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Bangkok Weather, Weather-Sensitive Investors, and Thai Government-Bond Returns

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Abstract

If the market is not efficient, bond returns can be set by weather-sensitive investors, thereby establishing a significant relationship between weather and investment returns. This study is the first study to test for the weather effects in the Thai government-bond market. Using a bond-return sample from July 2, 2001 to December 2015, applying full-period and sub-period tests, together, suggest that weather effects, especially temperature, exist in the Thai bond market. The effects do not weaken or disappear over time. They are, however, significant in some but not in the other sub-periods, and for some but not all the bonds. These findings are consistent with the explanation that the weather-sensitive investors participate in the inefficient bond market only in some periods and they prefer certain bonds over the others.

Keywords: *Investor mood, weather effects, Thai bond market*

Introduction

In efficient markets, good or bad weather when investors are trading assets cannot affect prices and returns because the fundamentals of the assets remain unchanged (Hirshleifer & Shumway, 2003). However, weather affects investors' mood (e.g. Howarth & Hoffman, 1984) which, in turn, influences economic decision-making (e.g. Lucey & Dowling, 2005). Prices and returns can rise or fall with the weather due to changing risk preference which leads marginal investors to lower or raise discount rates (Mehra & Sah, 2002), or due to mood misattribution which causes marginal investors to incorrectly associate good or bad weather and mood with good or bad prospects of the assets (e.g. Hirshleifer & Shumway, 2003).

It is important to test whether or not weather influences prices and returns. Significant influence implies that not only do economic but also behavioral factors determine the prices and returns. The tests for weather effects have been conducted extensively using national- and international-market data. Most of the studies examine the effects on stock returns. For example, for the U.S. market, Saunders (1993) and Akhtari (2011) reported that cloud cover outside Wall Street had a negative relationship with stock returns, but Trombley (1997) found that cloud-cover effects were neither clear nor strong for a sample period which came after that of Saunders (1993). Based on multiple-regression analyses, Worthington (2009) did not find the effects for Australian stocks. But Keef and Roush (2007) found significant temperature effects for the Australian market, when they applied a two-step technique to improve the efficiency of the test. For the Korean market, Yoon and Kang (2009) tested for the effects on stocks for cloud cover, humidity, and temperature and found significant effects for the period before but not after 1997. The results for the Chinese market are mixed. While Kang, Jiang, Lee, and Yoon (2010)–who considered temperature, humidity, and the sunshine, found the effects for stock returns, Lu and Chou (2012)–who considered the same Shanghai stocks but with a more extensive set of weather variables and a different sample period, found significant effects only for trading activities but not for returns. Dowling and Lucey (2005) found rainfall and humidity effects for the Irish stock market; Keef and Roush (2005) found temperature, the sunshine, and the wind in Auckland and the wind in Wellington could affect New Zealand stock index returns; Chang, Nich, Yang, and Yang (2006) found significant temperature effects for Taiwanese stock returns. As for the Spanish stock market, Pardo and Valor (2003) could not find significant effects when they considered sunshine and humidity as weather variables. Finally, for the Thai stock market, Nirojsil (2009) found temperature and humidity effects on the SET and SET 50 stock-index returns but not on the MAI stock-index returns. The results for the temperature effects on the SET stock-index return were supported by Sriboonchitta, Chaitip, Sriwichailamphan, and Chaiboonsri (2014).

The weather effects were also tested on international-market data. Hirshleifer and Shumway (2003) tested for sunshine effects for 26 national stock markets. The researcher found that, after controlling for rain and snow, their pooled-sample test could detect significant sunshine effects. Cao and Wei (2005) tested for and found temperature effects for stock markets in the U.S.A., Canada, the U.K., Germany, Sweden, Australia, Japan, and Taiwan. Dowling and Lucey (2008) considered the relationship of various weather variables with stock returns in 37 countries and found only temperature effects. Jacobsen and Marquering (2008) tested for temperature effects using a sample of 48 national stock markets. Despite the fact that the effects were significant for most sample countries, the effects disappeared or weakened once the analyses controlled for seasonal variables such as month-of-May dummy. Chaitip, Sriwichailamphan, Sriboonchitta, and Chaiboonsri (2010) tested for temperature effects on stock returns in Thailand, Malaysia, Indonesia, and Singapore. The researchers found significant effects for Thailand but not for the remaining three sample countries. Recently, Apergis, Gabrielsen, and Smales (2016) reported that weather variables in New York and London could even explain the movement of 58 stock indexes around the world.

There are few studies that have investigated the weather effects on bond returns and interest rates. Keef and Roush (2005) tested for the effects of temperature, the sunshine, the wind in Auckland, and the wind in Wellington and found significant effects on the interest rates on New Zealand bank bills and government bonds. Furhwirth and Sogner (2015) proposed an approach to accommodate indirect effects of weather and seasonal affective disorder (SAD) via a latent mood variable. The researchers found weather effects, not SAD effects, for both the U.S. stock and bond indexes.

In this study, I test for Bangkok-weather effects on Thai government-bond returns. Thailand is one of the most important emerging markets in the world. In 2015, its market capitalization of government securities was 208 billion U.S. dollars. In the sample countries of the *Asia Bond Monitor* (Asian Development Bank, 2016), in the fourth quarter of 2015, Thailand ranked fourth in terms of market capitalization after Japan, China, and Korea. The government-bond investors are dealers, local and foreign institutional investors, and high- net-worth, individual investors. Almost all of these traders and investors, except for foreign investors, domicile and execute their trades in Bangkok–Thailand's capital and only financial center. Despite its importance, Thailand's bond market has never been tested for weather effects. This study is the first study for the Thai market and appends the short list of bond-market studies. The results have important implications for the efficiency of the market (Yoon & Kang, 2009), the choice of asset-pricing models (Saunders, 1993), and the improvement of bond-trading strategies (Hirshleifer & Shumway, 2003).

Hirshleifer and Shumway (2003) pointed out that weather could affect stock prices and returns if it affected the fundamentals of firms such as agricultural or weather-related firms. Under this circumstance, weather effects were driven by economic, not behavioral factors. The fact that this study considers Bangkok weather and Thai government-bond returns helps to ensure that the weather effects if they exist, are driven by behavioral factors. On the one hand, almost all the bond investors are in the Bangkok metropolitan area. So, if bond investors and traders are weather-sensitive, the weather must be Bangkok weather. On the other hand, Bangkok weather can affect the operations in Bangkok of some firms in the property, construction, and construction-material sectors, and therefore raise or lower the firms' stock and bond returns. But it is unlikely these effects spill over to the government-bond market and significantly move the government-bond prices or yields.

I test for seven weather variables, including temperature, cloud cover, rainfall, relative humidity, wind speed, air pressure, and ground visibility. The set of these variables is the most comprehensive among those sets in previous studies for Thailand (e.g. Hirshleifer & Shumway, 2003; Dowling & Lucey, 2005; Nirojsil, 2009). Because weather variables can be correlated, I can test whether and how these variables individually and collectively influence the returns (Dowling & Lucey, 2005).

I compute the sample bond returns of different tenors from daily government-spot curves. The data run from July 2, 2001–the first day the Thai Bond Market Association constructed and reported the curve to the public, to December 30, 2015–the most recent date the Thai Meteorological Department made the weather sample available to this study. The long time series for bonds of different tenors allow this study to address at least three important hypotheses pertaining to weather effects. Firstly, because government bonds are remotely related to local Bangkok weather and because bond investors are high net-worth individuals and institutional investors, with good knowledge and information, the use of government-bond data will help to address whether these high net-worth individuals and institutional investors are weather-sensitive (Forgas, 1995). Secondly, the long sample can be separated into sub-samples. Patterns of significant and insignificant effects in these sub-samples help the study to differentiate the participating marginal-investor explanation (e.g. Goetzmann & Zhu, 2005) against the improving market-efficiency explanation (e.g. Yoon & Kang, 2009; Akhtari, 2011). Finally, the significant effects for certain bond tenors will help to address preferred tenors of weather-sensitive, marginal investors as in the preferred-habitat theory (Modigliani & Sutch, 1966).

Methodology

I follow the researchers, e.g. Dowling and Lucey (2005), to relate weather variables linearly with bond returns individually as in equation (1) and collectively as in equation (2).

$$r_t^i = a_0^i + a_j^i W_t^j + e_t^i \quad (1)$$

$$r_t^i = a_0^i + \sum_{j=1}^{J} a_j^i W_t^j + e_t^i, \quad (2)$$

where r_t^i is the return on the i-year government bond on day t, W_t^j is the weather variable j on day t, and e_t^i is the error term of the bond on day t. a_0^i is the intercept and a_j^i is the slope coefficient of the i-year bond on the weather variable j. The models are estimated by ordinary least square regressions. I use White's (1980) heteroskdasticity-consistent covariance matrix for hypothesis tests. If the weather variable W_t^j affects the i-year-bond return r_t^i, the coefficient a_j^i must be significantly different from zero. Moreover, in equation (2) if the J weather variables jointly affect the return, the Wald statistic for the joint hypothesis–$a_{j=1}^i = \cdots = a_{j=J}^i = 0$, must be distributed as a chi-square variable with J degrees of freedom.

Noticing that returns could be auto-correlated and conditionally heteroskedastic, researchers (e.g. Yoon and Kang, 2009) considered autoregressive, GARCH models for the analyses. In this study, I argue that the linear models in equations (1) and (2) are the correct models, while the autoregressive, GARCH models are mis-specified. During the sample period, the weather-variable data are missing at times due to faulty equipment or missed observations. When the weather variable W_{t-1}^j is missing, the lagged return and conditioning GARCH-information set for the return r_t^i on day t are not the ones on day t-1, but the ones on the previous day which the variable W_{t-1}^j was last observed.

Data

The data are daily. I compute the bond return r_t^i for the i-year tenor by $-i \times \left(s_t^i - s_{t-1}^i\right)$, where s_t^i and s_{t-1}^i are the government-spot rates for the i-year tenor on days t and t-1. The spot-curve data are constructed by the Thai Bond market association (Thai BMA) and run from July 2, 2001 to December 30, 2015. The tenors to be considered are Thailand's benchmark tenors of 3, 5, 7, 10, and 15 years.

The weather variables are dry-bulb temperature (℃), cloud cover (decile), rainfall (mm.), relative humidity (%), wind speed (knots per hour), air pressure (hectopascal), and ground visibility (km.). These variables are a collection of weather variables that have also been considered by previous studies (e.g. Dowling & Lucey, 2008; Lu and Chou, 2012); they are the most comprehensive set of variables among all the weather studies for Thailand (e.g. Hirshleifer & Shumway, 2003; Dowling & Lucey, 2005; Nirojsil, 2009). Despite the comprehensive nature of the variables used, some variables that were in previous studies are not included. For example, geomagnetic storms in Dowling and Lucey (2008) are not included because the storm data are not available. Wind direction in Worthington (2009) is not included because the direction cannot be averaged to proxy the daily direction and it is not a significant variable in Worthington (2009).

The weather is Bangkok weather, measured by the Thai Meteorological Department's weather station at Don Muang Airport. The weather data started on January 1, 1991 and ended on December 31, 2015. I retrieved the data from the Thai Meteorological Department's database. Thai government bonds trade over the counter, and dealers report execution and bid yields to the Thai BMA to construct the spot curve at 4.00 p.m. Following Hirshleifer and Shumway (2003), I calculate the daily weather variables by their average levels from 6.00 a.m. to 4.00 p.m.

Significant weather effects may be spurious due to weather and return seasonality (Hirshleifer & Shumway, 2003; Jacobson & Marquering, 2008). In order to avoid possible spuriousness, I de-seasonalized the weather variables, as in Hirshleifer and Shumway (2003), by their averages for each week of the year over the 1991-2015 sample period.

Table 1, panel 1.1 reports the descriptive statistics of the sample bond returns. The averages and standard deviations are high for long-tenor bonds. The returns are negatively skewed, fat-tailed, and auto-correlated. Normality is rejected by the Jarque-Bera tests for all the bonds. Because the models in equations (1) and (2) do not consider lagged returns while the bond returns are auto-correlated, the error term e_t^i will be auto-correlated and heteroskedastic. I correct this statistical problem by using White's (1980) heteroskedasticity-consistent covariance matrix in the analyses.

Table 1. Descriptive Statistics

Panel 1.1 Bond-Market Returns

Statistics	Tenor				
	3-Year	5-Year	7-Year	10-Year	15-Year
Mean	2.34E-05	3.98E-05	6.40E-05	1.13E-04	1.79E-04
S.D.	1.12E-03	2.43E-03	3.59E-03	5.43E-03	6.75E-03
Skewness	-0.8992	-0.4288	-0.5508	-0.8133	-0.1768
Excess Kurtosis	19.8945	8.4475	10.1849	11.2923	19.8655
Minimum	-0.0148	-0.0168	-0.0323	-0.0605	-0.0711
Maximum	0.0114	0.0196	0.0274	0.0372	0.0855
Jarque-Bera Stat.	101,868***	18,405***	26,792***	33,229***	100,780***
AR(1) Coefficient	0.3613***	0.2983***	0.2999***	0.2734***	0.2929***
Observations	6,127	6,127	6,127	6,127	6,127

Note: *** = Significance at the 99%-confidence level.

Panel 1.2 Untreated Weather Variables

Statistics	Temperature (℃)	Cloud Cover (decile)	Rainfall (mm.)	Relative Humidity (%)	Wind Speed (knots per hour)	Air Pressure (hectopascal)	Ground Visibility (k.m.)
Mean	29.9739	5.4684	0.3415	65.9481	5.6941	96.8359	8.8597
S.D.	2.1562	1.4240	1.5404	10.5586	2.3735	29.7429	1.4502
Skewness	-0.8150	-0.5623	7.9375	-0.4709	1.0708	0.3750	-1.1244
Excess Kurtosis	2.8484	-0.2794	84.6261	2.9606	1.8259	0.0041	1.2496
Minimum	8.1000	0.0909	0.0000	4.0909	0.2727	0.0000	2.5091
Maximum	36.3455	8.0000	27.5500	97.3636	18.8182	250.5455	14.2727
Jarque-Bera Stat.	4,004***	494***	2,746,116***	3,588***	2,927***	209***	2,443***
Observations	8,922	8,835	8,890	8,922	8,869	8,920	8,859

Note: *** = Significance at the 99%-confidence level.

Panel 1.3 Correlations and Variance Inflation Factors of De-seasonalized Weather Variables

Weather Variables	Temperature	Cloud Cover	Rainfall	Relative Humidity	Wind Speed	Air Pressure	Ground Visibility
Temperature	1.0000						
Cloud Cover	-0.3286***	1.0000					
Rainfall	-0.2628***	0.1821***	1.0000				
Relative Humidity	-0.2899***	0.5014***	0.2681***	1.0000.			
Wind Speed	0.0872***	-0.0443***	-0.0813***	-0.1319***	1.0000		
Air Pressure	-0.3420***	-0.1044***	0.0034	-0.1073***	-0.1029***	1.0000	
Ground Visibility	0.1414***	-0.1206***	-0.1620***	-0.2253***	0.1875***	-0.0047	1.0000.
Variance Inflation Factors	1.4483	1.4434	1.1366	1.4885	1.0611	1.2446	1.0974

Note: *** = Significance at the 99%-confidence level.

Panel 1.2 reports the descriptive statistics for the untreated weather variables. It is important to note that the numbers of observations are not equal due to missing data from faulty equipment or missed observations. The missing weather data support the use of liner models in equations (1) and (2) for the analyses in this study. Temperature, cloud cover, humidity, and ground visibility are negatively skewed; rainfall, wind speed, and air pressure are positively skewed. All the variables, except for cloud cover, have fat-tailed distributions. The normality hypothesis is rejected for all seven weather variables.

The bond returns and weather variables are not normally distributed. So, potentially, there are regression errors in equations (1) and (2). But the regression analyses in this study are reliable because the sample sizes are large.

Panel 1.3 reports the correlations and variance-inflation factors of de-seasonalized weather variables The absolute correlations range from 0.0034 for the air-pressure-and-rainfall pair to 0.5014 for the cloud-cover-and-humidity pair. Significant correlations motivated me to examine individual and collective effects of the variables (Dowling & Lucey, 2005). The largest variance inflation factor of 1.4885 is much smaller than ten. It is, therefore, unlikely that multicollinearity problems are present in the multiple-regression analyses (Menard, 2002).

Empirical Results

The results for the full sample from July 2, 2001 to December 30, 2015 are reported in Table 3, panel 3.1. Simple regressions indicate total effects, while multiple regressions indicate unique effects of the weather variables on bond returns. Neither simple nor multiple regressions find significant slope coefficients; the Wald statistics cannot reject the joint hypothesis of zero coefficients for any of the bond groups examined.

There are at least three possible explanations why the tests cannot find significant weather effects for the full-sample period. Firstly, Thailand's bond market was efficient. Although some investors were weather-sensitive, their economically-irrational behavior could not move the prices. Secondly, the market was inefficient in the early period of the sample and weather-sensitive, marginal investors set the prices. But the efficiency of Thailand's bond market improved over time, probably similar to what was found for Thailand's stock market by Buraprathep, Khanthavit, and Pattarathammas (2015) and Khanthavit (2016). Improving market efficiency drove away the weather effects in the later period (e.g. Yoon & Kang, 2009) and crowded out the significant effects in the full-sample test. Thirdly, the bond market was inefficient and the weather-sensitive, marginal investors set prices (e.g. Goetzmann & Zhu, 2005). If these weather-sensitive investors participated in the market only in some periods, the effects were significant in the periods in which they participate. The mixed significant and no effects for the sub-periods over the full sample period weakened the power of the tests.

In order to determine which explanation best describes the weather effects for the Thai bond market, I break the full-sample period into three sub-periods. The first sub-period is from July 2, 2001 to December 30, 2005; the second sub-period is from January 3, 2006 to December 30, 2010; the third sub-period is from January 4, 2011 to December 30, 2015. If the first explanation is correct, the tests must find no effects for any of the three sub-periods. But if the second explanation is correct, the tests must find significant effects in the earlier sub-periods. But the significance must weaken or disappear in the later sub-periods. Finally, if the third explanation is correct, the tests must find significant effects in at least one sub-period. But the significance must not show weakening or disappearing patterns over time. The test results for the three sub-periods are in panels 3.2 to 3.4 of Table 3.

Table 3. Tests for Bangkok-Weather Effects

Panel 3.1 Full-Sample Period (07/02/2001-12/30/2015)

Weather Variable	3-Year		5-Year		7-Year		10-Year		15-Year	
	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple
Temperature	7.84E-06	1.66E-05	1.45E-05	1.77E-05	3.36E-05	3.71E-05	6.07E-05	5.01E-05	8.61E-05	1.02E-04
Cloudiness	-4.47E-06	1.16E-05	-1.20E-05	-1.76E-05	-2.13E-06	-1.61E-05	7.45E-06	-4.87E-05	4.50E-07	-3.43E-05
Rainfall	-1.15E-05	3.60E-07	1.12E-06	6.09E-06	-2.39E-05	-2.46E-05	-6.14E-05	-6.71E-05	-4.02E-05	-2.57E-05
Humidity	3.36E-09	-8.51E-06	2.00E-06	4.14E-06	4.75E-06	1.01E-05	1.36E-05	2.69E-05	1.16E-05	2.66E-05
Wind Speed	8.00E-07	1.52E-06	1.06E-05	7.13E-06	2.37E-05	2.36E-05	2.26E-05	1.11E-05	4.48E-05	3.78E-05
Air Pressure	7.20E-07	-1.06E-06	-1.80E-07	3.80E-07	-1.48E-06	-1.00E-08	-4.98E-06	-3.49E-06	-3.01E-06	1.70E-07
Visibility	1.00E-08	1.06E-06	2.00E-08	3.00E-08	1.00E-08	1.00E-08	8.00E-08	1.00E-07	1.10E-07	1.10E-07
Wald Stat.	N.A.	2.00E-08	N.A.	1.4474	N.A.	2.6443	N.A.	7.0639	N.A.	4.9741

Note: N.A. = not applicable.

Panel 3.2 First Sub-period (07/02/2001-12/30/2005)

Weather Variable	3-Year		5-Year		7-Year		10-Year		15-Year	
	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple
Temperature	-6.30E-06	-2.19E-05	-2.70E-06	-1.69E-05	2.51E-05	1.56E-05	6.84E-05	-3.35E-05	1.40E-04	1.27E-04
Cloudiness	3.28E-05	4.86E-05	8.36E-05	7.45E-05	1.72E-04	1.82E-04	1.70E-04	2.24E-05	4.02E-05	3.12E-05
Rainfall	-7.40E-05	-8.02E-05	-7.01E-05	-7.95E-05	-1.36E-04	-1.68E-04*	-1.35E-04	1.44E-04	-2.00E-04*	-1.86E-04
Humidity	1.30E-07	1.26E-06	8.19E-06	9.50E-06	1.20E-05	1.31E-05	1.89E-05	-1.46E-04	1.16E-05	3.51E-05
Wind Speed	2.08E-05	1.90E-05	3.85E-05	3.52E-05	6.46E-05	7.26E-05	3.09E-05	2.19E-05	1.21E-04	1.16E-04
Air Pressure	1.43E-06	9.50E-07	-2.10E-07	-1.70E-07	-2.82E-06	-1.21E-06	-8.61E-06	1.58E-05	-3.2E-06	2.50E-06
Visibility	6.00E-08*	4.00E-08	1.20E-07	1.00E-07	1.00E-07	4.00E-08	2.10E-07	-7.04E-06	2.70E-07	1.60E-07
Wald Stat.	N.A.	6.8146	N.A.	6.1844	N.A.	7.9718	N.A.	1.90E-07	N.A.	6.2766

Note: * = Significance at the 90%-confidence level. N.A. = not applicable.

Panel 3.3 Second Sub-period (01/03/2006-12/30/2010)

Weather Variable	3-Year		5-Year		7-Year		10-Year		15-Year	
	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple
Temperature	2.98E-05	5.11E-05*	7.44E-05	1.01E-04*	1.48E-04**	1.96E-04**	2.67E-04**	2.80E-04*	2.60E-04*	3.34E-04**
Cloudiness	-3.00E-05	-7.30E-05	-9.58E-05	-1.52E-04	-1.31E-04	-2.29E-04	-2.23E-04	-3.98E-04	-3.38E-05	-1.51E-04
Rainfall	2.65E-05*	2.57E-05	6.12E-05	7.14E-05*	5.66E-05	6.68E-05	-6.38E-05	-5.72E-05	4.68E-05	7.09E-05
Humidity	6.10E-06	1.13E-05*	3.99E-06	1.29E-05	1.10E-05	3.12E-05	1.57E-05	7.37E-05**	2.20E-05	5.94E-05
Wind Speed	-5.14E-06	1.64E-05	1.12E-05	3.96E-05	1.50E-05	6.72E-05	6.27E-05	1.26E-04	6.75E-05	1.26E-04
Air Pressure	-8.40E-07	1.53E-06	-3.57E-06	5.10E-07	-6.36E-06	2.13E-06	4.00E-08	2.46E-06	-8.99E-06	7.89E-06
Visibility	-5.00E-08	-5.00E-08	-8.00E-08	-1.10E-07	-1.20E-07	-1.70E-07	2.60E-04*	-6.00E-08	1.10E-07	4.00E-08
Wald Stat.	N.A.	13.6040*	N.A.	10.8574	N.A.	14.2751**	N.A.	11.5302	N.A.	7.8365

Note: * and ** = Significance at the 90%- and 95%-confidence levels, respectively. N.A. = not applicable.

Panel 3.4 Third Sub-period (01/04/2011-12/30/2015)

Weather Variable	3-Year		5-Year		7-Year		10-Year		15-Year	
	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple	Simple	Multiple
Temperature	2.64E-06	7.10E-06	-2.01E-05	-2.39E-05	-5.56E-05*	-8.52E-05	-1.22E-04**	-1.16E-04	-1.03E-04	-1.17E-04
Cloudiness	-2.82E-05	-2.52E-05	-4.78E-05	-5.76E-05	-8.77E-05	-1.62E-04	3.90E-05	-6.85E-05	-1.15E-05	-1.07E-04
Rainfall	-1.26E-05	-1.05E-05	-1.55E-05	-1.93E-05	-3.66E-05	-5.57E-05	-1.94E-05	-6.69E-05	-3.07E-05	-5.96E-05
Humidity	-1.88E-06	1.70E-06	-1.17E-06	1.45E-06	-3.66E-05	7.18E-06	1.25E-05	1.32E-05	4.96E-06	7.41E-06
Wind Speed	-3.10E-06	-6.58E-06	-2.95E-06	-7.65E-06	4.53E-06	5.90E-07	1.25E-05	-8.03E-06	-4.60E-05	-1.96E-05
Air Pressure	1.49E-06	1.26E-06	3.00E-06	1.77E-06	4.29E-06	1.17E-06	4.20E-06	-8.80E-07	2.86E-06	-4.13E-06
Visibility	4.28E-09	2.62E-09	2.80E-09	-9.44E-11	2.00E-08	-1.91E-09	-5.00E-08	-3.00E-08	-8.00E-08	-9.00E-08
Wald Stat.	N.A.	4.9377	N.A.	3.6530	N.A.	10.5579	N.A.	5.5445	N.A.	2.8381

Note: * and ** = Significance at the 90%- and 95%-confidence levels, respectively. N.A. = not applicable.

Turn first to the results for the first sub-period in panel 3.2. The simple-regression analyses find a significant, positive ground-visibility effect for the 3-year bond and a significant, negative rainfall effect for the 7-year and 15-year bonds. The significance, however, is weak at the 90%-confidence level. The multiple regressions and Wald tests cannot detect any significant effect.

From panel 3.3, the weather effects are significant for all the bonds in the second sub-period. For the 3-year bond, the simple regressions find a significant rainfall effect, while the multiple regression finds significant temperature and humidity effects. The Wald test rejects the joint, zero-weather-effect hypothesis. The 5-year bond is temperature- and rainfall-sensitive in the multiple-regression analysis. But the simple regressions cannot find any significant effect. The temperature effect for the 7-year bond is very strong. It is significant at the 95%-confidence level in both the simple and multiple regressions. The Wald statistic is also significant at the 95%-confidence level. For the 10-year and 15-year bonds, the temperature effect is significant in both the simple and multiple regressions. In addition, for the 10-year bond, the simple regression finds a significant ground-visibility effect and the multiple regression finds a humidity effect. Finally, for the third sub-period in panel 3.4, there exist only significant temperature effects for 7-year and 10-year bonds from the simple-regression tests.

Discussion

From Table 3, the full-period tests cannot find significant weather effects. The sub-period tests find significant but weak ground-visibility or rainfall effects for 3-year, 7-year, and 15-year bonds. The results for the temperature effects are significant and strong for all the bonds in the second sub-period, while significant temperature effects are found only for the 7-year and 10-year bonds in the third sub-period. So, the fact that the full-period tests cannot find significant weather effects is explained by mixed significant and insignificant effects in the sub-periods, not by the lack of existence of weather effects in the Thai bond market. The results for the three sub-periods, during which significant effects are not weakening or disappearing over time, are consistent with the explanation that the weather-sensitive investors participate in the inefficient bond market only for some time periods, but not all times. Moreover, the significant effects only for the 7-year and 10-year bonds in the third sub-period suggest that the weather-sensitive investors may prefer the bonds of certain tenors as in the preferred-habitat theory (Modigliani & Sutch, 1966).

Nirojsil (2009) reported that the temperature effects were significant for the SET and SET-50 stock-index returns but not for the MAI stock-index returns. This result is interesting. For SET and MAI stocks, about 58% and 96% of the trading volumes are from small, individual investors, while the remainders are from local institutes, proprietary traders, and foreign investors (Khanthavit & Chaowalerd, 2016). The fact that the weather effects existed in for the SET and SET-50 stocks but not the MAI stocks suggests that the effects are from local institutes, proprietary traders, and foreign investors. In my study, in which the temperature effects are significant for the government-bond returns, the traders and investors are local institutes, foreign investors and high net-worth individual investors.

Forgas (1995) proposed that investors with limited knowledge tended to allow mood to interfere with decision making. For Thailand, these investors would refer to small, local individual investors (Dowling & Lucey, 2008). The results in this study for the bond market and in Nirojsil (2009) for the stock market–which relate high net-worth individual investors and institutional investors with significant weather effects, do not support Forgas (1995).

In the full-period and sub-period tests, significance and signs of the coefficients sometimes are not aligned. This finding can be due to fewer observations for the multiple-regression analyses than for the simple regressions. The usable observations are the ones on the days none of the weather variables are missing. Or, it can be due to the correlated weather variables supporting or cancelling one another's effects in the multiple regressions.

Furthermore, it is important to note that the temperature effects are significant for the 7-year and 10-year bonds in the second and third sub-samples. But the effects change signs from positive to negative. The sign changes are possible (e.g. Cao and Wei, 2005). Thailand is a very warm country. The average temperature in Bangkok is almost 30°C. High temperature is associated with aggression, risk taking, and rising prices. In the meantime, it is associated with apathy, risk averting, and falling prices. The positive or negative signs depend on the dominance of investors' aggression over apathy or the reverse.

Weather effects exist because weather conditions affect investors' mood and influence their economic decision making. In this study, rainfalls, ground visibility, temperature, and humidity are significant, influential weather conditions. So, what are the mechanisms that explain the influences of these weather conditions on mood? With respect to Wurtman and Wartman (1989), low sunlight associated with rainy and poor-visibility days causes serotonin levels to fall, which leads to bad mood. The temperature effects are from heat, which induces plasma concentrations of 5-hydroxytryptamine neurotransmitter and cortisol hormone. Five-hydroxytryptamine plays a major part in the control of emotions, while cortisol is related to mood state (McMorris et al., 2006). Finally, humidity at certain levels of temperature can cause discomfort, resulting in bad mood (Nastos, Paliatsos, Tritakis, & Bergiannaki, 2006).

Conclusion

Good or bad weather can change risk preference and cause mood misattribution of investors. In an inefficient market, mood-sensitive, marginal investors can move asset prices, thereby establishing a significant relationship between asset prices and weather conditions. In this study, I tested for the effects of Bangkok weather on the Thai government-bond returns. Using the full-sample period from July 2, 2001 to December 2015, the study could not find any significant effects for the bonds of any tenor. Further investigation into three sub-periods suggested that the insignificance was caused by mixed significant and insignificant effects in one but not the other sub-periods. The fact that the significant effects were found for the second and third sub-periods for some bonds, but weak for the first sub-period, was consistent with the market being inefficient and the weather-sensitive, marginal investors participating in the market only in some sub-periods and preferring to trade in only some segments of the market.

The efficiency of the Thai stock market is improving over time (Buraprathep et al., 2015; Khanthavit, 2016); it is likely that the efficiency of the Thai bond market is improving over time too. Unlike the findings of Yoon and Kang (2009) for the Korean stock market, the sub-sample results are not sufficient for me to draw a conclusion about the role of improving efficiency on the weather effects for the Thai bond market. It will be interesting to further study how the weather effects change as the market's efficiency improves over time. I leave this interesting study for future research.

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