An Empirical Analysis for Determinants of Interest Rate Swap Spread

Master thesis for Finance program

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Abstract

As one of the most popular derivatives to hedge interest rate risk, the variation of interest rate swap spread has been studied since its advent. Nevertheless, the variables in theory are regarded as determinant risk factors showing limited explanatory power. To investigate further, we conducted the cointegration test on each pair of variables which are considered in the financial and macroeconomic sense, and extend the classic Generalized Autoregressive Conditionally Heteroscedastic (GARCH) model by combining the Error correction model (ECM). Our testing results suggest that the changes in the swap spread negatively correlated with the slope of the yield curves of Treasury Securities and positively correlated with the implied volatility of Stock market, while other assumed determinant variables having a vague or even rather weak impact on the swap spread in general.

Table of contents

1. Introduction

We present our introduction as follows: background of interest rate swap, limitations of previous discussions, objective of this research and disposition of our paper.

1.1 Background

An interest rate defines the amount of money a borrower promises to pay the lender. There are many different types of regularly quoted interest rates which include mortgage rates, deposit rates, prime borrowing rates, and so on. The application of the interest rate relies on the credit risk since the higher the credit risk is, the higher the interest rate that is promised by the borrower is. A large number of empirical researches show that interest rate swaps are one of the major financial innovations since 1980s and the most popular derivative contracts used by U.S. firms (In, Brown and Fang, 2003). The interest rate swap market is one of the most important fixed-income markets in the trading and hedging of interest risk. According to Bank for International Settlement (BIS) statistics results on the notional amounts outstanding in the OTC Derivatives market, the total trading has reached USD 248,288 billion, which equals to six times world GDP at the end of 2004. The majority of this trading (USD 147.4 trillion) was interest rate swaps (Bank for International Settlement, 2005).

1.2 Limitations of previous discussions

The previous empirical research about the interest swap spread is what determines interest rate swap spreads and new findings why the interest rate swap spread fluctuate so much. Based on the previous research, we can see that the literature on swap spread focuses on the following factors: interest rate, credit risk, liquidity and default rate. Litezenberger (1992) and Turnbull (1987) showed that the most standard model in the interest rate swap market is to equal the present values of the cash flows arising from the fixed-rate side and the floating-rate side. In order to solve for the swap rate, Sorensen and Billier (1994) argue that the interest rate swap can be explained by using the option

pricing model since the credit risk between two counter-parties is asymmetric. Dai and Singleton (1997) showed that the level and slope of interest rate swap are important variables in interest rate swap rates. According to our research results, we find that the interest rate swap spreads have varied from a low roughly 25 basis points to more than 150 basis points, sometimes moving violently which is consistent with the previous research. In the previous research, they ignored the budget deficit and business cycle factor even though Lang, L., Litzenberger, R and Liu (1998) argued that the time series risk allocation among the swap counter parties varies over the business cycle.

1.3 The objective of this research

The objective of this research is to empirically examine the determinants of U.S interest rate swap spread changes. We try to investigate the determinant factors in the interest rate swap in the different maturity by applying the econometric techniques such as unit root test, cointegration test and GARCH model with error correction model. There are two important innovations in this paper. First, we add two additional important determinant factors in our regression of determinant of the swap spread. These two important determinant factors are budget deficit and business cycle. Even though Litzenberger also argues that the allocation of risks between swap counterparties varies over business cycles, we believe that it is not enough to just look at business cycle itself. We strongly believe that budget deficit and business cycle are very important determinant factors in the regression model. Second, we think there might be strong cointegration between budget deficit and business cycle based on the economic theory. In order to solve the problems, we add two error correction terms in the GARCH model to analyse the short-run dynamic relationships between those variables. We consider it as an extension of the GARCH model. Although the test results show that cointegration relationship between the dependent variable and independent variables across maturities are not quite one-to-one as we expected, it still shows a close relationship between budget deficit and business cycle indicating the importance of these two determinant factors.

We believe it is an interesting project due to the following reasons. First, interest rate swaps are the most popular and largest derivative contract in the world with a global size of 147.4 trillion dollars at end of 2004 (Bank of International Settlement, 2005). Second, for the first time, the important determinant factors such as budget deficit and business cycle together in the regression model are tested. Third, we are proposing a new view for looking at the interest rate swap and investigating the importance of the explanatory factors.

1.4 Disposition of this paper

In this paper, we define the swap spread as the difference between swap rate and treasury yield of same constant maturities in different maturity. In, Brown and Fang (2003), re-examined the relationship between the change of swap spread and change in the general level of interest, slope of yield curve, Treasury volatility, Liquidity volatility and default premium. We want to investigate stability of relationship between interest rate swap and other determining factors based on the multivariate extension of the generalized autoregressive conditional heteroskedasticity (GARCH) model. Also we add two additional important determinant factors in our regression of determinant of the swap spreads which are budget deficit and business cycle etc. Based on our test results, it reflects our strong belief that budget deficit and business cycle are very important determinant factors in the regression model. However, there might be strong cointegration between budget deficit and business cycle according to the economic theory and empirical test results. In order to solve the problems, we put the error correction terms in the GARCH model which have improved the regression based on our test results.

The rest of the paper is organized as follows. In section 2, we review the existing literature on interest rate swap spread, and explain the essentials, mechanics, and theoretical determinants of interest rate swap. In section 3, we discuss the data and define the variables we use. In section 4, we set up the empirical hypothesis and test models. In section 5, we perform regression analysis and provide the empirical evidence. We conclude the paper in section 6.

2. Literature Review

This part of the paper explains the essentials, mechanics of interest rate swap. Moreover it addresses the theoretical rationale and previous researches on interest rate swap spread.

2.1 Essentials of interest rate swap

The most common type of interest rate swap is the so called Plain Vanilla interest rate swap, namely the fixed/floating swap in which the fixed-rate payer promises to make periodic payments based on a fixed interest rate to a floating-payer, who in turn agrees to make variable payments which are indexed to either Treasury bond rates or the short-term London Interbank Offered Rate (LIBOR) [1] as defined in Hull's book (2005). Nevertheless, the size of the payment is only confined to the interest rate payment without exchanging the principle amount of the debt. Usually, the parties of the agreement are termed as counterparties. The early understanding for popularity of interest rate swap is that it lowers financing costs by providing the possibility for a firm to arbitrage the mispricing of credit risk, but the recent researches show that the inception of interest rate swap has coincided with a period of tremendous volatility in U.S. market interest rates, resulting in the rapid growth of interest rate derivatives on the part of firms to hedge cash flow against the impact of interest rate volatility (Bicksler, 2000). Same as other risk hedging derivatives, interest rate swaps are traded over the counter (OTC) market, in which the swap dealers are acting as intermediaries communicate offers to buy and sell with international commercial and investment banks, who are the main participants in such market. Furthermore, the expertise to manage the credit risk associated with swap deal is similar to bank lending, which gives the commercial banks the advantage to dominate the interest rate swap market (Smith, et al, 1986).

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[1] Traditionally, the short term LIBOR refers to three-month and six-month maturities.

2.2 Mechanics of interest rate swap

Basically, the mechanics of an interest rate swap is very straightforward. In the case of the Plain Vanilla swap the counterparties agree to exchange interest payments at the end of each of the T periods. As demonstrated by Hull (2005), the payments from each side of counterparties are arranged for the same dates, in which only the net amounts owed are exchanged. For example, let $\overline{r_s}$ denote the fixed rate and $r_s(t)$ denote the floating rate on a generic swap. At the end of a period, the fixed-rate payer must pay the difference between fixed interest payment and variable rate payment on the notional principal to the floating-rate payer if the swap's fixed rate is larger than the floating rate, i.e., $\overline{r_s} \succ r_s(t)$ and vice versa.

2.3 Theoretical determinants of interest rate swap spread

Conventionally, the swap spread is the major pricing variable which is defined as the difference between the interest rate swap rate and the par value of the Treasury bond rate of the same constant maturity. Under the assumption of absence of default risk and market imperfection, the swap rates of a default free swap contract should be equal to the default free par Treasury rates (Hua He, 2000). However, this does not match what we observed in the interest rate swap market. The main arguments of existing theoretical and empirical work on the determinant factors on swap spread are centered on the default probability of the counterparties, general level of interest rate, supply/demand shocks of the swap-specific-market, and volatility of interest rate as well as Treasury bill-LIBOR spread and the corporate bond quality spread. Among all these discussions, the default risk differential such as corporate bond spread, and the slope of the yield curve have proved to account for most explanations of the interest rate swap spread. Fehkle (2003) provided the analysis on swap default risk, and found that bilateral default risk is at least partially off-setting in an interest rate swap, which implies that negative swap spread is theoretically possible, if the swap seller has sufficiently higher default risk than the swap buyer. As to the slope of the yield curve, which is used as the predicted future interest

rate, presents the negative relationship with the swap spread on the condition of the economic development situation.

2.4 Empirical researches

A large body of literature on interest rate swap spread is focused on identifying determinant risk factors which explain the swap spread. The main existing theories provide an analysis in this regard from two perspectives. One is based on the liquidity convenience yield curve (liquidity premium) of Treasury Securities, and namely Treasury-swap spread in Treasury market. The other one discusses the spread in terms of default risk in the swap market.

The most representative framework for studying the determinants driving interest rate swap spreads is provided by Duffie and Singleton (1999, 1997). They developed a multi-factor econometric model of the term structure of interest rate swap yields, which demonstrates the impact of counterparty default risk and liquidity differences between Swap and Treasury Securities markets on the spread. Sun et al. (1993) observed the effect of counterparties' different credit rating (AAA and A) on swap rate bid –offer spread. The AAA bid rates are significantly lower than the A bid rates, whereas the AAA offer rates are significantly higher than the A offer rates. Furthermore, argued by Sorensen and Bolllier (1994), the price of the default risk depends on the value of two options, which in turn relies on the slope of yield curve and the volatility of the short term interest rate. Moreover, Cooper and Mello (1991) provide a model which takes the possibility of default by one side of counterparties to the swap agreement into account. As a result, if the fixed-rate payer is assumed to be the only counterparty at risk of defaulting, then the swap is basically characterized by the exchange of default risky fixed-rate bond for a default-free floating-rate bond which derives a relationship between equilibrium swap rate and the credit spread of a bond.

In contrast, Smith et al. (1988) examined the interest rate swap spread under the assumption of no default, no liquidity risk, and the fixed rate of interest rate swap is

expressed as the yield on a coupon-paying government bond. Likewise, Grinblatt (1995) introduced a framework to analyze the spreads under the assumption that simple interest rate swaps are intrinsically default free. He argued that the liquidity difference between government bonds and short term Eurodollar borrowing is the reason for the spread between discount rates used to value swaps and government bonds. The high liquidity of government bonds results in a liquidity premium, which is lost to an investor who receives fixed payment in a swap agreement. Therefore, the swap spreads are determined by the present value of current and future liquidity premium in his framework. The various swap spread curves generated by his model explain around 35% to 40% of the variation of US interest rate swap spreads. There are some other extant models trying to relate the corporate yields to the swap rates, which are called LIBOR swap spread. Brown et al. (1994) stated that interest rate swap spreads as functions of proxies for expected future levels of LIBOR over Treasury securities spreads, different measures of credit risk and hedging costs of the swap counterparties. All these variables are relevant to the swap spreads, but their relative importance fluctuates with the maturities of swaps. Dufresne and Solnik (2001) developed a model in which the default risk is enclosed in the swap term structure that is sufficient to explain the LIBOR-swap spread. Although the corporate bonds carry risk, they argued that the swap contracts are free of risk, since those contracts are indexed on credit-quality LIBOR rate. Accordingly, the swap spread between corporate yields and swap rates should express the market's expectations on credit quality of corporate bond issuers.

Furthermore, some recent researchers extend the investigation of the variation of interest rate swap spread by including some other possible determinant factors, such as expected LIBOR spreads and swap market structure. The LIBOR spread component is introduced by Brown, Harlow, and Smith (1994) and Nielsen and Ronn (1996): LIBOR rates are usually higher than the Treasury rates of the same maturity, and as a result, the difference is often referred to as the LIBOR spread. In this context, the swap sellers expect to pay a rate which is higher than the variable rate by the amount of LIBOR spread, thus the need to be compensated by a higher fixed rate leads to a positive swap spread.

The role of swap market structure on swap spread is based on the idea that demand/supply shocks in the swap market will influence the swap spread. These shocks derived from the original motivation of the swap market participants who try to arbitrage the debt market imperfection. The researches of Wall (1989) and Titman (1992) show that some borrowers prefer the financing strategies which involve paying fixed rate of swap when facing the market imperfection, such as the potential distress costs and asymmetrical information. Accordingly, the partly decreased or eliminated debt market imperfection creates the swap spread surplus for the swap contract counterparties.

In general, which of these determinant factors cause the variation of the interest rate swap spread is more mixed. Besides the individual determinant variable, the maturity of the swap contract can also account for the changes in the swap spread. Sun et al. (1993) found that the swap spreads generally increase with maturity in their empirical study of the swap rate. Minton (1997) extended their study which lead to the conclusion that interest rate swap spreads are not only related to the level and slope of the term structure, credit risk and liquidity premium, but also to the maturities.

Finally, Litzenberger (1992) demonstrated that allocation of risks between swap counterparties varies over a business cycle which leads to variation of swap spread.

3. Data Description

In this part we present the sources of data, and the explanation of dependent variable and independent variables.

3.1 Sources of data

To empirically investigate the importance of the determinants of interest rate swap spread in U.S derivative market, we use the monthly data of 2-, 5-, 7-, 10-year maturity from June 30, 1998 to March 31, 2007 for a total of 106 observations. Parts of the data sample were collected from Datastream and Ecowin, and others were kindly provided by Professor Hossein Asgharian. The whole data sample comprises U.S swap rates, government bond yields, double A and triple A corporate bond yields, and unemployment rates[2], budget deficit.

Figure 1 plots the swap rates of 2-, 5-, 7- and 10-year maturity during the period of June 1998 to December 2006, which represents the movement of short, medium and long term swap rates, respectively. As the graph shows, swap rates have climbed up from the end of 1998, and started to decline in December 2000. Since then, the swap rate keeps decreasing until June 2003; thereafter, the swap rate started to move upwards again.

Observing Figure 1 and Figure 2 together, the short-term swap rates peaked up to the long-term swap rates while the short-term yield curve of Treasury bonds moved above the long-term yield curve during January 2000 to February 2001. Further, from March 2001 to September 2005, the short-term swap rates have generally declined; the short-term swap rate moves along the same direction as yield curves. Hence, it is very clear that the swap rates vary with the changes in yield curves of Treasury bonds, which means there is a strong relation between them.
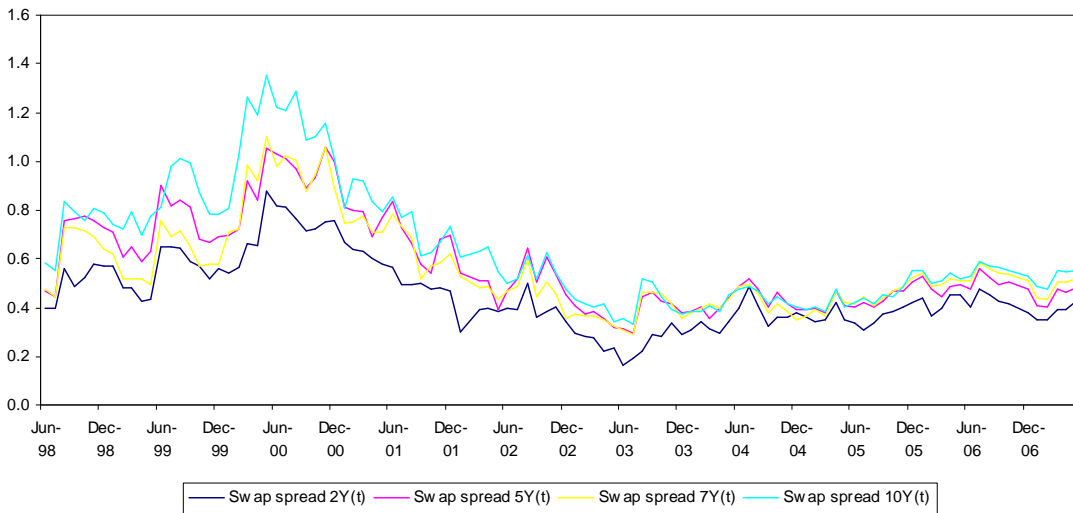
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[2] Used as proxy variable of business cycle.

Figure 1: The movement of swap rates
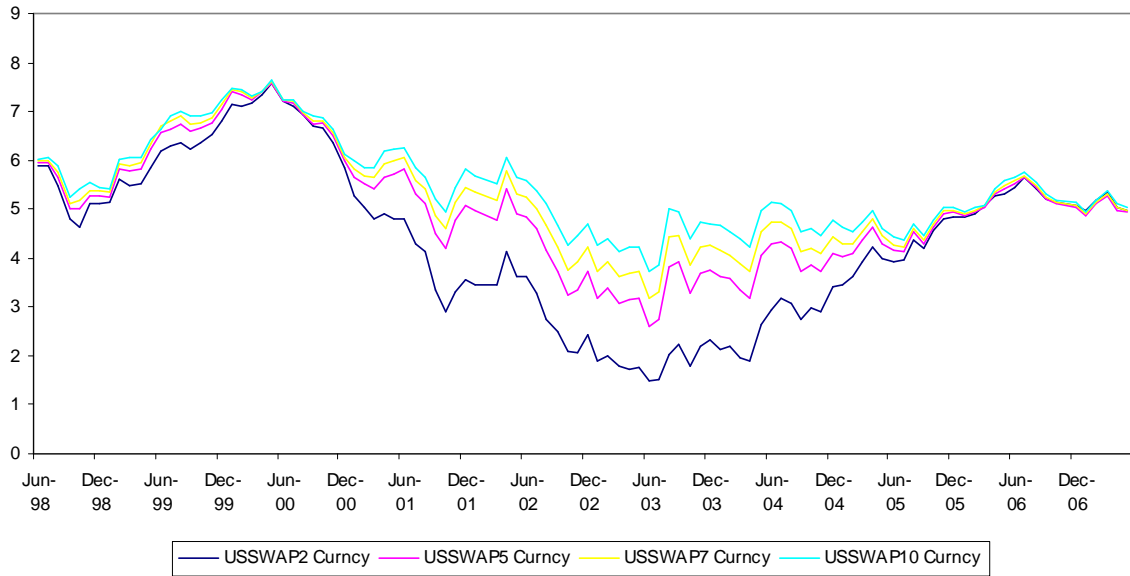
Figure 2: The movement of Treasury rates

From Figure 3, we can clearly detect that the movements of swap rate and Treasury rate are closely correlated in long term maturity. The graphs of the movement of swap rates and Treasury rates of other short, medium term are included in the appendix.

Figure 3: The movement of Swap rate and Treasury rate of 10-year maturity
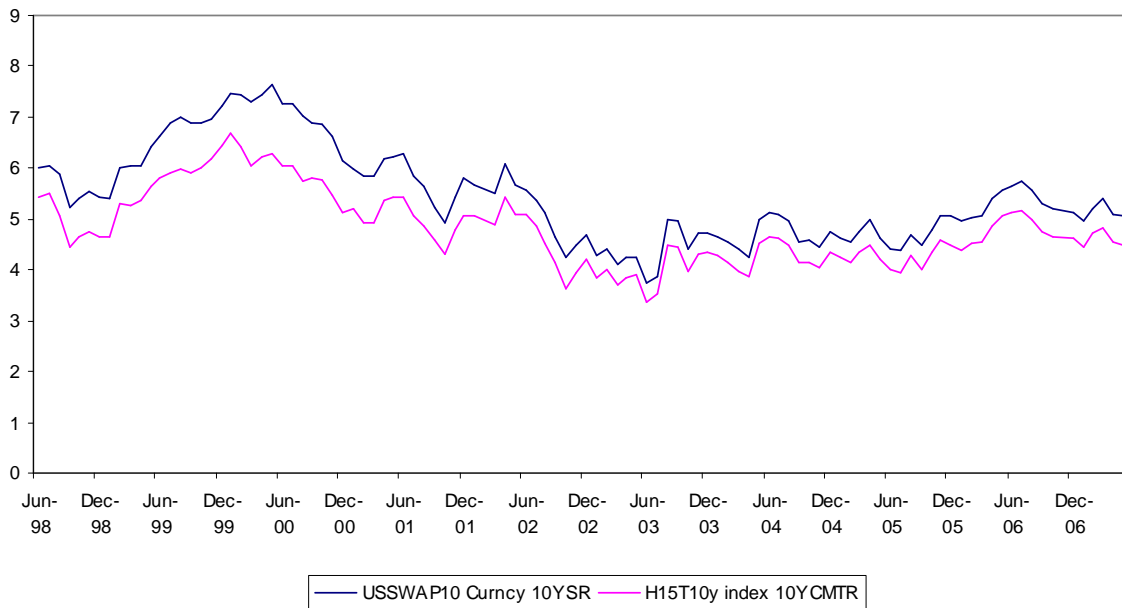
In addition, Table 1 provides the summary statistics at observed level for swap rates, Government bond yields as well as other proxy variables, such as default premium, slope of yield curve, budget deficit, and business cycle. The mean, standard deviation, minimum and maximum values of the determinant factors of 2-, 5-, 7- and 10- year maturity were listed. It is very easy to note that swap rates increase along with the increase in Government Bond yields as the year of maturity extends. However, we do observe that the swap spreads did not follow the exact same monotonic varying path. They grow from 2-year to 5-year maturity, then decline from 5-year to 7-year maturity, and again they increase from 7-year to 10-year maturity. It would be in a small hump shape if we would have plotted them in a graph. Compared to the wild variation of budget deficit from maximum of 189.8 to minimum -119.24 within the sample period, the business cycle shows much less fluctuations. Moreover, the implied volatility of Treasury market and Stock market in the chosen sample period are not as volatile as we expected.

Table 1: Summary Statistics (level)

	Mean	Standard Deviation	Minimum	Maximum
Government Bond Yield				
10-year	4,82	0,73	3,37	6,68
7-year	4,68	0,92	2,87	6,75
5-year	4,43	1,06	2,30	6,71
2-year	3,93	1,52	1,32	6,69
90-day	3,45	1,77	0,90	6,38
Swap Rates				
10-year	5,47	0,94	3,73	7,64
7-year	5,24	1,06	3,17	7,62
5-year	5,00	1,20	2,62	7,59
2-year	4,38	1,63	1,50	7,57
Swap Spreads				
10-year	0,64	0,25	0,33	1,35
7-year	0,56	0,18	0,29	1,10
5-year	0,58	0,19	0,30	1,06
2-year	0,45	0,15	0,17	0,88
AA-Corporate Bond Rates				
10-year	5,87	0,88	4,31	7,85
7-year	5,61	0,96	3,77	7,73
5-year	5,27	1,12	3,17	7,64
2-year	4,51	1,59	1,73	7,50
AAA-Corporate Bond Rates				
10-year	5,32	0,96	3,54	7,43
7-year	5,08	1,08	3,02	7,53
5-year	4,85	1,20	2,51	7,39
2-year	4,21	1,60	1,33	7,29
Proxy Variables Default Premium				
10-year	0,56	0,19	0,11	1,03
7-year	0,54	0,21	0,00	1,14
5-year	0,43	0,17	0,09	0,89
2-year	0,30	0,10	0,05	0,63
Slope	2,01	1,24	-0,08	4,28
Implied Stock Market Volatility	0,01	0,00	0,00	0,03
Implied Treasury Market Volatility	0,00	0,00	0,00	0,01
Governent Budget Deficit	-8,87	56,77	-119,24	189,8

Note: all the statistics values are obtained from data sample from June 1998 to March 2007.

3.2 Dependent variable

Interest rate swap spread is determined by the difference between swap rate and Treasury rate of same constant maturity. Since we focus on the most generic interest rate swap contract[3], the swap rate in this context refers to the fixed rate of interest that makes the value of the swap equal to zero at the contract date as noted by Lekkos (2001). The floating rate is typically indexed to some market-determined rate such as the Treasury rate or more commonly, the short term LIBOR as stated in the book of Hull (2005). In this paper, we adopt the former to calculate the swap spread.

Figure 4 graphs the movements of swap spreads of 2-, 5- 7-, and 10-year maturity during the chosen sample period. Clearly, the movements in short, medium and long term maturities show the strong tendency to move together all the time. Additionally, we can see that there is a peak at the end of 90s and beginning of 2000. The explanation could be that the financial crisis in 1998 might imply both a default risk event and a liquidity event. However, based on the Longstaff (2002), the U.S. government decision to reduce the supply of Treasury securities were entirely liquidity events which are not preceded or followed up by a default premium.

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[3] The most generic interest rate swap contract is the fixed-for-floating par swap.

Figure 4: The movement of Swap spreads
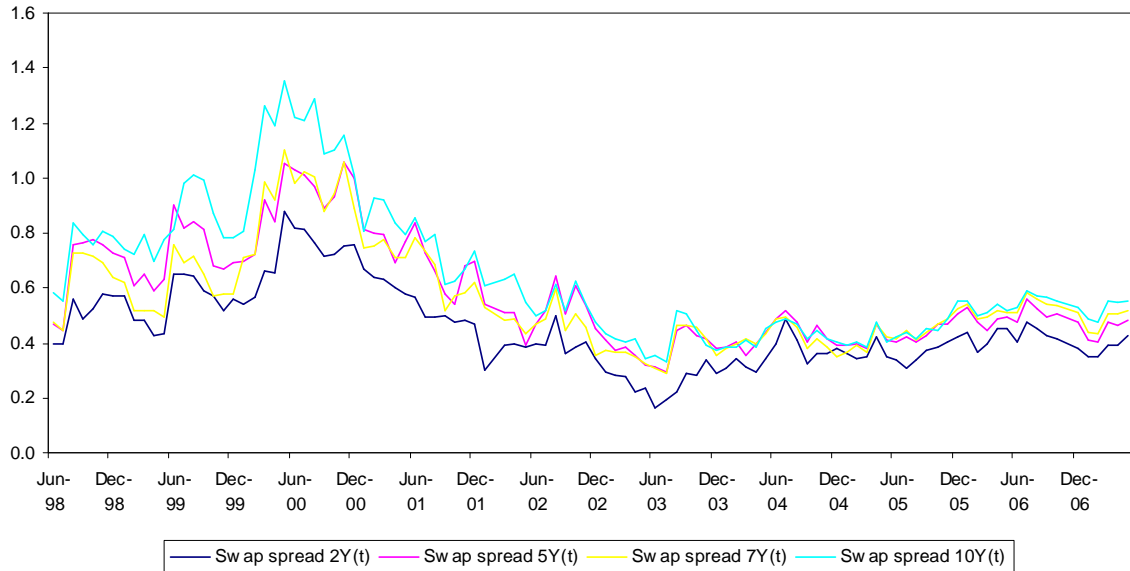
3.3 Independent variables

In theory, the interest rate swap spreads are determined given the current values of the stated independent variables. Accordingly, the swap spread changes are determined by the changes in these independent variables, and hence we also come up with our theoretical predictions in terms of changes in the level data[4].

Changes in default premium. Existing empirical evidence on the relationship between default risk premium and swap spread changes has not been proved statistically consistent over time even though the default premium has been considered the basic determinant factor on variation of swap spread. Take this interesting 'conflict' into account; we decided to include this variable into our model. In the earlier studies, quite a few researchers have studied this relation by using different proxy variables. For example, Minton (1997), Brown et al. (1994), and Duffie and Singleton (1997) used the difference between the yield on a portfolio of medium-maturity triple A bonds and the yield on a government bond of equal properties as a proxy for the default premium. Moreover, in the model developed by Sorensen and Bollier (1994), the probability of swap

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[4] In this paper, we use first difference of the level data to show the changes in the variables.

counterparty default and the economic cost of default for the solvent counterparty are evaluated simultaneously.

Nevertheless, a more general approach to this investigation is to assume that default risk in swaps can be precisely proxied with the information from the corporate bond market as noted by Milas (2001). For example, Chen and Selender (1994) developed a model to test the relations between the corporate bond quality spread and the movement of swap spread. In the same regard, we define the default premium as the difference between double A and triple A corporate bond yields of same constant maturities.

Changes in slope of the yield curve. As pointed out by Duffee (1998), there is a need for variables that can summarize the information in the Treasury Securities yields. Following the argument of Litterman and Scheinkman (1993) and Chen and Scott (1993), the slope of the Treasury bond yield fulfils this requirement. Moreover, Brown et al. (1997) states that the hedging costs rise as interest rate rises, resulting in a situation where the higher the interest rate is, the lower will be the swap spread offered by market makers. Additionally, Milas (2001) found that increases in the slope of the yield curve are associated with an expansion in economy and an improvement of business conditions, which in turn should alleviate any default concerns and cause swap spreads to decline.

In line with these research results, we included this variable into our model and defined the slope of the yield curve as the difference between 10-year and 90-day Treasury securities yields. Besides the expected contributions to variation of swap spreads, this proxy variable is also interpreted as an indication of expected future short term interest rate as well as an indication of overall economic health.

Changes in implied volatility of Treasury market. Our inclusion of this variable into our model is out of consideration for the strongly close correlation between swap rates and government bond yields over long term maturity, which we can see from the Figure 3 on

page 14. As for other maturities, please refer to Appendix. Hence, we believe the volatility in Treasury market have impact on movement of swap spreads. To better integrate this variable into swap spread investigation, we use the implied volatility[5] as a proxy of the volatility of Treasury market.

As stated in the Wikipedia dictionary, the implied volatility of an option contract is the volatility implied by the market price of the option based on an option pricing model. More specifically, the volatility, given a particular pricing model such as Black-Shole model, yields a theoretical value for the option equal to the current market price. This allows some non-option financial instruments such as Treasury bonds having embedded optionality, to also have an implied volatility.

Changes in implied volatility of Stock market. Similar rationale as above discussion, we need a variable which can catch the information in stock market. Theoretically, there is negative co-movement between the default probability and the stock price. As the stock price falls, the value of the asset is brought down, which in turn increases the default probability of the companies. Following this logic, the increased default probability will increase the companies' equity risk and hence the interest rate. Therefore, we consider that the information of the volatility in the stock market has its role in the swap spread changes.

We obtain this proxy variable by calculating the standard deviation of the daily observations from S&P 500, the theoretically rationale of using implied volatility is similar to that of implied volatility of Treasury market as explained above. Furthermore, since the value of the option increases with the volatility, it implies that the swap spread should increase with the volatility as well. On the other hand, this is very intuitive, as increased volatility increases the probability of default.

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[5] The implied volatility here is the embedded option price of the Treasury bonds calculated by Black-Shole formula.

Changes in budget deficit. There is only a limited study on this variable as a determinant risk factor on swap spread. The reason we want to include this variable into our model is that according to economic theory, the issuance of government bond increases with the increases in government budget deficit. Therefore, we consider that the Treasury rates might climb up or decline due to the demand/supply shock in Treasury bond market. Accordingly, we predict that a change in swap spread is related to the change in budget deficit. In this paper, we define this explanatory variable by using the monthly government budget deficit index.

Changes in business cycle. As argued by Lizenberger (1992), default risk allocation between swap counterparties varies with the business cycle; hence this variable should be controlled while testing the impact of default risk on swap spread. However, he did not show how exactly default risk allocation varies with business cycle and to which extent so that it needs to be controlled. Furthermore, there are rather limited researches in this regard. These questions motivate us to include this variable into our model. In this paper, we use U.S monthly unemployment rate as a proxy viable for business cycle.

4. Methodology

In this part we present the empirical hypothesis, description of test procedure and methodology we use to analyze data. The empirical models are extension of univariate GARCH model (Bollersle 1986), Cointegration model (Engel-Granger, 1987).

4.1 Empirical hypothesis

Based on the literature review, availability of reliable data, and the more important our research objectives, we arrive at the following empirical hypothesis:

(1) Changes in the IR swap spread will be related positively to changes in the default premium in corporate bond market.

(2) Changes in the IR swap spread will be related negatively to changes in the slope of yield curve of Treasury Securities.

(3) Changes in the IR swap spread will be related positively to changes in the implied Treasury market volatility.

(4) Changes in the IR swap spread will be related positively to changes in the implied Stock market volatility.

(5) Changes in the IR swap spread will be related positively to changes in the government budget deficit.

(6) Changes in the IR swap spread will be related positively to changes in the business cycle.

Based on the above empirical hypothesis, the appropriate regression equation which can be used to test the effects of determinant factors of interest rate swap spread is as follows:

$$\Delta swapspread_{i,t} = \alpha_{i,0} + \beta_{i,1}\Delta DP_t + \beta_{i,2}\Delta slope_t + \beta_{i,3}\Delta Tvolatility_t + \beta_{i,4}\Delta Svolatility_t$$

$$+ \beta_{i,5}\Delta BD_t + \beta_{i,6}\Delta BC_t + \varepsilon_{i,t}$$

$$\varepsilon_{i,t} \sim \left[0, \sigma^2{}_t\right]$$

Where i = 2-, 5-, 7- and 10-year indicating different maturities of the swap contract, and $\Delta swapspread_t$ (changes in swap spread), ΔDP_t (changes in default premium), $\Delta slope_t$ (changes in slope of Treasury rates), $\Delta Tvolatilti y_t$ (changes in implied volatility of Treasury market), and $\Delta Svolatility_t$ (changes in implied volatility of Stock market), ΔBD_t (changes in budget deficit), ΔBC_t (changes in business cycle) are defined as the first difference of observed level value of $swapspread_t$, DP_t, $slope_t$, $Tvolatility_t$, and $Svolatility_t$, BD_t, BC_t correspondingly. Later, we will run the regression of $\Delta swapspread_t$ against the variables of ΔDP_t, $\Delta slope_t$, $\Delta Tvolatilti y_t$, and $\Delta Svolatility_t$, ΔBD_t, ΔBC_t.

Further, according to our empirical hypothesis and research motivations described in independent variable part of data description, the explanatory variables are expected to have the following signs as shown in Table 2.

Table 2: Explanatory variables and predicted signs on the coefficient of the regression

Explanatory Variables	Description	Expected Sign
ΔDP	Changes in default premium of Corporate bonds	+
ΔSlope	Changes in 10-year minus 90-day Treasury yields	-
ΔTvolatility	Changes in implied volatility of Treasury market	+
ΔSvolatility	Changes in implied volatility of Stock market	+
ΔBD	Government Budget deficit	+
ΔBC	Business cycle	+

4.2 Test procedures

First, we started with Augmented Dickey-Fuller (ADF) unit root test to examine whether those thirteen time series of different maturities are stationary ($\Delta swapspread$, ΔDP , $\Delta slope$, $\Delta Tvolatility$, $\Delta Svolatility$, ΔBD , ΔBC) or not with a constant and a trend at 1% significance level.

Second, to continue the empirical testing, we perform GARCH test to investigate the impact of the changes in default risk premium slope, implied Treasury market volatility and implied Stock market volatility on the interest rate swap spread with the exclusion of the budget deficit and business cycle.

Third, to examine further, we apply the cointegration test to all the variables in pairs in order to measure the extent of correlation between them.

Finally, based on the obtained test results, we conduct the extension of a multivariate GARCH model by combining two Error Correction Terms into the regression. We will discuss the test models and test results in detail in the following sections.

4.3 GARCH model

To test and quantify the effect of determinant factors on interest rate swap spread, we use a Generalized Autoregressive Conditionally Heteroscedastic (GARCH) model developed in a univariate form by Bollersle (1986) which expresses the conditional variance changes over time as a function of past values of the squared errors and past conditional variances, leaving the unconditional variance constant. The basic specification of GARCH model is given by:

$$\sigma^2{}_t = \omega + \alpha_1 \eta^2{}_{t-1} + \beta_1 \sigma^2{}_{t-1},$$

The error term η_t denotes the real-valued discrete time stochastic process and φ_{t-1} is the information set available at time $t-1$.

$$\eta_t \,|\varphi_{t-1} \sim\, N(0, \sigma^2{}_t)$$

Where,

$\omega \succ 0$,

$\alpha_1 \geq 0$,

$\beta_1 \geq 0$,

$\alpha_1 + \beta_1 \prec 1$, is sufficient for wide sense of stationary

$$\eta_t = \sigma_t \varepsilon_t$$

$$\varepsilon_t \sim IID \text{ and } N(0, \sigma^2_t)$$

This is a GARCH (1, 1) model, in which σ^2_t is known as the conditional variance since it is a one-period ahead estimate for the variance calculated on the basis of any past information considered relevant. It is possible to interpret the current fitted variance, σ^2_t, as a weighted function of a long-term average value dependent on ω, information about volatility during the previous period ($\sigma_1 \eta^2_{t-1}$) and fitted variance from the model during the previous period ($\beta_1 \sigma^2_{t-1}$). Additionally, it is found that a GARCH (1, 1) specification is sufficient to capture the volatility dynamics in the data. Therefore, only one lagged squared error and one lagged variance is needed.

GARCH model has several advantages over the pure ARCH model. First of all, the GARCH model is more parsimonious, and avoids over-fitting. As a result, the model is less likely to breach non-negativity constraints (Brooks, 2002). Secondly, a relatively long lag in the conditional variance equation is often required. To avoid problems with negative variance parameter estimates a fixed lag structure is called for in application of the ARCH model (Bollerslev, 1986). In this light, the GARCH specification allows for both a longer memory and a more flexible lag structure. Thirdly, as pointed out by Bollerslev, the conditional variance is specified as a linear function of past sample variances only in the ARCH (q) model, whereas the GARCH (p, q) model allows lagged conditional variances to enter as well, this process corresponding to some kind of adaptive learning mechanism. Fourthly, the virtue of the GARCH model enables a small number of terms appear to perform as well as or better than an ARCH model with many.

Accordingly, in order to examine the effect of determinants of interest rate swap spread jointly and provide further insight of variation of interest rate swap spread, the above regression equation has been extended to a multivariate GARCH model of variables.

$$\sigma^2_t = \omega + \alpha_1 \eta^2_{t-1} + \beta_1 \sigma^2_{t-1} + \alpha_2 \eta 2_{t-1} + \beta_2 \sigma^2_{t-1} + \cdots + \alpha_q \eta^2_{t-q} + \beta_p \sigma^2_{t-p}$$

$$\sigma_t = \omega + \sum_{i=1}^{q} \alpha_i u^2_{t-i} + \sum_{j=1}^{p} \beta_j \sigma^2_{t-j}$$

Where,

$$q \succ 0, \qquad p \geq 0$$

$$\omega \succ 0, \qquad \alpha_i \geq 0, \qquad i = 1, \cdots, q,$$

$$\beta_j \geq 0, \qquad i = 1, \cdots p.$$

4.4 Cointegration model

According to the economic theory, we think the two variables: budget deficit and business cycle, might be cointegrated to some extent. A nonstationary variable tends to wander extensively but some pairs of nonstationary variables can be expected to wander in a way that they don't drift apart from each other (Kennedy, 2001). Under such consideration, we conduct the cointegation test between budget deficit and business cycle since the data are I(1) which means that ECM (Error Correction Model) estimating equation could be producing spurious results, such variables are said to be cointegrated. We want to purge and estimate the nonstationary variables by differencing and using only differenced variables if the data are shown to be nonstationary. We are quite interested in the cointegration between budget deficit and business cycle since the cointegrating combination is interpreted as an equilibrium relationship in which variables in the error-correction term in an ECM can be shown. By testing the cointegration of the above two variables, we could eliminate the unit roots. If the set of I(1) variables is cointegrated, then regressing one on the others should produce residuals I(0).

4.5 GARCH with Error Correction Terms Model (ECT)

A full Error Correction Model (ECM) is performed to analyze the short-run dynamic relationship between two variables. This Error Correction formulation in the regression is

$$\Delta SS_t = \alpha + \beta_1 \varepsilon_{BD,t-1} + \beta_2 \varepsilon_{BC,t-1} + \beta_3 \Delta BD_t + \beta_4 \Delta BC_t + \beta_5 \Delta SL_t + \beta_6 \Delta Svol_t \\ + \beta_7 \Delta Tvol_t + \beta_8 \Delta DP_t + \varepsilon_t$$

Error Correction Model is explained as follows:

First, we regress the swap spread on business cycle in the different maturity by using the Least Squares method.

$$SS_t = \alpha + \beta BC_t + \varepsilon_{BC,t}$$

The residuals

$$\varepsilon_{BC,t} = SS_t - \alpha - \beta BC_t$$

will be used for error correction in the final regression.

Second, we regress the swap spread on budget deficit using the Least Squares method.

$$SS_t = \alpha + \beta BD_t + \varepsilon_{BD,t}$$

The residuals

$$\varepsilon_{BD,t} = SS_t - \alpha - \beta BD_t$$

are also used for error correction.

Finally we insert the residuals into the model.

$$\Delta SS_t = \alpha + \beta_1 \varepsilon_{BD,t-1} + \beta_2 \varepsilon_{BC,t-1} + \beta_3 \Delta BD_t + \beta_4 \Delta BC_t + \beta_5 \Delta SL_t + \beta_6 \Delta Svol_t$$
$$+ \beta_7 \Delta Tvol_t + \beta_8 \Delta DP_t + \varepsilon_t$$

The coefficients are calculated by using GARCH specification.

5. Empirical findings

This section contains our research analysis and the empirical testing results which include ADF Unit root test results, GARCH model test results, Cointegration test results, GARCH with Error Correction Terms and Hypothesis test results.

5.1 ADF Unit root test results

To proceed our tests, we started with Augmented Dickey-Fuller (ADF) unit root test to examine whether these thirteen time series of different maturities are stationary ($\Delta swapspread$, ΔDP, $\Delta slope$, $\Delta Tvolatility$, $\Delta Svolatility$, ΔBD, ΔBC) or not with a constant and a trend at 1% significance level. The test result shows in the Table 3.

Table 3: Augmented Dickey-Fuller unit root test (first difference of the level data)

Varibles	1st Difference Constant only	1st Difference Constant and linear trend
ΔSwap spread 2Y	-11,792	-11,743
ΔSwap spread 5Y	-11,303	-11,280
ΔSwap spread 7Y	-12,094	-12,051
ΔSwap spread 10Y	-11,259	-11,222
ΔDP 2Y	-13,331	-13,267
ΔDP 5Y	-13,291	-13,259
ΔDP 7Y	-12,253	-12,244
ΔDP 10Y	-11,089	-11,826
ΔSlope	-9,133	-9,334
ΔTvolatility	-7,473	-7,387
ΔSvolatility	-8,987	8,944
ΔBudget deficit	-3,198	-3,547
ΔBusiness cycle	-8,731	-8,684

Note: both resulting test values of 1st difference & constant only and 1st difference & constant and linear trend are far more negative than the critical value at 1% significance level (-3.497). Therefore we concluded that 13 time series do not have unit root. In other words, they are stationary time series data.

5.2 GARCH analysis

In order to investigate the variation of swap spread, we test the volatility of swap spread based on the specification of GARCH model in the form of the following regression equation, in which we regress the changes in swap spread against changes in default premium, slope of yield curves, implied Treasury market volatility and implied Stock market volatility with the exclusion of budget deficit and business cycle[6]. The data used in this GARCH estimation is the first difference of the observed level data. The test results are presented in Table 4.

$$\Delta swapspread_{i,t} = \alpha_{i,0} + \beta_{i,1}\Delta DP_t + \beta_{i,2}\Delta slope_t + \beta_{i,3}\Delta Tvolatility_t + \beta_{i,4}\Delta Svolatility_t$$

$$+ \beta_{i,5}\Delta BD_t + \beta_{i,6}\Delta BC_t + \varepsilon_{i,t}$$

Table 4: GARCH Test Results

	2-year			5-year			7-year			10-year		
	Coefficient	Z-stat	P-value	Coefficient	Z-stat	P-value	Coefficient	Z-stat	P-value	Coefficient	Z-stat	P-value
β_1	0,005	-0,104	0,917	0,031	0,361	0,718	0,049	0,659	0,510	0,053	0,579	0,562
	(0.046)			(0.086)			(0.074)			(0.091)		
β_2	0,045	1,453	0,146	0,009	0,311	0,756	0,016	0,577	0,564	0,028	0,914	0,361
	(0.031)			(0.028)			(0.028)			(0.031)		
β_3	5,176	0,794	0,427	6,101	0,708	0,479	-2,237	-0,201	0,841	2,550	0,187	0,852
	(6.522)			(8.619)			(11.117)			(13.622)		
β_4	3,488	1,557	0,120	1,131	0,434	0,665	3,267	1,072	0,284	1,161	0,328	0,743
	(2.241)			(2.608)			(3.049)			(3.540)		
R^2		0,048			0,033			0,034			0,014	

Note: all the figures in ( ) are the standard errors.

It can be seen from Table 4, that the coefficients on four independent variables in the conditional variance equation are not all statistically significant. In particular, the proxy variables of implied volatility of Treasury market and implied volatility of Stock market which have 5.17 and 3.48 for 2-year maturity and 2.55 and 1.16 for 10-year maturity, respectively. Furthermore, the P-values of four maturities are overall not statistically significant even at a 10% significance level. In other words, the null hypothesis of our empirical research can not be rejected as statistically significant.

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[6] The reason of excluding these two variables here is that we suspect that these two variables are cointegrated, therefore, we conduct the cointegration test after we obtaining the results from the simple GARCH test.

5.3 Cointegration analysis

For all pairs of variables with a unit root, we tested for cointegrating functions. Table 5 shows the largest number of cointegrating functions found allowing for intercept and trend/no trend. Only swaps and default premiums of matching maturity are compared. The default premium of 2-year maturity did not have a unit root and is thus not included. The Table 5 results are consistent with our prediction of the cointegration between swap spread and budget deficit as well as swap spread and business cycle. It also shows a cointegration between 5-year swap spread and 5-year default premium, but not for swap spread and default premium of other maturities. Therefore we think that this is a spurious result due to the limited sample. There are also cointegration functions between different explaining variables, this might in it self be interesting but does not affect our regressions. Most notably we see two integrating functions between budget deficit and default premiums of all maturities which show that these variables tend to follow each other.

Table 5: Test for Cointegration functions

	DP5	DP7	DP10	Slope	BD	BC	S&P
SS2Y	-	-	-	No	1	1	No
SS5Y	2	-	-	No	1	1	No
SS7Y	-	No	-	No	1	1	No
SS10Y	-	-	No	No	1	1	No
Slope	No	No	No	-	No	2	No
BD	2	2	2	No	-	2	No
BC	No	No	No	2	2	-	No
S&P	1	1	No	No	No	No	-

5.4 Analysis of GARCH with Error Correction Terms

In Table 6 we show the estimated coefficients and the z-Statistics. A high (positive) z-Statistics value is good for a positive coefficient and a low (negative) is good for a negative coefficient. A z-Statistics of ± 1.96 or more means significance on the 5% level, ± 2.33 means significance on the 2% level and ± 2.58 or more means significance on the 1% level.

The significant results we find are: Business cycle of 5-year and 7-year maturity have significance on the 5% and 2% level respectively (negative correlation). The slope has significance on the 1 % level for all maturities (positive correlation). The stock market volatility has significance on the 5% level for the 7-year maturity (positive correlation). The default premium has significance at the 1% level for 2-year and -year maturity and at the 2% level for 5-year maturity and at the 5% level for the 10-year maturity (negative correlation).

Table 6: Coefficients, z-Statistics and R^2 for ECM

|	2YR		5YR		7YR		10YR	
	Coeff	z-Stat	Coeff	z-Stat	Coeff	z-Stat	Coeff	z-Stat
β_1	-0,110	-0,700	0,000	0,409	0,000	0,496	-0,141	-1,278
β_2	0,037	0,252	-0,116	-1,088	-0,147	-1,517	0,000	-0,319
β_3	0,000	0,214	0,000	0,135	0,000	0,060	0,000	-1,383
β_4	-0,080	-0,710	-0,364	-2,285	-0,343	-2,414	-0,274	-1,529
β_5	0,041	2,775	0,063	3,261	0,064	3,585	0,069	3,454
β_6	1,862	1,716	1,362	1,000	3,015	1,971	-0,352	-0,245
β_7	-1,035	-0,229	0,802	0,106	-10,031	-1,436	-5,263	-0,607
β_8	-0,202	-3,226	-0,209	-2,338	-0,162	-2,901	-0,607	-2,008
R^2	0,210		0,090		0,089		0,133	

5.5 Hypothesis Test Results

Here is our hypothesis analysis based on our regression results.

(1) Changes in the IR swap spread will be related positively to changes in the default premium in corporate bond market.

It is in the default premium that we find the strongest correlation with swap spread. ECM shows a strong correlation with z-statistics of –2.01 or better, indicating significance at the 5% level for 10-year maturity, and z-statistics of –3.2 3 for 2-year maturity indicating significance at the 1% level. However, this correlation is negative, disproving our hypothesis. The negative correlation can be quite easily seen in the above graph. The relation between swap spread does not fit with the intuitive assumption that uncertainty in the market will lead to larger swap spread and default premium. Clearly the relation has a more complicated explanation and further investigation is needed; this is however not within the scope of this thesis.

Figure 5: The movement of swap spread and default premium of 2-year maturity
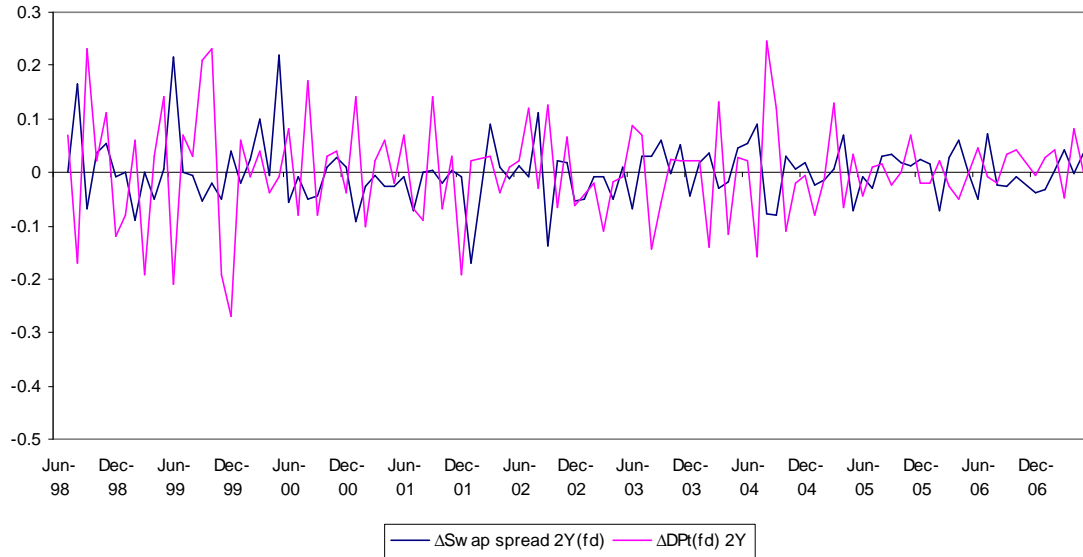
(2) Changes in the IR swap spread will be related negatively to changes in the slope of yield curve of Treasury Securities.

The ECM shows significance in the slope of yield curve only for 5 and 7-year maturity (z-Stat. of -2.28 and –2.41, respectively). This is significant at the 2% level. Therefore, our results strongly suggest that changes in the interest rate swap spread and the changes in the slope of yield curve of Treasury Securities. The observed correlation is negative which supports our hypothesis, which states that if future short term interest will be higher (positive slope), then there is less uncertainty in the market because of expected good times and less uncertainty leads to smaller swap spread.

Figure 6: The movement of swap spread of 2-year maturity and slope of Treasury yields
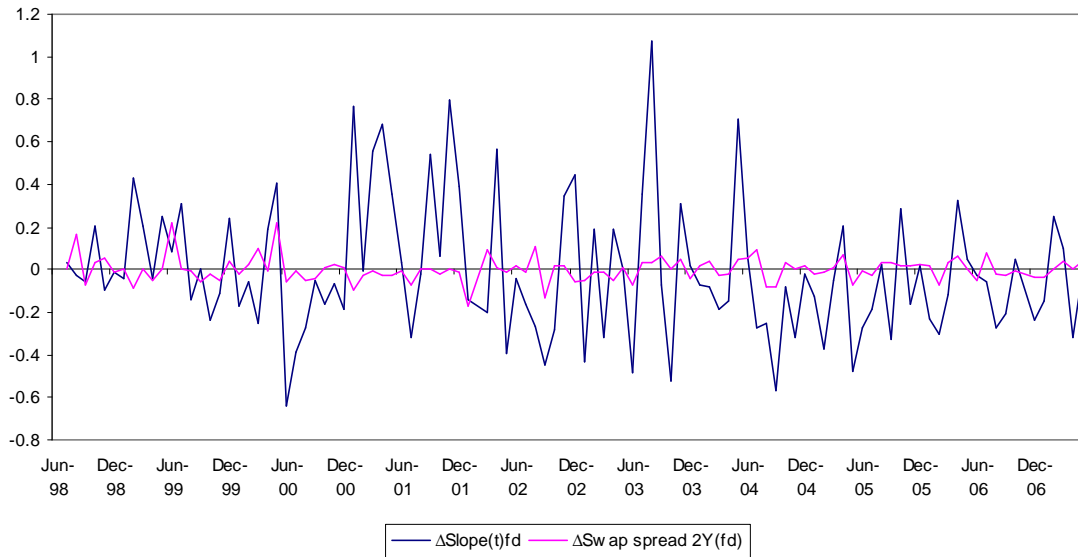
(3) Changes in the IR swap spread will be related positively to changes in the implied Treasury market volatility.

The Treasury market volatility shows no significant correlation with the swap (z-Stat. of -0.22895 and -0.60729 in 2 year and 10 year)**.** We can neither prove nor disprove our hypothesis from this data. However, it seams that any correlation would be quite weak. In the future, when more statistics are available, it might be possible to observe a correlation. It is, however, not possible now, due to the limited time that the swap spread market has existed.

(4) Changes in the IR swap spread will be related positively to changes in the implied Stock market volatility.

The stock market volatility shows a positive correlation with share spread with significance on the 5% level for the 7-year maturity. This supports our hypothesis, although only for the 7-year maturity. The reasoning behind our hypothesis is that both share spread and stock market volatility are signs of insecurity in the market and should thus be positively correlated.

(5) Changes in the IR swap spread will be related positively to changes in the government budget deficit index.

We see no significance for a correlation with government budget deficit (Z-Stat. of 0.21380and -1.38262 in 2 year and 10 year). Again, there is no significant correlation to prove or disprove the hypothesis. The statistics available are quite limited as the swap market has existed for only a short time. Any correlation would have to be quite strong to be visible.

(6) Changes in the IR swap spread will be related positively to changes in the business cycle.

The ECM shows a negative correlation for 5-year and 7-year maturity (z-Stat. of -2.28 and -2.41 respectively, significant at the 2% level). Even though it shows the strong correlation between these two variables, it disproves our hypothesis at the 2% level. Regression including Business cycle is complicated by the fact that date for Business cycle only exists on a quarterly basis and two out of three data points have to be interpolated in this regression. However, we did try interpolation in two ways; the one used in the presented regressions is simply that we assume the variable to be constant for the three months in a quarter. At the same time we tried with linear interpolation where we assumed the value of the quarter to apply for the middle month of the quarter and vary linearly until the middle month of the next quarter, i.e. if n is the middle month of quarter 1 and $n+3$ is the middle month of quarter 2, the values of the months in between are $BC_{n+1}=0.667*BC_n+0.333*BCn+3$ and $BC_{n+2}=0.333*BC_n+0.667*BC_{n+3}$. The results of the regressions with the two different interpolations schemes did not differ much and we chose to use the simpler one.

Figure 7: The movement of swap spread of 2-year maturity and business cycle
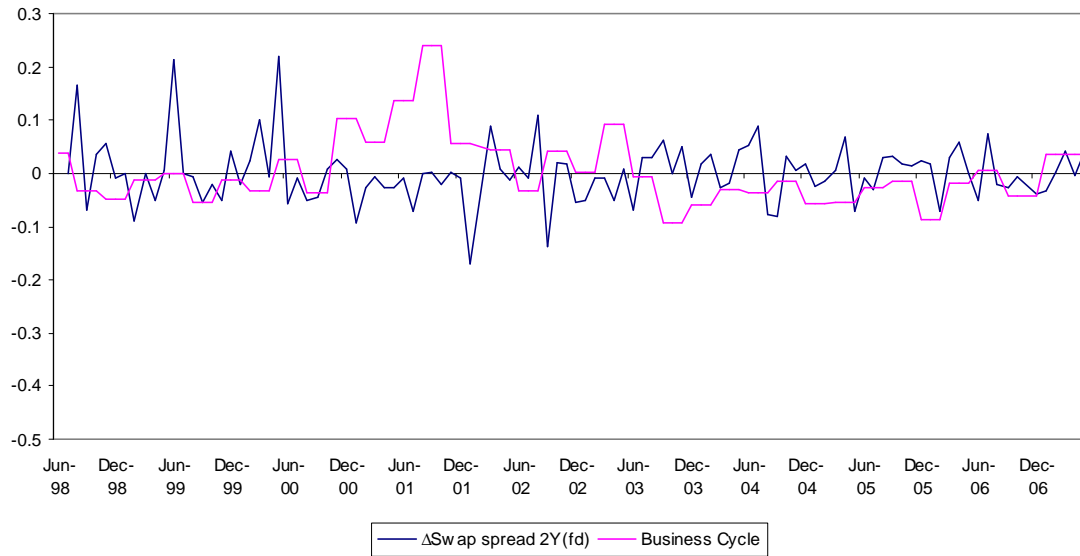
6. Conclusions

This part concludes what our empirical research is about, the data, the methodology we use and the results we obtained from the tests. Moreover, we point out what is missing in this study and present the research suggestions for future work.

Our paper uses a multivariate GARCH model with Error Corrections Terms (ECM) to investigate the determinants of swap spreads in the U.S. interest rate market. We have used monthly data of 2-, 5-, 7-, 10-year maturity from June 30, 1998 to March 31, 2007 for a total of 106 observations to empirically investigate the importance of the determinants of interest rate swap spread in U.S derivative market. According to our research results, we found that the movement of interest rate swap spread is negatively related to changes in the slope of yield curve of Treasury Securities which consistent with our hypothesis. We also found out that changes in the IR swap spread will be related positively to changes in the implied Stock market volatility; but we disprove our hypothesis that the changes in the swap spread will be related positively to changes in the default premium in corporate bond market. We found, however, that swap spreads in the U.S. market show negatively strong correlation with default premium with z-statistics of –2.01 or better. We also conclude that changes in the interest rate swap spread will be related negatively to changes in the business cycle. We think, however, that the business cycle is very complicated due to the nature of data. There is some evidence by Litzenberger (1992) that the allocation of risk between swap counter parties varies over business cycles.

We have to admit that there are some important factors which have not been built into our model. For example, we noticed swap spreads have a peak in the end of 1990s and early 2000. It might imply that swap spread is subject to some sort of shocks. We have not considered running regressions of determinants of swap spreads jointly for swap spreads of different terms to maturity. Based on the economy theory and empirical research results, it is shown that the interest rate swap market is not segmented to between different maturities (In, Brown and Fang, 2003). Further, there are some evidences that

the U.S. market also responds to conditions in the UK and Australia market due to the international links between financial markets. We leave these issues for future research.
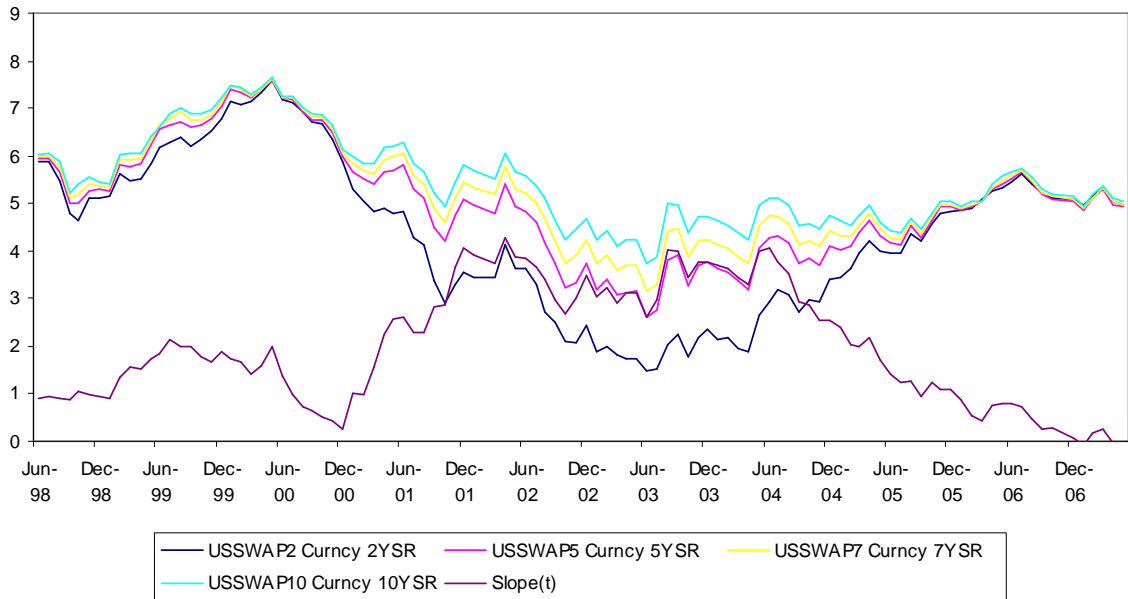
7. Acknowledgements

8. Appendix

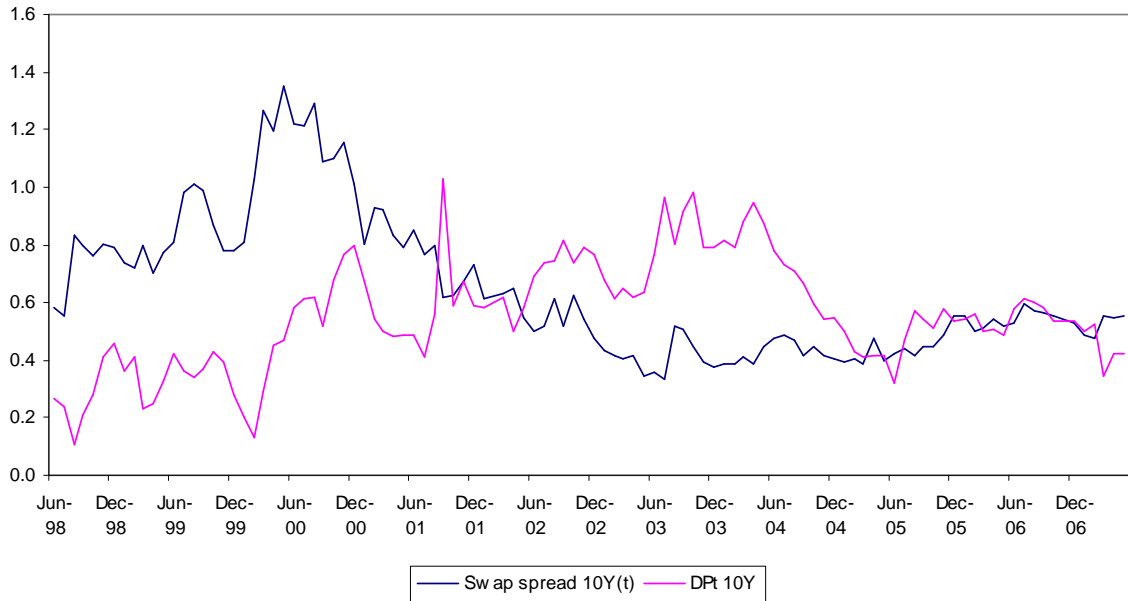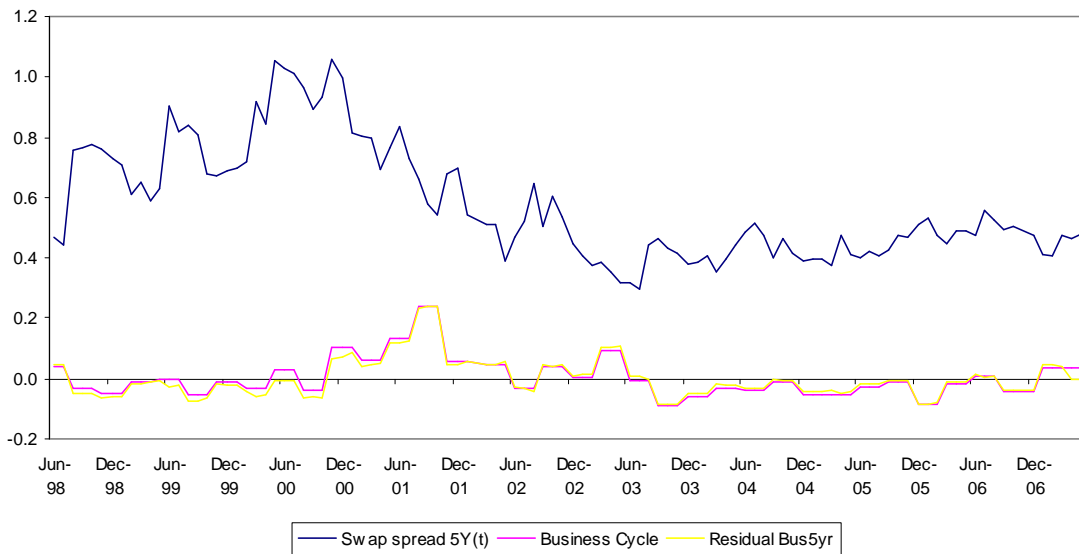## Figure 1: The movement of swap rate and the slope of the yield curve

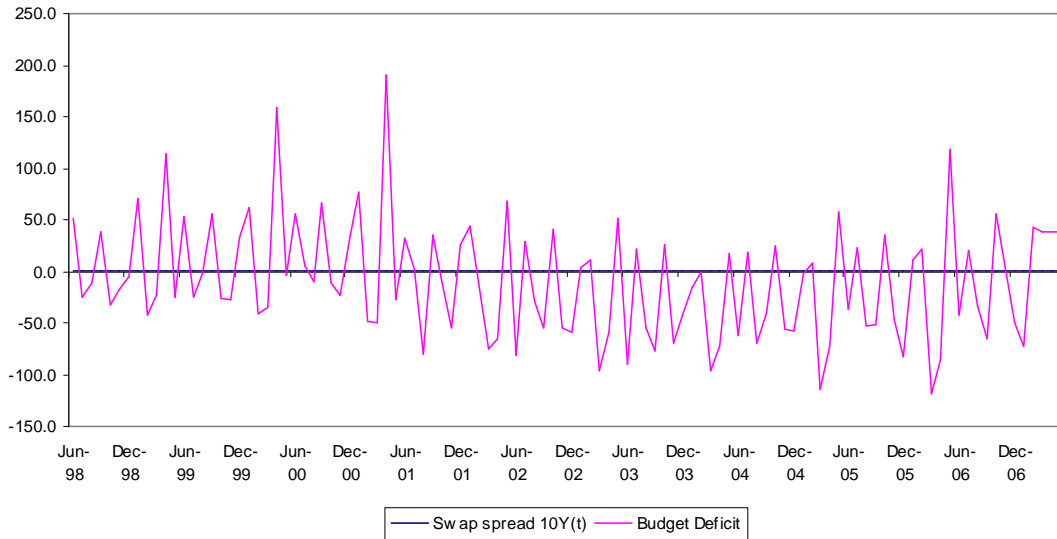## Figure 2: The movements of swap rates and the slope of the yield curve

Figure 3: The movement of swap spread and default premium

Figure 4: Output of univariate regression of swap spread, business cycle and residual business cycle of 5-year maturity

Figure 5: Output of univariate regressions of Swap Spread of 10-year maturity and Budget Deficit (Excel output)

From above Excel output, we couldn't see the correlation between swap spread and budget deficit due to the different scale clearly. So, we add the Eviews output to show the correlation by setting different scales in Figure 6.

Figure 6: Output of univariate regressions of Swap Spread of 10-year maturity and Budget Deficit (Eviews output)
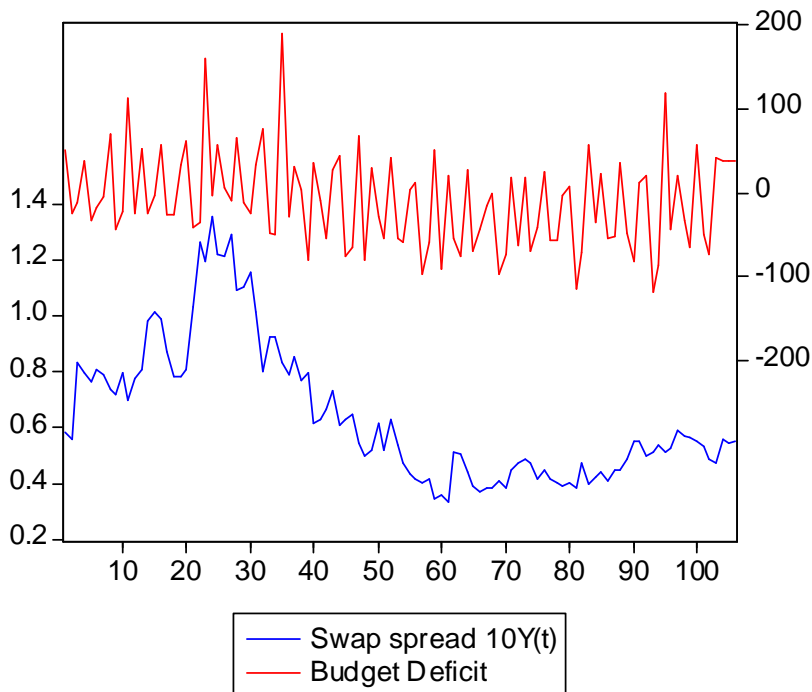
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