Asymmetric Jump Beta and Continuous Beta in Taiwan REIT Market

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Abstract

This paper utilizes recent advances in econometric theory, developed by Anderson, Bollerslev, and Diebold (2007), Barndorff-Nielsen and Shephard (2004), and Tauchen and Zhou (2006), to effectively separate the continuous and jump components of all REITs and stock indexes in Taiwan. We find that jump contributes approximately 62.4 percent of total variance for all REITs in Taiwan. In addition, we further decompose each of the volatility components into continuous systematic risk and jump systematic risk by extending CAPM and three-factor models. The empirical results show that the jump beta is significantly higher than the continuous beta for all REITs in Taiwan. This implies that the jump beta is the most relevant measure of co-movement with the market on days when the market experiences a jump. Furthermore, the R-squared of the modified model improves in REITs, compared with the traditional CAPM and three-factor model, implying the necessary of separating the continuous and jump components. Next, the continuous (jump) betas of most of REITs do not have significantly asymmetric effect (leverage effect). Forth, we find that the most jump risk is nonsystematic. This suggests that accounting for jump risk is most important in a non-diversified context where nonsystematic risk is present.

Keywords: Asset Price Volatility, REITs, Asymmetric Continuous Beta, Asymmetric Jump Beta

JEL Classifications: G10, B40

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1. Introduction

Asset price volatility is the most fundamental element of risk management. Therefore, financial economists must understand asset price volatility. In order to properly model the asset price process, most of the discrete time models have been of the generalized autoregressive conditional heteroskedastic (GARCH) type, while the continuous time models are based on diffusion models. Beginning with Merton (1976), financial economists have modeled price volatility as a combination of a smooth and continuous process, along with a much less persistent jump process (e.g., the jump-diffusion model). A thorough understanding of both the continuous and jump components of volatility is required to manage risk effectively. The goal of this paper is to investigate whether REITs, stock and bond markets in Taiwan has significant jump phenomenon by utilizing econometric techniques developed by Anderson, Bollerslev, and Diebold (2007), Barndorff-Nielsen and Shephard (2004), and Tauchen and Zhou (2006). By using high-frequency trade-by-trade data, one can effectively separate the continuous and jump components of the underlying price process. Furthermore, many studies (e.g., Liu et al. (1990), Peterson and Hsieh (1997)) have investigated the return association between equity REITs and the general stock market by using Capital Asset Pricing Model (CAPM, Sharpe 1964) and multi-factor asset pricing models. The second goal of this paper is to further decompose each of the volatility components into continuous beta risk and jump beta risk based on the CAPM model and multi-factor model. This decomposition is interesting because traditional standard factor models of risk implicitly assume that an asset's systematic risk is uncorrelated with jumps in the market (i.e., that the asset's beta does not change on days when the market experiences a jump). By decomposing we intend to discuss that is the jump beta risk higher than continuous beta risk, is the jump beta risk and continuous beta risk asymmetric, and is jump risk almost systematic or nonsystematic.

The difference between continuous betas and jump betas has important implications for risk management. With a total beta, one knows only the average level of systematic risk. However, given an asset's continuous and jump betas, one can explicitly calculate the asset's systematic risk conditional on whether or not the market experiences a jump. This is important for risk managers: if REITs behaves differently during a severe market downturn than it does at other times, this information offers the potential to significantly improve on calculations such as Value at Risk (VaR). Moreover, if REITs are combined in a well-diversified portfolio, then the REIT's systematic jump risk is more relevant than the REIT's total jump risk. This highlights the importance of decomposing total jump risk into its systematic and nonsystematic components.

Some discrete time series techniques were employed to examine the dynamic relationship between real estate and general financial markets. Kallberg, Liu, and Pasquariello (2002) conducted structural break tests and reported regime shifts in returns and volatility relationships between real estate and stock markets in eight Asian markets. Based on a bivariate GARCH model, Cotter and Stevenson (2006) found that daily REIT-stock correlations generally increased during the period from 1999 to 2005. Applying a multivariate DCC-GARCH model to a seven asset system, Huang and

Zhong (2006) argued that during the period from 1999 to 2005, daily conditional correlation between REITs and US equity was always positive but had a positive trend and daily correlations between REIT and US bond fluctuated around zero. Also using a DCC-GARCH model, Case, Yang, and Yildirim (2009) examined monthly conditional correlations between US stock and REIT markets from 1972 to 2008 and explored the implications for portfolio allocation.

In view of continuous time models, when estimating parameters in a jump-diffusion model, it has been difficult for financial economists to separate jumps from the underlying diffusion process, in part because the actual jump is not readily observable from the time-series data of the underlying asset returns. Most jump parameter estimates are based on numerical simulations, since direct estimates are difficult to obtain in all but a few special cases (Aı¨t-Sahalia 2004). Tauchen and Zhou (2006) pointed out that ‘‘the main message from the empirical literature seems to be that jumps are very important in asset pricing, but the estimation of jump parameters and the pricing of jump risk are not easy to implement.’’ This poses a serious practical challenge to risk managers. This paper uses econometric techniques provided by Anderson, Bollerslev, and Diebold (2007), Barndorff-Nielsen and Shephard (2004), and Tauchen and Zhou (2006) to accurately estimate the total volatility and the volatility of the underlying continuous-time process with measures they call the ‘‘Realized Volatility’’ (RV) and ‘‘Bi-power Variation’’ (BV) measures, respectively. The difference between these two measures provides an unbiased estimate of the jump component of prices. Based on this techniques, we further investigate whether REIT, stock and bond markets in Taiwan has significant jump risk phenomenon.

Many studies have investigated the return association between equity REITs and the general stock market. Gyourko and Linneman (1988), Giliberto (1993), Myer and Webb (1993), Han and Liang (1995), Liang, Chatrath and McIntosh (1996), and Oppenheimer and Grissom (1998), among others, showed that REITs are exposed to beta risk. The asset pricing models have been applied to investigate integration versus segmentation between the real estate market and the general financial markets since the first study of Liu et al. (1990) on this topic. Liu et al. (1990) used a single-factor model and reported that the US securitized real estate market integrates with the stock market, while the US private commercial real estate market is segmented from the stock market. Peterson and Hsieh (1997) showed that the risk premiums on equity REITs are significantly related to three Fama-French factors driving common stock returns, while mortgage REIT risk premiums are significantly related to two bond market factors as well as the three stock market factors. Using a series of commonly used multi-factor asset pricing models, Ling and Naranjo (1999) confirmed that US REITs are integrated with the stock market and the degree of such integration has significantly increased during the 1990s, while there is little evidence for integration between the real estate and stock markets when appraisal-based real estate returns are used. Using a multi-factor model where stock, bond, and direct real estate returns as proxies for underlying state variables determining these asset prices, Clayton and Mackinnon (2003) reported that while through 1970s and 1980s the US NAREIT returns were driven largely by the same economic factors that drive large cap stocks, they are more closely related to both small cap stock and real estate-related factors in 1990s. Downs and Patterson (2005) employed a generalized asset pricing model (i.e., a discount factor model) and showed that US REIT returns from 1972 to 1991 cannot be fully explained by stock and bond returns.

The standard equilibrium asset pricing model theorizes a positive and linear trade-off between return and systematic risks of capital assets. However, empirical evidence in small capitalization stocks and REITs seems to contradict the theoretical relationship. Betas of these stocks have responded asymmetrically in different market conditions. REIT beta was also found to have higher correlations with general market movements in declining markets than in rising markets (Goldstein and Nelling, 1999; Sagalyn, 1990; Chatrath, Liang and McIntosh, 2000; Chiang, Lee and Wisen, 2004). This asymmetric response of REIT returns reflect the risk preference of investors, who dislike downside risks. The results have significant implications for the portfolio management, in particular, the allocations of REIT in a mixed asset portfolio. The results imply that REITs are not an effective risk diversifier for a mixed asset portfolio in recessionary periods. Chathrath, Liang and McIntosh (2000) argues that asymmetry in beta is caused by the combined effects of decaying relationships between REIT returns and general market returns and higher stock market returns in the recent decade. The dividend yield spread hypothesis was also rejected, because the asymmetric beta responses were not found in utilities stocks, which share the same high dividend payout characteristics as REITs. They found similarity in the pattern of asymmetry in beta, but the variance effects (Glosten, Jagannathan and Runkel, 1993; Jagannathan and Wang, 1996) that drive the small capitalization stock beta asymmetry were not significant in REITs. Thus, the asymmetric beta hypothesis remains a puzzle.

This paper contributes to the literature in the following ways: First, we use an econometric technique which is developed by Andersen, Bollerslev and Diebold (2007) to verify the existence of jump in REITs, stock and bond markets in Taiwan. The test shows that the jump frequency in the real estate market occur on 6.45 % of trading days, while the stock market and the bond market jumps occur on 4.29% and 1.38 % of trading days. Therefore, the real estate market has higher jump frequency than the other markets in Taiwan. Next, prior literatures know the average level of systematic risk (total systematic risk). We extend the CAPM and three-factor models to decompose the stock and bond market's systematic risk into its continuous and jump components: the continuous beta risk and jump beta risk. This decomposition is interesting because that risk of the traditional CAPM and three-factor models implicitly assumes that the stock and bond market's systematic risk is uncorrelated with jumps in the market. Our empirical results find that jump beta risks are higher than continuous beta risks. Economically, this means the REITs co-move with the stock market much more on days when stock market experiences a jump. The R-squared of the model that decomposes jump risk into systematic and nonsystematic components improves in Taiwan REITs, compared with the traditional CAPM and three-factor model. Third, most of REITs in Taiwan do not have significantly asymmetric effect (asymmetric/leverage effect) in the continuous (jump) betas of the REITs. Forth, we decompose nonsystematic risk of systematic return in the stock and bond market into continuous and jump components, and we find that the most jump risk is nonsystematic. This suggests that accounting for jump risk is most important in a non-diversified context where nonsystematic risk is present.

The paper is organized into five sections. Section 1 gives the objectives and motivations of the study. Section 2 illustrates the theoretical framework and develops hypothesis to discuss the asymmetric continuous (jump) beta hypothesis. Section 3 describes the data used in the tests. Section 4 presents the modified CAPM and three-factor model, which is used to identify continuous (jump) beta and to further test asymmetric continuous (jump) betas of Taiwan REITs in the sample periods. Furthermore, we analyze the empirical results and draws relevant inference from the findings. Section 5 concludes the study.

2. Jump Detection Theoretical Framework

This section describes the methodology which is developed by Andersen, Bollerslev and Diebold (2007).

Let $p(t)$ denote a logarithmic asset price at time t. The continuous–time jump diffusion process traditionally used in asset pricing is expressed as a stochastic differential equation as follows:

$$dp(t) = \mu(t)dt + \sigma(t)dW(t) + \kappa(t)dq(t), \quad 0 \le t \le T, \tag{2.1}$$

where $\mu(t)$ denotes a continuous and locally bounded variation process, $\sigma(t)$ denotes a strictly positive stochastic volatility process, $W(t)$ is a standard Brownian motion, $q(t)$ is a counting process and $\kappa(t)$ is a measure of the size of the jump which conditional on a jump occurring. When jump occurs at time t, the value of $dq(t)$ is equal 1; otherwise the value of $dq(t)$ is equal 0. The quadratic variation for the cumulative return process, $r(t) \equiv p(t) - p(0)$, is then

$$[r,r]_t = \int_0^t \sigma^2(s)ds + \sum_{0<s\le t} \kappa^2(s) \tag{2.2}$$

If the jumps do not occur ($q(t) \equiv 0$), then the quadratic variation simply equals the continuous volatility (integrated volatility) because that the second return on right-hand side disappears (discounituious jump).

Let $r_{t,\Delta} \equiv p(t) - p(t-\Delta)$ denotes the discretely sampled Δ-period returns. And we define the monthly realized volatility (RV) by the summation of the corresponding $1/\Delta$ daily squared returns.

$$RV_{t+1}(\Delta) \equiv \sum_{j=1}^{1/\Delta} r^2_{t+j\bullet\Delta,\Delta} \tag{2.3}$$

For notational simplicity and without loss of generality, $1/\Delta$ is assumed to be an integer. Hence, follow Anderson and Bollersleve (1998), the realized volatility converges uniformly in probability to the increment in the quadratic variation process by the theory of quadratic variation, as the sampling frequency of the underlying returns increase. That is

$$RV_{t+1}(\Delta) \to \int_0^t \sigma^2(s)ds + \sum_{0<s\le t} \kappa^2(s) \tag{2.4}$$

Obviously, the realized volatility can be separated into two processes: the continuous sample path process and the jump process. Thus, the quadratic variation is consistent for the continuous volatility without jumps. Define the standardized realized bi-power variation (BV) as:

$$BV_{t+1}(\Delta) \equiv \mu_1^{-2} \sum_{j=2}^{1/\Delta} \left| r^2_{t+j\bullet\Delta,\Delta} \right| \left| r^2_{t+(j-1)\bullet\Delta,\Delta} \right|, \tag{2.5}$$

where $\mu_1^{-2} = \sqrt{\pi/2}$. Then, as $\Delta \to 0$ the equation (2.5) is possible to show, 1

$$BV_{t+1}(\Delta) \to \int_0^t \sigma^2(s)ds. \tag{2.6}$$

Hence, the contribution to the quadratic variation process is a result of the jumps may be consistently estimated by

$$RV_{t+1}(\Delta) - BV_{t+1}(\Delta) \to \sum_{0<s\le t} \kappa^2(s) \tag{2.7}$$

This is fundamental theory and empirical for this article.

According to Dunham and Friesen (2008), the ratio statistic defines as follow:

$$RJ_T = \frac{RV_t - BV_t}{RV_t} \tag{2.8}$$

With the absence of jumps, the equation (2.8) will converge to a standard normal distribution. Then

$$ZJ = \frac{RJ_t}{\sqrt{\{(\frac{\pi}{2})^2 + \pi - 5\}\frac{1}{m}\max(1, \frac{TP_t}{BV_t^2})}} \to N(0,1) \quad , \tag{2.9}$$

where $m = 1/\Delta$ and TP_t as shown in the following:2

[1] According to Andersen, Bollerslev and Diebold (2007), the realized power variation (for $\Delta \to 0$) follows that in general for $0 < p < 2$, $RPV_{t+1}(\Delta, p) \equiv \mu_p^{-1} \Delta^{1-p/2} \sum_{j=1}^{1/\Delta} \left| r_{t+j\bullet\Delta,\Delta} \right|^p \to \int_t^{t+1} \sigma^p(s)ds$, where $\mu_p \equiv 2^{p/2}\Gamma(\frac{1}{2}(p+1))/\Gamma(1/2) = E(|Z|^p)$. Therefore, the $PRV_{t+1}(\Delta, p)$ diverges to infinity for $p > 2$. And the impact of the discontinuous jump process disappears in the power variation measures with $0 < p < 2$, while $PRV_{t+1}(\Delta, 2) \equiv RV_{t+1}(\Delta)$ converges to the continuous volatility plus the jump volatility.

[2] According to Andersen, Bollerslev and Diebold (2007), the realized power variation (for $\Delta \to 0$) follows that in

$$TP_t \equiv m\mu_{4/3}^{-3}\frac{m}{m-2}\sum_{j=3}^{m}\left|r_{t,j-2}\right|^{4/3}\left|r_{t,j-1}\right|^{4/3}\left|r_{t,j}\right|^{4/3} \rightarrow \int_{t-1}^{t}\sigma_s^4 ds \quad 3, \tag{2.10}$$

where $\mu_{4/3} = 2^{2/3}\Gamma((4/3+1)/2)/\Gamma(1/2)$.

We choose a value which is significant at the 5% critical value to confirm of jumps. Hence, the actual jump calculates as $J_t = sign(r_t)\times\sqrt{(RV_t - BV_t)\times I_t}$, where I_t is equal to one when jump occurs and zero otherwise.

3. Empirical Results

3.1. Data Description

Our sample contains three markets: the REITs, the bond market and stock market in Taiwan over the period from May 1, 2007 to January 31, 2011. The Weighted Price Index of the Taiwan Stock Exchange (TAIEX) and the 30-days commercial paper rate4 on a daily interval over the same sample periods are used to compute the general stock market returns and the bond market returns. The data are obtained from the International Financial Statistics (IFS). Before testing for jump risk, we first check whether the series is stationary using the Augmented Dickey and Fuller method (ADF). The tests do not reject the null hypothesis. Hence, all data are converted into the form of rates of change by calculating them as the difference of the natural logarithms of the data series.

3.2. Empirical Properties of the Data

Table 1 shows the cross-sectional summary statistics for realized volatility and bi-power variation for all samples including 8 firms of Taiwan REITs, TAIEX and 30-days commercial paper rate. In panel A, the variable of realized volatility (RV) approximates the total monthly return variance, while the realized bi-power variation (BV) estimates the continuous return variance. The standard deviations are calculated as the square root of these variables. The values of $RV^{1/2}$ in TAIEX and short-run interest rate are higher than Taiwan REITs, suggesting that the equity and bond markets have more volatility than real estate market in Taiwan. In order to measure the proportion of continuous volatility to total volatility, it also constructs the ratio of BV/RV. For stock market, approximately 42 percent of the total variance is due to continuous variance. The 37.8 percent is for the real estate market, while for the bond market only about 1 percent of total variance is attributable to the continuous return component.

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general for $0 < p < 2$, $RPV_{t+1}(\Delta, p) \equiv \mu_p^{-1}\Delta^{1-p/2}\sum_{j=1}^{1/\Delta}\left|r_{t+j\bullet\Delta,\Delta}\right|^{p} \rightarrow \int_t^{t+1}\sigma^p(s)ds$,

where $\mu_p \equiv 2^{p/2}\Gamma(\tfrac{1}{2}(p+1))/\Gamma(1/2) = E(|Z|^p)$. Therefore, the $PRV_{t+1}(\Delta, p)$ diverges to infinity for $p > 2$. And the impact of the discontinuous jump process disappears in the power variation measures with $0 < p < 2$, while $PRV_{t+1}(\Delta,2) \equiv RV_{t+1}(\Delta)$ converges to the continuous volatility plus the jump volatility.

[3] TP denotes the tri-power quarticity robust to jumps from Barndorff-Nielsen and shephard (2004).

[4] Since the data of the bond market in Taiwan fail to obtain the time series data completely, we use the high trading frequency 30-days commercial paper rate to be proxy of the bond market.

Panels B and C presents risk measures and the characteristics of the jumps. Total risk is computed as the variance of the total monthly return, while jump risk is the variance in monthly jump returns[5]. The difference between jump risk and total risk is continuous risk, which is defined as the variance of the continuous monthly return. The percentage of total risk attributable to jumps is calculated as the jump variance divided by the total variance. Jump contributes approximately 61 percent of total variance for the real estate market, 42 percent f total variance for the stock market, while 5.6 percent of the total variance is due to jump component in the bond market. Furthermore, the ratio between jump months and total months is the jump frequency. On days when a jump occurs, the jump size is calculated as the square root of the difference between realized volatility and the bi-power variation measure. As for the jump frequency, jumps in the real estate market occur on 6.45 percent of trading days, while the equity market and the bond market jumps occur on 4.29% and 1.38 percent of trading days. Therefore, the real estate market has higher jump frequency than the other markets in Taiwan, but the stock market has higher jump size than the other market.

Table 1. Summary Statistics of Return Data

	Cross-section distribution for Taiwan REIT				**Sample means reported**	
	Mean	**Median**	**Max**	**Min**	**TAIEX**	**Bond market**
Panel A: Jump Model Parameters						
RV	0.206%	0.179%	0.387%	0.129%	0.529%	0.531%
$RV^{1/2}$	3.711%	3.489%	5.331%	2.783%	6.644%	3.723%
BV	0.083%	0.072%	0.164%	0.048%	0.2134%	0.058%
$BV^{1/2}$	2.259%	2.153%	3.315%	1.628%	4.212%	0.615%
BV/RV	37.82%	37.05%	40.22%	36.25%	41.50%	1.40%
$(BV/RV)^{1/2}$	60.55%	60.02%	62.57%	59.24%	64.03%	2.80%
Panel B: Risk Measures						
Total risk	0.018%	0.017%	0.030%	0.012%	0.024%	0.054%
Jump risk	0.011%	0.011%	0.023%	0.007%	0.010%	0.003%
Continuous risk	0.007%	0.001%	0.007%	0.005%	0.014%	0.051%
Panel C: Properties of Jump Risk						
Jump frequently	6.454%	6.587%	9.929%	3.631%	4.287%	1.383%
Jump size	0.0289	0.0271	0.0412	0.0222	0.0510	0.0358

[5] The value is equal to 1 on jump days; otherwise, the value is equal 0.

4. Empirical Methodology and Results

4.1. Decomposing Systematic Risk into Continuous and Jump Components

The distinction between systematic and nonsystematic risk has been explicitly recognized at least since Sharpe (1964), and jumps have been explicitly recognized in stochastic volatility and option pricing models for many years (Merton 1976; Bates 1991). To date, little work has examined the systematic and nonsystematic characteristics of jumps for REITs market. This section first develops an empirical methodology that decomposes total jump risk into systematic and nonsystematic components based on the CAPM model and three-factor model. Next, we test the asymmetric jump and continuous beta effects based on the CAPM model and three-factor model.

4.1.1. The modified CAPM model

It is common to express daily returns for an asset in terms of a factor model. Without loss of generality, consider the standard single-factor model (such as the CAPM) for the returns of asset i:

$$R_{it} = \alpha_i + \beta_{it} R_{Mt} + \eta_{it}, \qquad i = 1,2,...,8. \tag{4.1}$$

Equation (4.1) does not distinguish between the continuous and jump components of total return, but does decompose total return into systematic $(\beta_{it} R_{Mt})$ and nonsystematic $(\alpha_i + \eta_{it})$ components. Any market jump is embedded in R_{Mt}, while any nonsystematic jump unique to REIT i is included in the error term.

In this section, we further decompose each REIT's systematic risk into its continuous and jump components. This decomposition is interesting because standard factor models of risk implicitly assume that an asset's systematic risk is uncorrelated with jumps in the market (i.e., that the asset's beta does not change on days when the market experiences a jump). The modified CAPM model is as follows:

$$R_{it} = \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i} J_{Mt} + \eta_{it}, \tag{4.2}$$

where $J_{Mt} = sign(R_t) \times \sqrt{(RV_t - BV_t) \times I_t}$ is the signed magnitude of the jump return for the stock market, and I_t is equal to one when jump of stock market occurs and zero otherwise. $\beta_{1i}(R_{Mt} - J_{Mt})$ represents continuous systematic risk and $\beta_{2i} J_{Mt}$ represents jump systematic risk of REIT i. The value of η_{it} is nonsystematic risk. The equation (4.2) is built up to test whether the return on REIT market is influenced by jump beta of the stock market.

The existing literature views REITs as a hybrid of stocks and bonds in terms of return and risk exposure in the short-run (e.g., Ling and Naranjo (1997), Peterson and Hseih (1997), Karolyi and Sanders (1998)), with increased exposure to real estate revealed in longer term price dynamics (e.g., Mei and Lee (1994), Geltner and Rodriguez (1998)). Intuitively, REIT returns should be related to returns on stocks because REITs are influenced to some degree by the same macroeconomic variables that affect stock returns. The relatively fixed nature of the cash flows derived from income-property with long-term leases and high credit quality tenants, together with the high dividend yield REITs provide to investors, implying that REIT returns and risks should also be related to macroeconomic variables that affect bond returns. Essentially, this means that returns to stock and bond indices can act as proxies for the unobservable state variables that are common both to REITs, stocks and bonds. Hence, we expand the modified CAPM model to include the bond market factor, as follows:

$$R_{it} = \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i} J_{Mt} + \beta_{3i}(R_{Bt} - J_{Bt}) + \beta_{4i} J_{Bt} + \eta_{it} \tag{4.3}$$

where $J_{Bt} = sign(R_t) \times \sqrt{(RV_t - BV_t) \times I_t}$ is the signed magnitude of the jump return for the bond market, and I_t is equal to one when jump of bond market occurs and zero otherwise.

4.1.2. The Asymmetric Response Model

Different versions of asymmetric response models have been used by researchers to test the asymmetric beta hypothesis, (e.g., Glascock (1991) and Goldstein and Nelling (1999)). We decompose systematic risk into continuous and jump components and include a dummy variable for declining market state to test the asymmetry continuous beta hypothesis. Furthermore, we include a dummy variable for down-jump signal to test the asymmetry jump beta hypothesis. Based on a CAPM model, in which the return on a individual REIT, R_{it}, is specified as a linear function of stock, as follows:

$$R_{it} = \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i} J_{Mt} + \beta_{3i} D(R_{Mt} - J_{Mt}) + \beta_{4i} D_J J_{Mt} + \eta_{it}, \tag{4.4}$$

where β_{3i} is the comparable continuous systematic risk coefficient of stock markets represented by a market dummy D, which has a value 1 when the excess market return is negative; and 0 otherwise. If the estimated value of β_{3i} is significantly non-zero, the asymmetric continuous beta exists. If the coefficient is positive, we have the similar results as Goldstein and Nelling (1999), which imply a higher systematic risk in declining markets than in rising markets. However, if β_{3i} is significant and negative, we have the Glascock (1991) results, which imply that REITs provide effective risk diversification in non-recessionary periods. Furthermore, β_{4i} is the comparable jump systematic risk coefficient of stock markets represented by a market dummy D_J, which has a value 1 when the jump magnitude is negative; and 0 otherwise. If the estimated value of β_{4i} is significantly non-zero, the asymmetric jump beta exists. If the coefficient is positive, it implies a higher jump systematic risk in bad signal than in good signal.

The expanded empirical asymmetric response CAPM framework, in which the return on a individual REIT, R_{it}, is specified as a linear function of stock and bond, is defined as follows:

$$\begin{aligned} R_{it} = {} & \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i} J_{Mt} + \beta_{3i}(R_{Bt} - J_{Bt}) + \beta_{4i} J_{Bt} + \beta_{5i} D(R_{Mt} - J_{Mt}) \\ & + \beta_{6i} DJ_{Mt} + \beta_{7i} D(R_{Bt} - J_{Bt}) + \beta_{8i} DJ_{Bt} + \eta_{it},\ i = 1,2,\ldots,8 \end{aligned} \tag{4.5}$$

where β_{7i}, β_{8i} is the comparable jump systematic risk coefficient of stock and bond markets represented by a market dummy, D, which has a value 1 when the excess market return is negative; and 0 otherwise. If the estimated value of β_{7i}, β_{8i} is significantly non-zero, the asymmetric jump

REIT beta exists. If the coefficient is positive, we have the same results as Goldstein and Nelling (1999), which imply a higher systematic risk in declining markets than in rising markets. However, if β_{7i}, β_{8i} is significant and negative, we have the Glascock (1991) results, which imply that REITs provide effective risk diversification in non-recessionary periods.

4.2. Empirical results

4.2.1. Jump beta v.s continuous beta?

The result is shown in Table 2. Panel A reports the coefficients of the traditional CAPM model for Taiwan REITs. The total systematic risk in Panel A is estimated by regressing total monthly returns for REITs on the total monthly return for the stock market. The coefficients of total return beta are all significant in the firms of REITs which suggests that systematic risk of stock market has a positive effect on real estate market. These findings are compatible with Giliberto (1993), Han and Liang (1995) and Oppenheimer and Grissom (1998), who indicated that the REITs are exposed to beta risk. However, if the stock price has jump risk, traditional CAPM model will fail to capture important characteristics of abnormal shock event. Hence, to investigate further whether the continuous components and jump components of the stock market have different effects on the real estate market, it further decomposes total systematic risk into its continuous and jump components, shown in Panel B. We find that the R-squared of the model that decomposes jump risk into systematic and nonsystematic components improves in Taiwan REITs, compared with the traditional CAPM model. Next, considering the jump beta risk, the values of β_{1i} and β_{2i} are statistically significant for most Taiwan REITs, indicating that continuous beta risk and jump beta risk in the stock market has an effect on the real estate market. That is, the returns on real estate market are correlated with the stock market when the stock market experiences a jump. Particularly, the coefficients of β_{1i} is not significant in REITs of 01008T.TW, implying the return of REITs of 01008T.TW is affected by the jump beta factor of the stock market rather than the continuous beta factor of the stock market. Therefore, it will be meaningful to explore the jump and continuous components of the stock market based on the CAPM model.

Many studies have investigated the return association between equity REITs and the general stock market (e.g., Ambrose et al, 1992; Myer and Webb, 1993). However, one limitation of CAPM framework is that it ignores the common factors that could influence the observed market. For example, Glascock, Lu and So (2000) examines the integration of REITs, stock and bond returns. They show that REITs are cointegrated with the bond market. Therefore, a multi-factor return generating approach is utilized in order to capture the relationship of REITs, stock and bond returns. Table 3 shows the coefficients of the three-factor model of these variables. In Panel A, the coefficients of total return beta of stock market are all significant in Taiwan REITs, while the coefficients of total systematic risk of bond market are all not significant. This indicates that the return of REITs is not influenced by the bond market. Comparing with traditional CAPM framework in Table 2, the R-squared (in Table 3) of the three-factor model fail to improve in Taiwan REITs. One possible explanation is that Taiwan REITs are equity types, and thus have lower relationship with the bond market. As mentioned above, similarly we decompose each stock systematic risk into its continuous and jump components in three-factor model. This decomposition is interesting because standard three-factor model of risk implicitly assume that an asset's systematic risk is uncorrelated with jump in the stock market. Comparing with Panel A, the most R-squared of modify models are higher than standard models suggesting that the former model has more explanatory power than the later model. Especially in REITs of 01008T.TW, the R-squared value rises from 14 percent to 28 percent, implying it is necessary to separate the continuous risk and jump risk from the systematic risk of stock return in three-factor model. We also find that jump beta risks are higher than continuous beta risks. Economically, this means the REITs co-move with the stock market much more on days when stock market experiences a jump.

This paper further analyzes the explanatory power to the REIT return when we decompose bond market. The result is shown in Panel C. The most R-squared values are improved when adding the jump of bonds market. Especially, the significance of β_{3i} and β_{4i} in REITs of 01007T.TW and 01001T.TW suggests that continuous beta risk and jump beta risk explain the discrepancies between real estate and bond markets. Comparing with Panel B in Table 2, the most R-squared are increased. This is very interesting phenomena. If we do not decompose the continuous and jump risks of bond markets, the modify CAPM model is the best model. But, when we decompose systematic risk of bond into continuous and jump components, the modify three-factor model has better explanatory power than modify CAPM model.

4.2.2. Is continuous beta asymmetric?

We further expand our model to include a dummy variable for declining market state to test the asymmetric continuous beta hypothesis, and include a dummy variable for negative jump size to test the asymmetric jump beta hypothesis. The results of asymmetric continuous beta tests in Panel C are estimated similarly using Glascock (1991) approach that includes a dummy variable for bear market, which is defined by negative excess market returns, in the standard CAPM framework. The results show that the coefficients, β_{3i}, are significant and negative in 01004T.TW. This result is also consistent with some previous studies, e.g., Glascock (1991), that claim asymmetry in REIT beta exists and REITs provide effective risk diversification in non-recessionary periods. Unfortunately, other Taiwan REITs are also positive yet not significant. Therefore, there seems to be symmetric continuous beta risk relationship between declining markets and rising markets.

4.2.3. Is jump beta asymmetric?

Except the business cycle, the good news and bad news of the market could influence the relationship between different markets. This concept of leverage effect is first proposed by Black (1976). Many studies have widely used this concept to analyze the financial markets, e.g., Koutmos, 1998; Wu and Xiao, 2002; Chen, et al., 2003; Mohanty, 2006. When the markets was suffered by the positive (good news) and the negative (bad news) of the information shock, if the bad news of the information affect the volatility of asset price more large than the good news of the information, namely the existence of the leverage effect in this market. For this reason, we want to examine whether the asymmetric jump beta exists when markets suffer the shocks in this subsection. The results of asymmetric jump beta tests are shown in Panel C. The result shows that the coefficient, β_{4i}, is significant and positive in 01004T.TW, indicating the jump beta risk with bad news is higher than with good news. This means, the bad shocks probably limit the wealth and investment plans of the investors. Ignoring this phenomenon, the investor maybe undervalues the relationship between assets and to work out the wrong decisions. Hence, the REITs fail to be a defensive asset is used to hedge against extreme downside risk in the volatile market. However, in most of REITs, jump betas of the REITs do not have significantly asymmetric/leverage effect. This means, when pricing the derivatives of the REITs, it is not necessary to distinguish between the positive and the negative of jump size of the REITs. Under this situation, the compound Poisson process can directly used in asset pricing of REITs in Taiwan.

The above section compares total beta with its continuous and jump betas of each REITs. Next, we also show the average estimated parameter which is listed in Table 4. Based on CAPM model and three-factor model, the average total beta of the REITs is about 0.35. And the average jump beta is higher than the average continuous beta in the stock market, while the average continuous beta is higher than the average jump beta in the bond market. Economically, the returns of REITs are correlated with stock market on days when the stock market has a jump. We also find the difference between the average continuous and the average jump beta is significant at the 10% significant level in the bond market.

Table 2. Results of decomposing systematic risk into continuous and jump components for CAPM model

	01005T.TW	01002T.TW	01007T.TW	01006T.TW	01001T.TW	01004T.TW	01003T.TW	01008T.TW
Panel A: Traditional CAPM								
$R_{it} = \alpha_i + \beta_{1i} R_{Mt} + \eta_{it}$								
α_i	0.000412	0.000280	0.000113	0.000193	2.99E-05	2.48E-05	-5.35E-05	1.53E-05
	(0.000431)	(0.000207)	(0.000299)	(0.000479)	(0.000292)	(0.000375)	(0.000292)	(0.000447)
β_{1i}	0.383573***	0.271643***	0.224355***	0.584425***	0.316879***	0.355407***	0.341296***	0.350163***
	(0.108769)	(0.052150)	(0.075578)	(0.120999)	(0.073755)	(0.094803)	(0.073632)	(0.112783)
$\overline{R}$	0.206293	0.372619	0.150778	0.336638	0.284075	0.228805	0.317668	0.164126
Panel B: Modify CAPM_ Continuous and Jumps Betas								
$R_{it} = \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i} J_{Mt} + \eta_{it}$								
α_i	0.000479	0.000295	0.000139	0.000259	6.82E-05	3.45E-05	1.91E-07	0.000120
	(0.000420)	(0.000208)	(0.000300)	(0.000471)	(0.000288)	(0.000381)	(0.000279)	(0.000411)
β_{1i}	0.261856**	0.245699***	0.177211*	0.464226***	0.247385***	0.337811***	0.243993***	0.160993
	(0.123447)	(0.061201)	(0.088290)	(0.138577)	(0.084752)	(0.112019)	(0.082133)	(0.120923)
β_{2i}	0.287361**	0.251135***	0.187090**	0.489413***	0.261947***	0.341498***	0.264382***	0.200631*
	(0.117069)	(0.058039)	(0.083729)	(0.131418)	(0.080373)	(0.106231)	(0.077890)	(0.114675)
$\overline{R}$	0.251933	0.367764	0.152014	0.363349	0.308300	0.212168	0.378794	0.296918
Panel C: Modify CAPM_ Asymmetry Continuous and Jumps Betas								
$R_{it} = \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i} J_{Mt} + \beta_{3i} D(R_{Mt} - J_{Mt}) + \beta_{4i} D_J J_{Mt} + \eta_{it}$								
α_i	-0.000373	0.000168	-1.12E-05	0.000780	-4.07E-05	-0.000825	-0.000295	-0.000373
	(0.000710)	(0.000362)	(0.000523)	(0.000815)	(0.000502)	(0.000638)	(0.000483)	(0.000710)
β_{1i}	0.319774	0.290429**	0.213022	0.292535	0.289116*	0.627267***	0.344010**	0.319774
	(0.214593)	(0.109343)	(0.157932)	(0.246186)	(0.151658)	(0.192734)	(0.145932)	(0.214593)

β_{2i}	0.048114	0.203677*	0.167415	0.658754**	0.214157	0.048971	0.162652	0.048114
	(0.214773)	(0.109435)	(0.158065)	(0.246394)	(0.151785)	(0.192896)	(0.146055)	(0.214773)
β_{3i}	-0.327351	-0.095816	-0.062031	0.357510	-0.092208	-0.608362*	-0.210732	-0.327351
	(0.366257)	(0.186621)	(0.269551)	(0.420179)	(0.258842)	(0.328948)	(0.249070)	(0.366256)
β_{4i}	0.294007	0.087989	0.049386	-0.323000	0.086128	0.552628*	0.191701	0.294007
	(0.333783)	(0.170074)	(0.245651)	(0.382924)	(0.235892)	(0.299782)	(0.226986)	(0.333783)
$\overline{R}$	0.276481	0.340576	0.113407	0.343440	0.276283	0.237939	0.359206	0.276481

The Std. Errors are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level, respectively.

Table 3. Results of decomposing systematic risk into continuous and jump components for three-factor model

	01005T.TW	01002T.TW	01007T.TW	01006T.TW	01001T.TW	01004T.TW	01003T.TW	01008T.TW
Panel A: Traditional Three-Factor Model								
$R_{it} = \alpha_i + \beta_{1i} R_{Mt} + \beta_{2i} R_{Bt} + \eta_{it}$								
α_i	0.000412	0.000280	0.000113	0.000193	2.98E-05	2.47E-05	-5.36E-05	1.55E-05
	(0.000436)	(0.000209)	(0.000303)	(0.000484)	(0.000296)	(0.000380)	(0.000295)	(0.000452)
β_{1i}	0.383575***	0.272054	0.224779***	0.583593***	0.317008***	0.355514***	0.341459***	0.349992***
	(0.110085)	(0.052705)	(0.076437)	(0.122331)	(0.074641)	(0.095946)	(0.074514)	(0.114139)
β_{2i}	-4.90E-05	-0.010895	-0.011194	0.021840	-0.003403	-0.002843	-0.004301	0.004429
	(0.065566)	(0.031391)	(0.045526)	(0.072860)	(0.044456)	(0.057145)	(0.044380)	(0.067981)
$\overline{R}$	0.187395	0.359519	0.131809	0.322290	0.267131	0.210489	0.301579	0.144311
Panel B: Modify Three-Factor Model _ Continuous and Jumps Betas								
$R_{it} = \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i} J_{Mt} + \beta_{3i} R_{Bt} + +\eta_{it}$								
α_i	0.000479	0.000295	0.000139	0.000259	6.81E-05	3.45E-05	8.69E-08	0.000120
	(0.000425)	(0.000210)	(0.000303)	(0.000476)	(0.000292)	(0.000385)	(0.000282)	(0.000416)
β_{1i}	0.261814**	0.245606***	0.177109*	0.464354***	0.247335***	0.337783***	0.243926***	0.160958
	(0.124933)	(0.061833)	(0.089268)	(0.140166)	(0.085757)	(0.113372)	(0.083088)	(0.122382)
β_{2i}	0.287371**	0.251157***	0.187115**	0.489381***	0.261959***	0.341504***	0.264397***	0.200634*
	(0.118478)	(0.058638)	(0.084656)	(0.132923)	(0.081326)	(0.107514)	(0.078795)	(0.116058)
β_{3i}	-0.005417	-0.012061	-0.013296	0.016583	-0.006475	-0.003625	-0.008601	-0.003905
	(0.063729)	(0.031541)	(0.045536)	(0.071499)	(0.043745)	(0.057832)	(0.042384)	(0.062428)
$\overline{R}$	0.233822	0.354645	0.133135	0.348669	0.291808	0.193030	0.364281	0.279844
Panel C: Modify Three- Factor Model _ Asymmetry Continuous and Jumps Betas								

$$R_{it} = \alpha_i + \beta_{1i}(R_{Mt} - J_{Mt}) + \beta_{2i}J_{Mt} + \beta_{3i}(R_{Bt} - J_{Bt}) + \beta_{4i}J_{Bt} + \beta_{5i}D(R_{Mt} - J_{Mt}) + \beta_{6i}DJ_{Mt} + \beta_{7i}D(R_{Bt} - J_{Bt}) + \beta_{8i}DJ_{Bt} + \eta_{it}$$

α_i	-0.000365	0.000172	-4.48E-05	0.000685	-0.000188	-0.000950	-0.000161	-0.000365
	(0.000812)	(0.000407)	(0.000552)	(0.000908)	(0.000545)	(0.000654)	(0.000530)	(0.000812)
β_{1i}	0.355426	0.333886***	0.355786**	0.425463	0.400801**	0.834169***	0.418742	0.355426
	(0.244044)	(0.122378)	(0.166033)	(0.272824)	(0.163759)	(0.196501)	(0.159223)	(0.244044)
β_{2i}	0.043160	0.200061*	0.142688	0.645826**	0.203536	9.44E-05	0.149455	0.043160
	(0.227905)	(0.114285)	(0.155053)	(0.254782)	(0.152929)	(0.183506)	(0.148693)	(0.227905)
β_{3i}	0.022106	0.046095	0.097764	0.246802	0.271843	0.116078	-0.100998	0.022107
	(0.439135)	(0.220209)	(0.298761)	(0.490923)	(0.294670)	(0.353586)	(0.286507)	(0.439135)
β_{4i}	0.085133	0.091889	0.299560**	0.267138	0.197803	0.422599**	0.205211	0.085132
	(0.205267)	(0.102933)	(0.139651)	(0.229474)	(0.137739)	(0.165278)	(0.133923)	(0.205267)
β_{5i}	-0.372042	-0.147281	-0.245152	0.197745	-0.225691	-0.887890**	-0.307509	-0.372042
	(0.405709)	(0.203447)	(0.276020)	(0.453555)	(0.272240)	(0.326672)	(0.264698)	(0.405709)
β_{6i}	0.329836	0.132046	0.207851	-0.190714	0.200170	0.796778**	0.271883	0.329836
	(0.367426)	(0.184250)	(0.249975)	(0.410757)	(0.246551)	(0.295847)	(0.239721)	(0.367426)
β_{7i}	0.076407	0.062130	0.249118	0.063554	-0.042068	0.366822	0.340519	0.076407
	(0.527102)	(0.264321)	(0.358609)	(0.589264)	(0.353697)	(0.424416)	(0.343899)	(0.527102)
β_{8i}	-0.058165	-0.053839	-0.227347	-0.044639	0.030225	-0.349671	-0.282467	-0.058164
	(0.459847)	(0.230595)	(0.312852)	(0.514077)	(0.308567)	(0.370263)	(0.300019)	(0.459847)
$\overline{R}$	0.202473	0.295982	0.164855	0.312770	0.280815	0.324858	0.349846	0.202473

The Std. Errors are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level, respectively.

4.2.4. Decomposing Nonsystematic Risk into Continuous and Jump Components

In the equation (4.1), it separates systematic risk into continuous and jump components. However, all nonsystematic risks do not separated continuous and jump risk. Therefore, in this section, we decompose nonsystematic risk into continuous and jump components. As mentioned above, the value of η_{it} is total nonsystematic risk. Define the nonsystematic jump return ($NonJump$) and nonsystematic continuous return ($NonCon$) as follows:

$$NonJump = J_{it} - \hat{\beta}_{2i} J_{iRt} - \hat{\beta}_{4i} J_{iBt},$$

$$NonCon = v_{it} - (J_{it} - \hat{\beta}_{2i} J_{iRt} - \hat{\beta}_{4i} J_{iBt}).$$

Hence, it can decompose total risk into systematic (jump and continuous) and nonsystematic risks (jump and continuous). This study defines total risk as the variance of total monthly returns and the systematic continuous (jump) risk as squared continuous (jump) systematic risk multiplied by the variance of continuous (jump) market returns. Nonsystematic jump risk is defined as the sample variance of NonJump and nonsystematic continuous risk is defined as the sample variance of NonCon. The result is shown in Table 4. It finds that most jump risk is nonsystematic, suggesting that accounting for jump risk is most important in a non-diversified context, where nonsystematic risk is present. Furthermore, the average estimated parameter is listed in Table 4. For the two models, the average total beta for the REITs firms is about 0.35. And the average jump beta is higher than the average continuous beta in stock market, while the average continuous beta is higher than the average jump beta in bond market. Economically, the returns of REITs are correlated with stock market on days when the stock market has a jump. We also find the difference between the average continuous and the average jump beta is significant in bond market.

In Summary, our study results in several important findings. First, the jump beta is higher than the continuous beta in the REITs market in Taiwan, thus the jump beta is the most relevant measure of co-movement with the market on days when the market experiences a jump. Taiwan REITs seems to behave differently during a severe market downturn than it does at other times, and this information offers the potential to significantly improve on calculations such as Value at Risk (VAR). Second, the asymmetric continuous betas is negative, although only one of the eight REITs is significant, indicating the continuous betas are higher during up markets and lower during down markets. Such behavior may imply that, REITs returns would be less affected during periods of significant market decline and could be a defensive asset in declining market. Third, this evidence indicates that there is no asymmetric/leverage effect in risk premia of stock effects on REITs returns. Finally, most jump risk is nonsystematic, with systematic jump risk contributing less than 4% of total return variance. This would suggest that accounting for jump risk is most important in a non-diversified context where nonsystematic risk is present.

Table 4. Decomposing jump risk into systematic and nonsystematic components

	Mean	Median	Max	Min	Std Dev.
Panel A: Cross-section Distribution for REITs in Taiwan REIT _CAPM model					
Estimated parameter					
Total return beta(S)	0.353468	0.34573	0.584425	0.224355	0.106311
Continuous beta(S)	0.267397	0.246542	0.464226	0.160993	0.096069
Jump beta(S)	0.285432	0.263165	0.489413	0.18709	0.09546
Differece(Con-jump)	-0.01804	-0.01748	-0.00369	-0.03964	0.012085
Percentage total risk					
Systematic jump risk(S)	3.5282%	3.8842%	6.1721%	1.0915%	1.7974%
Systematic continuous risk(S)	0.6964%	0.7833%	1.2374%	0.1690%	0.3670%
Nonsystematic jump risk(S)	49.4807%	49.1697%	51.8918%	47.8980%	1.4175%
Nonsystematic continuous risk(S)	46.2947%	46.2267%	47.7145%	44.6925%	1.0117%
Panel B: Cross-section Distribution for REITs in Taiwan REIT _ multi-factor model					
Estimated parameter					
Total return beta_1(S)	0.353497	0.345726	0.583593	0.224779	0.105926
Total return beta_2(B)	-0.0008	-0.00312	0.02184	-0.011194	0.010513
Continuous beta1(S)	0.29896	0.273414	0.513432	0.165421	0.107106
Jump beta2(S)	0.317707	0.291548	0.539497	0.205191	0.106126
Differece(Con1-jump2)	-0.01875	-0.01814	-0.004654	-0.03977	0.011943
Continuous beta3(B)	0.181445	0.214829	0.305548	0.022339	0.100987
Jump beta4(B)	0.154762	0.182599	0.264104	0.018574	0.087158
Differece(Con3-jump4)	0.026684*	0.03223	0.041444	0.003765	0.013886
Percentage total risk					
Systematic jump risk(S)	2.7497%	2.8153%	4.5028%	1.0771%	1.1979%
Systematic continuous risk(S)	0.5453%	0.5957%	0.8616%	0.1780%	0.2492%
Systematic jump risk(B)	16.8529%	21.3198%	26.6698%	0.2529%	10.3357%
Systematic continuous risk(B)	0.0667%	0.0847%	0.1055%	0.0011%	0.0405%
Nonsystematic jump risk	40.9989%	39.3022%	51.7418%	35.5649%	5.9043%
Nonsystematic continuous risk	38.7864%	36.8825%	46.5968%	34.5277%	5.0043%

Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level, respectively.

5. Conclusions

This paper uses an econometric technique which is developed by Andersen, Bollerslev and Diebold (2007) to verify the existence of jump in REITs, stock and bond markets in Taiwan. This test shows that jump contributes approximately 62.4 percent of total variance for all REITs in Taiwan. Next, previous studies only know the average level of systematic risk (total beta). We extend the CAPM and three-factor models to decompose the stock and bond market’s systematic risk into the continuous beta risk and jump beta risk. Our empirical results find that jump beta risks are higher than continuous beta risks. Economically, this means the REITs co-move with the stock market much more on days when stock market experiences a jump. This implies that REITs behave differently during a severe market downturn than it does at other times, this information offers the potential to significantly improve on calculations such as Value at Risk (VAR). The R-squared of the model that decomposes jump risk into systematic and nonsystematic components improves in Taiwan REITs, compared with the traditional CAPM and three-factor model. Third, most of REITs in Taiwan do not have significantly asymmetric continuous beta effect and asymmetric/leverage effect. Forth, we decompose nonsystematic risk of systematic return in the stock and bond market into continuous and jump components, and we find that the most jump risk is nonsystematic. This suggests that accounting for jump risk is most important in a non-diversified context where nonsystematic risk is present.

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