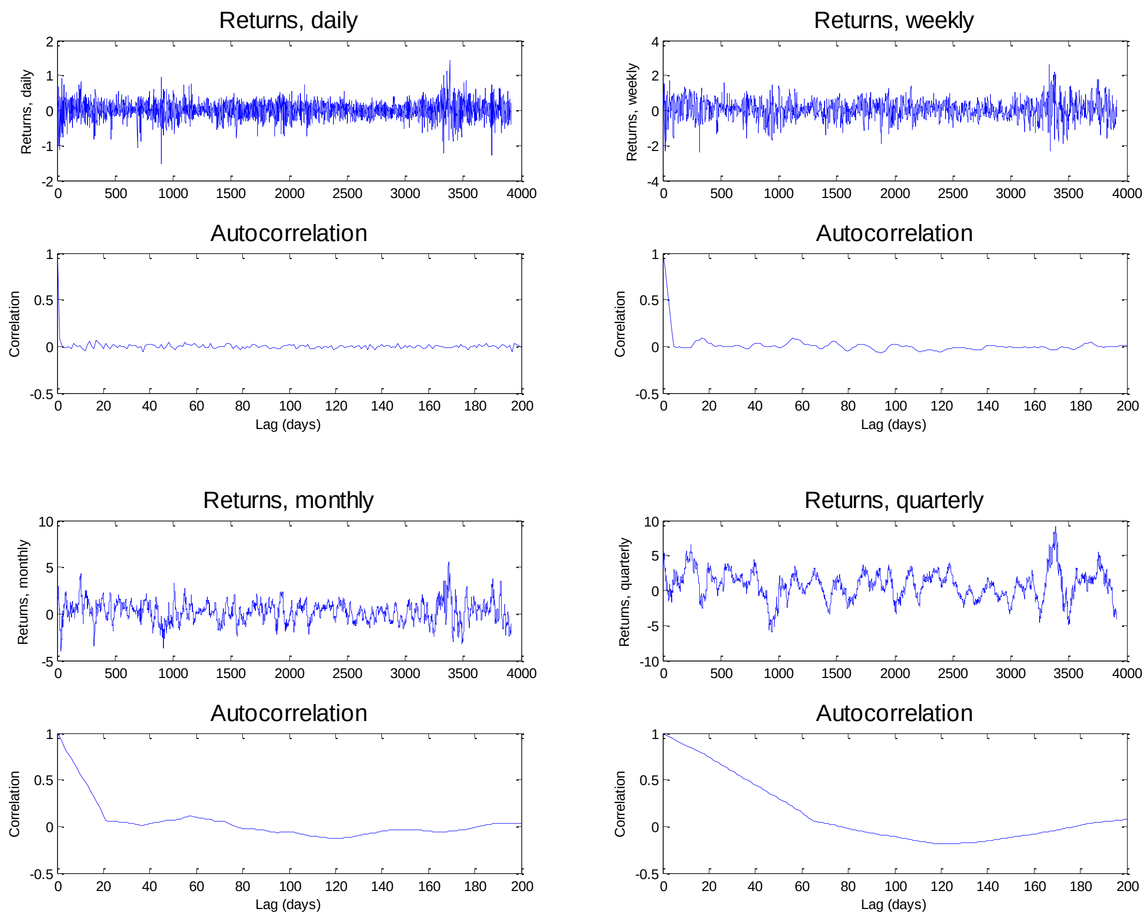






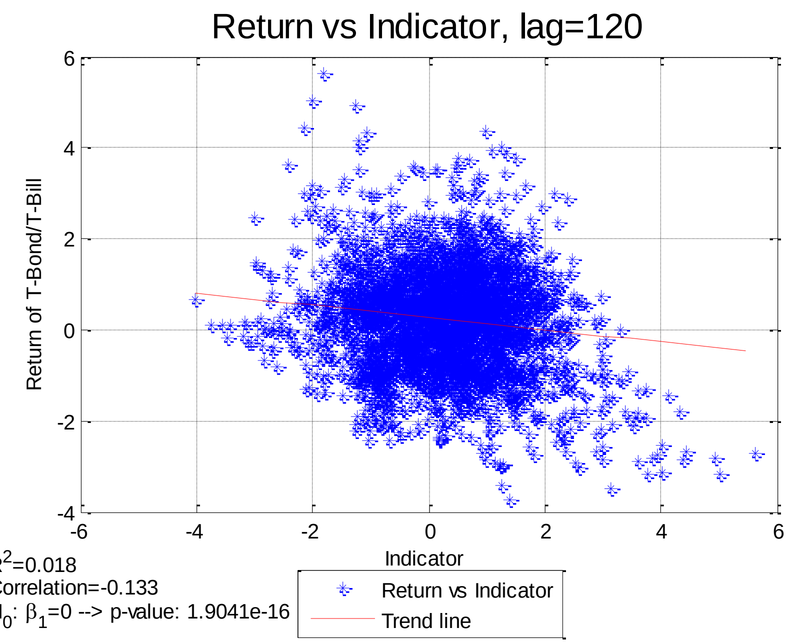
Regardless of which time interval the return is calculated on, the evidence for a momentum strategy to work is quite weak. Except for the case with the weekly returns, the correlations increase as the time interval for which the return is calculated on increases. But using quarterly returns, the correlation is still low. Also, the statistical significance of the slope of the trend line is not very high.

The autocorrelation of a series is a measure of how well lagged values of the series can predict the value of the series today, i.e. how good the series would be as an indicator for itself. Below, autocorrelation plots for daily, weekly, monthly and quarterly returns can be seen. Naturally, from a lag of zero days to a lag of the same amount of days as the return is calculated on, the autocorrelation plot is linear since the returns initially are calculated on the same data which gradually is shifted.



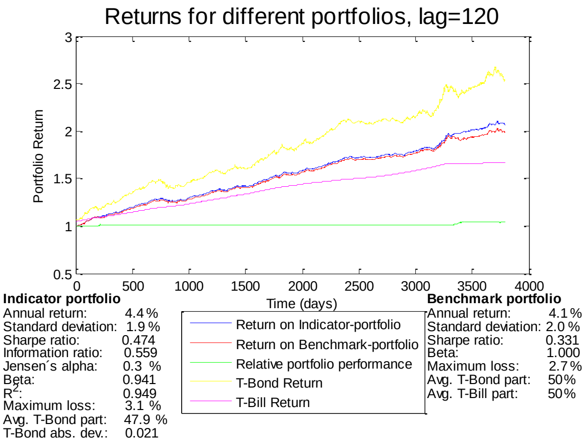
In all cases, the autocorrelation is very low. The largest correlations are found in the monthly returns case at a 120 day lag and in the quarterly returns case at a 130 day lag.

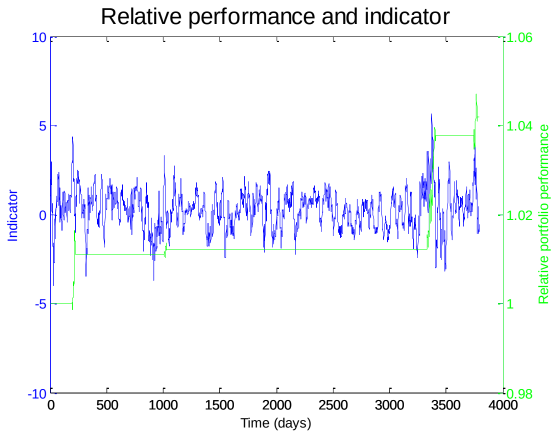
Investigating the case for the monthly returns closer yields the following plot:



Returns on the T-Bond/T-Bill quota larger than two often give negative returns on the same quota 120 days later. For returns smaller than three, the data points form a circle around the origin which does not give any clues on future returns.

Running the test model set to act only on indicator values larger than three yields the following:





The return and Sharpe ratio is higher for the indicator portfolio than for the benchmark whereas the standard deviation is the same and the maximum loss is lower. The relative performance curve shows that indicator values larger than three only have occurred once before the 2008 financial crisis, after which the indicator portfolio gains most of its excess return. Hence, this strategy is not very reliable.