Modelling the Credit Spreads and Long-Term Relationships of Thai Yankee Bond Issues*

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The present study investigates the yield spread between Thai government bonds issued in the US domestic market ('Yankee' bonds) and US Treasury bonds, to determine the long-term equilibrium dynamics and the factors that affect changes in credit spreads. The sample period investigated was from May 5, 1999 to March 26, 2002. The results suggest that the long-term equilibrium relationship holds only between Thai Yankee bonds and long-term US bonds, rather than shorter or equivalent maturity bonds. Also, changes in the credit spreads of Thai Yankee bonds are generally negatively related to changes in the Stock Exchange of Thailand (SET) index (see http://www.set.or.th/th/index.html). Changes in US Treasury bonds also tend to negatively affect spreads on short Thai Yankee bonds and positively affect spreads on long Thai Yankee bonds, although other macroeconomic factors – including exchange rate and capital flow variables – were generally not important.

Keywords: credit spreads, long-term equilibrium, Thailand, Yankee bonds.

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I. Introduction

Many emerging economies experienced significant reductions in international bank lending in the period after the Asian crisis. One key policy response by governments to the resulting decline in liquidity was to develop domestic bond markets, thereby facilitating the channelling of domestic savings to domestic corporate investment. Due to existing impediments within the financial system, and in order to ensure that developing domestic bond markets were not crowded out, some governments also expanded or initiated new debt programs in either international Eurobond markets or foreign domestic bond markets, notably the US. These later non-resident issues in the US are termed 'Yankee' issues by the financial markets. However, how should these bond issues be priced, and what are the factors that affect the yields of these instruments? For example, current market practice assumes that the yield paid by an emerging market issuer is a function of a benchmark yield – generally derived from the US Government term structure – plus a spread for potential default risk (De Almeida et al., 1998). Also, models on the pricing of credit spreads (Longstaff and Schwartz, 1995; Jarrow et al., 1997) suggest that asset and interest-rate factors negatively affect changes in credit spreads, while more recent studies suggest that key macroeconomic variables (such as exchange rates) are also important (Collin-Dufresne et al., 2001).

The objective of the present study is to examine these issues in more detail by investigating the relationship that exists between Government of Thailand bonds issued in the US bond market (Thai Yankee Bonds) matched with another set of US government bonds of varying maturity. This enables precise modelling of the yield spread between these two different risk classes of bonds and overcomes concerns that arise from spreads calculated from interpolated yields using spline or other techniques (Kim et al., 1998). The sample period covers daily data for the period from May 5, 1999 to March 26, 2002 (747 observations).

Understanding these relationships is important for a number of reasons. First, the results of this study will provide evidence on the nature of the risk premium that exists between the Thai and US bond markets. These findings will also provide a framework for investigating the international bonds issued by other developing countries. Second, the results will also assist the pricing and risk management of emerging market debt in international markets because the market practice of applying a yield spread to a risk-free bond of equivalent maturity assumes an equilibrium relationship between these bonds. Third, the study will provide an insight into the long-term equilibrium relationship between different maturity classes of Thai and US government bonds. Historically, studies investigating long-term equilibrium relationships have been restricted to securities of developed countries (Hiraki et al., 1996).

These issues are investigated using empirical models based on Hall et al. (1992), and Batten et al. (2000) for the cointegration relationships between Thai Yankee and US government bonds, and the regression model proposed by

Longstaff and Schwartz (1995) for explaining the yield spread. To accommodate the time varying volatility of the return series, a generalized autoregressive conditional heteroskedasticity (GARCH) specification of the Longstaff and Schwartz (1995) empirical model is used in this paper. In addition, we also consider two additional independent variables consistent with Collin-Dufresne et al. (2001) to accommodate macroeconomic uncertainty. The first is the volume of trading on the Thai stock market (which could proxy for capital flows). The other variable is the US Dollar–Thai Bhat exchange rate.

The paper is set out as follows. In the next section a brief discussion is provided on the Thai bond market. Then the data and method employed in this study is described. The results are then presented, and the final section allows for some concluding remarks.

II. Background on the Thai Bond Market

The first Thai government bond was issued in Europe in 1905. In 1933 the Ministry of Finance (MOF), on behalf of the Thai Government, issued the first domestic bonds. With the establishment of the Central Bank of Thailand (BOT) in 1942, the debt issuance role was adopted by the BOT. Although the BOT did not formally underwrite government issues (the exception being treasury bills), in practice the BOT did buy unsold portions of government issues.

During this embryonic period for the Thai bond market, government bonds comprised more than 90% of total bond issues outstanding. The growth spurt of the government bond market was attributed to the implementation of the National Economic and Social Development Plan in 1961. The government fiscal plan focused on developing the industrial sector and infrastructure. This led to a long period of budget deficits that were financed through the issuance of government bonds. From 1970 until 1993, the government required commercial banks to hold government debt securities or guaranteed state-enterprise bonds as a condition to open new branches. The required percentage was fixed at 15% of total deposits and then raised to 16% in 1978. This requirement was eventually cancelled in May 1993.

As a result of the economic crisis in mid-1997, activity in the Thai bond (primary and secondary) market waned. However, changes in economic policy instituted by the Thai Government to ameliorate the liquidity and financial aspects of the Asian financial crisis led to significant growth in the government and corporate bond markets. A large fiscal deficit, along with a plan to support the recapitalization of the distressed financial sector, led to the issuance of Thai Bhat 500 billion worth government bonds. The economic problems concomitant with the economic crisis forced commercial banks to be reluctant to grant new loans to the private sector. Thus, both state enterprises and the private sector started to issue new bonds for restructuring debt and funding new projects. These markets expanded so that, by the end of 2000, the outstanding value of total bonds issued in the market had increased from Bhat 547 billion in 1996 to

Bhat 1269 billion (470 issues). Trading volume in the secondary market had also increased from a daily average of Bhat 822 million in 1996 to Bhat 5494 million in 2000.[1]

The focus of the present paper is on the spread of international bonds issued by Thai borrowers in international markets, specifically those bonds issued in US domestic bond markets. The attractive feature of the Yankee bond market is that it is available to non-investment grade corporate issuers (with credit rating lower than BBB).[2] Emerging market issuers are generally unable to tap the international Eurobond market, which has a preference for investment grade issues, and is also largely a US-dollar-denominated market.[3] However, from the borrowers' perspective the degree of substitutability of these different markets is ultimately a function of cost. For example, there were significant increases in the level of offshore issues in the period prior to 1995, largely associated with the decline in spreads of issues over US Treasury bonds of similar maturity (Kamin and von Kleist, 1999). During this period, lenders favored Asian issues. For instance, spreads on Latin American issues with the same characteristics as Asian issues were 39% higher. This may have been due to Latin American and Eastern European countries exhibiting greater price volatility than Asian economies and/or greater supply, because Latin American countries issued more bonds than Asian countries.

The key features of each successful international issue by Asian borrowers (which encouraged high-yield investors) were: (i) the size of the issue (which ensured adequate liquidity); (ii) the size of the spread (which compensated investors for the risks of holding emerging market bonds); and (ii) the marketing of the issues (which included government and central banker representation during the international promotion or 'roadshow' prior to the actual issue arranged by high-profile and credible bookrunners).[4] Also, issues tended to have a simple fixed-rate pricing structure and were generally quasi-government, if not sovereign, issues. It is doubtful if a more complex structure (for example

1. Further information on the Thai bond market is available from the Thai Bond Dealing Center website, available from: URL:http://www.thaibdc.or.th The spot exchange rate was approximately 4.3 Bhat to the US Dollar in October, 2002.

2. Non-investment grade issuers are those with a credit rating lower than BBB, as defined by Standard & Poor's Rating Agency, or Baa3 by Moody's Investor Services. See the Standard and Poor's website, http://www.standardandpoors.com, or the Moody's Investor Services website, www.moodys.com, for more details.

3. Worldwide, the US Dollar is the most frequently used currency of Eurobond issue (with US$1673.4 billion) followed by: the Japanese Yen (US$407.1 billion); the Deutsche Mark (US$369.4 billion); the Pound (US$308.3 billion); the French Franc (US$191.3 billion); the Swiss Franc (US$141.5 billion); the Italian Lire (US$117.9 billion); the Dutch Guilder (US$105.3 billion); the ECU (US$99.3 billion); and, finally, the Luxembourg Franc (US$37.8 billion) in outstandings. (Bank for International Settlements, 1998).

4. Capital Data Bondware (Euromoney) generally list the following firms as the major bookrunners of emerging market bonds: (i) JP Morgan; (ii) Merrill Lynch; (iii) Credit Suisse First Boston; (iv) Union Bank of Switzerland; and (v) Lehman Brothers.

having a call feature) would have found favor with investors, or if smaller tranches offered over a range of maturities would have satisfied the market's desire for liquidity,[5] because smaller issues fragment the distribution of bonds. However, the key feature of very large ('jumbo') Eurobond issues by prime-name corporations is that they are all simple, fixed-rate US-dollar-denominated securities. In the case of Thailand, in the period from 1994 to 2000, international issues increased from US$0.3 billion to US$13.3 billion (Bank for International Settlements, 2000). We focus on one segment of these issues – Thai Government issues in the US market.

III. Data and Method

Daily Thai bond data was obtained from the Reuters Fixed Income Database for the period from May 5, 1999 to March 26, 2002 (747 observations). This database comprised 520 outstanding bonds that were denominated in a number of currencies: (i) 451 in Thai Bhat; (ii) 51 in US Dollars; (iii) 15 in Japanese Yen; and (iv) two in Deutsche Mark and French Franc. A sample listing of US-dollar-denominated bonds at February 2002, by Thai issuers, is provided in Appendix I. This listing includes both Eurobonds and Yankee issues. The Reuter's Database only recorded five Thai Government Yankee issues outstanding in the US. The remaining 46 issues were non-government issues or issues in Euromarkets (Eurobonds). All the Thai Government issues carried a long-term foreign currency Moody's rating of Baa3 or Standard & Poor's BBB minus. All bonds were fixed rate, semi-annual coupons priced on a 30/360-day basis:

(i) 7.84% coupon maturing on August 15, 2001
(ii) 8.25% coupon maturing on March 15, 2002
(iii) 6.27% coupon maturing on September 30, 2003
(iv) 8.09% coupon maturing on August 15, 2004
(v) 7.75% coupon maturing on April 15, 2000
(vi) 7.07% coupon maturing on September 30, 2013.

The yields obtained were calculated as the International Securities Markets Association yield to maturity and were indicative daily bids provided by market practitioners at the close of trading. Only three bonds – (i), (iii), and (vi) – had a complete set of daily prices and were selected for use in this study. The first bond had prices to January 31, 2001, while the latter two bonds had prices to the March, 26 2002. Collectively, the issue size of these bonds was small, with US$210 million outstanding. While the small issue size is of some concern due to obvious concerns over liquidity, these concerns arise in all emerging market studies and should not preclude investigation.

5. It is difficult to assess what issue size is necessary to maintain adequate liquidity. One of the world's largest Eurobond issuers (Federal Home Loan Mortgage Corporation or Freddie Mac) suggests that single maturity issues of at least US$4 billion every quarter is necessary (Lee, 1998).

Market practice is to price risky bonds as a spread on an underlying risk-free benchmark security, typically a US government of equivalent maturity and coupon. Fortunately, given the depth of the US Treasury bond market, there were a number of US T-bonds with equivalent maturity to the three Thai government bonds described above:

(i) 7.875% coupon maturing on August 15, 2001
(ii) 5.75% coupon maturing on August 15, 2003
(iii) 11.875% coupon maturing on November 15, 2003
(iv) 12.0% coupon maturing on August 15, 2013
(v) and a Federal Home Loan Mortgage Bank (FHLB) bond 6.535% coupon maturing on September 30, 2013.

Looking specifically at the Thai 6.27% 2003 bond and the US 5.75% 2003 T-bond over a sample period which saw yields fall significantly, in line with monetary policy changes in the USA, the yield on the US bond ranged 2.16–6.88%, while the Thai bond ranged 4.23–9.09%. The standard deviation of the Thai bond was slightly higher (1.40) than the US bond (1.38). Consistent with market-pricing practice, the correlation between Thai and US bonds was highest for bonds of the same maturity. For example, the US 5.75% 2003 bond and the Thai 6.27% 2003 had a correlation of 0.9899. The correlations between the various bonds are provided in Table 1. An interesting feature of these results is that the correlations between any two of the Thai bonds tended to be higher than those correlations between US bonds of equivalent maturity. It appears the Thai bonds were all being grouped as one, whereas maturity differences were more pronounced for the US bonds.

Having obtained a set of daily yields for the Thai Yankee bonds, the various factors that affect these yields must be established. Though a variety of statistical techniques may be applied to the data, it would be appropriate to examine:

Table 1 Correlation Coefficients of Thai Yankee Bonds and US Benchmark Bonds

	Thai Yankee bonds			*US bonds*			
	7.84% 2001	*6.27% 2003*	*7.07% 2013*	*7.87% 2001*	*5.75% 2003*	*11.875% 2013*	*6.535% 2003*
TH 7.84% 2001	1.000000	0.912453	0.823389	0.940383	0.783940	0.772678	0.747092
TH 6.27% 2003	0.912453	1.000000	0.913264	0.893701	0.989988	0.989662	0.988483
TH 7.07% 2013	0.823389	0.913264	1.000000	0.729999	0.877818	0.871588	0.961527
US 7.875% 2001	0.940383	0.893701	0.729999	1.000000	0.848937	0.822754	0.751255
US 5.75% 2003	0.783940	0.989988	0.872971	0.848937	1.000000	0.999036	0.999016
US 11.875% 2003	0.772678	0.988483	0.877818	0.822754	0.999036	1.000000	0.931965
US 6.535% 2013	0.747092	0.900858	0.871588	0.751255	0.921400	0.931965	1.000000
US 12% 2013	0.773486	0.918654	0.961527	0.786231	0.898353	0.890066	0.973550

Notes: TH, Thai Yankee bonds; US, US government and US government agency bonds.

(i) the long-run dynamics of the yields within a cointegration framework; and (ii) those factors which affect the changes in spreads on the risky bonds. The cointegration framework follows from Hall et al. (1992) and Batten et al. (2000). The empirical framework for investigating changes in credit spreads is based on Longstaff and Schwartz (1995), who suggested a two-factor model based on asset and interest-rate factors as driving changes in risky bond yields. In addition, we also consider two additional variables consistent with Collin-Dufresne et al. (2001): (i) an exchange rate (the US Dollar–Thai Bhat spot exchange rate); and (ii) a proxy for capital flows (the volume of trading on the domestic stock exchange; SET). A further innovation of this paper is that we accommodate the presence of autocorrelation and heteroskedasticity using the autoregressive (AR) and GARCH framework of Bollerslev (1986) and Bollerslev and Wooldridge (1992).

III.1 A cointegration framework

Batten et al. (2000) denote the continuously compounded yield to maturity of a k period pure-discount bond as $R^*(k,t)$ ($k = 1,2,\ldots$) with $F(k,t)$ the forward rate of a contract at time t to buy a one period discount bond that matures at $t + k$. Using their notation a general relationship between maturities of pure discount, bonds is

$$R^*(k,t) = \frac{1}{k}\sum_{j=1}^{k} E_t[R^*(1,t+j-1)] + A(k,t) \quad \text{with} \quad A(k,t) = \frac{1}{k}\sum_{j=1}^{k} a(j,t). \tag{1}$$

Traditional theories of the term structure (Hall *et al.*, 1992) focus on the properties of the premiums $A(k,t)$. The pure expectation hypothesis asserts that $A(k,t)$ are zero, while the expectation hypothesis asserts that the premium is constant.

In the case of corporate bonds, there is a risk premium over an otherwise similar government bond. For a corporate bond, there is a risk that the coupon or principal payment may not be met, implying a distinction between the promised and expected return on the bond. Because of this uncertainty, investors demand a risk premium. Let $D(k,t)$ denote the risk premium for a corporate bond over an otherwise similar government bond, and then from (1) we get the following model for the yield of a corporate bond

$$R(k,t) = R^*(k,t) + D(k,t). \tag{2}$$

Thus, combining equation 1 and 2,

$$\begin{aligned} R(k,t) - R(1,t) &= R^*(k,t) - R^*(1,t) + D(k,t) - D(1,t) \\ &= \frac{1}{k}\sum_{j=1}^{k-1}\sum_{i=1}^{j} E_t[\Delta R^*(1,t+i)] + A(k,t) + D(k,t) - D(1,t) \end{aligned} \tag{3}$$

where $\Delta R^*(1,t+i) = R^*(1,t+i) - R^*(1,t+i-1)$.

Given that $R^*(1,t+i)$ are $I(1)$ (integrated of order one), the differences $\Delta R^*(1,t+i)$ are therefore stationary, implying that the (double) summation term in the last line of (3) is also stationary. Therefore, the important result predicted from theory is that the yield spread $R(k,t) - R(1,t)$ is stationary because the maturity premiums $A(k,t)$ and default-risk premiums $D(k,t) - D(1,t)$ are stationary.

III.2 Changes in credit spreads

A key empirical implication of the Merton (1974), Longstaff and Schwartz (1995) valuation model for risky fixed-rate bonds is that credit spreads are driven by two factors: (i) an asset-value factor; and (ii) an interest-rate factor. A key empirical concern is whether this model is applicable for sovereign issues. The regression equation form of the Longstaff and Schwartz model (their notation) is given by

$$D(k,t) - D(1,t) = \Delta S_t = a + b\Delta Y_t + c\Delta I_t + \varepsilon_t \qquad (4)$$

where $\Delta S_t = S_t - S_{t-1}$, S_t = the actual credit spread which is the difference between a risky bond (i.e. a Thai Yankee bond) of a specified maturity (X_t) and a US government T-bond of the same maturity (Y_t). The change in the US rate is defined as $\Delta Y_t = Y_t - Y_{t-1}$. As suggested by Longstaff and Schwartz, the change in the asset-value factor is proxied by the return on a broad stock market index (in this instance the Stock Exchange of Thailand (SET) index), where ΔI_t is the natural logarithm of the daily change on the stock index (I_t). Finally, a, b, and c are regression coefficients.

The b and c coefficients in these regressions are expected to be negative (i.e. $b < 0$ and $c < 0$). The explanation that $c < 0$ is non-controversial and an intuitive explanation lies with the degree of solvency of the issuer – when an issuer's value increases, the probability of default falls. As noted by Longstaff and Schwartz (1995), the explanation for the expected negative value on (c), the interest-rate factor, is due to the increase in the drift of the risk-neutral process as interest rates increase, which causes the risk-neutral probability of default to fall. Thus, as interest rates rise, the credit spread is expected to decline. However, this theoretical relationship may or may not occur, depending on the correlation between the issuer's assets and liabilities, and interest rate movements, as well as the form of the volatility of interest rates. Also, as noted by Duffee (1999), when the correlation between default-free interest rates and the value of the issuing firm's assets is negative, the value of the firm's assets is more stable, and the likelihood of default is therefore reduced. This occurs because a decline in the firm's assets is accompanied by an increase in the instantaneous interest rate, allowing the growth rate of the firm's assets to rise. This in turn pushes the firm away from default.

There are four key empirical issues that need to be addressed at this point. First, is it possible to proxy the Thai Government risk using a stock market index and, if so, should an adjustment be made for the exchange rate, because the other two variables are denominated in US dollars? Thailand offers a rare insight into this first issue, because there are a number of listed corporations on the Thai stock market that are majority-owned by the Thai Government. For example, Krung Thai Bank is both a listed firm and a firm that carries the same credit rating as the Thai Government in international debt markets. In the later empirical analysis we use a number of alternate proxies for the asset-factor variable and find no statistically significant differences in the results. This was probably due to the high correlation between changes in the prices of alternate measures and the SET index (the magnitude was 0.898 for the Krung Thai Bank and 0.916 for the Thai Military Bank, which has a slightly lower credit rating).

The second empirical issue concerns the need to adjust for the effects of exchange rate movements on the returns of the SET index, while also accommodating broader effects associated with macroeconomic uncertainty. In this context, we follow the recommendation of Collin-Dufresne et al. (2001), that exchange rates provide a good proxy for macroeconomic uncertainty when the study employs daily data. In fact, the Thai Bhat had a 0.911 negative correlation to the SET index during the sample period (i.e. if the US Dollar appreciated against the Bhat, the SET index fell). One could easily argue that these effects were due to short-term capital flows. For example foreign investors intending to buy Thai stocks would need to first sell dollars to buy Bhat. Trading volume on the SET index may also be associated with macroeconomic uncertainty, and so this variable was also considered (the US Dollar–Thai Bhat exchange rate and trading volume on the SET was positively correlated at 0.2600). Thus, both changes in exchange rate movements (ΔF) and changes in SET volume (ΔV) are expected to be positively associated with changes in credit spreads.

The third empirical issue concerns the significance of the regression intercept expressed in equation (4). We expect that this coefficient should be indistinguishable from zero. Were this not the case, then a constant risk premium would be expected from the returns on the bonds other than those due to interest rate and asset risk factors.

Finally, there is the need to accommodate autocorrelation in the residuals or, as is readily observable in the return series, the presence of volatility clustering which is symptomatic of non-constant variance. Thus, to provide further insights into the properties of credit-spread returns, the simple ordinary least-squares regression equation of credit spreads adopted by Longstaff and Schwartz (1995) and Collin-Dufresne et al. (2001) has been extended in this study by incorporating the GARCH specification of Bollerslev (1986), within an autoregressive moving average framework (ARMA). This framework allows for two AR terms at one and two lags (AR1 and AR2, respectively), and two moving average terms at one and two lags (MA1 and MA2). For simplicity, we apply a GARCH (1,1) at time t, where:

$$\Delta S_t = a + b\Delta Y_t + c\Delta I_{t-1} + d\Delta F_t + e\Delta V_{t-1} + \mathrm{AR}(1) + \mathrm{AR}(2) + \mathrm{MA}(1) + \mathrm{MA}(2) + \varepsilon,$$

$$\sigma^2 = \alpha + \beta\varepsilon_{t-1}^2 + \gamma\sigma_{t-1}^2 \tag{5}$$

Note that, to accommodate time-zone differences between trading on Thai Yankee bonds in the US and trading on the stock exchange in Thailand, the SET index (I) and the SET index trading volume variable (V) are both lagged one time-period (one day).

IV. Results

IV.1 Description of spreads

Spreads between Thai Yankee bonds and the underlying US bond were calculated. Two sets of spreads were calculated for the Thai 6.27% 2003 bond (the US 5.75%, which had a slightly short maturity, and the US 11.875%, which had a slightly longer maturity). Two sets of spreads were also calculated for the Thai 7.07% 2013 bond (the US12%, which had a slightly earlier maturity and the FHLB 6.535%, which had the exact maturity). This enabled five sets of spreads to be used in the later analysis. These are recorded in Table 2, with the correlations recorded in Table 3.

The mean spread for the various maturity bonds varied from 1.11% to 2.05%, depending on the maturity over the sample period. The spreads between the Thai 6.27% 2003 bond and the Thai 7.07% 2013 bond and their respective US

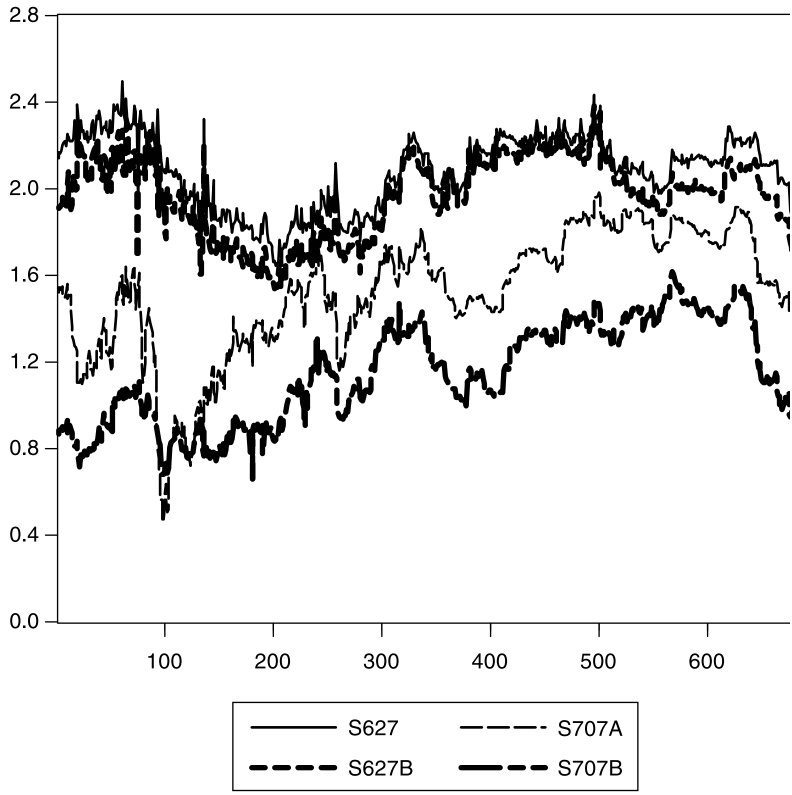
Table 2 Descriptive Statistics for Spreads Between Thai Yankee Bonds and US Benchmark Bonds

	S6.27% 2003–1	*S6.27% 2003–2*	*S7.07% 2013–1*	*S7.07% 2013–2*	*S7.84% 2001*
Mean	2.048823	1.935955	1.490969	1.117556	1.942502
Median	2.095000	1.968000	1.510000	1.089000	1.957538
Maximum	2.492000	2.381000	1.980000	1.616000	2.361312
Minimum	1.476000	1.394000	0.459000	0.352000	1.071712
Standard deviation	0.197736	0.203790	0.293520	0.244949	0.181855
Skewness	–0.574666	–0.419641	–0.725182	0.001990	–1.021193
Kurtosis	2.619174	2.223555	3.280235	1.873656	5.303717

Table 3 Correlation Between Spreads on Thai Yankee Bonds and US Benchmark Bonds

	S6.27% 2003–1	*S6.27% 2003–2*	*S7.07% 2013–1*	*S7.07% 2013–2*	*S7.84% 2001*
S6.27% 2003–1	1.000000	0.962952	0.415171	0.477714	0.836434
S6.27% 2003–2	0.962952	1.000000	0.461819	0.541346	0.747901
S7.07% 2013–1	0.415171	0.461819	1.000000	0.913546	0.747461
S7.07% 2013–2	0.477714	0.541346	0.913546	1.000000	0.753814
S7.84% 2001	0.836434	0.747901	0.747461	0.753814	1.000000

Figure 1 Plot of the Spread Between Thai Yankee and US Government Bonds, 5 May 1999–26 March 2002



Notes: S627, Thai 6.27% (30/9/2003)–US 5.75% (15/8/2003); S627B, Thai 6.27% (30/9/2003)–US 12% (15/8/2003); S707A, Thai 7.07% (30/9/2013)–FHLB 6.535% (30/9/2013); S707B, Thai 7.07% (30/9/2013)–US 12% (15/8/2003).

benchmarks are provided in Fig. 1. It is clear from this figure how spreads increased over the sample period, reaching a peak of nearly 2.5% in mid-2000, then declining again in 2001 and 2002. Descriptive statistics provided in Tables 2 and 3 show the other moments and the correlations between the various spreads. Interestingly, the two spreads on the longest maturity bond (2013 maturity) were smaller than on the shorter bonds. This is consistent with US evidence, suggesting that credit spreads decline as maturity increases (Pedrosa and Roll, 1998). The correlation between spreads was also positive, with the largest correlations between bonds of similar maturity. The lowest correlations were between spreads on the shortest bonds (2001 maturity) and the longest bonds (2013 maturity).

Table 4 Johansen Cointegration and Stationarity Tests of Thai Yankee Bonds with US Government Bonds

Bond pairs	*Trace statistic for cointegration**	*ADF test for stationarity of the spread*
Bonds with the equivalent maturity		
Thai 7.84% 15/08/2001–US 7.875% 15/08/2001	6.172	−1.13
Thai 6.27% 30/09/2003–US 5.75% 15/08/2003	3.884	−0.93
Thai 6.27% 30/09/2003–US 11.875% 15/11/2003	4.046	−1.34
Thai 7.07% 30/09/2013–FHLB 6.535% 30/09/2013	10.296	0.12
Thai 7.07% 30/09/2013–US 12% 15/08/2013	7.433	−0.40
Short Thai bonds with long US bonds		
Thai 7.84% 15/08/2001–US 5.75% 15/08/2003	17.792*	−0.59
Thai 7.84% 15/08/2001–US 11.875 15/11/2003	19.729*	−0.85
Thai 7.84% 15/08/2001–FHLB 6.535% 30/09/2013	13.775	−0.77
Thai 7.84% 15/08/2001–US 12% 15/08/2013	19.981*	−0.93
Thai 6.27% 30/09/2003– FHLB 6.535% 30/09/2013	10.824	−1.74
Thai 6.27% 30/09/2003–US 12% 15/08/2013	21.062**	−2.05
Long Thai bonds with short US bonds		
Thai 6.27% 30/09/2003–US 7.875% 15/08/2001	12.401	−1.43
Thai 7.07% 30/09/2013–US 5.75% 15/08/2003	10.876	−2.28
Thai 7.07% 30/09/2013–US 11.875% 15/11/2003	9.430	−2.51
Thai 7.07% 30/09/2013–US 7.875% 15/08/2001	14.036	−1.93
Critical values		
5%	15.41*	−2.87*
1%	20.04**	−3.45**

Notes: ADF, augmented Dickey-Fuller test with four difference lags and an intercept. The null hypothesis is that the series are not cointegrated; the intercept is restricted within the cointegration space.

IV.2 Cointegration analysis between Thai Yankee bonds and US government bonds

Given that the risk premiums, $D(k,t)$ defined in Section 3, can be assumed stationary, theory predicts that the series should be cointegrated with a cointegration vector (1,–1). Table 4 reports the Johansen unrestricted cointegration analysis, with the corresponding trace statistic ratio for various combinations of bond pairs between the three Thai Yankee bonds and the various US government bonds. The augmented Dickey–Fuller tests for stationarity of the spreads are also reported. Not reported in this table are the stationarity tests for the yields. The full sample test statistics show no evidence against the null hypothesis that there was a unit root in yield levels, but the data clearly reject the null hypothesis that there was a unit root in the difference. A reasonable conclusion from these results is that each yield to maturity is integrated at order one (i.e. they are an $I(1)$ process), with all tests supporting the unit root hypothesis at the 1% level of significance for all the data series. However, all combinations of spread (levels) are non-stationarity, which suggests that the spreads also follow $I(1)$ processes, or equivalently, that the stochastic trends that play the dominating role in the behavior of the yields, are independent of one another. The five lags proved to be sufficient to ensure that the residuals were not serially correlated.

Contrary to the theoretical predictions, the results from the cointegration trace-statistic tests indicate that the Thai bonds are not cointegrated with the US government bonds of equivalent maturity. This also means that the risk spreads $D(k,t)$, as defined in Equation 3, should be $I(1)$ series. This implies that the Thai Yankee bonds and the US government bonds do not have any ties with one another, and that the two bond markets are effectively independent in terms of pricing. This suggests that pricing the Thai Yankee bonds as a spread over the equivalent maturity US government bond may not be appropriate, or was not appropriate during the sample period investigated. The alternate perspective is that this anomalous result may be due to the specific sample period studied. Researchers investigating these same relationships in the international bonds of other emerging countries may provide further insights into this issue.

The results were more statistically significant for combinations of short-maturity Thai bonds and long-maturity US bonds, with almost all bond pairs cointegrated at the 5% level. What is interesting is that the long-maturity Thai bonds are not cointegrated with shorter maturity US bonds. Thus, it appears from these results that the defining pricing relationship exists between the US long-bonds and the Thai bonds of a shorter maturity. These two results suggest that the expectations of US interest-rate direction – which are factored into the risk premium on long US bonds – appear to dominate the direction of Thai Yankee bond yields, rather than immediate concerns over default.

Cointegration relationships were also calculated between various pairs of Thai Yankee bonds and pairs of US bonds. These results are not reported in Table 4. In the case of the Thai Yankee bonds, the cointegration trace statistic between the 2003 and the 2001, and between the 2003 and the 2013 maturities were all significant at the 5% level (with ratios of 15.606 and 14.529, respectively). However, the short- (2001) and long-bonds (2013) were not cointegrated, which is consistent with independent-return processes. Consistent with other cointegration studies on the US term-structure (Hall et al., 1992), the US bond pairs were clearly cointegrated, at least at the 5% level. The exception was between the two sets of bonds with the similar maturity but different coupon. The 5.75% and the 11.875% 2003 bonds had low trace statistics (9.319), as did the 6.535% (FHLB) and the 12% 2013 bonds (7.508), which rejects cointegration at the 5% level.

III.3 Changes in credit spreads

Various combinations of spreads between short-term and long-term Thai Yankee and the US government bonds were examined. The analysis involved two main classes of spreads: (i) spreads on bonds of similar maturity; and (ii) spreads on bonds of different maturity. When spreads on bonds of the same maturity are examined, the risk premium is dominated by credit or potential default risk. Other investigations of credit spreads have tended to focus on relationships between bonds of the same maturity. In contrast, investigating credit spreads on bonds of different maturity will automatically factor in a term-structure component, because the yield of the longer maturity bond will include a premium for uncertainty concerning future interest-rate changes.

Regressions of the change in the credit spread against the change in the US government bond and the return on the SET index were conducted using the Bollerslev (1986) GARCH (1,1) specification described by equation (5). The analysis was conducted with the SET index in Thai Bhat terms and a separate exchange-rate variable (the change in the spot Thai Bhat against the US Dollar). The GARCH (1,1) specification was undertaken to adjust for the time-varying volatility structure of the return series, while the ARMA (2,2) specification was undertaken to accommodate autocorrelation in the regression residuals at up to two lags. To ensure that the statistical significance of the results was not affected by conditionally non-normally distributed residuals, we also applied the methods described by Bollerslev and Wooldridge (1992) when calculating the standard errors. Adopting this procedure tended to reduce the statistical significance of the asset factor for the credit spreads on longer maturity bonds. These adjusted results are reported in Table 5, which displays only the variables that were statistically significant.

The intercept term (a) was not statistically significant. A significant alpha would have implied a risk premium in addition to that proposed by theory. The coefficients of the asset factor (c) were generally negative and all statistically significant at the 99.9% level. This suggests that changes in credit spreads are negatively related to changes in the stock market index. This result is consistent with theory and is an important result for emerging market issuers. The interest-rate factor (b) was negative for six out of eight of the regressions, with the exception being the two long-dated bonds where the coefficient was positive. This latter result suggests that long-term Thai Yankee bonds are more likely to respond positively to changes in long-term US interest rates, where the risk premium is dominated by concerns over inflation. However, the short-term bonds are more likely to change in response to changing perceptions about default risk. Also, while the exchange-rate variable was positive in two cases, it generally was not important. These last two exceptions are of interest because they relate only to the spreads on long-term Thai Yankees. Here the inference is clear – exchange rate changes appeared to either discourage or encourage investors to hold Thai Yankee bonds. If the Bhat appreciated, then investors bought Thai Yankee bonds, which saw spreads fall, whereas if the dollar appreciated, then investors sold Thai Yankee bonds, which saw spreads rise. Interestingly, the volume of trading on the SET index had no apparent relationship to changes in the spread on Thai Yankee bonds. This is probably due to positive changes in volume being associated with both heavy buying and selling. Thus, the overall effect of changes in trading volume on spreads is indeterminate.

The size of the coefficients – and therefore their contribution to the return on the credit spread – was of a similar order, while the adjusted R^2 suggested that the model was a better predictor of the credit-spread behavior in shorter rather than longer maturity bonds, when the spread was based on bonds of equal maturity. Including autoregressive and moving average terms were also important in terms of correctly specifying three of the eight regression equations. This is evident by the statistical significance of the AR and MA coefficients. Fortunately, most equations did not require this adjustment, which is consistent with a poorly functioning market where prices do not respond immediately to new information. The results do suggest that the spread on the long-term Thai Yankee bond (2013 maturity) required up to 2 days to adjust to new price information. This was the likely consequence of investors having difficulty trading-off the conflicting effects of US interest rate changes and the likely effect on the default probability of the Thai Yankee bond(s).

The statistical significance of the variance equation is specified by the three terms (alpha, beta and gamma in Table 5). The constant, α, represents the long-term average; the coefficient β of the ARCH term represents the significance of volatility observed in the previous period; and the coefficient γ of the GARCH term represents the forecast variance from the last period. These coefficients are generally all significant in the eight spreads investigated in the sample. The first coefficient, α, with a near zero value, was statistically significant but not economically significant, whereas the other two volatility coefficients tended to be of importance. However, the size of the β and γ coefficients were not of a similar order, with the latter coefficient being larger in five out of the eight cases. This result suggests that forecast volatility has a more important effect on predicting variance, than past volatility.

V. Conclusions

In the present study, the yield spreads between Thai Yankee bonds and US treasury bonds of different maturity were investigated. There were two objectives: (i) to determine the long-term equilibrium dynamics in the cointegration framework of Hall et al. (1992) and Batten et al. (2000); and (ii) to investigate how interest rate, asset and key macroeconomic factors affected changes in credit spreads as predicted by Longstaff and Schwartz (1995) and Collin-Dufresne et al. (2001). The results from cointegration analysis suggest that the long-term equilibrium relationships hold between Thai Yankee bonds and long-term US bonds, rather than shorter or equivalent maturity US bonds. This result suggests that the expectations of US interest rate direction – which is factored into the risk premium on long US bonds – appears to dominate the direction of Thai Yankee bond yields, rather than immediate concerns over default. The implication of this result for markets is that there are definite limitations to the simple approach for pricing and managing the risk of Thai bonds using equivalent maturity US treasury bonds.

Table 5 Regressions of Changes in Credit Spreads Between Thai Yankee Bonds and US Government Bonds

Various spreads between Thai and US bonds	*GARCH (1,1) estimation of changes in credit spreads* $\Delta S = a + b\Delta Y + c\Delta I(-1) + d\Delta F + e\Delta V(-1) + AR(1) + AR(2) + MA(1) + MA(2) + \varepsilon,\ \sigma^2 = \alpha + \beta\varepsilon^2_{t-1} + \gamma\sigma^2_{t-1}$													
	a	b	c	d	e	$AR(1)$	$AR(2)$	$MA(1)$	$MA(2)$	α	β	γ	AR^2	F
Same Maturity	–	0.3808	−0.2578	–	–	–	–	–	–	0.0008	0.3024	0.3975	13.95	15.26
Thai 7.84% 15/08/2001–		−11.80	−2.84							4.06	4.98	3.56		
US 7.875% 15/08/2001*		(0.000)	(0.005)							(0.000)	(0.000)	(0.000)		(0.000)
Thai 6.27% 30/09/2003–	–	−0.3116	−0.0986	–	–	–	−0.3446	–	–	0.0000	0.1194	0.8621	15.37	12.07
US 5.75% 15/08/2003		−10.66	−2.81				2.50			5.30	8.82	61.61		
		(0.000)	(0.005)				(0.012)			(0.000)	(0.000)	(0.000)		(0.000)
Thai 6.27% 30/09/2003–	–	−0.7329	–	–	–	–	–	–	–	0.0000	0.3636	0.5741	18.20	14.88
US 11.875% 15/11/2003		−5.14								3.30	3.1153	7.564		
		(0.000)								(0.000)	(0.000)	(0.000)		(0.000)
Thai 7.07% 30/09/2013–	–	0.1626	−0.3038	0.4657	–	–	–	–	–	–	0.0531	0.9392	3.73	3.15
FHLB 6.535% 30/09/2013		1.94	−1.876	1.84							2.01	33.08		
		(0.051)	(0.065)	(0.061)							(0.044)	(0.000)		(0.000)
Thai 7.07% 30/09/2013–	–	0.2038	−0.3291	1.6666	–	−0.1047	−0.8855	0.1394	0.8369	0.0009	1.5243	−0.0049	5.9	2.15
US 12% 15/08/2013		11.65	−6.24	6.93		−2.69	−23.89	3.19	19.41	19.78	9.07	−1.99		
		(0.000)	(0.000)	(0.000)		(0.007)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)
Different Maturity	–	−0.2210	0.1916	–	–	−0.2081	–	–	−0.7424	–	0.1602	0.8723	15.87	6.68
Thai 6.27% 30/09/2003–		2.74	1.7619			−1.95			−8.64		2.29	20.99		
US 12% 15/8/2013		(0.000)	(0.078)			(0.000)			(0.000)		(0.000)	(0.000)		(0.000)
Thai 7.07% 30/09/2013–	–	−0.3568	−0.2467	–	–	–	–	–	–	0.0002	–	–	15.2	11.98
US 11.875% 15/11/2003		−7.16	−1.79							9.74				
		(0.000)	(0.000)							(0.000)				(0.000)
Thai 7.07% 30/09/2013–	–	−0.3324	–	–	–	–	–	–	–	–	1.2667	–	16.5	13.09
US 5.75% 15/08/2003		−8.19									1.744			
		(0.000)									(0.081)			(0.000)

Notes: The table reports the results from a GARCH (1, 1) specification of the regression model $\Delta S = a + b\Delta Y + c\Delta I(-1) + d\Delta F + e\Delta V(-1) + \mathrm{AR}(1) + \mathrm{AR}(2) + \mathrm{MA}(1) + \mathrm{MA}(2) + \varepsilon$, $\sigma^2 = \alpha + \beta\varepsilon^2_{t-1} + \gamma\sigma^2_{t-1}$. The term ΔY is the daily change in the US government T-Bond with various maturities, ΔS is the change in the credit spread, and ΔI is the natural logarithm of the daily change on the SET index. F is the change in the US dollar Thai Bhat exchange rate, and V is trading volume on the SET index. AR1, AR2, MA1 and MA2 are AR and moving average terms at lags 1 and 2, respectively. Z-statistics and associated probability values (in parentheses) are reported below each of the regression coefficients. The model was estimated using the heteroskedasticity consistent covariance procedure of Bollerslev and Wooldridge (1992). The sample period was from the May 5, 1999 to the March 26, 2002, except for the first spread (*), where the sample period was from May 5, 1999 to the January 31, 2001.

Also, a GARCH (1,1) specification derived from the regression equations proposed by Longstaff and Schwartz (1995) and Collin-Dufresne et al. (2001) to accommodate the time-varying volatility structure of credit-spread returns, suggests that credit spreads of Thai Yankee bonds are negatively related to changes in the Thai SET index and are generally negatively related to changes in US interest rates. The exception to this rule is long-term Thai Yankee bonds, where the relationship was positive. Because an exchange-rate variable was also positively correlated with these long-term Thai Yankee bonds, the inference is that investors were responding to changes in the Dollar–Bhat exchange rate by either buying or selling Thai Yankee bonds, even though they were denominated in US Dollars.

The present study suggests clear extensions for other researchers in both Asia-Pacific and emerging countries. Many emerging countries issue Yankee bonds or bonds in international markets, thus it would be interesting to determine whether the credit-spread behavior of these issues is in line with our results. Despite the limitation of data availability on emerging market bonds, it would also be important to determine whether these relationships were consistent across various sample periods, for example before and after critical political and economic events, such as changes in domestic governments, or the introduction of financial market reforms.

Appendix I Outstanding US Dollar Issues by Thai Corporations at February 2002

Issuer	*Coupon*	*Maturity*	*Agency*	*Rating*
Advance Agro Public Co Ltd	13	15/11/2007	MOO	NR
Bangkok Bank Public Company Ltd	1.5	07/08/2006	MOO	Ba1
Bangkok Bank Public Company Ltd	7.25	15/09/2005	MOO	Ba3
Bangkok Bank Public Company Ltd	8.25	15/03/2016	MOO	Ba3
Bankthai Public Co Ltd	7.875	19/06/2002	–	–
Banpu Public Co Ltd	2.75	10/04/2003	–	–
Banpu Public Co Ltd	3.5	25/08/2004	–	–
Cogeneration Public Co Ltd	2.5	12/02/2007	–	–
Electricity Generating Authority Of Thailand	6.9375	25/03/2005	–	–
Electricity Generating Authority Of Thailand	7	14/10/2008	MOO	A3
Electricity Generating Authority Of Thailand	7	14/10/2008	MOO	A3
Finance One Public Co Ltd	5.75	17/06/2003	–	–
Hemaraj Land and Development Public Co Ltd	3.5	09/09/2003	–	–
Industrial Finance Corporation Of Thailand	7.2875	22/04/2002	–	–
Industrial Finance Corporation Of Thailand	7.125	04/08/2002	MOO	Ba1
Industrial Finance Corporation Of Thailand	6.875	01/04/2003	MOO	Ba1
Industrial Finance Corporation Of Thailand	7.375	14/01/2007	MOO	Ba1
Industrial Finance Corporation Of Thailand	7	04/08/2007	MOO	Ba1
Jasmine Submarine Telecommunications Co Ltd	8.483	30/05/2011	–	–
Juldis Develop Public Co Ltd	4.25	22/12/2003	–	–
Kiatnakin Finance Public Co Ltd	4	30/11/2003	–	–

Appendix I (Cont'd)

Issuer	*Coupon*	*Maturity*	*Agency*	*Rating*
Krung Thai Bank Public Co Ltd	9.00688	29/09/2004	MOO	Ba3
Land & House Public Co Ltd	5	29/04/2003	–	–
Loxley Public Co Ltd	3.5	20/04/2005	–	–
Mdx Public Company Ltd	4.75	17/09/2003	–	–
Nakornthon Bank Public Co Ltd	7.865	11/06/2006	–	–
Petroleum Authority Of Thailand	6.9375	30/03/2005	–	–
Ptt Exploration and Production Public Co Ltd	7.625	01/10/2006	MOO	Baa3
Robinson Department Store Public Co Ltd	4.25	07/04/2004	–	–
Sg Asia Credit Public Co Ltd	3.75	17/11/2003	–	–
Siam Syntech Construction Public Co Ltd	4.5	25/02/2002	–	–
Sino-Thai Engineering and Construction Public	1.75	17/12/2003	–	–
Sritha Superware Public Co Ltd	3.25	13/06/2006	–	–
Tanayong Public Co Ltd	3.5	01/03/2004	–	–
Thai Central Chemical Public Co Ltd	3.75	25/10/2003	–	–
Thai Military Bank Public Co Ltd	8.96	17/05/2005	MOO	B1
Thailand	8.25	15/03/2002	MOO	Baa3
Thailand	6.27	30/09/2003	MOO	Baa3
Thailand	8.09	15/08/2004	MOO	Baa3
Thailand	7.75	15/04/2007	MOO	Baa3
Thailand	7.07	30/09/2013	MOO	Baa3
The Siam Commercial Bank Public Co Ltd	3.25	24/01/2004	MOO	Ba3
The Siam Commercial Bank Public Co Ltd	7.5	15/03/2006	MOO	Ba3
Tipco Asphalt Public Co Ltd	2.75	19/09/2006	–	–
Total Access Communications Public Co Ltd	2	31/05/2006	MOO	B2
Total Access Communications Public Co Ltd	8.375	04/11/2006	S & P	BB
Tpi Polene Public Co Ltd	2.75	08/02/2006	–	–
Union Asia Finance Public Co Ltd	3.375	22/12/2003	–	–
United Communication Industry Public Co Ltd	7.78	15/12/2003	–	–
Wall Street Finance and Securities Public Co Ltd	3.75	03/02/2004	–	–
Wattachak Public Co Ltd	3.5	06/12/2003	–	–

Notes: MOO, Moodys Investor Services; S & P = Standard & Poor's Rating Agency.

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