กลยุทธ์การซื้อขายสำหรับตราสารที่ให้รายได้คงที่โดยใช้ความคลาดเคลื่อนของราคาและความคลาดเคลื่อนของปัจจัยของเส้นอัตราผลตอบแทน

TRADING STRATEGIES FOR FIXED INCOME SECURITIES USING PRICING ERROR AND YIELD CURVE FACTOR ERROR

อรสิรี ตั้งสัจธรรม
จุฬาลงกรณ์มหาวิทยาลัย

บทคัดย่อ

งานวิจัยนี้ศึกษาและพัฒนากลยุทธ์การซื้อขายสำหรับตราสารที่ให้รายได้คงที่โดยอาศัยความคลาดเคลื่อนของราคาและความคลาดเคลื่อนของปัจจัยของเส้นอัตราผลตอบแทน สัญญาณการซื้อขายของกลยุทธ์ทั้งสองนี้เกิดขึ้นโดยสองวิธีคืออาศัยสมมุติฐานในการกลับสู่ค่าเฉลี่ยและการพยากรณ์แบบอนุกรมเวลา ผู้วิจัยได้ทำการศึกษาเชิงประจักษ์โดยอาศัยหลักฐานจากตลาดพันธบัตรรัฐบาลในประเทศเยอรมัน โดยได้ทำการตรวจสอบความสามารถในการทำกำไรและความสัมพันธ์สำหรับแต่ละกลยุทธ์ภายใต้ข้อกำหนดเดียวกัน ผลการวิจัยพบว่ากลยุทธ์ที่ดีที่สุดหรือให้กำไรสูงที่สุดของกลยุทธ์ที่อาศัยความคลาดเคลื่อนของราคา ให้ผลตอบแทนประมาณ 8% โดยกลยุทธ์นี้เกิดขึ้นจากสมมุติฐานในการกลับสู่ค่าเฉลี่ยของความคลาดเคลื่อนของราคา นอกจากนี้ยังพบว่ากลยุทธ์ที่ดีที่สุดของกลยุทธ์ที่อาศัยความคลาดเคลื่อนของปัจจัยบนเส้นอัตราผลตอบแทนให้ผลกำไรประมาณ 4% สัญญาณการซื้อขายของกลยุทธ์นี้เกิดขึ้นจากสมมุติฐานในการกลับสู่ค่าเฉลี่ยของระดับของเส้นอัตราผลตอบแทน อย่างไรก็ตามผลการวิจัยพบว่าผลตอบแทนเหล่านี้ไม่ได้เกิดขึ้นอย่างสม่ำเสมอกล่าวคือพบผลตอบแทนติดลบในการซื้อขายบางครั้ง อันเนื่องมาจากช่วงเวลาของข้อมูลที่ใช้ในการศึกษาวิจัยเป็นช่วงของวิกฤติเศรษฐกิจในประเทศสหรัฐอเมริกาซึ่งส่งผลให้เศรษฐกิจตกต่ำทั่วโลก

คำสำคัญ: ตราสารที่ให้รายได้คงที่, กลยุทธ์การซื้อขาย, ความคลาดเคลื่อนของราคา, เส้นอัตราผลตอบแทน, การกลับสู่ค่าเฉลี่ย

ABSTRACT

This research studies and develops trading strategies for fixed income securities based on bond pricing error and factor error, which is the deviation of yield curve on particular trading day from a historical average or forecasted yield curve. In both pricing-error based and factor-error based strategies, the trading signals are derived by two ways which are the mean-reversion and the estimation using time-series model. This empirical study has been conducted for the German Government Bond

Market. We examine the profitability of each strategy with the same restrictions and study the correlation among these trading strategies. The results show that the best strategy (highest profit) of pricing-error based strategies provides approximately 8% return. This strategy uses the assumption of mean-reversion on historical pricing errors. Furthermore, for factor-error based strategies, the best trading strategy yield approximately 4% return. The trading signals in this strategy are derived by the assumption of mean-reversion on the level of yield curve. However, the returns from these strategies are not consistent over time. We find negative returns on some trading days. The reason might be our sample period, which is the time period of January 2006 to December 2009. This is the period of financial crisis in the United States which results in economic downturn around the world.

Keywords: Fixed Income Securities, Trading Strategy, Pricing Error, Yield Curve, Mean Reversion

Introduction

One of the most important decisions making for an investment management is the allocation of funds among asset classes. The two major asset classes are equities and fixed income securities. In the past, fixed income securities were simple investment products. Most investors purchased these securities with the intent of holding them to their maturity dates. However, nowadays, the fixed income world has changed. The hold-to-maturity investors have been replaced by institutional investors who actively trade fixed income securities. Trading in fixed income securities is a profitable business in global investment banks. Therefore, it is worthwhile to study the trading strategies on this class of assets.

Trading strategies on fixed income assets can be deployed ranging from simple arbitrage trading to complex trading based on technical or market views on the term structures of interest rates. In this research, we focus on two groups of strategies. The first one is trading strategies based on pricing error of the bonds. The error is defined as the market price minus the model price. We will derive trading signals for our strategies based on the assumption that a pricing error mean-reverts to its historical error. In addition, the time-series models will be used to forecast the error for another set of trading signals. A related paper is Jankowitsch & Nettekoven (2008), which provides empirical evidence for the German government bond market in which risk-adjusted trading strategies based on bond pricing errors are found to yield about 15 basis points per annum abnormal return compared to benchmark portfolios. These abnormal returns are continuously achieved over the whole time period of the study.

Another group of strategies is a set of yield curve trading strategies based on the view that the yield curve mean-reverts to an unconditional curve, which is the historical average. Furthermore, similar to the pricing error, we will also use the time-series models to forecast yield at each maturity to be another reference for our strategies. Following Litterman & Scheinkman (1991), we consider the three aspects of the yield curve, which are the level, slope and curvature. For these strategies, we will start from the market view that the yield curve is a mean-reversion process. This mean-reverting yield curve strategies try to take benefit from the deviations in the yield curve on a particular trading day relative to a historical average and forecasted yield curve. These deviations are also called in this paper as the factor errors. Three commonly used trading strategies for bonds are (1) bullet strategy, which is constructed so that maturities of bonds are concentrated at a particular part of the yield; (2) ladder strategy, which involves investments across a range of maturities; and (3) barbell strategy, which is constructed by investing in two ends of the yield curve and selling the middle portion, or vice versa, see Fabozzi (1986). It is easy to say that bullet strategy is essentially a bet on the level of the interest rates whereas ladder and barbell strategies are bets on the yield spread and curvature, respectively. We will construct a portfolio of yield-curve trading strategies centering on each aspect. Empirical study on this strategy was shown in Chua et al. (2006). They found that some mean-reverting strategies on a risk-adjusted basis were highly profitable and outperformed their benchmarks.

Research Question

We will study the profitability and correlation of these two groups of trading strategies. The interesting points are whether they are positively or negatively correlated in their signal and performance. Moreover, we will examine whether they still provide a profit in different time period.

Data

The German government bond market is one of the largest and most liquid markets in the European Monetary Union. Therefore, the bonds of this market are usually used as input to estimate the euro-denominated term structure of riskless interest rates and are the benchmarks in EMU bond markets. In this study, we will use times series data, which are daily and monthly data, of euro-denominated German government bonds in form of prices and yields for the time period of January 2006 to December 2009 from the Datastream. The German government bonds in this study are the series of principal and coupon STRIPs. Moreover, we also employ the term structures which are estimated by Svensson's model (Svensson, 1994) at the same time period from website of Deutsche Bundesbank. They are available daily and monthly. Additionally, we will use the Euribor money rate, which is the benchmark for the money and capital markets in the euro zone, from the website of Deutsche Bundesbank at the same time period to be a short term interest rate for borrowing and deposit in the one-month tenor.

Methodology

In our study, due to the assumption of mean reversion on the pricing error and yield of bonds, firstly, the character of pricing error and yield will be tested whether they revert to their mean. After that, we will examine the profitability of each portfolio which is constructed from different strategies based on pricing error and factor error which is the deviation of yield curve on particular trading day from a historical average or forecasted yield curve.

In this study, we use the following trading rules: the holding period of each strategy is fixed at one month to be more closely to real-world investment decision where the investment horizon is certainly longer than one day. We impose the condition of cash neutrality, so any excess cash is deposited at the 1-month tenor. Similarly, the additional funding is also carried out at the 1-month tenor. On each trading day, we will observe the defined trading signals. Then, we sell all bonds in our portfolio for which we observe a sell signal. All other sell signals have no consequence since we do not allow short selling of bonds. The reason is that although short selling is feasible in the EMU government bond market, borrowing costs may be immoderately high. After selling the bonds we have a certain amount of money including the repayments. We will observe a buy signal and invest in that bond. The invested cash amount in each bond will be duration-weighted. As the holding period is one month, duration of a bond with X-months maturity will be $(X-1)$ months. In addition, we explicitly include transaction costs. According to Dimson & Hanke (2004), most of the transactions take place within the quoted bid-ask spread. Thus, for each bond, the whole bid-ask spread has to be paid and therefore completely incorporate transaction costs. In our dataset, we have bid and ask price quotations of all bonds. We assume that bonds are bought at the ask-price quotation and sold at the bid-price quotation. The return of the trading strategy is

$$y_t^{portfolio} = \frac{\sum_{i=1}^{n_{t-1}} w_{i,t-1} \cdot P_{i,t} + deposited/borrowed_{t-1} \cdot \left(1 + (1/12) \cdot r_{t-1}^{MMY}\right) + repayment}{\sum_{i=1}^{n_{t-1}} w_{i,t-1} \cdot P_{i,t-1} + deposited/borrowed_{t-1}} - 1 \qquad (1)$$

where $y_t^{portfolio}$ is the return at time *t* of each portfolio

r_{t-1}^{MMY} is the one-month money market rate of return at time *t-1*

n_t is a number of outstanding bonds in the portfolio at time *t*

$w_{i,t}$ is a nominal value invested in bond *i* at time *t*

$P_{i,t}$ is a market price of bond *i* at time *t*

The trading portfolios using pricing error and factor error are constructed as follow;

1. Pricing error

For the trading strategies based on pricing error of the bonds, we mainly follow Jankowitsch & Nettekoven (2008). In the first step, we will employ the parameters used in estimating term structure of interest rates for the German government bond market from website of Deutsche Bundesbank. The term structure is constructed from the estimation procedure suggested by Svensson (1994). In this model, the spot rate, $r_{0,t}$, is given by

$$r_{0,t} = \beta_0 + \beta_1 \cdot \left(\frac{1-\exp(-t/\tau_1)}{(t/\tau_1)}\right) + \beta_2 \cdot \left(\frac{1-\exp(-t/\tau_1)}{(t/\tau_1)} - \exp(-t/\tau_1)\right) + \beta_3 \cdot \left(\frac{1-\exp(-t/\tau_2)}{(t/\tau_2)} - \exp(-t/\tau_2)\right) \qquad (2)$$

where β_0, β_1, β_2, β_3, τ_1, τ_2 are the free parameters. The parameters can be obtained by performing a non-linear optimization with the parameter restrictions $\beta_0 > 0$, $\tau_1 > 0$, and $\tau_2 > 0$. This procedure is widely used by practitioners as well as central banks and other financial institutions. In the next step, we will calculate the pricing error which is defined as the market price (clean price plus accrued interest) minus the model price (sum of discounted cashflows using the estimated term structure), as used in the research of Jankowitsch and Nettekoven (2008). After that, we will derive our trading signals which can be separated into two sets. The first set will focus on mean reversion effect of the pricing errors. The second set is more general which also incorporates trading on the expansion of observed mispricing forecasted by using time-series model.

1.1 Mean-reversion

The actual pricing error of a bond is compared to the average of its recent historical values. A simple way is to use the deviation of the actual pricing error from the moving average computed over the last k trading days for each bond i:

$$\mu_{i,t} = \frac{1}{k} \cdot \sum_{j=t-k}^{t-1} \varepsilon_{i,j} \tag{3}$$

$$\sigma_{i,t} = \sqrt{\frac{1}{k-1} \cdot \sum_{j=t-k}^{t-1} \left(\varepsilon_{i,j} - \mu_{i,j}\right)^2} \tag{4}$$

where $\varepsilon_{i,j}$ is the pricing error of bond i on day j.

$\mu_{i,t}$ is the average of the pricing error for bond i on particular day t over the last k trading days

$\sigma_{i,t}$ is the standard deviation of the pricing error for bond i on particular day t over the last k trading days

Using the information above we define the following trading signals based on the multiplier m:

if $\varepsilon_{i,t} > \mu_{i,t} + m \cdot \sigma_{i,t}$ then bond i is overpriced

if $\varepsilon_{i,t} < \mu_{i,t} - m \cdot \sigma_{i,t}$ then bond i is underpriced

The set of trading signals above is useful to trade against potential mispricing in the market.

1.2 Forecasting

We use time-series models to forecast the pricing errors and thus obtain trading signals. The trading signals from the forecasted strategy are similar to the trading signals from the moving average strategy as will be shown later in this session. Therefore, firstly, we have to select the appropriate time-series model by focusing on Autoregressive Integrated Moving Average, ARIMA(p,d,q), and Generalized

Autoregressive Conditional Heteroscedasticity, GARCH(p,q), at the same time, also called ARIMA-GARCH. These two models include the effect of various time-series models all together. Thus, using these two models, we will get the proper model for our data set. Their general forms can be written by

ARIMA(p,d,q) ;

$$\Delta_d \varepsilon_{i,t} = \theta + \alpha_1 \Delta_d \varepsilon_{i,t-1} + \alpha_2 \Delta_d \varepsilon_{i,t-2} + \cdots + \alpha_p \Delta_d \varepsilon_{i,t-p} + \beta_0 u_{i,t} + \beta_1 u_{i,t-1} + \beta_2 u_{i,t-2} + \cdots + \beta_q u_{i,t-q} \quad (5)$$

where $\varepsilon_{i,t}$ is the pricing error for bond i on particular day t

θ is a constant term

α, β are parameters of Autoregressive and Moving Average respectively

$u_{i,t}$ is the white noise stochastic error term for bond i on particular day t

Δ_d is the *d*th-order differences

p is the order of Autoregressive

d is the amount of differencing to generate the stationary time series

q is the order of Moving Average

GARCH(q,p) ;

$$\sigma^2_{i,t} = \mu + \beta_1 u^2_{i,t-1} + \cdots + \beta_q u^2_{i,t-q} + \gamma_1 \sigma^2_{i,t-1} + \cdots + \gamma_p \sigma^2_{i,t-p}$$

(6)

where $\sigma^2_{i,t}$ is the variance of the white noise stochastic error term for bond i on particular day t

$u_{i,t}$ is the white noise stochastic error term for bond i on particular day t

μ is a constant term

β is a parameter of the square error term

γ is a parameter of the conditional variance

q is the number of lagged terms of the square error term

p is the number of lagged terms of the conditional variances

Then, for a particular day *t* of our data set we estimate the coefficients of the time-series models, and calculate the expected error and its standard error for the next twenty-two trading days, *t+22*, because our holding period will be one month. From these results, we can obtain the respective values for the time-series of pricing errors, $\hat{\varepsilon}_{i,t+22}$ and $\hat{\sigma}_{i,t+22}$. Then, the further setup is similar to the previous strategy:

if $\varepsilon_{i,t} > \hat{\varepsilon}_{i,t+22} + \mathrm{m} \cdot \hat{\sigma}_{i,t+22}$ then bond i is overpriced

if $\varepsilon_{i,t} < \hat{\varepsilon}_{i,t+22} - \mathrm{m} \cdot \hat{\sigma}_{i,t+22}$ then bond i is underpriced

Note that in this setup the multiplier is directly related to the width of the confidence interval of the forecast. Assuming the normal distribution for the errors, a multiplier of 1.96 would define a 95%, and a multiplier of 1.65 would define a 90% confidence interval.

2. Factor error

For another set of trading strategies which focus on a set of yield curve trading strategies, we mainly follow Chua et al. (2006).The strategies are based on the view that the yield curve mean-reverts to an unconditional curve, which is the historical average of all the yields observed for each maturity. Moreover, we also use time-series models to forecast yield of each bond. These forecasted yields will be used as another reference. These strategies, also called in this paper as trading strategies based on factor errors, the holding period of each trade is one-month, so the relevant forward yield curve to compare against the unconditional yield and forecasted yield is the one-month forward yield curve. The one-month forward interest rate at a maturity of x months is calculated as follows.

$$e^{r_{1,x} \cdot \frac{x}{12}} \cdot e^{r_{0,1} \cdot \frac{1}{12}} = e^{r_{0,x+1} \cdot \frac{x+1}{12}} \quad (7)$$

where $r_{0,x}$ is the spot rate at a maturity of x months

$r_{1,x}$ is the one-month forward interest rate at a maturity of x months.

In addition, the yield for average unconditional yield curve at each maturity at any date is calculated as the moving average of all the yields observed for that maturity over the last k months. We define the average unconditional yield curve at any date as this set of yields over all the maturities. Furthermore, the forecasted yield is obtained from time-series model similar to the pricing error strategy. Similarly, the forecasted unconditional yield curve is this set of yield over all the maturities. We consider three classes of mean-reverting yield curve strategies: level, spread, and curvature.

2.1 Level

2.1.1 Mean-reversion

This strategy takes the view that the average level of the yield curve mean-reverts to that of the average unconditional yield curve. In this trade, we compare the average of all yields on the one-month forward yield curve at a particular date against the average of all yields on the unconditional yield curve. If the average interest rate level for the one-month forward yield curve is higher (lower) than the average for the unconditional yield curve, the expectation is that one-month forward yield curve would shift down (up). The implied strategy is to buy (sell) all the bonds with maturities longer than one month.

2.1.2 Forecasting

This strategy will use ARIMA-GARCH, similar to the forecasting mispricing, to forecast yields for the forecasted unconditional yield curve. In the same way as the mean-reversion, we compare the average of all the one-month forward yields against the average of all the forecasted yields on a particular day. If the average yields level for the one-month forward yield curve is higher (lower) than the average of all the forecasted yields, the expectation is that one-month forward yield curve would shift down (up). The implied strategy is to buy (sell) all the bonds with maturities longer than one month.

2.2 Spread

2.2.1 Mean-reversion

This strategy focuses on mean-reversion of yield spread for the whole yield curve. We consider the spread between the 359-month and 1-month maturities on the one-month forward yield curve and compare it with that of the average unconditional yield curve. If the one-month forward yield spread is larger (smaller) than the historical average, the expectation is that the slope of the yield curve would fall (rise). The implied strategy is to buy (sell) the 360-month bond and sell (buy) the 2-month bond.

2.2.2 Forecasting

This strategy compares the spread between the 359-month and 1-month maturities on the one-month forward yield with the corresponding spread of forecasted yields, using ARIMA-GARCH model. If the one-month forward yield spread is larger (smaller) than the forecasted, the expectation is that the slope of the yield curve would fall (rise). The implied strategy is to buy (sell) the 360-month bond and sell (buy) the 2-month bond.

2.3 Curvature

The curvature is defined as follows. Take three zero-coupon bonds, with maturities of X, Y and Z months and corresponding one-month forward yields of $r_{1,X}$, $r_{1,Y}$ and $r_{1,Z}$. The curvature of the yield curve, as defined by the three bonds, is:

$$c(X,Y,Z) \equiv \frac{r_{1,Y} - r_{1,X}}{Y - X} - \frac{r_{1,Z} - r_{1,Y}}{Z - Y} \qquad (8)$$

2.3.1 Mean-reversion

This strategy is based on the mean reversion of the curvature for the entire yield curve. Specifically, we consider the maturities of 1-month, 179-month (the mid-point) and the 359-month bond, on the one-month forward yield curve. We compare the curvature, as measured by equation (8), for these three bonds on the one-month forward yield curve with the average unconditional yield curve. If the one-month forward curvature is lower (higher) than the unconditional curvature, the expectation is that the curvature would increase (decrease). The implied trade is to buy (sell) the 2-month and 360-month bond and sell (buy) the 180-month bond, on the current yield curve.

2.3.2 Forecasting

This strategy also considers the curvature for the maturities of 1-month, 179-month (the mid-point) and the 359-month bond, on the one-month forward yield curve. We compare that curvature, as calculated by equation (8), with the curvature of the forecasted yield from ARIMA-GARCH model. If the curvature is expected to increase (decrease), the implied trade is to buy (sell) the 2-month and 360-month bond and sell (buy) the 180-month bond, on the current yield curve.

Results and Analysis

Theoretically, the pricing errors of all bonds on a particular day and each bond over the observed time period should be purely random. In our dataset, the pricing errors seem to be autocorrelated as shown in figure 1 which shows the time series data of pricing errors for representative bonds in our sample. The pricing errors of each bond do not oscillate around zero over time. The bonds stay overpriced or underpriced for at least couple of months. This means that there are some deviations in prices of bonds from the market conditions. Therefore, there are some arbitrage opportunities which we can yield abnormal returns.

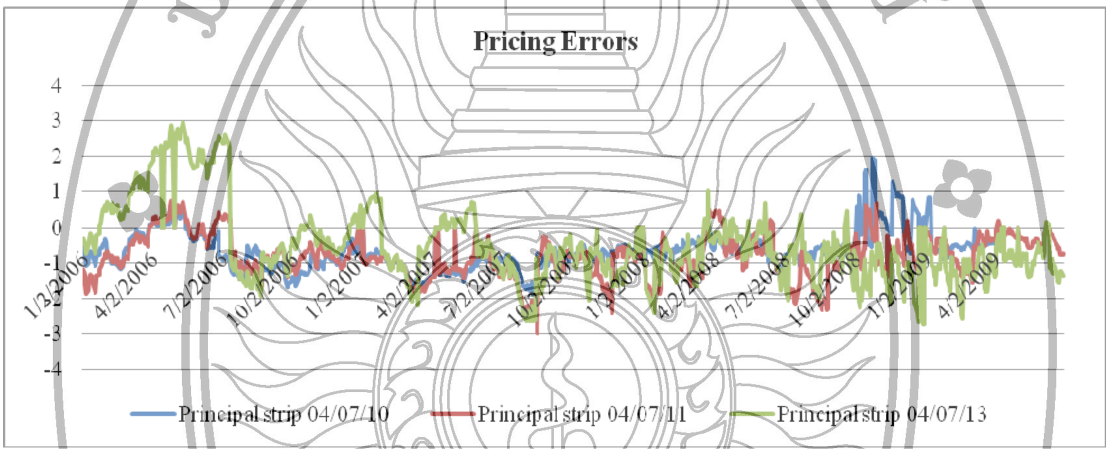

Figure 1: The time series of pricing errors for three representative bonds

This research uses the pricing errors and several parametric values for the trading signal of the pricing error approaches stated above. For the mean-reversion of pricing-error based strategies, the number of days k for the calculation of the moving average and standard deviation of past pricing errors are 5, 10, 15, 20, 30, 60, and 90 days. The multiplier m is set to 0.5, 1, 1.5, 2, 2.5, and 3, respectively. Furthermore, for the forecasting of pricing-error based strategies, we try several time-series model and find that each bond is suitable with different model. For example, the Coupon Strip whose maturity date is on January 2018 is suitable with GARCH (1,1), the Principal Strip whose maturity date is on July 2013 is suitable with GARCH(1,0) and so on. Each pricing-error based strategy finds both negative and positive returns along the sample period. The maximum return from the pricing-error based strategies is around 8% on average, as shown in figure 2. It is obtained by combining a number of 60 days with a multiplier of 3 for the trading signal from the mean-reversion strategy. However, the negative returns in this study might occur because our sample period, which is the time period of January 2006 to December 2009, is a time of financial crisis in the United States. This crisis has a huge impact to the financial market around the world. Moreover, the results show that the trading signal from the assumption of mean-reversion outperforms the trading signal which incorporates trading on the expansion of observed mispricing forecasted by using time-series model. These results might also due to the financial crisis in our sample period. The crisis leads to the change in market condition. Therefore, the pattern of pricing error in which we use to fit the time-series model may be changed in the forecasted period.

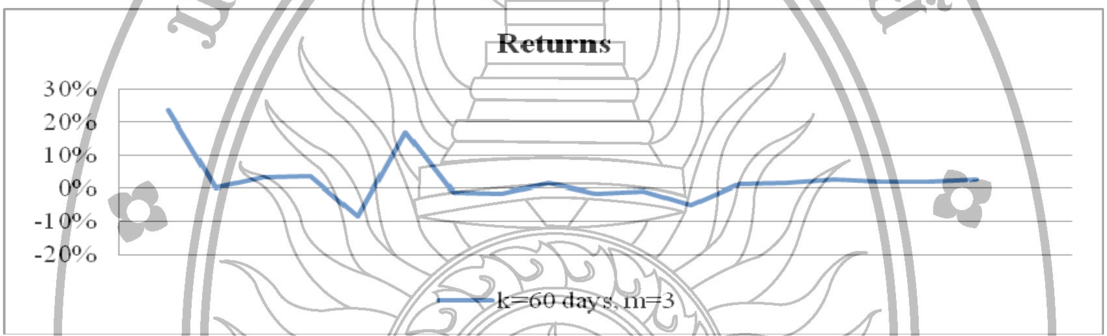

Figure 2: The returns of the best strategy from the pricing-error based strategy

In addition, this research uses the historical yields of German Government Bonds and also several parametric values for the trading signal of the factor error approaches. For the mean-reversion of factor-error based strategies, the number of months for the calculation of the moving average of historical yield curve are 5, 10, 15, 20, and 30 months. Additionally, for the forecasting of factor-error based strategies, we test several time-series model and find that each bond is suitable with different model. For some bonds, the proper time-series model is also different from the time-series model of the pricing error approach. For example, the Coupon Strip whose maturity date is on January 2018 is suitable with GARCH (1,2), which is different from the pricing error approach, the Principal Strip whose maturity date is on July 2013 is suitable with GARCH(1,0), which is the same as the pricing error approach and so on. For the factor-error based strategies, there are a few strategies which can earn positive returns. It is also because of the financial crisis in the time period of our sample. The economic downturn leads to the less effect of mean-reversion on the yield curve. The best strategy from the factor-error based yield the return of 4% on average. This strategy is the mean-reversion based on the view of error on the level of yield curve with the moving average of historical yield over the last 10 months, as shown in figure 3 and 4.

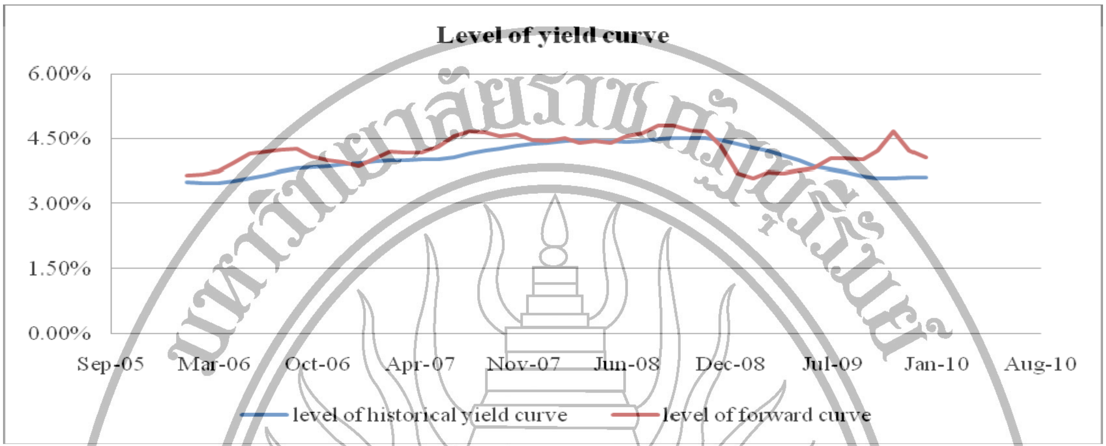

Figure 3: The level of historical yield curve, average of the last 10 months, and the level of forward curve on each trading day

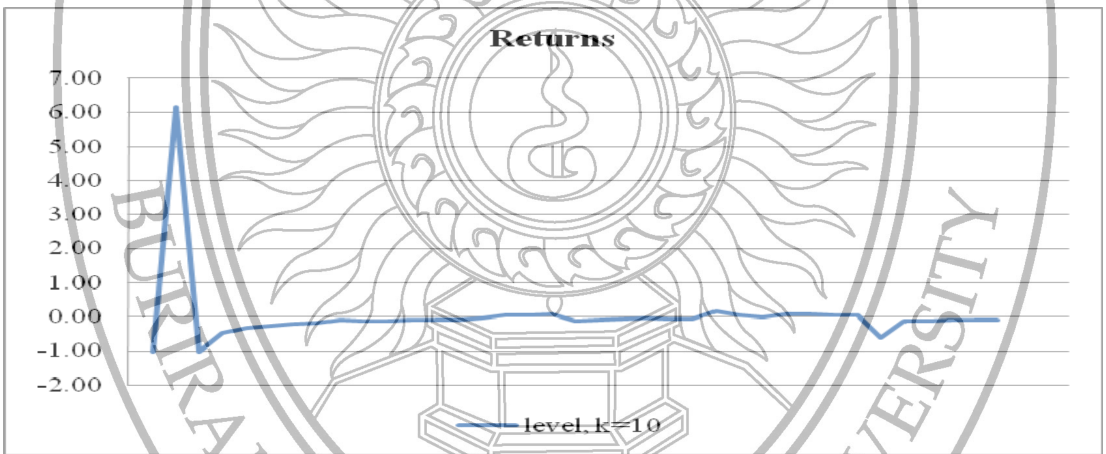

Figure 4: The returns of the best strategy from the factor-error based strategy

Conclusion

In summary, this study focuses on the strategies in trading fixed income securities. These strategies based on different trading signals which are derived from different ways. We compare their trading activities and their performance in German Government bond market. We find that the best strategy which produces the highest profit from pricing-error based strategies provides approximately 8% return. This is the strategy from the mean-reversion of the historical pricing errors. Moreover, for factor-error based strategies, the maximum return is approximately 4%. This strategy derives the trading signal by the assumption of mean-reversion of the level of yield curve. We can conclude that these strategies still provide a profit in the different time period. However, the returns from these strategies are not consistent over time. There are some negative returns on some trading days because our sample period, which is the time period of January 2006 to December 2009, is the period of financial crisis in the United States which results in economic downturn around the world.

Further Study

This study shows that the trading strategies above can provide a profit to the fixed income investors in German Government Bond Market. The Government Bond is another product which is interesting because it is low risk. Therefore, it will be more useful to Thai investors if we examine these strategies in Thai Government Bond Market. Furthermore, the strategies may be improved by using the pricing error and factor error approaches together. They might provide more accurate signal when they are used together.

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