ARE BUSINESS CYCLE, MARKET SKEWNESS AND CORRELATION RISK PRICED IN SWAP MARKETS?

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Abstract
The existing literature suggests interest rate swap spreads are largely driven by liquidity factors. We find that U.S. dollar swaps also price risks from the business cycle and market skewness as well as the time varying correlation structure between long and short term interest rates. Our findings demonstrate that the swap spread contains significant components of these risks: pro-cyclical elements of business cycle risk (counter-cyclical elements during the crisis period); positive risk premia for skewness risk (when controlled for crisis events); and negative (positive) risk premia for correlation risk when the correlation between underlying interest rates is high (low). These results are robust across a number of sample periods and monetary policy environments, including recent actions by the U.S. Federal Reserve during the Global Financial Crisis.

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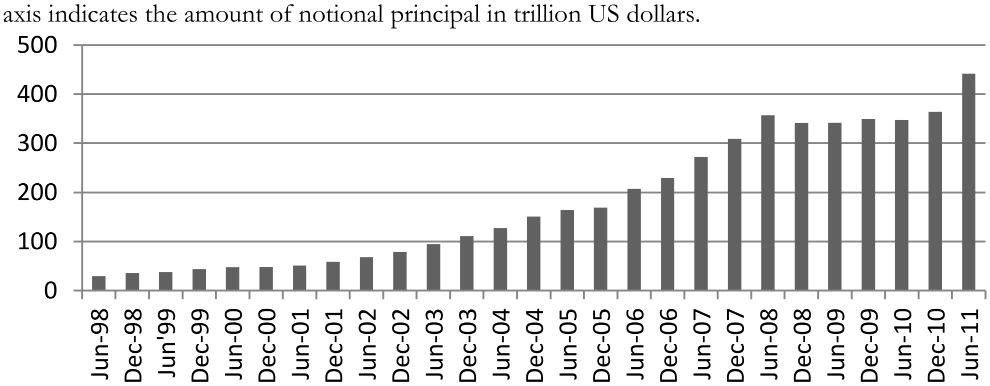
1 INTRODUCTION

Understanding and identifying those risk factors that drive asset prices and their underlying derivatives remains a crucial task for fund managers and regulators. In fact, the recent global financial crisis and the failure of several giant financial corporations, including Lehman Brothers and AIG, highlight the importance of understanding the risks inherent in one particular group: over-the-counter (OTC) derivative products, which are typically used for risk management and trading. Of the myriad contracts now available for these purposes, one in particular stands out - interest rate swaps (IRSs) - due to the scale of positions now held by financial intermediaries and their clients. For example, Bank for International Settlement (BIS) data shows that in terms of notional principal, interest rate swaps are the most important OTC derivative, while interest rate risk is itself the most important of the risks traded.[1] Figure 1 shows the growth of interest rate swap.

Figure 1: Growth of Interest Rate Swap Markets

This figure shows the growth of IRS in 'notional principal', which is used as a reference to determining the net interest payments in a swap contract. The figure is based on semi-annual data collected from Bank for International Settlement (BIS 2011). The left axis indicates the amount of notional principal in trillion US dollars.



[1] BIS (2011: Table 19) shows that of the US$707.8 trillion of notional OTC amounts outstanding in June 2011, 62.4% (US$441.2 trillion) were interest rate swap contracts, while interest rate contracts in total (including FRA's and options) were 78.3% (US$553.8 trillion). See also Figure 1.

The primary objective of this paper is to better understand the dynamics and drivers of swap prices than revealed by the existing empirical literature. Our findings extend a number of recent studies, including Feldhütter and Lando (2008), by showing the importance of business cycle, market skewness risk and correlation effects, on swap prices in addition to well-known liquidity and default factors.

The major concern in swap pricing is the spread, being the difference in yield between the rate of the swap and the underlying riskless security of equivalent maturity (typically a Treasury security) traded in the cash markets. This spread represents the relative price of risk [Kobor, Shi and Zelenko (2005)], and is typically modelled as a risk premium that compensates for both default risk and liquidity risk [e.g., Cooper and Mello (1991); Duffie and Huang (1996); Duffie and Singleton (1997) and Liu, Longstaff and Mandell (2006)]. Stock market risk, or volatility, can also be used as a determinant of the swap spread [Sultan (2006); Afonso and Strauch (2007) and Asgharian and Karlsson (2008)] due to the known correlation between net asset prices and corporate credit spreads (e.g. Merton (1974) and Longstaff and Schwartz, 1995). However, a number of studies including Wall and Pringle (1989), Litzenberger (1992), Minton (1997), Gupta and Subrahmanyam (2000), Grinblatt (2001) and Feldhütter and Lando (2008) find little support for default risk being the sole determinate, and instead find that liquidity risk dominants. These studies argue that the default risk of a swap is minimal and is mitigated by several factors largely driven by the contractual arrangements detailed in the swap agreement.[2] Nonetheless, the existing empirical literature does not completely explain the dynamics of swap prices, which suggests that there are a number of remaining factors that should also help explain swap spreads.

Detailed analysis of the asset pricing literature indicates that there are a number of possible factors that have received less attention in the swap literature than in studies of options, equity and bond markets.

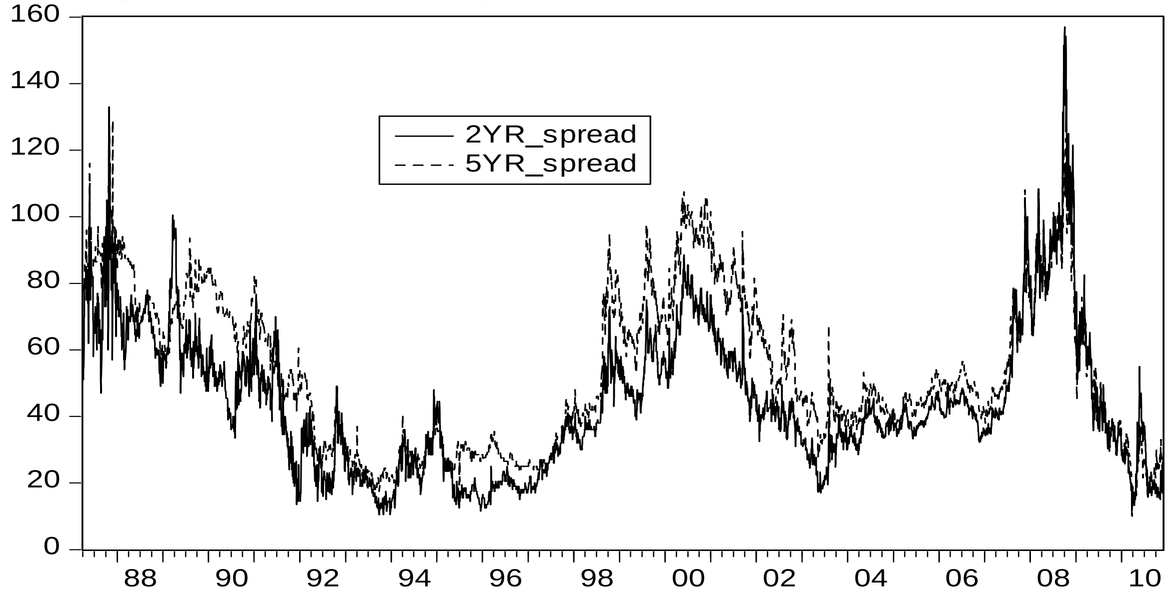
[2] Litzenberger (1992) shows that the default risk component of swap spread can be mitigated in the following manner: (i) the default risk is minimum because no principal payments are exchanged except the net interest payments, (ii) the netting provisions allow that in the event of default the counterparties settle all contracted liabilities, (iii) as the swap's default probability reflects the joint probability of the firm being financially distressed and the swap having a negative value to the firm, a firm's default probability on a swap is much lower than on a bond, and (iv) swaps with counterparties whose credit quality is lower are usually collateralised so that the potential loss in the event of default is minimum.

These include: (i) business cycle risk; (ii) skewness risk; and (iii) correlation risk [e.g., Adrian and Rosenberg (2008); Driessen, Maenhout and Vilkov (2009) and Buraschi, Porchia and Trojani (2010)]. In line with these studies, we examine the effects of the business cycle, market skewness and correlation risk across a range of maturities in the U.S. interest rate swap market. Our empirical findings are robust, and can be shown to be both theoretically and empirically appealing. The analysis, shows that swap spreads contain largely pro-cyclical elements of business cycle risk (counter-cyclical elements during the crisis period), positive risk premia for skewness risk (when controlled for crisis events) and negative (positive) risk premia for correlation risk when the time-varying correlation between underlying interest rates is high (low). For ease of understanding, these risks and their influences on swap spreads are briefly discussed below.

Business cycle risk: Business cycle risk is one of the systematic risks that influence all the financial products. Swap product is no exception. Litzenberger (1992) argues that the time series allocation of defaults between swap counterparties varies over the business cycle. This implies that the swap spread is sensitive to changes in business and economic conditions. This is articulated in Figure 2, which shows the US 2- and 5-year swap spread (in basis points) over Treasury rates of corresponding maturities. Figure 2 illustrates the the point that swap spread varies with the US business cycle. Hence, this study expects that swap market prices entail a component of business cycle risk, because an increase in business cycle risk is an indication of the increased probability of default. Consequently, swap spreads should rise with the business cycle risk since investors and speculators would expect that the risk premia related to default risk should also increase. A positive relationship would assert that the swap spread is pro-cyclical unlike stock and bond returns [Lang, Litzenberger and Liu (1998)]. In contrast, a negative association would indicate that swap spreads may contain a counter-cyclical element [Lekkos and Milas (2001)].

Figure 2: US Swap Spread

This figure shows the US 2- and 5- year swap spreasd (in basis points) over Treasury rates of corresponding maturities. The figure is based on the data collected from DataStream (DataStream codes for 2-year and 5-year spreads are: ICUSS2 and ICUSS5). The sample covers the daily data from 1st April, 1987 to 30th November, 2010.



Skewness risk: Recent asset pricing literature shows that higher order moments have an influence on the asset's returns. Of the several higher order moments, Adrian and Rosenberg (2008) show that financial constraints risk or market skewness risk that may induce non-normality in market returns, is a market risk factor that affects the asset's returns. Skewness risk should exist in the swap market for several reasons including heterogeneity in firm access to funding and borrowing restrictions, and the credit risk premium differential across domestic and overseas markets. For instance, the LIBOR and TIBOR differentials or the 'Japan premium' as identified by Batten and Covrig (2004), and the credit risk differentials across the domestic and international markets as identified by Nishioka and Baba (2004), are indicative of systematic skewness risk that could be present in market interest rates, such as swap rates.

Correlation risk: Correlation risk is deemed to exist, if the time-varying correlation between the underlying interest rates (fixed and floating rates) is stochastic, statistically insignificant and poses a threat to the determination of market interest rates, including swaps. In a typical swap contract, there are two counterparties: one paying a fixed interest rate and the other paying a variable interest rate on a hypothetical 'notional principal'. The correlation risk in the swap is defined as the risk originating from the time-varying correlations between these two rates: fixed and variable rates [Sultan (2006)]. The correlation risk is high (low) if the fixed rate and the floating rate do not (do) co-vary causing some uncertainty regarding future movements in interest rates.

The risks noted above are also characterised as systemic risk. For instance, Elton et al. (2001) argue that when corporate bond returns move systematically with other assets, say equity returns, then expected bond returns would require a risk premium to compensate for the non-diversifiability of that risk. Elton et al. (2001) indicate two reasons why systemic risk exists in bond markets. First, if the expected default loss co-varies with the equity prices, that is, the default risk goes up (down) with the fall (rise) in stock prices, then it introduces a systemic risk. Second, the reward for risk from financial markets changes over time. If such changes affect both the markets (e.g., bond and stock markets) simultaneously, then these changes introduce a systematic influence. Given that swaps have some features similar to those of bond markets, Cortes (2003), Afonso and Strauch (2007) and Asgharian and Karlsson (2008) find that swap spreads vary positively with stock market volatility and hence, the swap spread can contain a systematic risk premium. As will be discussed in more detail in the data section, this study obtains business cycle risk and skewness risk from stock market data. Thus, we decompose business cycle and skewness risk in this study from the systemic risk component.

In a similar sense, correlation risk is also a systemic risk as the co-variation between the fixed and floating rate can introduce a kind of price risk in the swap. Therefore ignoring the correlation between underlying interest rates could lead to serious errors in pricing and hedging based on the traditional empirical structure, which does not allow the correlation to be included in the pricing model. Unfortunately, with the exception of Sultan (2006), as far as it could be ascertained, there is no other study that examines the influence of correlation risk on the swap spread. This study fills that gap by studying the impact of correlation risk on various swap maturities.

Importantly, we adopt a novel approach to extract the business cycle risk and market skewness risk factors from market returns using a factor spline GARCH model (hereafter, FS-GARCH) recently developed by Rangel and Engel (2012). This model provides better measures of these variables as evidenced by several recent studies such as Engle and Rangel (2008), Azad et al (2011) and Azad et al (2012). Another important contribution of this paper is that, unlike the existing literature, this paper uses the GMM approach to reduce the estimation problem arising from the serial correlation problem in the residuals particularly due to volatility aggregates of the spline measure [see also, Rangel and Engle (2012)] and to avoid the endogeneity problem associated with simultaneous causality and possible correlation of errors with the regressors. These problems occur due to the use of the lagged dependent variable (lagged swap spread) as well as spline-smoothing in the FS-GARCH model. These two problems may lead to inconsistency of OLS estimation and hence a GMM approach is preferred.

The empirical analysis in this paper demonstrates that the above-mentioned three risk factors persist significantly even after including default and liquidity risks. The empirical results are also robust to sub-sample analysis. This suggests that if pricing models do not incorporate these risks then the models would be seriously biased and thus, ignoring these factors will inflict instability on the pricing and hedging of swap positions. Instead, if market participants (dealers and market makers) put due emphasis on these risks, they can determine the appropriate risk premia, while policy makers can take appropriate measures to reduce (but not entirely remove) these risks.

The rest of this paper is structured as follows. Section 2 discusses the relevant literature and develops hypotheses based on that literature. Section 3 describes the data, while Section 4 explains the methodology used. The empirical results of the full sample are then presented along with those of the sub-sample in Section 5. Section 6 concludes.

2 LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

This section reviews the literature related to business cycle, skewness and correlation risk in financial markets. These risks are discussed below with their relevance to swap markets and three relevant hypotheses are explained:

H1: The swap spread is positively associated with the business cycle.

If asset returns comprise business cycle risk, expected returns should incorporate rewards for accepting that risk [Adrian and Rosenberg (2008) and Lettau, Ludvigson and Wachter (2008)]. Related to the business cycle risk in swaps, Litzenberger (1992) argues that risk allocation between swap counterparties co-varies with the business cycle. Similarly, Lang et al. (1998) argue that, unlike common stock and bond returns, which usually contain counter-cyclical elements as shown in many studies [e.g. Fama and French (1989); Campbell and Cochrane (1999) and the references therein], swap spreads contain pro-cyclical elements. Using this argument, Lang et al. (1998) control for the business cycle (proxied by the unemployment rate) in explaining the determinants of U.S. swap spreads and conclude that swap spreads follow the business cycle. Few studies including those of Cortes (2006), Ito (2007) and Azad, Fang and Wickramanayake (2011) also note that the swap market is affected by business cycle risk. However, none of these studies has exclusively explored whether business cycle risk is a priced risk factor that can explain a substantial proportion of the swap spread.

The pro-cyclical assumption of Lang et al. (1998) implies that business cycle risk increases the swap spread since it increases the probability of default, which in turn increases the credit risk between the two counterparties. A similar explanation is also available in Cãtao and Kapur (2004). They provide a theoretical link between business cycle risk and the probability of default. They show that business cycle risk reduces the (aggregate) debt/GDP threshold and eventually raises the level of interest rates, which in turn increases the tendency among hedgers to use derivatives for hedging interest rate risk [Beber and

Brandt (2009)]. The rising demand for swaps pushes the swap fixed rate up[3] and since the fixed rate payer faces increases counterparty default risk, this translates into an increase of the swap spread. Lekkos and Milas (2001) identify pro-cyclical behaviour in the shorter maturities of U.S. swap spreads and counter-cyclical behaviour in the longer maturities of U.S. swap spreads. However, the question of whether business cycle risk is a priced risk is not examined by Lekkos and Milas (2001).

The high (low) level of business cycle risk increases (decreases) preferences for fixed-income assets, which motivates (frustrates) derivative activities [Loeys and Panigirtzoglou (2005); Cailleteau and Mali (2007)]. Given hedgers' preferences, if a particular swap maturity has a higher exposure to business cycle risk than other maturity(ies), for that specific maturity dealers and swap makers would demand extra premiums to cover additional risk. Therefore, business cycle risk would increase the swap spread of that maturity.

The question now remains as to how best to proxy business cycle risk. We follow Adrian and Rosenberg (2008) and use the long-term volatility of stock returns to measure the influence of business cycle risk on the cross section of stock returns.[4] One benefit of using this proxy is that it addresses potential movements in key economic variables including the volatility of interest rates, slope of the yield curve, unemployment, inflation and GDP or industrial production [Engle and Rangel (2008) and Adrian and Rosenberg (2008)].[5] Moreover, the use of stock market volatility in proxying business cycle risk is motivated by Merton's (1974) theoretical study on pricing default risk. So unlike Lang et al. (1998), who use unemployment as proxy of business cycle risk, Adrian and Rosenberg's (2008) approach of using stock market volatility in proxying the business cycle risk is theoretically justified. The theoretical pricing of default risk in Merton (1974) implies that stock price volatility and the associated higher volatility of

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3 The swap is traded on the fixed rate.

4 Rigobon and Sack (2003); Bedendo, Cathcart and El-Jahel (2004) and Churm and Panigirtzoglou (2005), among others show that default probability increases with stock market volatility.

5 A number of studies [Schwert (1989), Engle and Rangel (2008) and Engle, Ghysels and Sohn (2008)] find that the long-term volatility of stock returns co-varies with macroeconomic variables.

firm value increases the default risk. Consistent with this theoretical argument empirical research on swaps find that stock market volatility and swap spreads are positively correlated [e.g. Cortes (2003), Afonso and Strauch (2007) and Asgharian and Karlsson (2008)]. From this viewpoint, business cycle risk can be extracted from stock returns and is expected to be positively correlated with the swap spread.

H2: The swap spread is positively associated with market skewness.

There is a growing body of literature that contends that since asset returns are typically non-normal, higher-order moments (and co-moments) matter in determining risk premiums [e.g. Chung, Johnson and Schill (2006)]. We argue that variation in one of the higher moments, namely skewness, is an important risk which swap counterparties need to consider in determining swap spreads. Chung et al. (2006) attribute the significance of pricing higher moments to two issues: (i) the weakness of the traditional CAPM, which allows investors to price market risk only and (ii) the ambiguity in providing consistent economic meaning of the Fama and French (1993, (1995) risk factors. The weakness of traditional CAPM motivates Fang and Lai (1997) to derive a four-moment CAPM where, using the U.S. data, they find a positive risk premium for skewness risk. The list of research in investigating the economic meaning of Fama–French risk factors is non-exhaustive.

The preference-based explanation, as in Kraus and Litzenberger (1976) and Harvey and Siddique (2000), implies that skewness risk is priced as investors dislike it, while the inter-temporal hedging of volatility risk, as in Adrian and Rosenberg (2008), indicates that skewness risk is priced because of the time variation of volatility in asset returns. In other words, the time variation in volatility drives the time variation in skewness.

Although there are a number of papers that highlight the importance of managing skewness in asset pricing [for a review of literature, see Chung et al. (2006)], to provide an explanation for the swap market we combine the findings in the following studies [Peek and Rosengren (2001); Batten and Covrig

(2004); Covrig, Low and Melvin (2004); Ito and Harada (2004); Nishioka and Baba (2004) and Adrian and Rosenberg (2008)]. Adrian and Rosenberg (2008) argue that skewness risk is a measure of the tightness of financial constraints. They note that the increase in skewness risk makes financial constraints more binding and so the distribution of asset returns becomes non-normal (skewed). In swaps, this could be related to the firms' access to funding or borrowing restrictions, in particular the issuing of bonds. That is, financially constrained firms are expected to pay more spreads to their counterparties. Nishioka and Baba (2004), also argue that skewness risk exists in the swap market due to the credit risk premium differential between domestic and overseas markets. An example of this premium is the credit risk differential that triggered the 'Japan premium' offered by the Japanese issuers due to their credit quality deterioration [e.g., Peek and Rosengren (2001); Batten and Covrig (2004); Covrig et al. (2004) and Ito and Harada (2004)].

The 'Japan premium' or the difference in credit risk/spread is an indication of market-wide skewness risk. When a swap product is exposed to skewness risk, an existence or increase of skewness induces cross-border counterparties to demand higher spreads. And the hedgers who are interested in hedging their positions are ready to pay for insurance against increases in skewness. Therefore, if there is a significantly higher skewness risk in swaps, then swap spreads should contain a risk premium component related to this risk. This implies that theoretical studies should incorporate this risk into pricing models and empirical analysis should examine whether there is a risk premium attached to the skewness.

H3: The swap spread is negatively (positively) associated with the correlation risk at times of high (low) correlation between underlying interest rates.

The third factor is correlation risk, which while mentioned in the prior swap literature [e.g., Wei (1994); Mahoney (1997) and Sultan (2006)], has not been modelled extensively. The choice of correlation risk is attributed to the notion that correlation between assets change over time. The theory suggests that if the correlation structure is temporal, then the hedge ratio should be adjusted to account for the most recent information relating to the correlation [Engle (2002)]. And in the case of swaps, the correlation between underlying interest rates (fixed and floating rates) also change, thereby requiring swap users and dealers to price correlation risk. The rationale behind pricing correlation risk in swaps is due to the time varying correlation in interest rates across the term structure. This necessitates pricing models to calibrate using dynamic correlations.

Correlation risk is found to be a priced risk factor in different financial markets [see Sultan (2006), Driessen et al. (2009) and Buraschi et al. (2010)]. Importantly, the treatment of correlation risk varies across financial markets. For instance, in stocks and bonds markets, a market-wide increase in correlations adversely affects investors' welfare by limiting the diversifications within and across markets, while a decrease in correlation improves portfolio diversification. Notably, low correlation does not persist for long since no-arbitrage conditions force the markets to co-vary on average, and correlations increase during crisis periods. Unlike stock and bond markets, a higher correlation between fixed and floating interest rates should not reduce investors' welfare. Rather, a high correlation indicates pricing efficiency in both the interest rates markets. In either case of higher or lower correlation, the time-varying correlation structure provides useful information for investors. Similar to other financial markets, the correlations between fixed and floating interest rates provide critical inputs for managing, hedging and diversifying interest rate risks in swaps.

How does correlation risk affect the price of swap contracts? It is well known that in an interest rate swap contract, there are two counterparties: one paying the fixed rate and the other paying the floating rate. Markets expect that both these rates move together. In fact, before the emergence of swaps, the fixed rate and floating rate markets were operating separately and thus were isolated from each other. This attribute motivated market participants to move from one market to the other using their expectation about the shape of the yield curve [Handjinicolaou (1991)]. However, with the appearance of swaps, market players were able to look at both fixed and floating rate markets simultaneously and therefore better understand the behaviour of these markets. A fixed rate borrower not only needs to have a clear understanding (including pricing mechanism) of the fixed rate market (long end of the term structure) but also has to follow developments in the floating-rate market (short end of the term structure). This process and hence the notion of market efficiency, ensures that pricing is consistent in both the fixed rate and floating rate markets. Under efficient pricing, a higher correlation is virtually expected to limit arbitrage and is an indication of the minimum pricing anomaly/uncertainty. Market makers cannot demand additional risk premiums from hedgers. As a result, a highly significant time-varying correlation is expected to decrease the credit spread in the swap. Although a higher correlation reduces the swap spread, it does not necessarily decrease the value of swaps. Instead, it brings about several benefits [Sultan (2006)]. For example, an increased correlation between fixed rates and floating rates (i) reduces uncertainty among swap participants about the future movements of interest rates, (ii) reduces dealers' hedging costs thereby allowing them to charge lower spread in subsequent contracts, (iii) improves the economic value of swap cash flows by decreasing mark-to-market risk of interest rate swaps and increases the effectiveness of interest rate swap usage, and (iv) improves the effectiveness of interest rate futures in hedging interest rate swaps.

In contrast, when the time-varying correlation between the fixed rate and the floating rate is significantly low (i.e., markets do not move together) and continues to drop over time, it poses some threat/uncertainty to pricing and determining hedging costs [Sultan (2006)]. In such an environment, dealers including market makers demand higher spreads, while users dislike a lower correlation since they need to pay a higher spread. According to this view, correlation risk and swap spread are negatively related: the lower the correlation, the higher the spread. That is, swap spreads should increase (decrease) due to the low (high) correlation between the underlying interest rates.

When investigating the influence of correlation risk, one can look at constant or the time-changing structure of the correlation between fixed and floating interest rates. Since economic fundamentals play a vital role in the determination or movement of interest rates, it is impractical to rely on constant correlation. It is rather plausible to utilise the time-changing correlation to dynamically update the information on the co-movement of two interest rates.

3 DATA DESCRIPTION

3.1 DATA FOR DEPENDENT VARIABLE AND RISK PROXIES

To determine whether business cycle, skewness and correlation risk are priced in swaps spreads, we measure the dependent variable the ‘swap spread’ as the observed difference between the swap yield and the Treasury yield of the corresponding maturity. Following Adrian and Rosenberg (2008), business cycle risk and market skewness risk are obtained from the S&P 500 composite price index and collected from Datastream. The reasons for using stock index return data are that (i) the stock market is universally accepted to be the most active market and is found to be highly correlated with business cycle risk [Schwert (1989)], (ii) swap counterparties are usually large corporations, which are listed on stock exchanges, (iii) this approach minimises the computational burden of separately estimating business cycle risk and skewness risk from each swap maturity, and finally (iv) it reduces the estimation errors by producing common measures that can be used for all swap maturities. To measure the third independent variable ‘correlation risk’, this study follows Sultan (2006), who obtains the time-varying correlation between fixed rate and floating rate. The fixed rate is the U.S. Treasury bond (note) yield corresponding to the relevant swap maturity and the floating rate is interbank rate, which is the 6-month London interbank offered rate (LIBOR) in U.S. dollars. The full sample covers daily data from April 1987 to November 2010, which includes the period of the Global Financial Crisis.

3.2 DEFAULT RISK, LIQUIDITY RISK AND SUB-SAMPLE ANALYSIS

In order to check the robustness of the results, we include default and liquidity risk as control variables. As noted earlier, a number of the theoretical and empirical studies find that these two risks matter and have positive influences on swap spreads [Brown, Harlow and Smith (1994), Duffie and Singleton (1997), Minton (1997), Lang et al. (1998) and Gupta and Subrahmanyam (2000)]. These studies argue that as the swap default spreads are unobservable, the default risk in swaps can be accurately proxied with information from the corporate bond market. Hence, similar to Duffie and Singleton (1997) and Gupta and Subrahmanyam (2000), we use the spreads between the yields on BBB-rated corporate bonds and AAA-rated corporate bonds as reported by Standard and Poor's as a proxy for the corporate spread or default risk premium. These data are also collected from DataStream, Bloomberg and Federal Reserve Statistical Release H.15.[6] In addition to default risk, liquidity risk is considered a crucial factor in determining the swap spread [e.g., Duffie and Singleton (1997); Grinblatt (2001) and Liu et al. (2006)]. Following these studies, liquidity risk is proxied as the spread difference between the floating rate (LIBOR) and fixed rate (Treasury bill) of the same maturities. This difference is interpreted as an increase in the liquidity advantage of government securities over floating rate loans [Grinblatt (2001)]. Specifically we measure liquidity risk as the difference between 6-month LIBOR and the 6-month T-bill rate[7]. Data are obtained from Bloomberg and DataStream.

Finally, the whole sample is divided into various different sub-samples using the crisis events relevant to swap markets. Of the different events and crises noted in Table 1, some of the events are country specific, while others (for instance, LTCM crisis and global financial crisis) are pandemics affecting most of the economies around the world.

[INSERT TABLE 1 ABOUT HERE]

[6]See for details, http://www.federalreserve.gov/releases/H15/data.htm.

[7] Note, this spread is also commonly referred to as the 6-month TED spread (Treasury to Eurodollar).

Of the events noted in Table 1, the Asian Financial Crisis (AFC) is taken from Fang and Muljono (2003) to reflect the influence of a currency crisis on the swap market. The AFC was followed by the Russian Government bond default (RGBD) in August 1998 and the LTCM crisis in September 1998. These two crises adversely affected swap markets [Apedjinou (2005)]. Following these events, Japan's Long-Term Credit Bank (LTCB) and Nippon Credit Bank (NCB) failed in November 1998. These events are taken as they occurred closely with the aforementioned events (i.e., AFC, LTCM and RGBD). For all the above events, a sub-sample is considered that covers the data from July 1997 to November 1998.[8] The second sub-sample that spans the data from January 1999 through June 2007 is taken as a normal period. The third sub-sample focuses on the GFC period starting from July 2007 to November 2010. Altogether three sub-samples are finally taken into consideration to reflect the changes in relationship between risk proxies and swap spreads in tranquil and turbulent periods.

4 METHODOLOGY

As this study uses the maturities of 2-, 3-, 5-, 7- and 10- year swaps, the swap spread, ss_t, of each maturity is defined as follows:

$$ss_t = IRS_t - TB_t \tag{1}$$

where ss_t is the swap spread of each maturity, IRS_t is the swap mid-rate (bid-ask average) as reported in DataStream and TB_t is the Treasury bond yield. In most prior studies [e.g., Duffie and Singleton (1997) and Afonso and Strauch (2007)], a substantial proportion of the variation in the swap spreads is explained by their own shocks indicating that swap spread is influenced by its market-specific activity. Duffie and Singleton (1997) argue that this market-specific shock accounts for 35 to 48 percent. That is, after

[8] Other minor country-specific events [e.g., the US's liquidity shortage due to Y2K (millennium date change) in November 1999; Japan's sovereign credit rating downgrades in September 2000 and November 2001; and mortgage prepayment hedging activity in July 2003 by the U.S. mortgage prepayment hedgers. These events are assumed to have marginal cross-border effects [Cortes (2006)].

accounting for other risk factors, a substantial fraction of the variation in swap spreads is left unexplained. Feldhütter and Lando (2008) also use the 'swap factor' and default risk factor to decompose the swap spread. Based on the discussion in Duffie and Singleton (1997) and Feldhütter and Lando (2008), it is critical to add the lagged swap spread as one of the independent variables. Afonso and Strauch (2007) employ such a specification with other variables. Thus, the functional form with lagged dependent variable and three new risk proxies can be written as:

$$ss_t = a_0 + a_1 ss_{t-1} + a_2 bcyc_t + a_3 skew_t + a_4 corr_t + \varepsilon_t \quad (2)$$

Since prior studies [e.g., Liu et al. (2006) and Feldhütter and Lando (2008)] emphasise default risk and liquidity risk in their discussion of the behaviour of swap spreads, adding these two risk factors in equation (2) takes the following form:

$$ss_t = a_0 + a_1 ss_{t-1} + a_2 bcyc_t + a_3 skew_t + a_4 corr_t + a_5 def_t + a_6 liq_t + \varepsilon_t \quad (3)$$

Equation (2) specifies the relationship between the swap spread and new risk proxies only, while equation (3) specifies the relationship between the swap spread and all risk proxies. $bcyc_t$ is the business cycle risk, $skew_t$ is the skewness risk, $corr_t$ stands for the correlation risk, def_t indicates default risk and liq_t stands for the liquidity risk. $bcyc_t$ and $skew_t$ are obtained from the factor spline GARCH model of Rangel and Engle (2012) on the S&P 500 index.

To simplify the methodology section, the FS-GARCH model is explained in Appendix A. This Appendix shows how the business cycle risk and the skewness risk are obtained using the FS-GARCH model. $corr_t$ is measured through time-varying correlations between the observed fixed and floating interest rates. To obtain dynamically correct estimates of the intensity of fixed and floating rate co-movements, their time-varying correlation is estimated by employing the Dynamic Conditional Correlation (DCC) model of Engle (2002). Related to this, Rangel and Engle (2012) argue that with unconditional techniques such as rolling correlations or exponential smoothing, the sensitivity of the estimated correlations to volatility changes would restrict inferences about the true nature of the relationship between variables, especially during periods of high volatility. Hence, the use of DCC is more appealing than competing models. DCC is widely used in the asset pricing literature and, for this reason its discussion is omitted from the main text but provided in Appendix B, which explains how the time-varying correlations between the Treasury bill and the LIBOR are estimated.

For specifications (2) and (3), the Generalized Method of Moment (GMM) is used for two reasons. The first is to reduce the estimation problem arising from the serial correlation problem in the residuals particularly due to volatility aggregates of the spline measure [see also, Rangel and Engle (2012)]. The second is to avoid the endogeneity problem associated with simultaneous causality and possible correlation of errors with the regressors. These problems occur due to the use of the lagged dependent variable (lagged swap spread) as well as spline-smoothing in the FS-GARCH model. These two problems may lead to inconsistency of OLS estimation and hence, the GMM is preferred. Furthermore, the GMM is the most preferred approach due to its superior ability to exploit stationarity restrictions [Durlauf, Johnson and Temple (2005)]. Therefore, equations (2) and (3) are estimated by the GMM with robust Newey and West (1987) standard errors, and 2 to 4 lags of the lagged dependent and explanatory variables are used as instruments. The heteroskedasticity and autocorrelation (HAC) covariance matrices are used as weighting options with Schwarz Bayesian Information Criteria (SBIC) and automatic lag selection to avoid specification bias. Post-estimation diagnostics for the GMM estimations are also conducted. The next section reports and discusses the estimation results.

[INSERT TABLE 2 ABOUT HERE]

5 RESULTS AND DISCUSSION

5.1 PRELIMINARY STATISTICS

First we report and discuss the preliminary statistics. As Table 2 indicates, the swap spread is mostly positive with the exception of the 7-year maturity, which indicates that swap rates sometimes were higher than U.S. Treasury bond (US-TB) yields. The reverse (negative spread) occurs when there is a substantial demand to receive fixed interest payments. If banks and corporations prefer paying floating and receiving fixed interest rates then the increased demand for receiving fixed drives down the yield of interest rate swaps [see also Ito (2008)].

The daily average business cycle risk (BCYC) and the skewness risk (SKEW) are 0.16%. These are obtained from the S&P500 index using the FS-GARCH model of Rangel and Engle (2012). To reiterate, these two risks are proxied by the long-term and the short-term components of stock market volatility. Adrian and Rosenberg (2008) also adopt the same approach. However, they use the C-GARCH model of Engle and Lee (1999). The correlation risk (CORR) measured as the relation between the fixed-rate (Treasury bond) and the floating-rate (6-month US-LIBOR rate) are the estimated DCC time-varying correlation coefficients. These risk proxies vary from a minimum of -0.26 (TB5_LIB) to a maximum of 0.72 (TB5_LIB). The average correlation coefficient between the Treasury bond yields and the LIBOR does not vary much across different maturities of TBs. The average risk premiums for default risk (DEF) and the liquidity risk (LIQ), as shown in last two columns of Table 2, are positive.

[INSERT TABLE 3 ABOUT HERE]

Table 3 shows the sample correlations among the swap spreads as well as between the swap spreads and the independent variables. No negative correlation among the swap spreads is observed. The correlations between the closest maturities are higher than between the most distant. For example, the correlation between the 2-year spread and 3-year spread is higher (0.9405) than the correlation between the 2-year spread and 10-year spread (0.6470). These observations suggest that the information components of individual swap maturities may be different and so one needs to incorporate different swap maturities for a clear understanding of market behaviour [Csávás, Varga and Balogh (2008)]. The swap spreads are also positively correlated with the following independent variables: business cycle risk, skewness risk, default risk and liquidity risk, whereas the correlations between swap spreads and correlation risks are either negative or insignificant. This illustrates that the relationship between underlying fixed and floating interest rates is uncertain. All the risk measures (excluding correlation risk) appear to have higher correlations with the shorter maturities than with the longer maturities. This suggests that compared to longer maturities, shorter maturities are more exposed to those risks, and therefore contain higher risk premia. Finally, the correlations among the independent variables are mixed.

[INSERT TABLE 4 ABOUT HERE]

Table 4 presents the unit root test results of the dependent variables (different swap maturities) and two independent variables: default risk and liquidity risk. The unit root null is rejected for all the variables except for the 10-year swap (*t-statistics* are shown in bold in Table 4). One possible explanation for the finding on the 10-year swap yield is that it is affected by arbitrage linked to the 10-year U.S. T-bond futures contract, which is also a deliverable contract. To avoid a spurious result the time-series regression for the 10-year swap is excluded.[9] Note that the unit root test is not required for the three risk proxies (business cycle risk, skewness risk and correlation risk) as this is already confirmed at the time of modelling those risks.

[INSERT TABLE 5 ABOUT HERE]

[9]In the cases when the unit root is detected in the level data, it is customary to use the first differenced data. However, to be consistent, this study only uses the level data.

5.2 MAIN RESULTS

The estimation results in this section are based on two models. Model one (*MI*) involves the estimation results relating to equation (2) with the three new risk factors, while Model two (*MII*) involves the estimation results relating to equation (3) with all five risk factors. As noted earlier, the use of the lagged dependent variable requires application of the GMM estimation technique. In Table 5 the GMM estimation results on whether the U.S. swap spreads contain risk premiums related to skewness risk, business cycle risk and correlation risk - even after controlling for default risk and liquidity risk - are reported. The table presents results for swap maturities of 2-, 3-, 5- and 7-year, since the 10-year is excluded due to presence of a unit root.

For all models (*MI* and *MII*) and maturities, the lagged swap spread is the most significant factor. This result is consistent with the empirical findings of Afonso and Strauch (2007) for European swap markets and the theoretical studies of Duffie and Singleton (1997) and Feldhütter and Lando (2008). In Table 5, *MI* suggests that of the three new risk factors, business cycle risk is positive and significant for all maturities- a finding that supports hypothesis H1. The positive coefficient also asserts that the U.S. swap spreads contain a pro-cyclical element [Lang et al. (1998)]. Lekkos and Milas (2001) provide mixed evidence for the U.S. market with regard to the cyclical behaviour of the U.S. swap spread. They identify pro-cyclical behaviour for shorter maturity and counter-cyclical behaviour for the longer maturity. However, it should be noted that neither Lang et al. (1998), nor Lekkos and Milas (2001), investigate whether business cycle risk is also a priced risk factor. The finding that skewness risk is negative and significant for 3- and 7-year swaps is inconsistent with H2. It is therefore important to determine whether this result holds after controlling for default risk and liquidity risk in *MII*. The correlation risk is negative and significant for 7-year swap (H3 partially supported).

The inclusion of default risk and liquidity risk in *MII* (Table 5) does not affect the significance of business cycle risk for any maturity (H1 remains supported). Skewness risk turns out to be insignificant for 7-year swap and remains significant only for the 3-year swap. This implies that the skewness risk premium is negative only for the 3-year swap. The correlation risk remains unaffected for the 7-year swap. As hypothesised (H3), the swap spread is negatively (positively) associated with correlation risk at times of high (low) correlation between underlying interest rates. The results relating to correlation risk are, to some extent, consistent with Sultan's (2006) study in terms of the coefficient sign but not in terms of the significance. Sultan (2006) uses 2-, 5- and 10-year U.S. swap spreads and finds that the coefficient signs for the correlation risks are negative for all maturities but not significant. He also finds that the correlation risk reduces the volatility of swap spread for those maturities. The differences in results between this study and those of Sultan (2006) could be due to the different models used in obtaining the correlation risk measures used in the final estimation. Unlike Sultan (2006), this study uses Engle's (2002) DCC approach to obtain time-varying correlation risk and other risk proxies in explaining the various swap spreads. Figures 1–4 in Appendix C indicate the DCC time-varying correlations between the underlying interest rates for the U.S. market. As for the default risk and liquidity risk, the coefficient of the default risk is positive and significant for 2- and 5-year swaps, while that of the liquidity risk is significant only for 2-year swap. The next section shows whether the above findings hold for various sub-samples.

[INSERT TABLE 6 ABOUT HERE]

5.3 SUB-SAMPLE ANALYSIS

As noted earlier, economic events and crises are expected to influence the relationship between the swap spread and its risk determinants [see also Eom, Subrahmanyam and Uno (2002); Fang and

Muljono (2003) and Apedjinou (2005)]. Therefore, as a robustness check, the sample was divided into a number of different sub-samples to determine the effects of well-documented periods of financial crisis.

Specifically, three sub-samples are considered. The first sub-sample is characterised as 'crisis period -1', which includes the Asian financial crisis (AFC), Long-term Capital Management (LTCM), the Russian government bond default crisis (RGBD), the Japanese Long-term Credit Bank (LTCB) and Nippon Credit Bank (NCB) crises. Since all these events occurred consecutively, the sub-sample 'crisis period -1' comprises all these events. Data for this sub-sample spans from June 1997 to November 1998.

The second sub-sample is a 'normal period' spanning from January 1999 to June 2007. The third sub-sample, 'crisis period -2', refers to the global financial crisis (GFC) starting from July 2007 to December 2009. It is worth noting that for brevity the sub-sample analysis covers the empirical results of only 2- and 5- year swaps using equation (3).

The sub-sample analysis on the U.S. swap markets, presented in Table 6, shows that both 2-year and 5-year swaps exhibit pro-cyclical behaviour during the 'crisis period -1' (AFC, LTCM, RGBD, LTCB and NCB) and the normal period, but counter-cyclical behaviour during the GFC period. The reason is that the duration and strength of the recessions were stronger in the GFC period than the 'crisis period 1' and the normal period. Thus, the positive coefficient sign of business cycle risk for most sub-samples is consistent with the whole sample analysis in Table 5.

Skewness risk is significant only during the crisis periods (for the 2-year swap, it is 'crisis period -2', and for the 5-year swap, it is 'crisis period -1'). For most of the sub-samples, however, skewness risk remains insignificant. This is consistent with the full sample analysis in Table 5. For the 2-year swap, correlation risk is positive in all the sub-samples but significant only during crisis periods. During the normal period, correlation risk is insignificant, which is consistent with the full sample analysis. For the 5-year swap, correlation risk is negative and significant in both crisis periods, but positive and significant in the normal period. As stated earlier, the negative (positive) coefficient is driven by higher (lower) correlations between underlying interest rates. The positive coefficient during the normal period is again consistent with the full sample analysis. That is, the coefficient sign is dominated by the normal period.

As for the default risk and liquidity risk, default risk is more important during the crisis period than the normal period, while liquidity risk is important in both the normal and crisis periods. These result are in agreement with other studies, which show the major portion of the swap spread is explained by liquidity risk [Gupta and Subrahmanyam (2000); Grinblatt (2001); Liu et al. (2006) and Feldhütter and Lando (2008)].

6 CONCLUSION

This paper investigates whether business cycle, market skewness and correlation risk are priced in U.S. swap markets after controlling for default risk, liquidity risk and varying sample periods. Three main hypotheses were tested: (i) whether business cycle risk and swap spreads are positively correlated, implying the pro-cyclical behaviour of the swap spread; (ii) whether skewness risk had a positive influence on the determination of the swap spread; and (iii) whether correlation risk reduces (increases) swap spread at the time of higher (lower) correlation between the underlying interest rates (fixed and floating interest rates).

GMM estimation techniques (equations 2 and 3) were utilised to ensure the robustness of reported results and as a robustness check, the full sample was divided into a number of sub-samples. The empirical findings show that the swap spread is positively correlated with business cycle risk (with mostly counter-cyclical behaviour in crisis periods) and skewness risk, but negatively (positively) correlated with the correlation risk when the correlation between underlying interest rates is high (low).

These results suggest that these risk measures should be included in swap pricing models to better determine swap spreads. Utilising these additional measures should also enable policy makers and other users to better forecast the movement of swap spreads in relation to other risks and financial products.

REFERENCES

Adrian, T. & Rosenberg, J. (2008). Stock returns and volatility: Pricing the short-run and long-run components of market risk. *Journal of Finance, 63*(6), 2997-3030.

Afonso, A. & Strauch, R. (2007). Fiscal policy events and interest rate swap spreads: Evidence from the eu. *Journal of International Financial Markets, Institutions and Money, 17*(3), 261-276.

Apedjinou, K. M. (2005). *What drives interest rate swap spreads. Phd thesis chapter.* PhD, Columbia University.

Asgharian, H. & Karlsson, S. (2008). An empirical analysis of factors driving the swap spread. *Journal of Fixed Income, 18*(2), 41-56.

Azad, A. S. M. S., Fang, V. & Wickramanayake, J. (2011). Low-frequency volatility of yen interest rate swap market in relation to macroeconomic risk. *International Review of Finance, 11*(3), 353-390.

Batten, J. & Covrig, V. (2004). The japan premium and the floating-rate yen euromarket. *Journal of the Asia Pacific Economy, 9*(3), 288-300.

Beber, A. & Brandt, M. W. (2009). Resolving macroeconomic uncertainty in stock and bond markets. *Review of Finance, 13*(1), 1-45. doi: 10.1093/rof/rfn025

Bedendo, M., Cathcart, L. & El-Jahel, L. (2004). *The shape of the term structure of credit spreads: An empirical investigation*. SSRN. Retrieved from http://ssrn.com/paper=686854

Brown, K. C., Harlow, W. V. & Smith, D. J. (1994). An empirical analysis of interest rate swap spreads. *Journal of fixed income, 3*(4), 61.

Buraschi, A., Porchia, P. & Trojani, F. (2010). Correlation risk and optimal portfolio choice. *Journal of Finance, 65*(1), 393-420.

Cailleteau, P. & Mali, A. (2007). Why is credit risk priced so low? A perspective on global liquidity. *Moody's International Policy Perspectives, February 2007* 1-8.

Campbell, J. Y. & Cochrane, J. H. (1999). By force of habit: A consumption-based explanation of aggregate stock market behavior. *Journal of Political Economy, 107*(2), 205-251.

Cãtao, L. & Kapur, S. (2004). *Missing link: Volatility and the debt intolerance paradox*. IMF Working Paper, No. WP/04/51. Retrieved from http://ssrn.com/paper=878874

Chung, Y. P., Johnson, H. & Schill, Michael J. (2006). Asset pricing when returns are nonnormal: Fama-french factors versus higher-order systematic comoments. *The Journal of Business, 79*(2), 923-940.

Churm, R. & Panigirtzoglou, N. (2005). *Decomposing credit spreads*. Bank of England Working Paper no # 253. Bank of England Working Paper No # 253. Bank of England, Threadneedle Street, London, EC2R 8AH.

Cooper, I. A. & Mello, A. S. (1991). The default risk of swaps. *Journal of Finance, 46*(2), 597-620.

Cortes, F. (2003). Understanding and modelling swap spreads. *Quarterly Bulletin, Bank of England* (Winter).

Cortes, F. (2006). Understanding the term structure of swap spreads. *Bank of England Quarterly Bulletin, (Spring).*

Covrig, V., Low, B. S. & Melvin, M. (2004). A yen is not a yen: Tibor/libor and the determinants of the japan premium. *Journal of Financial & Quantitative Analysis, 39*(1), 193-208.

Csávás, C., Varga, L. & Balogh, C. (2008). The forint interest rate swap market and the main drivers of swap spreads. *Magyar Nemzeti Bank (MNB) Occasional Papers No # 64*.

Driessen, J., Maenhout, P. & Vilkov, G. (2009). The price of correlation risk: Evidence from equity options. *Journal of Finance, 64*(3), 1377-1406.

Duffie, D. & Huang, M. (1996). Swap rates and credit quality. *Journal of Finance, 51*(3), 921-949.

Duffie, D. & Singleton, K. J. (1997). An econometric model of the term structure of interest-rate swap yields. *Journal of Finance, 52*(4), 1287-1321.

Durlauf, S. N., Johnson, P. A. & Temple, J. R. W. (2005). Chapter 8 growth econometrics. In A. Philippe & N. D. Steven (Eds.), *Handbook of economic growth* (Vol. Volume 1, Part 1, pp. 555-677): Elsevier.

Elton, E. J., Gruber, M. J., Agrawal, D. & Mann, C. (2001). Explaining the rate spread on corporate bonds. *Journal of Finance, 56*(1), 247-277.

Engle, R. (2002). Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics, 20*(3), 339-350.

Engle, R. & Lee, G. (1999). A permanent and transitory component model of stock return volatility. In engle, r., white, h. (eds.), cointegration, causality, and forecasting: A festschrift in honor of clive w.J. Granger. Oxford university press, new york, pp. 475-497.

Engle, R. F., Ghysels, E. & Sohn, B. (2008). *On the economic sources of stock market volatility*. Finance Working Papers No. FIN-08-043, Stern School of Business, New York University.

Engle, R. F. & Rangel, J. G. (2008). The spline-garch model for low-frequency volatility and its global macroeconomic causes. *Review of Financial Studies, 21*(3), 1187-1222. doi: 10.1093/rfs/hhn004

Eom, Y. H., Subrahmanyam, M. G. & Uno, J. (2002). Transmission of swap spreads and volatilities in the japanese swap market. *Journal of Fixed Income, 12*(1), 6.

Fama, E. F. & French, K. R. (1989). Business conditions and expected returns on stocks and bonds. *Journal of Financial Economics, 25*(1), 23-49.

Fama, E. F. & French, K. R. (1993). Common risk factors in the returns on stocks and bonds* 1. *Journal of financial economics, 33*(1), 3-56.

Fama, E. F. & French, K. R. (1995). Size and book-to-market factors in earnings and returns. *The Journal of Finance, 50*(1), 131-155.

Fang, V. & Muljono, R. (2003). An empirical analysis of the australian dollar swap spreads. *Pacific-Basin Finance Journal, 11*(2), 153-173.

Feldhütter, P. & Lando, D. (2008). Decomposing swap spreads. *Journal of Financial Economics, 88*(2), 375-405.

Grinblatt, M. (2001). An analytic solution for interest rate swap spreads. *International Review of Finance, 2*(3), 113-149.

Gupta, A. & Subrahmanyam, M. G. (2000). An empirical examination of the convexity bias in the pricing of interest rate swaps. *Journal of Financial Economics, 55*(2), 239-279.

Handjinicolaou, G. (1991). *The role of managing interest rate swaps in financial markets*: Interest Rate Swaps edited by Carl R. Beidleman, Business One Irwin, Homewood, Illinois, pp. 25-60.

Harvey, C. & Siddique, A. (2000). Conditional skewness in asset pricing tests. *Journal of Finance, 55*(3), 1263-1295.

Ito, T. (2007). The analysis of interest rate swap spreads in japan. *Applied Financial Economics Letters, 3*(1-3), 1-4.

Ito, T. (2008). *The interest rate swap spreads and monetary policy in japan*. 21st Australasian Finance and Banking Conference, 16-18 December, 2008, Sydney. Retrieved from http://ssrn.com/paper=1261569

Ito, T. (2010). Global financial crisis and us interest rate swap spreads. *Applied Financial Economics, 20*(1), 37-43.

Ito, T. & Harada, K. (2004). Credit derivatives premium as a new japan premium. *Journal of Money, Credit and Banking, 36*(5), 965-968.

Kobor, A., Shi, L. & Zelenko, I. (2005). *What determines us swaps spreads?* World Bank, Working Paper, No # 62.

Kraus, A. & Litzenberger, R. H. (1976). Skewness preference and the valuation of risk assets. *Journal of Finance, 31*(4), 1085-1100.

Lang, L. H. P., Litzenberger, R. H. & Liu, A. L. (1998). Determinants of interest rate swap spreads. *Journal of Banking and Finance, 22*(12), 1507-1532.

Lekkos, I. & Milas, C. (2001). Identifying the factors that affect interest-rate swap spreads: Some evidence from the united states and the united kingdom. *Journal of Futures Markets, 21*(8), 737-768.

Lettau, M., Ludvigson, S. C. & Wachter, J. A. (2008). The declining equity premium: What role does macroeconomic risk play? *Review of Financial Studies, 21*(4), 1653-1687. doi: 10.1093/rfs/hhm020

Litzenberger, R. H. (1992). Swaps: Plain and fanciful. *Journal of Finance, 47*(3), 831-850.

Liu, J., Longstaff, F. A. & Mandell, R. E. (2006). The market price of risk in interest rate swaps: The roles of default and liquidity risks. *Journal of Business, 79*(5), 2337-2359.

Loeys, J. & Panigirtzoglou, N. (2005). Volatility, leverage and returns. *Global Market Strategy, J.P. Morgan Securities Ltd., London*, October 19.

Mahoney, J. (1997). Risk management of correlation products. *European Financial Management, 3*(2), 155-174.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. *Journal of Finance, 29*(2), 449-470.

Minton, B. A. (1997). An empirical examination of basic valuation models for plain vanilla u.S. Interest rate swaps. *Journal of Financial Economics, 44*(2), 251-277.

Newey, W. & West, K. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica: Journal of the Econometric Society, 55*(3), 703-708.

Nishioka, S. & Baba, N. (2004). *Credit risk taking by japanese investors*. Bank of Japan Working Paper Series. Bank of Japan Working Paper Series, No. 04-E-7, July.

Peek, J. & Rosengren, E. S. (2001). Determinants of the japan premium: Actions speak louder than words. *Journal of International Economics, 53*(2), 283-305.

Rangel, J. G. & Engle, R. F. (2012). The factor-spline-garch model for high and low frequency correlations. *Journal of Business and Economic Statistics, 30*(1), 109-124.

Rigobon, R. & Sack, B. (2003). Measuring the reaction of monetary policy to the stock market. *Quarterly Journal of Economics, 118*(2), 639-669.

Schwert, G. W. (1989). Why does stock market volatility change over time? *Journal of Finance, 44*, 1115-1153.

Sultan, J. (2006). Modeling correlation risk *Risk management*. Boston: Academic Press, 273-294.

Wall, L. D. & Pringle, J. J. (1989). Alternative explanations of interest rate swaps: A theoretical and empirical analysis. *Financial Management, 18*(2), 59-73.

Wei, J. (1994). Valuing differential swaps. *The Journal of Derivatives, 1*(3), 64-76.

APPENDIX A: MODELLING BUSINESS CYCLE RISK AND SKEWNESS RISK

This appendix explains how the business cycle risk and skewness risk are estimated from the S&P 500 index. To facilitate this, we use the FS-GARCH model of Rangel and Engle (2012). To illustrate Rangel and Engle's FS-GARCH, let us start with the familiar GARCH (1,1) model, which can be used to extract the aggregate market volatility:

$$r_t - E_{t-1}(r_t) = \sqrt{\boldsymbol{h}_t}\varepsilon_t \qquad \varepsilon_t \mid \Phi_{t-1} \sim N\ (0,1) \tag{A.1}$$

Following Adrian and Rosenberg (2008) and Rangel and Engle (2012), $\boldsymbol{h}_{i,t}$ is decomposed into two components: long-term (LT) and short-term (ST) which proxy business cycle risk (BCYC) and skewness risk (SKEW), respectively as follows:

$$\boldsymbol{h}_t = LT_t . ST_t \tag{A.2}$$

$$LT_{,t} = \gamma_o exp\left(\gamma_1 t + \sum_{j=1}^{k} \omega_j \left(\left(t - t_{j-1}\right)_+\right)^2\right) \tag{A.3}$$

$$ST_t = \left(1 - \alpha - \beta - \frac{c}{2}\right) + \alpha\left(\frac{\varepsilon_{t-1}^2}{LT_{,t-1}}\right) + c\left(\frac{\varepsilon_{t-1}^2}{LT_{t-1}}\right) I_{r_{t-1<0}} + \beta ST_{t-1} \tag{A.4}$$

where, r_t is the return on stock index (i.e., S&P 500) on day t and $E_{t-1}(r_t)$ is the expected return at $t-1$. $\boldsymbol{h}_t$ is the conditional volatility. LT_t and ST_t characterize business cycle risk (BCYC) and skewness risk (SKEW), respectively, on day t . Equations (A.1) through (A.4) are estimated to obtain the business cycle risk and skewness risk. Φ_{t-1} denotes an extended information set including the history of stock return changes up to day $t-1$. Given the estimates for $\gamma = (\gamma_o\ \gamma_1)'$ and $\omega_j\ (j = 1 \text{ to } k)$ a sequence of $\{t_j\}_{j=1}^{k}$ (where $t_1 > 1$ and $t_k \leq T$, denotes a division of the time horizon *T* in *k* equally spaced intervals) can be estimated. This study estimates the following parameters for the above FS-GARCH model:

$\alpha, \beta, c, \gamma = (\gamma_o\ \gamma_1)'$ and $\omega_j\ (j = 1 \text{ to } k)$. In choosing 'optimal' number of knots *k*, we use BIC (Bayesian Information Criteria). *k* governs the cyclical pattern in LT_t. Large values of *k* imply more frequent cycles, the 'sharpness' (i.e., the duration and strength) of which is measured through coefficients $\{\omega_j\}$. The term $I_{r_{t-1}<0}$ in (A.4) is an indicator function of negative shocks to accommodate the leverage effects (asymmetric volatility impact) on the skewness risk component. The presence of leverage effect is judged through the significance of parameter c .

APPENDIX B: MODELLING TIME-VARYING CORRELATIONS BETWEEN TB AND LIBOR

This appendix explains Engle's (2002) DCC approach, which is used to calculate the correlation risk between the underlying interest rates (fixed rate and floating rate). To explain Engle's (2002) DCC model, let $y_t = [y_{1,t} y_{12,t}]'$ be a 2 × 1 vector containing changes in the fixed rate (i.e., 6-month Treasury bill rate) and the floating rate (i.e., 6-month LIBOR) series. The conditional distribution of these series can be modelled using the Engle's DCC approach as follows:

$$y_t = \varepsilon_t \sim N(0, H_t) \, \forall \, t = 1, \dots, T \quad \text{(B.1)}$$

$$\varepsilon_t = D_t \eta_t \quad \text{(B.2)}$$

where, $\varepsilon_t = (\varepsilon_{1t}, \quad \varepsilon_{2t})'$, $\eta_t = (\eta_{1t}, \quad \eta_{2t})'$ and H_t is a conditional variance co-variance matrix, which is explained below. $D_t = diag[\sqrt{h_{1,t}}, \sqrt{h_{2,t}}]$ is a 2×2 diagonal matrix of time-varying standard deviations from univariate GARCH models and η_t is the standardized shock. The elements in equation (B.2) follow the univariate GARCH (1,1) processes in the following manner:

$$h_{i,t} = c_{0i,t} + c_{1i,t}\varepsilon^2_{i,t-1} + c_{2i,t}h_{i,t-1} \quad \forall i = 1,2 \quad \text{(B.3)}$$

$$H_t = E + (\varepsilon_t \varepsilon_t' | F_{t-1}) = D_t R_t D_t \quad \text{(B.4)}$$

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad \text{(B.5)}$$

$$Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1 \eta_{t-1}\eta'_{t-1} + \theta_2 Q_{t-1} \quad \text{(B.6)}$$

where $h_{i,t}$ is the conditional variance of interest rates $i = 1,2$ (i.e., fixed rate and floating rate) $Q_t^* = \begin{pmatrix} \sqrt{q_{11}} & 0 \\ 0 & \sqrt{q_{22}} \end{pmatrix}$ is the diagonal component of the square root of the diagonal elements of

$Q_t = \begin{pmatrix} q_{11} & q_{12} \\ q_{21} & q_{22} \end{pmatrix}$. The key element of interest in R_t is $\rho_{12,t} = q_{12} / \sqrt{q_{11,t} q_{22,t}}$, which represents the time varying conditional correlation between the two interest rates (fixed rate and floating rate). The conditional covariance is updated by equation (B.6). The scale parameters θ_1 and θ_2 represent the effects of previous standardized shock and conditional correlation persistence, respectively. Whether time-varying correlation exists between the underlying interest rates is examined through the significance of either of these scale parameters.

APPENDIX C: FIGURES OF TIME-VARYING CORRELATIONS BETWEEN TB AND LIBOR

This set of figures shows the time-varying correlation coefficients between various maturities of US-TB and 6-month US-LIBOR, where the former is used as a fixed rate and the latter is used as a floating rate. The DCC model used to compute the time-varying correlation is explained in Appendix B. The sample covers the daily data from 1st April, 1987 to 19th November, 2010.

Figure 1: 2-year TB and 6-M LIBOR

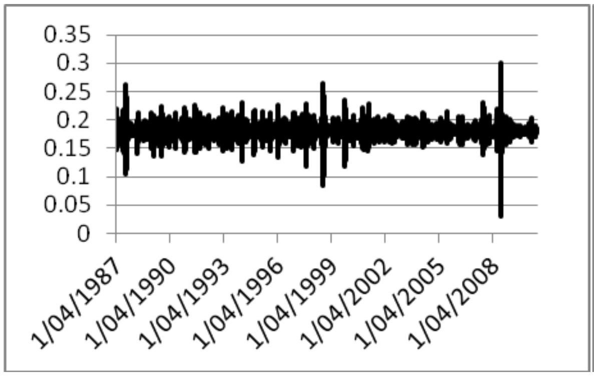

Figure 2: 3-year TB and 6-M LIBOR

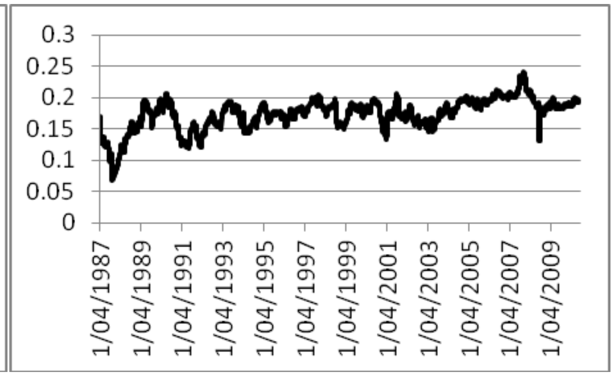

Figure 3: 5-year TB and 6-M LIBOR

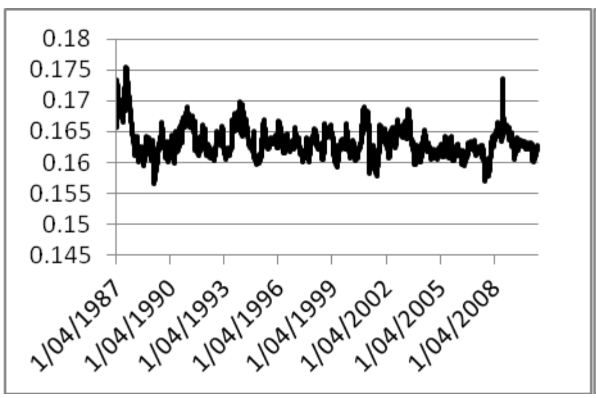

Figure 4: 7-year TB and 6-M LIBOR

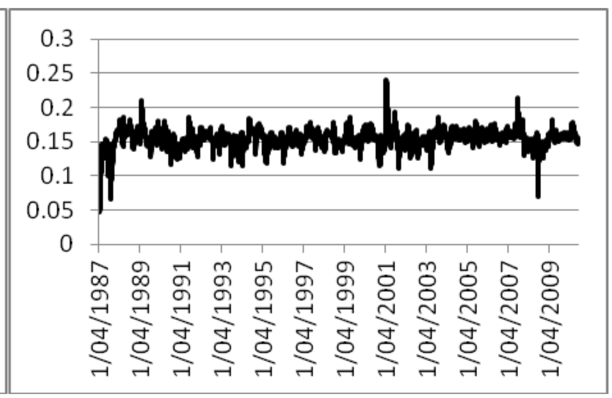

Table 1: Crisis Events

This table indicates the crisis events that affected the swap market. The last column indicates prior studies that mentioned the economic events related to swap markets. ‡ Many empirical studies provide evidence that, due to cross-border capital flows, these two crises caused contagion in various markets and countries. LTCB stands for Long-Term Credit Bank and NCB stands for Nippon Credit Bank.

Crisis Events	Periods	Source/Reference
Asian financial crisis (AFC)	July 1997 – July 98	‡, Ito (2010)
Russian Government bond default	August 1998	Apedjinou (2005)
Long-Term Capital Management (LTCM) crisis	September 1998	Apedjinou (2005)
Failure of Japan's LTCB and NCB	November 1998	Eom et al. (2002), Ito (2007)
Global Financial Crisis (GFC)	July 2007 – Jan 2010	‡, Ito (2010)

Table 2: Descriptive Statistics

This table shows the descriptive statistics of the US. BCYC is the business cycle risk, SKEW is the skewness risk and TB_LIB are the correlation risks for different maturities [TB stands for the yield on U.S. Treasury bond (with TB2 for 2-year, TB3 for 3-year and so on) and, LIB is the 6-month dollar-LIBOR rate]. Following Adrian and Rosenberg (2008) business cycle risk (BCYC) and skewness risk (SKEW) are calculated from the daily market return data (log-difference of the S&P 500 price index data from DataStream). However, unlike Adrian and Rosenberg (2008) this study uses the FS-GARCH model of Rangel and Engle (2012) to allow the asymmetry in the skewness risk component. Correlation risk between TB and the 6-Month dollar-LIBOR is estimated using Engle's (2002) DCC approach. DEF stands for default risk, calculated as the yield spread between 10-year BBB and AAA corporate bond reported by Bloomberg. LIQ stands for the liquidity risk calculated as the difference between the 6-month Eurodollar rate and 6-month T-bill following Ito (2010). Swap spreads are shown in percentage. * indicates that p-values for all J-B (Jarque–Bera) statistics are significant at 1%. The sample covers the daily data from April 1, 1987 to November 19, 2010.

	Swap Spread					BCYC	SKEW	Correlation Risks					DEF	LIQ
	2-year	3-year	5-year	7-year	10-year			TB2_LIB	TB3_LIB	TB5_LIB	TB7_LIB	TB10_LIB		
Mean	0.4442	0.5198	0.5375	0.5693	0.5768	0.1629	0.1628	0.1798	0.1737	0.1589	0.1514	0.1432	0.9643	0.6023
Max	1.5700	1.5225	1.2400	1.2700	1.3650	0.2289	1.4079	0.3866	0.4090	0.7217	0.3716	0.3690	3.5000	4.6800
Min	0.1050	0.1375	0.1000	-0.0325	0.0775	0.1002	0.0649	-0.2251	-0.2157	-0.2550	-0.0604	-0.0868	0.5000	-0.0400
Std. Dev	0.2149	0.2167	0.2300	0.2389	0.2388	0.0393	0.0921	0.0161	0.0216	0.0999	0.0109	0.0106	0.4147	0.5231
Skewness	0.9690	0.6307	0.4214	0.2482	0.6569	-0.1007	4.3436	-4.1294	-0.7339	0.3741	-1.0233	-1.6695	3.2156	2.7060
Kurtosis	4.3760	3.4191	2.1065	2.2676	3.0142	1.7432	37.1834	108.9439	34.2647	4.2295	82.2886	106.4000	16.5362	15.0504
J-B*	1404	439	374	195	429	403	309178	2783555	241480	511	1550699	2638219	5582	43371
N	5965	5965	5965	5965	5965	5965	5965	5916	5916	5916	5916	5916	5965	5965

Table 3: Correlation between Swap Spread and its Risk Determinants

This table shows the descriptive statistics of the US. IRS stands for interest rate swap spread, shown in percentage. BCYC is the business cycle risk, SKEW is the skewness risk and TB_LIB are the correlation risks for different maturities [TB stands for the yield on U.S. Treasury bond (with TB2 for 2-year, TB3 for 3-year and so on) and, LIB is the 6-month dollar LIBOR rate]. Following Adrian and Rosenberg (2008), business cycle risk (BCYC) and skewness risk (SKEW) are calculated from the daily market return data (log-difference of the S&P 500 price index data from DataStream). However, unlike Adrian and Rosenberg (2008), this study uses the FS-GARCH model of Rangel and Engle (2012) to allow the asymmetry in the skewness risk component. Correlation risk between TB and the six-month dollar LIBOR is estimated using Engle's (2002) DCC approach. DEF stands for default risk, calculated as the yield spread between 10-year BBB and AAA corporate bond reported by Bloomberg. LIQ stands for the liquidity risk calculated as the difference between the six-month Eurodollar rate and six-month T-bill following Ito (2010). * indicates that p-values for all J-B (Jarque–Bera) statistics are significant at 1%. The sample covers the daily data from April 1, 1987 to November 19, 2010.

	IRS2	IRS3	IRS5	IRS7	IRS10	BCYC	SKEW	TB2_LIB	TB3_LIB	TB5_LIB	TB7_LIB	TB10_LIB	DEF	LIQ
IRS2	1	0.9405	0.9039	0.8021	0.6470	0.6172	0.5753	-0.0349	-0.0009	0.0574	-0.0235	-0.0178	0.4583	0.7727
IRS3	0.9405	1	0.9433	0.8736	0.7292	0.6747	0.5775	-0.0468	0.0026	0.0775	-0.0385	-0.0323	0.4548	0.6403
IRS5	0.9039	0.9433	1	0.9506	0.8283	0.7080	0.5256	-0.0578	0.0029	0.0810	-0.0329	-0.0261	0.3428	0.5825
IRS7	0.8021	0.8736	0.9506	1	0.8440	0.6228	0.4211	-0.0543	0.0034	0.0892	-0.0329	-0.0273	0.1619	0.4051
IRS10	0.6470	0.7292	0.8283	0.8440	1	0.6782	0.3792	-0.0566	0.0060	0.0941	-0.0316	-0.0217	0.2090	0.3267
BCYC	0.6172	0.6747	0.7080	0.6228	0.6782	1	0.5445	-0.0287	0.0025	0.0406	-0.0092	-0.0042	0.3578	0.4307
SKEW	0.5753	0.5775	0.5256	0.4211	0.3792	0.5445	1	-0.0809	0.0068	0.1346	-0.1148	-0.1178	0.5456	0.5804
TB2_LIB	-0.0349	-0.0468	-0.0578	-0.0543	-0.0566	-0.0287	-0.0809	1	-0.1472	-0.6601	0.8425	0.7801	-0.0167	-0.0110
TB3_LIB	-0.0009	0.0026	0.0029	0.0034	0.0060	0.0025	0.0068	-0.1472	1	0.0839	-0.2047	-0.2096	0.0024	0.0066
TB5_LIB	0.0574	0.0775	0.0810	0.0892	0.0941	0.0406	0.1346	-0.6601	0.0839	1	-0.6466	-0.6052	0.0784	0.0450
TB7_LIB	-0.0235	-0.0385	-0.0329	-0.0329	-0.0316	-0.0092	-0.1148	0.8425	-0.2047	-0.6466	1	0.9556	-0.0464	-0.0348
TB10_LIB	-0.0178	-0.0323	-0.0261	-0.0273	-0.0217	-0.0042	-0.1178	0.7801	-0.2096	-0.6052	0.9556	1	-0.0393	-0.0346
DEF	0.4583	0.4548	0.3428	0.1619	0.2090	0.3578	0.5456	-0.0167	0.0024	0.0784	-0.0464	-0.0393	1	0.6365
LIQ	0.7727	0.6403	0.5825	0.4051	0.3267	0.4307	0.5804	-0.0110	0.0066	0.0450	-0.0348	-0.0346	0.6365	1

Table 4: Unit Root Test of the Dependent and Independent Variables

This table shows the ADF unit root test statistics of the dependent variables (swap spreads with different maturities) and the explanatory variables. IRS stands for interest rate swap spread. MacKinnon's (1996) p-values for ADF test statistics are: -3.4319, -2.8621 and -2.5671 at 1%, 5% and 10% respectively.

Series	t-Stat	Prob.
IRS2	**-3.3651**	0.0123
IRS3	**-3.0688**	0.0290
IRS5	**-3.1406**	0.0238
IRS7	**-2.8133**	0.0564
IRS10	-2.1064	0.2423
DEF	**-2.7321**	0.0686
LIQ	**-3.7389**	0.0036

Table 5: Are Business Cycle Risk, Skewness Risk and Correlation Risk Priced in the U.S. Swap Market? (Full Sample)

This table reports the estimation results from the following two regression models (see equations 2 and 3 for models *MI* and *MII* respectively):

$$MI: ss_t = a_0 + a_1 ss_{t-1} + a_2 bcyc_t + a_3 skew_t + a_4 corr_t + \varepsilon_t$$
$$MII: ss_t = a_0 + a_1 ss_{t-1} + a_2 bcyc_t + a_3 skew_t + a_4 corr_t + a_5 def_t + a_6 liq_t + \varepsilon_t$$

where, ss_t refers to swap spread. 2, 3, 5 and 7 year swap spreads are considered for the US. BCYC is the business cycle risk, SKEW is the skewness risk and CORR is the correlation risk for different maturities. Following Adrian and Rosenberg (2008), business cycle risk (BCYC) and skewness risk (SKEW) are calculated from the daily market return data (log-difference of the S&P 500 price index data from DataStream). However, unlike Adrian and Rosenberg (2008) this study uses the FS-GARCH model of Rangel and Engle (2012) to allow the asymmetry in the skewness risk component. Correlation risk between TB and 6-Month dollar-LIBOR is estimated using the DCC approach of Engle (2002). Default risk (DEF) is calculated as the yield spread between 10-year BBB and AAA corporate bond reported by Bloomberg. Liquidity risk (LIQ) is calculated as the difference between 6-month Eurodollar rate and 6-month T-bill following Ito (2010). In parentheses are the *t*-statistics, which are adjusted for autocorrelation and heteroskedasticity by using the Newey-West method and pre-whitening based on Schwarz Bayesian Information Criteria (SBIC) automatic lag selection. The Hansen's *J*-statistics (*p*-values for this test are reported in parentheses) examines the validity of the instruments with the null hypothesis that the instruments are uncorrelated with residuals. In most cases, up to four lags of the explanatory variables and of lagged swap spreads are taken as instruments. *, **, and *** denote 10%, 5%, and 1% significance levels, respectively. The sample covers the daily data from April 1, 1987 to November 19, 2010.

		2-year		3-year		5-year		7-year	
	Predicted sign	*MI*	*MII*	*MI*	*MII*	*MI*	*MII*	*MI*	*MII*
Intercept		-0.0011	**-0.0410****	-0.0027	0.0025	-0.0007	**-0.0410*****	**0.0113****	**0.0180****
(*t*-stat)		(-0.1048)	(-2.4080)	(-1.2705)	(0.5821)	(-1.0319)	(-3.6863)	(2.5159)	(2.0801)
SS(-1)		**0.9911*****	**0.9159*****	**0.9923*****	**0.9913*****	**0.9951*****	**0.9503*****	**0.9967*****	**0.9958*****
(*t*-stat)		(503.6692)	(92.1187)	(534.2113)	(523.5697)	(845.7269)	(109.9740)	(1023.748)	(1021.559)
BCYC	+	**0.0322*****	**0.1178*****	**0.0377*****	**0.0509*****	**0.0185*****	**0.2451*****	**0.0236*****	**0.0166****
(*t*-stat)		(4.9639)	(2.5829)	(4.4667)	(5.3065)	(2.7012)	(3.1698)	(3.8556)	(2.5386)
SKEW	+	-0.0047	0.0123	**-0.0134*****	**-0.0209*****	-0.0009	-0.0056	**-0.0092*****	-0.0020
(*t*-stat)		(-1.5371)	(0.7852)	(-4.4546)	(-2.8865)	(-0.2641)	(-0.5903)	(-4.1647)	(-0.7323)
CORR	− /+	0.0030	-0.0094	0.0145	-0.0216	0.0026	0.0120	**-0.0780*****	**-0.1148****
(*t*-stat)		(0.0539)	(-0.1180)	(1.2942)	(-0.8934)	(1.3208)	(1.3629)	(-2.6098)	(-2.0198)
DEF	+	-	**0.0590*****	-	0.0006	-	**0.0301*****	-	-0.0011
(*t*-stat)			(6.6657)		(0.5586)		(4.5920)		(-1.5398)
LIQ	+	-	**0.0196*****	-	0.0003	-	0.0026	-	0.0007
(*t*-stat)			(4.1078)		(0.4348)		(0.9708)		(1.4201)
J-statistics		14.8758	13.2772	5.0447	14.3504	10.9909	15.3044	12.0353	28.1242
(*p*-value)		(0.1883)	(0.7174)	(0.8304)	(0.4239)	(0.8100)	(0.3577)	(0.4428)	(0.1367)

Table 6: Sub-sample Analysis

This table reports the estimation results from the following regression model (see equation 3 for details):

$$ss_t = a_0 + a_1 ss_{t-1} + a_2 bcyc_t + a_3 skew_t + a_4 corr_t + a_5 def_t + a_6 liq_t + \varepsilon_t$$

where, ss_t refers to swap spread, the dependent variable. 2 and 5 year swap spreads are considered for sub-sample analysis. BCYC is the business cycle risk, SKEW is the skewness risk and TB_LIB are the correlation risks. Following Adrian and Rosenberg (2008), business cycle risk (BCYC) and skewness risk (SKEW) are calculated from the daily market return data (log-difference of the S&P 500 price index data from DataStream). However, unlike Adrian and Rosenberg (2008), this study uses the FS-GARCH model of Rangel and Engle (2012) to allow the asymmetry in the skewness risk component. Correlation risk (CORR) between US-TB and 6-Month dollar-LIBOR is estimated using the Engle's (2002) DCC approach. Default risk (DEF) is calculated as the yield spread between 10-year BBB and AAA corporate bond reported by Bloomberg. Liquidity risk (LIQ) is calculated as the difference between 6-month Eurodollar rate and 6-month T-bill following Ito (2010). Sub-sample 1 includes the following crises: AFC, LTCM, RGBD, LTCM and NCB spanning daily data from June 1997 to November 1998. Sub-sample 2 is a normal period covering the daily data from January 1999 to June 2007, while sub-sample 3 focuses on the GFC using the daily data from July 2007 to December 2009. In parentheses are the *t*-statistics, which are adjusted for autocorrelation and heteroskedasticity by using the Newey-West method and pre-whitening based on Schwarz Bayesian Information Criteria (SBIC) automatic lag selection. The Hansen's *J*-statistics (*p*-values for this test are reported in parentheses) examines the validity of the instruments with the null hypothesis that the instruments are uncorrelated with residuals. In most cases, up to four lags of the explanatory variables are taken as instruments. *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

	2-year			5-year		
Sub-sample	*1*	*2*	*3*	*1*	*2*	*3*
Intercept	**-0.1342*** **	-0.0214	-0.0128	**-0.1669*** **	**-0.0340*** **	**0.3690** **
(*t*-stat)	(-4.3149)	(-0.7489)	(-0.6961)	(-8.8548)	(-1.7986)	(2.0616)
SS(-1)	**0.8659*** **	**0.9788*** **	**0.9707*** **	**0.8824*** **	**0.9938*** **	**0.9324*** **
(*t*-stat)	(25.2170)	(172.4797)	(112.8295)	(76.6226)	(109.9046)	(38.7219)
BCYC	**0.4648*** **	**0.0258** **	**-0.3296*** **	**0.6666*** **	0.0416	**-1.6492* **
(*t*-stat)	(4.0384)	(2.0482)	(-4.0955)	(8.4734)	(1.2696)	(-1.8405)
SKEW	0.0117	0.0069	**0.0414*** **	**0.0603*** **	0.0033	-0.0364
(*t*-stat)	(0.8925)	(0.8117)	(6.0017)	(5.7945)	(0.1946)	(-0.6080)
CORR	**0.3082*** **	0.1532	**0.2948*** **	**-0.0489*** **	**0.0110* **	**-0.1060** **
(*t*-stat)	(4.2312)	(1.1200)	(8.1038)	(-7.5902)	(1.7988)	(-2.4180)
DEF	0.0291	-0.0044	**0.0140*** **	**0.0985*** **	**0.0261* **	-0.0071
(*t*-stat)	(1.1468)	(-1.5166)	(4.3742)	(5.5803)	(1.8815)	(-1.0546)
LIQ	**0.0370*** **	**0.0054*** **	**0.0151*** **	**0.0493*** **	**0.0122** **	**0.0288** **
(*t*-stat)	(3.5840)	(2.8871)	(3.4675)	(3.4609)	(2.1013)	(2.0599)
J-statistics	9.7563	4.3302	14.0614	3.2751	11.3932	5.8961
(*p*-value)	(0.4621)	(0.8884)	(0.6627)	(0.9742)	(0.4109)	(0.8802)