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商業本票利率行為：資料頻率與重大事件

The Behavior of Commercial Paper Rates: Data Frequencies and Great Events

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摘要：由於包含貨幣市場金融商品的投資組合逐漸受到投資人的歡迎，所以許多相關研究已經開始探討短期利率行為。本研究旨在調查 4 種不同頻率（日、週、月與季資料）的商業本票利率動態變化與 5 項重大事件（臺海導彈危機、亞洲金融危機、921 大地震、2000 年總統大選與 911 恐怖攻擊）對商業本票利率行為的影響。實證結果首先發現，商業本票的日、週、月與季報酬率在「極」長期（超過 20 年）是負自我相關。其次，重大事件對於商業本票利率的均數復歸速度產生顯著地衝擊。再者，商業本票利率水準高低對商業本票利率波動性具有關鍵性的影響。最後，商業本票利率的隨機漫步假設在低頻率資料（月與季資料）被拒絕的證據是比高頻率資料（日與週資料）更為明顯。

關鍵詞：商業本票利率；資料頻率；重大事件；均數復歸；隨機漫步

Abstract: The behavior of short-term interest rates has been examined in numerous studies because portfolios, including money market instruments, are popular with investors. This study examines the dynamics of commercial paper rates across the four different frequencies (*i.e.,* daily, weekly, monthly, and quarterly data) and the influence of the five great events (*i.e.*, the Taiwan Strait missile crisis, the Asian financial crisis, the 921 earthquake, the 2000 presidential

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election, and the 911 terrorist attacks) on commercial paper rate behavior. The empirical results indicate that first the daily, weekly, monthly, and quarterly returns on commercial papers are all negatively autocorrelated in the "very" long term (more than 20 years). Second, the great events have an important impact on the mean-reverting speed of commercial paper rates. Third, the level of commercial paper rates is crucial to the determination of commercial paper rate volatility. Finally, the rejection of the random walk hypothesis of commercial paper rates for low frequency data (monthly and quarterly data) is stronger than that for high frequency data (daily and weekly data).

Keywords: Commercial paper rates; Data frequencies; Great events; Mean reversion; Random walk

1. Introduction

Although many researchers have examined the dynamics of short-term interest rates, there is no consensus among researchers regarding whether short-term interest rates follow a mean reversion process.[2] In contrast with a few earlier studies, which found insignificant mean-reverting tendency in short-term interest rates (*e.g.*, Brailsford and Maheswaran, 1998; Christopher, 2003), the majority showed supportive evidence for the mean reversion behavior of short-term interest rates (*e.g.*, Dahlquist, 1996; Adkins and Krehbiel, 1999; Staikouras, 2006; Koutmos and Philippatos, 2007; Smallwood and Norrbin, 2008; Kim and Ji, 2011). The previous studies on mean reversion of short-term interest rates mostly focused on the Treasury bill rate behavior in Europe and the US (*e.g.*, Chan *et al.*, 1992; Dahlquist, 1996; Koutmos, 1998; Staikouras, 2006; Koutmos and Philippatos, 2007; Christiansen, 2010). Some investigated the mean-reverting tendency of LIBOR (*e.g.*, Adkins and Krehbiel, 1999), Eurodollar interest rates (*e.g.*, Christopher, 2003), and Eurocurrency interest rates (*e.g.*, Smallwood and

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[2] Mean reversion refers to a propensity that financial asset prices will move back to their long-term averages.

Norrbin, 2008), but they rarely discussed mean reversion of commercial paper rates (in particular, for emerging markets). Like Treasury bills, commercial papers are also one of the main instruments in the money market. In contrast to Treasury bill rates reflecting government default risk, commercial paper rates reflect the default risk of enterprises. When the default risk of enterprises always responds to the economic climate, the examination of commercial paper rate behavior will help us to understand how short-term interest rates respond to the business operating environment.

If the speed of mean-reverting of commercial paper rates can be detected, then the portfolio performance, including instruments in the money market, should obviously improve. Because the participants with different investment horizons in the money market focus on different holding period returns, the issue of short-term interest rate behavior across frequencies has attracted significant attention in previous studies (*e.g.*, Koutmos, 1998; Engle and Rangel, 2008). Although it is easier to find the mean reversion when adopting low frequency data (*e.g.*, quarterly returns and monthly returns) to investigate the behavior of commercial paper rates, the conclusions regarding mean reversion using low frequency data are more likely to be contaminated by insufficient observations. As a result, a comparison of the mean-reverting speed between low and high frequency data (*e.g.*, weekly returns and daily returns) is necessary for obtaining a complete picture of the price behavior of commercial papers.

Most of the earlier studies indicated the dependence of the volatility of interest rates on their level (*e.g.*, Cox, Ingersoll, and Ross, 1980; Chan *et al.*, 1992; Brenner, Harjes, and Kroner, 1996), but the dependence appears to be sensitive to the frequency of the data used (Koutmos, 1998). This implies that the dynamics of interest rates may have different features at different frequencies. Additionally, the research of interest rate volatility has been limited to the field of matured countries (especially the US) but the benefits of analyzing the features of short-term interest rates in emerging markets are obvious. Studies focusing on the sensitivity of interest rate volatility to its level changes across frequencies for the Taiwanese money market are beneficial in understanding the interest rate dynamics in emerging markets.

The occurrences of great events not only have a big impact on investors' sentiments but also trigger changes in their investment strategies. Therefore, great events may yield a shift toward higher volatility of commercial paper rates and structural breaks of commercial paper rate behavior. It is informative to explore the influence of great events on commercial paper rate behavior of an emerging money market across frequencies. The more sophisticated a money market, the more long-term investors or institutional investors exist that plan their investment strategy using a detailed and complete analysis. This means that the noise traders' influence on commercial paper rates becomes lower in matured markets. The number of noise traders in the money market of Taiwan, an emerging money market, is more than in a matured money market. The Taiwanese commercial paper rates are able to be affected easily by great events, which may lead to irrational fluctuations.

The aim of this study is to investigate the behavior of commercial paper rates across frequencies and around great events associated with less sophisticated money markets. Several important contributions beyond the scope of previous studies are made. First, this study examines the mean reversion of commercial paper rates across the four different frequencies (*i.e.*, daily, weekly, monthly, and quarterly data). Second, this study investigates the elasticity of commercial paper rate volatility to its levels across the four different frequencies. Third, the influence of data frequencies and great events on the rejection of random walk hypothesis is explored. Finally, this study compares the differences in commercial paper rate behavior before and after the five great events (*i.e.*, the Taiwan Strait missile crisis, the Asian financial crisis, the 921 earthquake, the 2000 presidential election, and the 911 terrorist attacks).

The remainder of the paper is organized as follows. The second section discusses the great events in Taiwan during the research period. The data sources and research methodology are introduced in the third section. The empirical results are presented in the fourth section, while the final section concludes and summarizes the findings of the paper.

2. Great Events in Taiwan during the Research Period

Table 1

The Economic Growth Rate for the Asian Tigers

Year	Taiwan	Hong Kong	Singapore	South Korea
1996	5.54%	4.3%	8.2%	7.0%
1997	5.48%	5.1%	8.3%	4.7%
1998	3.47%	-6.0%	-1.4%	-6.9%
1999	5.97%	2.6%	7.2%	9.5%
2000	5.80%	8.0%	10.1%	8.5%
2001	-1.65%	0.5%	-2.4%	4.0%
2002	5.26%	1.8%	4.2%	7.2%
2003	3.67%	3.0%	3.8%	2.8%
2004	6.19%	8.5%	9.2%	4.6%
2005	4.70%	7.1%	7.6%	4.0%
2006	5.44%	7.0%	8.7%	5.2%
2007	5.98%	6.4%	8.2%	5.1%
2008	0.73%	2.3%	1.5%	2.3%

Data source: National Statistics, R.O.C.

Taiwan is a saucer-shallow economy composed of a high-tech industry and small and middle-sized enterprises that are easily impacted by great events. A review of both great domestic and international events occurring from January 5, 1982 to February 22, 2012 (the research period of this study) indicates that the Taiwan Strait missile crisis in 1996, the Asian financial crisis in 1997, the Taiwan's 921 earthquake in 1999, the first political party ruling shift in Taiwan in 2000, and the 911 terrorist attacks in 2001 had a significant impact on the Taiwanese financial market.[3] From Table 1, Taiwanese economic growth remained positive during 1996-1998 (with 5.54%, 5.48%, and 3.47% where other Asian tigers, Hong Kong, Singapore, and South Korea experienced growth rates in 1998 of -6.0%, -1.4%, and -6.9%, respectively). Meanwhile, the Taiwanese stock market experienced a bullish trend (during 1996-1998 the Taiwan Capitalization Weighted Stock Index reached a peak of 10256.10 points on August

[3] Although the research period of this study is January 5, 1982 to February 22, 2012, the variance ratio test of Poterba and Summers (1998) used by this study requires the sub-period longer than ten years to acquire sufficient observations. Due to the need of the long sub-periods for the comparison of commercial paper rate behavior between pre-event and post-event, this study focuses on the great events that happened during 1993-2001.

27, 1997 and a low of 4672.67 points on February 7, 1996 while the closing prices of the Taiwan Capitalization Weighted Stock Index were 5146.04 and 6418.43 points on January 4, 1996 and December 31, 1998, respectively). With a stable financial system in Taiwan and the proper governmental response to the Taiwan Strait missile crisis and Asian financial crisis, the above two great events exerted limited impact on the financial market in Taiwan, including the commercial paper market. Pilbeam (2001) also indicated that the Taiwanese economy experienced less of an impact during the Asian financial crisis than other East Asian countries.

Although Taiwan experienced less impact from the Taiwan Strait missile crisis and Asian financial crisis on its economy and financial market, the Taiwanese economy was in a recession during 1999-2001.[4] This may have resulted from the bubble burst of the Internet economy, but after 2002 the rest of the Asian tigers, Hong Kong, Singapore, and South Korea, experienced economic recovery and more positive growth while Taiwan's economy remained in a downturn and experienced sluggish GDP growth. Thus, great events occurring during 1999-2001 may have affected the confidence of investors or economic structure of Taiwan. In a review of great events during 1999-2001 in Taiwan, first, on September 21, 1999, Taiwan was struck by the most serious natural disaster in history, the 921 earthquake. It resulted in a death toll of 2,455 lives and economic loss of NT$ 360 billion,[5] devastating Taiwan's economic strength. There is a need to compare commercial paper rate behavior before and after this natural disaster. Second, the first change in a ruling political party occurred in Taiwan on March 18, 2000 when the Nationalist Party (or Kuomintang) lost its 56-year (1945-2000) dominance of the government. This event resulted in China's mistrust of the new ruling political party (Democratic Progressive Party) resulting in the economic cooperation between Taiwan and China being affected by a poor political relationship. It is worth further discussing whether this political power shift

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[4] Taiwan's annual economic growth rate reaches a historical low of -1.65% in 2001 and an average of 3.37% during 1999-2001, which is significantly lower than the average growth rate of 4.48% during the 1997-1998 Asian financial crisis and one of 6.78% during 1989-1998 (data source: National Statistics, R.O.C.).

[5] Data source: The 921 Earthquake Post-disaster Recovery Commission, Executive Yuan, R.O.C.

impacted the investors' confidence of commercial paper. The terrorist attacks on September 11, 2001 were the greatest international event during 1999-2001. The attacks on the US impacted financial markets around the world, and since the US is the most important ally country and major export market of Taiwan, Taiwan was inevitably affected. This study, thus, investigates the impact of this great international event on commercial paper rate behavior.

As mentioned previously, it is understandable why the Taiwan Strait missile crisis in 1996, the Asian financial crisis in 1997, the 921 earthquake in 1999, the presidential election in 2000, and the 911 terrorist attacks in 2001 are selected as research subjects. This study includes the impact of great events on commercial paper rate behavior because the belief is that: First, interest rate, exchange rate, and stock price are the three most important financial asset indicators in the financial field and research in the financial field always focuses on short-term interest rate behavior. After Chan *et al.* (1992) proposed a comparison of short-term interest rate behavior models raised by previous studies and presented one single continuous-time short-term interest rate model, later studies often used Chan *et al.*'s model to empirically analyze (*e.g.*, Adkin and Krehibel, 1999) or improve the capturing of the interest rate dynamic based on the proposal of Chan *et al* (*e.g.*, Dahlquist, 1996; Koutmos, 1998; Koutmos and Philippatos, 2007). Previous literature, however, rarely examined the impact of great events on short-term interest rate behavior and thus, this study includes the impact of great events on commercial paper rate behavior. In addition, the earlier studies examined the impact of great events on stock price and exchange rate behavior (*e.g.*, Sarno and Taylor, 1999; Karolyi, 2002; Caporale, Cipollini, and Demetriades, 2005), but seldom addressed the impact of great events on interest rate behavior, therefore, it deserves an in-depth analysis. In the end, before the occurrence of these five great events, during 1982-1995, the average rate on 90-day commercial paper in the secondary market was 7.481% and after the occurrence, during 2002-2011, the average rate on 90-day commercial paper in the secondary market was 1.973% (since 1999, the government in Taiwan started to stimulate economic recovery by adopting a gradual drop in the rediscount rate announced by the Central Bank. This policy resulted in the dramatic fall of

Taiwanese short-term interest rates to the lowest level in the past 50 years). Whether the dramatic deviance of interest rate levels results in structural change is one of the motivators behind this study. In short, based on the above three reasons, which are the importance of short-term interest rate behavior, the neglect of the effect of great events on short-term interest rates, and the possibility of the structural change of short-term interest rates, this study examines the commercial paper rate dynamic and its mean-reverting tendency, as well as whether great events result in a structural change of commercial paper rates to further understand commercial paper rate behavior.

3. Data and Methodologies

3.1. Data

Earlier studies mostly adopted the Treasury bill rates for the approximation of short-term interest rates, but Treasury bill trading in Taiwan remains at a low volume and this approximation is not suitable. In terms of trading volume of financial instruments in the Taiwanese money market, commercial paper is the one with the highest liquidity (in 2008, the secondary market trading of Taiwanese commercial paper exceeded NT$ 39 trillion accounting for more than 80% of total bill market trading) and among them, the trading of the second type commercial paper (financing commercial paper; CP2) has the highest volume. In regard to the maturity of financial instruments, previous literature indicated the utilization of the interest rate of three-month financial instruments in the money market for the approximation of the short-term interest rate (*e.g.*, Larrain and Pagano, 1993; Koutmos, 1998; Staikouras, 2006). Based on the above reasons for high liquidity of commercial papers and the suggestion of previous literature, this study uses the 90-day CP2 rates for the approximation of the short-term interest rates.

The data used in this study consists of the daily, weekly, monthly, and quarterly returns on the CP2 of the secondary market with maturities of 90 days. The daily series of annualized percentage rates on the 90-day CP2 was obtained from the database of the *Taiwan Economic Journal* (TEJ). The study period

started on January 5, 1982 and ended on February 22, 2012. For obtaining the daily, weekly, monthly, and quarterly returns on the 90-day CP2, the annualized percentage rates were respectively divided by 365, 52, 12, and 4. Weekly, monthly, and quarterly series were based on Wednesday's rates, the end of the month rates, and the end of the quarter rates, respectively. There were 8,281 daily return observations, 1,572 weekly return observations, 360 monthly return observation, and 119 quarterly return observations. Additionally, this study established ten sub-periods (*i.e.*, before and after the five great events), to analyze the impact of these great events on the behavior of commercial paper rates across frequencies for less sophisticated money markets.

3.2. The Investigation on the Dynamics of Commercial Paper Rates

For improving the ability of capturing the dynamics of short-term interest rates, Chan *et al.* (1992) used a model with a single continuous time process to examine the volatility of interest rates and the speed of mean-reverting. This study adopts the model of Chan *et al.* (1992) provided below for the investigation on the dynamics of commercial paper rates:

$$dr = (\alpha + \beta r)dt + \sigma r^{\lambda} dw, \tag{1}$$

where r is commercial paper rates;[6] α, β, σ, and λ are the parameters; and w follows a Brownian motion (Chan *et al.*, 1992; Koutmos, 1998).

Equation (1) indicates that the level of commercial paper rates, r, has a significant impact on the conditional mean and the conditional variance of changes in the commercial paper rates. In addition, β is a measure of the speed of mean reversion (*i.e.*, the behavior of commercial paper rates will exhibit the tendency of mean reversion if $\beta < 0$).

According to the argument of Chan *et al.* (1992), the discrete-time econometric specification of the single continuous time process is as follows:

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[6] In Chan *et al.*'s study (1992) *r* refers to the Treasury-bill rates.

$$r_{t+1} - r_t = \alpha + \beta r_t + \varepsilon_{t+1}, \tag{2}$$

$$E_t(\varepsilon_{t+1}) = 0, \tag{3}$$

$$E_t(\varepsilon_{t+1}^2) = \sigma^2 r_t^{2\lambda}, \tag{4}$$

where E_t is the conditional expectation for time t; ε_{t+1} is the error term for time $t+1$; and $E_t(\varepsilon_{t+1}^2)$ is the conditional variance of the error term for time $t+1$. As can be seen from equations (2), (3), and (4), the conditional variance of the error term for time $t+1$ is dominated by the level of commercial paper rates for time t.

To get a more reliable statistical inference, the generalized error distribution (GED) was used by Koutmos (1998) in the parameter estimation of Chan *et al.*'s model (1992). This study also uses the methodology of Koutmos (1998) to investigate the dynamics of commercial paper rates. According to Koutmos' model (1998), the parameters α, β, σ, and λ can be obtained via maximum likelihood estimation. Koutmos (1998), however, found that the sensitivity of interest rate volatility to its level changes was below unity. Therefore, the likelihood function and the functional form of the GED can be described as follows:

$$L(\eta) = \sum_{t=0}^{T-1} \log f[\mu_{t+1}, E_t(\varepsilon_{t+1}^2), \tau], \tag{5}$$

$$f(\mu_{t+1}, \sigma_{t+1}, \tau) = \frac{\tau}{2}[\Gamma(3/\tau)]^{1/2}[(1/\tau)]^{-3/2}(1/\sigma_{t+1}) \exp\{-[\Gamma(3/\tau)/\Gamma(1/\tau)]^{\tau/2}|\varepsilon_{t+1}/\sigma_{t+1}|^{\tau}\}, \tag{6}$$

$$\varepsilon_{t+1} \sim GED[\mu_{t+1}, E_t(\varepsilon_{t+1}^2), \tau], \tag{7}$$

$$\mu_{t+1} = \alpha + \beta r_t, \tag{8}$$

where η is the parameter vector; $\Gamma(\cdot)$ is the density function of the Gamma distribution; τ is the degrees of freedom; $f(\cdot)$ is the conditional density function with τ degrees of freedom; and μ_{t+1} is the conditional mean for time $t+1$ (Koutmos, 1998). According to Koutmos (1998), the normal distribution is present if τ =2, while double exponential distribution is present if τ =1.

3.3. The Variance Ratio Test of Poterba and Summers (1988) for the Commercial Papers Rates

This study mainly applies the variance ratio test of Poterba and Summers (1988) to investigate the mean reversion tendency of commercial paper rates. The variance ratio test divides the variance of returns through different horizons by the variance of one-year holding period returns. While the period of this study is from January 5, 1982 to February 22, 2012, for the daily returns, most materials are selected from dates before December 31, 2000 because prior to that date there are six business days a week for the Taiwanese commercial paper market. Therefore, if it is counted as the one-year holding period return, which is transferred from the daily returns, in this study a 288-day (288 business days) return, R_{1t}^{288}, is the one-year holding period return. As mentioned above, for daily, weekly, monthly, and quarterly returns, the variance ratios, $VR(k_1)$, $VR(k_2)$, $VR(k_3)$, and $VR(k_4)$, are specified respectively as follows:

$$VR(k_1)=\frac{Var\left(R_{1t}^{k_1}\right)}{k_1}\Big/\frac{Var\left(R_{1t}^{288}\right)}{288}, \tag{9}$$

$$VR(k_2)=\frac{Var\left(R_{2t}^{k_2}\right)}{k_2}\Big/\frac{Var\left(R_{2t}^{52}\right)}{52}, \tag{10}$$

$$VR(k_3)=\frac{Var\left(R_{3t}^{k_3}\right)}{k_3}\Big/\frac{Var\left(R_{3t}^{12}\right)}{12}, \tag{11}$$

$$VR(k_4)=\frac{Var\left(R_{4t}^{k_4}\right)}{k_4}\Big/\frac{Var\left(R_{4t}^{4}\right)}{4}, \tag{12}$$

where $R_{1t}^{k_1}=\sum_{i=0}^{k_1-1}R_{1t-i}$; $R_{2t}^{k_2}=\sum_{i=0}^{k_2-1}R_{2t-i}$; $R_{3t}^{k_3}=\sum_{i=0}^{k_3-1}R_{3t-i}$; $R_{4t}^{k_4}=\sum_{i=0}^{k_4-1}R_{4t-i}$; $R_{1t}^{k_1}$, $R_{2t}^{k_2}$, $R_{3t}^{k_3}$, and $R_{4t}^{k_4}$ denote the holding period returns for k_1-day, k_2-week, k_3-month and k_4-quarter, respectively; $Var(R_{1t}^{k_1})$, $Var(R_{1t}^{288})$, $Var(R_{2t}^{k_2})$, $Var(R_{2t}^{52})$, $Var(R_{3t}^{k_3})$, $Var(R_{3t}^{12})$, $Var(R_{4t}^{k_4})$ and $Var(R_{4t}^{4})$ are the variance of

$R_{1t}^{k_1}$, R_{1t}^{288}, $R_{2t}^{k_2}$, R_{2t}^{52}, $R_{3t}^{k_3}$, R_{3t}^{12}, $R_{4t}^{k_4}$ and R_{4t}^{4}, respectively.

Equations (9) to (12) indicate that when the cross holding periods returns are uncorrelated, then the variance ratios of the daily, weekly, monthly, and quarterly returns on commercial papers, $VR(k_l)$, $l=1,2,3,4$, are equal to 1. Additionally, as the variance ratio increases to more than a one-year holding period and is affected by the transitory components, then after lagging for a period of time $VR(k_l)<1$ and $VR(k_l)>1$ show negative and positive autocorrelation for commercial paper rates, respectively. In the end, as the variance ratio is less than the one-year holding period, $VR(k_l)<1$ refers to positive autocorrelation for commercial paper rates, while $VR(k_l)>1$ refers to negative autocorrelation for commercial paper rates.

A comparison of the methods of investigating mean reversion between equation (2) and equations (9)-(12) reveals that the methods of Chan *et al.* (1992) and Koutmos (1998) are more easily affected by data frequency than the variance ratio test of Poterba and Summers (1988). If higher frequency daily or weekly data is used (the previous term here refers to one day or one week before), it is more likely that the conclusions regarding mean reversion using daily or weekly return data will be contaminated by other factors (*e.g.*, bid-ask spread, infrequent trading and so on). Furthermore, Poterba and Summers (1988) neglected the effect of commercial paper rate volatilities, which is either positive (increasing interest rates) or negative (reducing interest rates). For example, the dramatic increase or decrease of commercial paper rates will result in the increase of their variance, but the method of Poterba and Summers (1988) cannot determine which (increase or decrease) causes the increasing variance. If the commercial paper rate was first dramatically increased and then slightly increased, the same empirical result would occur as that of, "the commercial paper rate that dramatically increased and then slightly decreased." The former, however, during the research period did not gradually return to the long-term average level. Then, the biased conclusion with mean reversion exhibition of commercial paper rates may be derived.

3.4. The Variance Ratio Test of Lo and MacKinlay (1988) for the Commercial Papers Rates

In addition to the investigations on the dynamics and the mean reversion of commercial paper rates, this study applies the variance ratio test of Lo and MacKinlay (1988) to explore whether the commercial paper rates across frequencies follow random walk in order to completely understand the behavior of commercial paper rates. Compared to the variance ratio test of Poterba and Summers (1988), the variance ratio test of Lo and MacKinlay (1988) had three features: First, the variance ratio test of Poterba and Summers (1988) used the variance on the one-year holding period returns as a benchmark and calculated the ratio of the variance on the k-year holding period returns divided by k to the variance on the one-year holding period returns, while Lo and MacKinlay (1988) applied the number of the base observations accumulated to compute variance ratio and their autocorrelation coefficient estimators of the first-order differences to calculate the variance ratio for a certain period with base observations. Second, the variance ratio test of Lo and MacKinlay (1988) can calculate the standard test statistic for the variance ratios to examine whether the commercial paper rates follow random walk or fit a mean-reverting process, which is different from the variance ratio test of Poterba and Summers (1988). Finally, Lo and MacKinlay (1988) used the autocorrelation coefficient estimators of the first-order differences of commercial paper rates to calculate the approximate value of variance ratio, and the autocorrelation coefficient estimators of the first-order differences of commercial paper rates are affected by the number of the base observations of commercial paper rates accumulated to compute variance ratio. Thus, the accuracy of variance ratios is dominated by the number of base observations of commercial paper rates accumulated to compute variance ratios.

According to the variance ratio test of Lo and MacKinlay (1988), the variance ratio [$Mr(q)$] and the standard test statistic for the variance ratio [$Z^*(q)$] are as follows:

$$Mr(q) = \sum_{j-1}^{q-1} \frac{2(q-j)}{q} \hat{\rho}(j) \tag{13}$$

$$Z^*(q) = \sqrt{\mathrm{nq}}\, Mr(q) / \sqrt{\hat{\theta}(q)} \tag{14}$$

$$\hat{\theta}(q) = \sum_{j=1}^{q-1} [\frac{2(q-j)}{q}]^2 \hat{\delta}(j) \tag{15}$$

$$\hat{\delta}(j) = \frac{\sum_{h=j+1}^{nq} (r_h - r_{h-1} - \hat{u})^2 (r_{h-j} - r_{h-j-1} - \hat{u})^2}{[\sum_{h=1}^{nq} (r_h - r_{h-1} - \hat{u})^2]^2} \tag{16}$$

$$\hat{u} = \frac{1}{nq} \sum_{h=1}^{nq} (r_h - r_{h-1}) \tag{17}$$

where, q is the number of base observations accumulated to compute variance ratio. nq is the number of base observations. $\hat{\rho}(j)$ refers to the jth-order autocorrelation coefficient estimators of the first-order differences of commercial paper rates across frequencies. r_h refers to the h-th base observation of commercial paper rates across frequencies (Lo and MacKinlay, 1988).

Lo and MacKinlay (1988) argued that the null hypothesis of random walk for commercial paper rates should be rejected as $Mr(q)$ was significantly different from zero. In addition, if commercial paper rates fit a mean reversion process, then $1+Mr(2)$ is significantly less than 1 [*i.e.*, $Mr(2)$ is significantly less than zero] and the absolute value of the significant negative $Z^*(q)$ should be larger as q increases.

Notably that the methods of Chan *et al.* (1992), Koutmos (1998), Poterba and Summers (1988), and Lo and Mackinlay (1988) all examined the mean-reverting speed of financial asset prices. If commercial paper rates are mean-reverting, then the behavior of commercial paper rates will demonstrate two types of characteristics as bellow: The first is to be described from the perspective of commercial paper rate level and its first-order difference that believes the higher the commercial paper rate for time t-1, the smaller first-order difference of commercial paper rates will be found for time t. Another type of characteristic is

described from the perspective of volatility of commercial paper rates at different return measurement intervals (*i.e.*, holding periods) that believe the average volatilities of commercial paper rates per unit time interval at the longer return measurement interval shall be smaller than those at the shorter return measurement interval. Only when one of two said types of characteristics is satisfied (or both are satisfied), will commercial paper rates gradually return to the long-term average level. Chan *et al.* (1992) and Koutmos (1998) constructed their method based on the first type of characteristic and investigated the existence of negative autocorrelation between the commercial paper rates at the previous term and current term, while Poterba and Summers (1988) used the second type of characteristics and surveyed whether variance of commercial paper rate for k-unit time interval divided by k is smaller than that for 1-unit time interval (Poterba and Summers utilized a one-year holding period as the benchmark and one year to distinguish short- and long-term).

The variance ratio test of Lo and Mackinlay (1988) was constructed on both above characteristics of mean-reverting. Although, as the variance ratio test of Poterba and Summers (1988) did, the variance ratio test of Lo and Mackinlay (1988) also measured variance ratios of the research variable (in this study, research variable refers to commercial paper rates) at the return measurement intervals, yet Lo and Mackinlay (1988) used the autocorrelation coefficient estimators of the first-order differences of research variable to calculate the approximate value of variance ratio. Hence, the empirical results regarding mean reversion applying the variance ratio test of Lo and Mackinlay (1988) are rationally expected to be approximate to ones exploiting the method of Koutmos (1998).

4. Empirical Results

4.1. The Dynamics of Commercial Paper Rates across Frequencies

This study applies the methodology of Koutmos (1998) to investigate the dynamics of commercial paper rates across four different frequencies for the

money market in Taiwan (*i.e.*, the less sophisticated market compared with the US). Before examining the dynamics of commercial paper rates, this study adopted the augmented Dickey-Fuller (ADF) unit root test of Said and Dickey (1984) to investigate whether the return data on the commercial paper across the four frequencies exhibit the stationary characteristic for the avoidance of spurious regression resulting from a non-stationary data structure. The empirical results indicate that all four return data on the commercial paper for the three models (*i.e.*, "the pure random walk model," "the model with a drift term," and "the model with a drift and linear time trend") display stationary characteristics.[7] Therefore, this study can use the return data on the commercial paper across the four different frequencies to examine the behavior of commercial paper rates.

Table 2 presents parameter estimates of the model given by equations (2)-(8) using return data across the four frequencies. The results of daily returns in Table 2 show that parameter α for the daily return data is insignificantly different from zero, but parameter β for the daily return data is significantly less than zero. Parameter β represents the speed of mean-reverting; its significance means that there appears to be evidence of mean reversion in the commercial paper rates for the daily return data. According to the argument of Koutmos (1998), mean reversion is hard to detect in frequent data such as daily and weekly; however, in my findings, the significant evidence of mean reversion using daily return data is inconsistent with Koutmos' (1998) studies. The reason for the existence of the mean reversion tendency of the daily return data in my findings may arise from the low level of sophistication in the Taiwanese commercial paper market. The Taiwanese commercial paper market was established in 1976 and it only has a history of 36 plus years. Comparatively, the development history of Taiwanese commercial paper market is shorter than that of Europe, the US, and Japan. Before 1995, there were only three bills financing corporations and by the end of 2008 the number had increased to 14, indicating, few players in the market. By July 9, 2001, when the Act Governing Bills Finance Business was implemented, the trading in the money market finally had its legal base. Since

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[7] This study doesn't report the results of the ADF unit root test for shortening.

then, Taiwanese commercial paper market has experienced significant growth. Overall, the structure of market participants of commercial paper is mainly institutional investors and its market maturity is greater than that of the Taiwanese stock market composed primarily of retail investors. However, when compared to the commercial paper markets of developed countries, Taiwanese commercial paper is at a comparatively low sophistication level. The low sophistication of the Taiwanese investors causes the prices of money market instruments to deviate frequently from their intrinsic value, and then the behavior of mean reversion is detected in the high frequency data.

Parameters σ and λ represent the linkage between the conditional variance of commercial paper rates and their level (Koutmos, 1998). From the results of daily returns in Table 2, parameters σ and λ for the daily return data are both significantly more than zero. These findings support the claims in the previous literature (*e.g.*, Chan *et al.*, 1992; Koutmos, 1998) that showed that the dependence of interest rate volatility on its level is the most important feature of short-term interest rate dynamics. Moreover, in contrast with the findings of Chan *et al.* (1992), the elasticity of Treasury bill rates is 1.5, this study, as in the findings of Koutmos (1998), finds the estimator of λ for the daily return data is less than one (*i.e.*, 0.613). According to equations (2) to (4), the estimator of the elasticity of commercial paper rates, 0.613, indicates that the volatility of the commercial paper rates will change by approximately 1.226 basis points (*i.e.*, 2λ) if their level changes by one basis point. The estimator of λ for daily return data is less than one, which also means that the commercial paper rates process is stationary.

The results of daily returns in Table 2 display that the estimator of parameter τ for the daily return data is somewhat less than one and significantly greater than zero. This result is inconsistent with the claim that the normal distribution requires the estimated degrees of freedom (*i.e.*, parameter τ) be equal to 2. In other words, according to the argument of Koutmos (1998), the above result regarding the estimator of τ means that the shape of the distribution of commercial paper rates for daily return data may be a double exponential or Laplace density function.

Table 2

Maximum Likelihood Estimates of the Koutmos' (1998) Models Using Daily, Weekly, Monthly, and Quarterly Returns on the Commercial Papers

Frequencies	α	β	σ	λ	τ
Daily Returns	2.63×10^{-6} (0.956)	-4.54×10^{-4} (-2.965)**	0.001 (78.562)**	0.613 (56.251)**	0.784 (59.416)**
Weekly Returns	4.59×10^{-5} (0.696)	-0.001 (-1.165)	5.36×10^{-7} (49.770)**	0.662 (45.978)**	0.860 (42.385)**
Monthly Returns	0.001 (2.542)**	-0.008 (-3.156)**	1.32×10^{-6} (30.172)**	0.627 (52.760)**	1.278 (67.802)**
Quarterly Returns	0.029 (4.171)**	-0.060 (-5.297)**	0.001 (40.323)**	0.584 (49.394)**	1.137 (59.216)**

Note: "*" and "**" refer to significant at the 10 and 5 percent level, respectively; Figures in parentheses are *t*-statistic.

The results using weekly returns are also presented in Table 2. Compared with the results of daily returns in Table 2, excluding the parameter β, there are no significant differences between the results of the daily return data and those of the weekly return data. The results of weekly returns in Table 2 show that first, the parameter α remains insignificantly different from zero, both statistically and numerically. Although the tendency of mean reversion for the weekly returns on the commercial papers (*i.e.*, parameter β) is statistically insignificant, both the negative value of parameter β and its marginal significance (*i.e.*, the absolute value of *t*-statistic is greater than 1) indicate the weak evidence of mean-reverting tendency for weekly return data. Second, the parameters σ and λ linking volatility to the level of commercial paper rates are significantly greater than zero. This implies the positive dependence of commercial paper rate volatility on its level for weekly return data. Third, the sensitivity of commercial paper rate volatility to its level (*i.e.*, parameter λ) is less than one and implies the process of weekly returns on commercial papers is stationary. Finally, as in the results using the daily return data, the estimator of τ for the weekly return data is also

somewhat less than one and significantly more than zero. This means that the probability density function of weekly returns on commercial papers violates the assumption of normality.

Although the parameter α in the results of monthly returns in Table 2 is insignificantly different from zero, the results using monthly returns are similar to those using the daily and weekly return data. In detail, both the parameters σ and λ are a significant positive value as those of daily and weekly return data, indicating the significant interrelationship between commercial paper rate volatility and its level. Additionally, parameter β of monthly return data is significantly smaller than zero and its absolute *t*-statistic is greater than those of daily and weekly return data. The higher statistical significance of parameter β provides supportive evidence for the existence of mean reversion of monthly returns on commercial paper and sustains the argument that from low frequency data, it is easier to detect the tendency of mean reversion than from high frequency data. However, interestingly the parameter τ using monthly data is above unity and higher than those using daily and weekly data. According to Koutmos' (1998) argument, the distribution of short-term interest rates is normal if τ =2. Therefore, the double exponential or Laplace density function is less appropriate for the distribution of monthly returns on commercial papers than for the distribution of the daily and weekly return data.

For further investigation of the impact of data frequencies on the commercial paper dynamics, this study also introduces quarterly returns for empirical analysis that indicate the similar result of monthly returns where the estimators of α, β, σ, λ, and τ are 0.029, -0.060, 0.001, 0.584, and 1.137, respectively (as shown in the result of quarterly returns in Table 2). This result not only finds the dependence of commercial paper rate volatility on its level and the tendency of mean reversion for the quarterly return data, but also supports the argument: The lower the frequency data, the easier detection by mean reversion. Meanwhile, the double exponential or Laplace density function is more suitable for the distribution of return data with a higher frequency.

4.2. The Dynamics of Commercial Paper Rates across Frequencies for the Periods before and after the Five Great Events

In terms of the selection of great events, this study selects the most serious impasse in cross-strait relations (the Taiwan Strait missile crisis in 1996), the greatest economic event (the Asian financial crisis in 1997), the most devastating natural disaster (the 921 earthquake in 1999), the greatest political event (the presidential election in 2000), and the most closely linked international event (the 911 terrorist attacks in 2001) faced by Taiwan during the research period as research subjects. Great events may lead to an obvious change of commercial paper rate behavior in emerging markets such as Taiwan because Sias, Starks, and Tinic (2001) indicated that when there are more noise traders in a market (*i.e.*, an emerging market), the returns tend to show higher volatility and outstanding mean reversion. In addition, the five great events selected by this study have different attributes while different types of great events may result in difference of commercial paper rate behavior. As a result, the comparison of the dynamics of commercial paper rates for the periods before and after the above five great events will help understand the difference among the impact of a cross-strait impasse, economic event, natural disaster, political event, and international event on commercial paper rate behavior.

Panel A of Table 3 presents parameter estimates of the model given by equations (2)-(8) using daily return data for the periods before and after the five great events, respectively. From Panel A of Table 3, the majority of the estimators of parameter α are statistically insignificant for the periods before and after the five great events. In addition, this study supports that the level of commercial paper rates is a crucial determinant of the volatility of commercial paper rates because the estimators of parameters σ and λ are all positive and statistically significant using daily return data for the periods before and after the five great events. The result also shows that the sensitivity of volatility on commercial paper rates is less than one and that the volatility is dependent on the level of commercial paper rates. Moreover, in terms of parameter τ, its estimators using daily return data are all less than one for the periods before and after the five great

events, and this implies that normality is not an appropriate probability density function for the daily returns on commercial papers. In the end, the estimators of parameter β are significantly less than zero for the periods after the Taiwan Strait missile crisis, the Asian financial crisis, and the 921 earthquake, but it is a positive value for the period after the 911 terrorist attacks. The above result indicates that the main influence of the great events on commercial paper rate behavior is the changes in the speed of mean-reverting around the great events.

In short, comparing the difference of the dynamics using daily return data for the periods between before and after the five great events, the changes in the dynamics appear to be insensitive to the five great events excluding the speed of mean-reverting (parameter β). If the five great events are viewed as a single event, the statistical significance of the estimated parameters for the period before the "whole" five great events is also similar to that after the "whole" five great events (as shown in the first three lines and the last three lines in Panel A of Table 3). In terms of the comparison between the impacts of "individual" great events, the most insensitive evidence among them is the reaction to the Taiwan Presidential election in 2000. The reasoning for this may arise from the fact that the effects of the 2000 Taiwan Presidential election on the commercial paper rate volatility are smaller than those of the Taiwan Strait missile crisis, the Asian financial crisis, the 921 earthquake, and the 911 terrorist attacks in the US. The empirical results provide evidence that the variation of commercial paper rates depends on fundamental economic factors, and that the impact of political factors on the level of commercial paper rates is limited.

For determining why cross-strait impasse, financial crisis, natural disasters, and international events generate a more profound impact on commercial paper rate dynamics than political events, three possible reasons are listed: The difference of substantial economic loss, the changes in investors' sentiments, and the expectation of investors. The 921 earthquake caused Taiwan an economic loss as high as NT$ 360 billion and according to S&P report,[8] the 911 terrorist attacks generated a loss to the US of US$ 150 billion as the US is one of the leading

[8] S&P is the abbreviation of Standard and Poor's Corporation.

trading partners of Taiwan. However, the presidential election held in 2000 did not cause Taiwan any substantial economic loss. As a result, there is a limited difference of commercial paper rate dynamics between before and after the 2000 presidential election. Furthermore, although the influence of the Asian financial crisis on Taiwan's economy is small in comparison with other Asian countries, investors' sentiments after the Taiwan Strait missile crisis and the Asian financial crisis are more pessimistic than those after the 2000 presidential election. In the end, since Taiwanese democratic reform in the 1980s, political development has matured. Investors in the financial market speculated that the shift in ruling power in Taiwan and the result of the presidential election in 2000 did not deviate from the expectations of investors, so this political event has less of an impact on financial asset price behavior than the other four.

The estimators of the parameters using weekly return data for the periods before and after the five great events are presented in Panel B of Table 3. A comparison of the parameters listed in Panel A of Table 3 with those in Panel B of Table 3 reveals that they are similar excluding parameter β. The results of weekly return data again indicate that the main influence of the great events on commercial paper rate dynamics is the difference of mean-reverting tendency between before and after the great events. However, in contrast to the results of the daily return data, the results using weekly return data reveal a significant tendency of mean reversion for the period before the great events excluding the 911 terrorist attacks. This implies that the data frequencies had an impact on the mean-reverting speed of commercial paper rates around the great events. Additionally, as in the results of the daily return data, the differences of estimators of parameters σ, λ, and τ using weekly return data for the periods before and after the five great events are all somewhat obscure. This means that the great events did not affect the linkage between the conditional variance of commercial paper rates and their level as well as the shape of the distribution of commercial paper rates.

Panel C of Table 3 presents the estimators of the 5 parameters using monthly return data for the periods before and after the five great events. As for the findings of weekly return data, Panel C of Table 3 shows that the statistical

significance of parameters σ, λ, and τ using monthly return data for the periods before the five great events are almost identical to those after the five great events. In addition, excluding the 921 earthquake, the supportive evidence of mean reversion only exists for the periods before the great events. The above results indicate that the impact of great events on commercial paper rate dynamic using monthly return data mainly presents a significantly different picture for the tendency of mean reversion before the events with that after the events.

The estimators of the 5 parameters using quarterly return data for the periods before and after the five great events are shown in Panel D of Table 3. From Panel D of Table 3, the differences of the statistical significance of parameters α, β, σ, λ, and τ using quarterly return data for the periods between before and after the five great events are all somewhat obscure. This not only proves the argument that it is easier to detect the tendency of mean reversion from low frequency data, but also indicates that the influences of great events on commercial paper rate dynamic using the low frequency data are lower than those using high frequency data.

Table 3

Maximum Likelihood Estimates of the Koutmos' (1998) Models Using Daily, Weekly, Monthly, and Quarterly Returns on the Commercial Paper before and after the Five Great Events

	α	β	σ	λ	τ
Panel A: Daily Returns					
Before Missile Crisis	6.39×10^{-6}	-3.66×10^{-4}	0.001	0.586	0.737
(Before Five Great Events)	(0.438)	(-0.542)	(16.345)**	(47.582)**	(58.745)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	4.53×10^{-6}	-0.001	0.001	0.641	0.860
(1996/03/08 to 2012/02/22)	(2.275)**	(-4.759)**	(59.227)**	(56.189)**	(63.292)**
Before Financial Crisis	4.40×10^{-6}	-2.83×10^{-4}	0.001	0.592	0.746
(1982/01/05 to 1997/06/30)	(0.319)	(-0.435)	(18.601)**	(49.650)**	(60.030)**
After Financial Crisis	7.42×10^{-6}	-0.001	2.20×10^{-4}	0.633	0.851
(1997/07/02 to 2012/02/22)	(2.568)**	(-7.582)**	(54.02)**	(52.463)**	(62.519)**
Before 921 Earthquake	1.32×10^{-6}	-9.96×10^{-5}	0.001	0.573	0.761
(1982/01/05 to 1999/09/20)	(0.101)	(-0.159)	(23.096)**	(48.713)**	(59.377)**
After 921 Earthquake	3.28×10^{-6}	-0.001	1.58×10^{-4}	0.670	0.818
(1999/09/23 to 2012/02/22)	(1.363)	(-2.630)**	(52.730)**	(54.704)**	(64.311)**
Before Presidential Election	3.36×10^{-6}	-2.03×10^{-4}	0.001	0.579	0.770
(1982/01/05 to 2000/03/17)	(0.273)	(-0.343)	(24.289)**	(47.878)**	(65.924)**

After Presidential Election	$7.60e\times10^{-7}$	-1.57×10^{-4}	1.59×10^{-4}	0.662	0.805
(2000/03/20 to 2012/02/22)	(0.294)	(-0.580)	(60.806)**	(53.812)**	(63.557)**
Before 911 Terrorist Attacks	2.29×10^{-7}	-1.95×10^{-5}	0.001	0.584	0.767
(1982/01/05 to 2001/09/11)	(0.020)	(-0.035)	(27.370)**	(46.955)**	(61.970)**
After 911 Terrorist Attacks	-4.32×10^{-6}	0.001	2.56×10^{-4}	0.659	0.812
(After Five Great Events)	(-1.331)	(1.608)	(53.329)**	(52.846)**	(66.075)**
(2001/09/12 to 2012/02/22)					
Panel B: Weekly Returns					
Before Missile Crisis	0.002	-0.016	1.49×10^{-4}	0.634	0.893
(Before Five Great Events)	(3.790)**	(-4.561)**	(55.734)**	(42.796)**	(48.124)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	-5.50×10^{-6}	1.57×10^{-4}	5.22×10^{-7}	0.680	0.836
(1996/03/08 to 2012/02/22)	(-0.068)	(0.113)	(17.680)**	(47.573)**	(38.955)**
Before Financial Crisis	0.002	-0.016	8.62×10^{-5}	0.638	0.902
(1982/01/05 to 1997/06/30)	(3.796)**	(-4.652)**	(49.978)**	(43.814)**	(46.139)**
After Financial Crisis	-1.06×10^{-6}	4.65×10^{-5}	2.74×10^{-4}	0.672	0.824
(1997/07/02 to 2012/02/22)	(-0.012)	(0.033)	(17.132)**	(44.793)**	(40.220)**
Before 921 Earthquake	0.002	-0.015	1.49×10^{-4}	0.624	0.918
(1982/01/05 to 1999/09/20)	(3.858)**	(-4.611)**	(60.081)**	(39.879)**	(45.683)**
After 921 Earthquake	-3.94×10^{-6}	1.19×10^{-4}	2.26×10^{-7}	0.715	0.820
(1999/09/23 to 2012/02/22)	(-0.045)	(0.076)	(14.193)**	(45.622)**	(39.416)**
Before Presidential Election	0.001	-0.013	8.93×10^{-7}	0.617	0.915
(1982/01/05 to 2000/03/17)	(3.666)**	(-4.613)**	(56.143)**	(37.331)**	(46.292)**
After Presidential Election	5.52×10^{-6}	-1.63×10^{-4}	1.35×10^{-6}	0.725	0.827
(2000/03/20 to 2012/02/22)	(0.067)	(-0.098)	(17.599)**	(51.719)**	(41.248)**
Before 911 Terrorist Attacks	2.76×10^{-4}	-0.003	1.49×10^{-4}	0.620	0.910
(1982/01/05 to 2001/09/11)	(1.027)	(-1.135)	(49.984)**	(40.183)**	(46.205)**
After 911 Terrorist Attacks	-1.62×10^{-5}	4.68×10^{-4}	3.26×10^{-7}	0.716	0.838
(After Five Great Events)	(-0.116)	(0.138)	(18.589)**	(46.544)**	(37.689)**
(2001/09/12 to 2012/02/22)					
Panel C: Monthly Returns					
Before Missile Crisis	0.057	-0.110	3.01×10^{-4}	0.584	1.386
(Before Five Great Events)	(4.365)**	(-5.381)**	(37.183)**	(47.825)**	(68.579)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	-5.66×10^{-5}	4.37×10^{-4}	3.25×10^{-7}	0.650	1.140
(1996/03/08 to 2012/02/22)	(-2.465)**	(1.317)	(17.220)**	(58.318)**	(57.662)**
Before Financial Crisis	0.057	-0.111	4.68×10^{-4}	0.592	1.381
(1982/01/05 to 1997/06/30)	(4.824)**	(-5.796)**	(31.259)**	(48.133)**	(67.392)**
After Financial Crisis	5.58×10^{-7}	-3.98×10^{-6}	1.73×10^{-6}	0.649	1.195
(1997/07/02 to 2012/02/22)	(1.007)	(-1.185)	(22.252)**	(56.890)**	(58.577)**
Before 921 Earthquake	0.062	-0.124	3.30×10^{-4}	0.595	1.351
(1982/01/05 to 1999/09/20)	(5.577)**	(-6.842)**	(37.085)**	(50.145)**	(66.187)**
After 921 Earthquake	1.34×10^{-4}	-0.010	3.31×10^{-7}	0.643	1.204
(1999/09/23 to 2012/02/22)	(2.583)**	(-3.664)**	(17.947)**	(55.943)**	(59.458)**
Before Presidential Election	0.054	-0.107	1.96×10^{-4}	0.598	1.345
(1982/01/05 to 2000/03/17)	(5.162)**	(-6.133)**	(37.332)**	(51.714)**	(64.894)**
After Presidential Election	-8.68×10^{-6}	5.82×10^{-5}	1.71×10^{-6}	0.637	1.213

(2000/03/20 to 2012/02/22)	(-0.506)	(0.325)	(12.835)**	(56.806)**	(61.539)**
Before 911 Terrorist Attacks	0.026	-0.060	3.02×10^{-4}	0.602	1.348
(1982/01/05 to 2001/09/11)	(3.165)**	(-3.982)**	(36.181)**	(51.179)**	(65.702)*
After 911 Terrorist Attacks	6.55×10^{-6}	-4.14×10^{-5}	1.69×10^{-6}	0.636	1.212
(After Five Great Events)	(1.497)	(-1.496)	(18.013)**	(53.095)**	(58.985)*
(2001/09/12 to 2012/02/22)					
Panel D: Quarterly Returns					
Before Missile Crisis	0.421	-0.261	0.007	0.563	0.958
(Before Five Great Events)	(3.442)**	(-4.091)**	(49.586)**	(48.125)**	(56.432)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	0.029	-0.068	1.34×10^{-4}	0.606	1.307
(1996/03/08 to 2012/02/22)	(3.409)**	(-4.208)**	(23.091)**	(51.797)**	(61.801)**
Before Financial Crisis	0.457	-0.278	0.018	0.568	0.944
(1982/01/05 to 1997/06/30)	(3.978)**	(-4.557)**	(45.348)**	(49.879)**	(57.624)**
After Financial Crisis	0.023	-0.047	0.002	0.599	1.316
(1997/07/02 to 2012/02/22)	(2.646)**	(-4.212)**	(27.941)**	(49.521)**	(60.289)**
Before 921 Earthquake	0.342	-0.225	0.001	0.570	1.039
(1982/01/05 to 1999/09/20)	(3.487)**	(-4.271)**	(41.615)**	(46.545)**	(60.524)**
After 921 Earthquake	0.038	-0.081	0.004	0.602	1.245
(1999/09/23 to 2012/02/22)	(3.062)**	(-3.905)**	(24.094)**	(52.833)**	(63.807)**
Before Presidential Election	0.341	-0.225	0.001	0.575	1.052
(1982/01/05 to 2000/03/17)	(3.736)**	(-4.537)**	(42.647)**	(50.630)**	(58.409)**
After Presidential Election	0.052	-0.110	0.004	0.596	1.241
(2000/03/20 to 2012/02/22)	(4.529)**	(-5.536)**	(26.878)**	(48.694)**	(62.059)**
Before 911 Terrorist Attacks	0.331	-0.221	0.007	0.578	1.045
(1982/01/05 to 2001/09/11)	(3.963)**	(-4.715)**	(33.428)**	(49.512)**	(59.167)**
After 911 Terrorist Attacks	0.077	-0.181	0.002	0.595	1.239
(After Five Great Events)	(3.692)**	(-4.268)**	(29.511)**	(48.343)**	(60.058)**
(2001/09/12 to 2012/02/22)					

Note: "*" and "**" refer to significant at the 10 and 5 percent level, respectively; Figures in parentheses are *t*-statistic.

4.3. The Mean Reversion of Commercial Paper Rates across Frequencies

This study uses the variance ratio test of Poterba and Summers (1988) to examine the mean-reverting speed of commercial papers rates, and counts the variance ratios of the daily, weekly, monthly, and quarterly return data across different observation periods. The variance ratio [*i.e.*, $VR(k_l)$] refers to the ratio of the variance on the *k*-year holding period returns divided by *k* to the variance on the one-year holding period returns. Therefore, as the time interval of a certain holding period increases to more than one year, $VR(k_l)<1$ shows negative

autocorrelation (*i.e.*, the commercial paper rates are affected by the transitory components and follow a mean reversion process) while $VR(k_1)>1$ shows positive autocorrelation. On the other hand, as the time interval of a certain holding period is less than the one year, $VR(k_1)<1$ refers to positive autocorrelation, while $VR(k_1)>1$ refers to negative autocorrelation. Table 4 displays the Poterba and Summers' (1988) variance ratios of commercial paper rates across the four frequencies.

From Table 4, the results of the daily, weekly, monthly, and quarterly return data all show that the commercial paper rates experience positive autocorrelation for the short term (shorter than one year) and negative autocorrelation for the "very" long term (more than 20-year or 24-year).[9] That is, this study finds the evidence of mean reversion over "very" long horizons for the Taiwanese commercial paper market. Further, in comparison with the supportive evidence of mean reversion of weekly, monthly, and quarterly return data after lagging for more than 24 years, the empirical results of the daily return data display that mean reversion is pronounced for holding period returns on commercial papers after lagging for more than 20 years. The findings of the daily return data are inconsistent with the proposition of Balvers, Wu, and Gilliland (2000) that higher frequency data offer less additional information to detect a mean-reverting component. This study suggests that the reason for the significant mean-reverting behavior of the high frequency data might be from thin trading in the Taiwanese commercial paper market. In addition, the low sophistication of the Taiwanese commercial paper market may also contribute to the negative autocorrelation of high frequency data.

The results of monthly returns in Table 4 showing the negative autocorrelation of commercial paper rates after lagging for more than 24 years indicate the mean reversion of monthly returns on commercial papers in Taiwan, these empirical results vary from the findings of Hays *et al.* (2000) (who declared the finding of negative autocorrelation of short-term interest rates after lagging for more than one year). Explanations for the inconsistent results may arise from

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[9] The long term refers to a return measurement interval that is greater than one year.

different research methods being used and the possible long-time overreaction of investors in the Taiwanese commercial paper market. Comparatively speaking, investors in Taiwan are more likely to overreact to information shocks for a longer period of time than those in the US money markets, which leads to the slow speed of mean-reverting.

Table 4

The Poterba and Summers' (1988) Variance Ratios of Commercial Paper Rates across Frequencies

	Return Measurement Interval										
	1 Day	1 Week	1 Month	1 Quarter	2 Years	4 Years	8 Years	12 Years	16 Years	20 Years	24 Years
Daily Returns	0.004	0.026	0.101	0.288	1.764	2.837	4.084	3.497	2.042	0.782	0.338
Weekly Returns	—	0.023	0.092	0.265	1.781	2.925	4.642	4.417	2.321	1.284	0.379
Monthly Returns	—	—	0.102	0.287	1.780	2.929	4.645	4.401	2.940	1.233	0.367
Quarterly Returns	—	—	—	0.294	1.772	2.926	4.674	4.469	3.027	1.298	0.377

Note: "—" refers to the uncountable variance ratio because of the different data types.

On the whole, the implication of mean-reverting evidence in this study regarding the Taiwanese commercial paper market coincides with previous research, which focuses on short-term interest rates in developed countries (Adkins and Krehbiel, 1999; Casassus and Collin-Dufresne, 2005; Staikouras, 2006). The empirical results suggest that commercial paper rates across frequencies are negatively autocorrelated in the 'very" long term and adopting a contrarian strategy [10] for commercial paper investment will obtain better performance compared to using a momentum strategy.[11] In addition, this study shows evidence of countering the weak-form efficient commercial paper market

[10] The contrarian investing is a strategy of exploiting mispricing, which buys the underperforming financial assets over the past 5 years (past losers) and sells the outperforming ones over the past 5 years (past winners).

[11] The momentum investing is a strategy of exploiting mispricing, which buys the outperforming financial assets over the past 6 months (recent winners) and sells the underperforming ones over the past 6 months (recent losers).

and investors' preference for long-term investment as a result of risk consideration.

4.4. The Mean Reversion of Commercial Paper Rates across Frequencies for the Periods before and after the Five Great Events

In order to further understand the influence of the great events on the mean reversion behavior of commercial paper rates, this study analyzes the changes of mean-reverting speed for the periods before and after the Taiwan Strait missile crisis, the Asian financial crisis, the Taiwan 921 earthquake, the Taiwan Presidential election in 2000, and the 911 terrorist attacks, respectively. Moreover, the influential differences of these great events on the behavior of commercial paper rates across the four frequencies are compared. The empirical results are listed in Table 5.

The empirical results across the four frequencies in Table 5 all show that both before and after the five great events, the variance ratios of Poterba and Summers (1988) with less than 1-year return measurement interval are smaller than 1. This implies that the commercial paper rates are positively autocorrelated in the short-term (less than 1 year). Additionally, the commercial paper rates are negatively autocorrelated after lagging 2, 4, 6 or 8 years except for those after the Taiwan Strait missile crisis and the Asian financial crisis (*i.e.*, the variance ratios of Poterba and Summers (1988) with 8-year return measurement interval are greater than 1). The above results do not contradict the finding of the whole research period in Table 4: The commercial paper rates are positively and negatively autocorrelated in the short-term and "very" long-term (more than 20 years), respectively.

Comparing the variance ratios of Poterba and Summers (1988) exploited by this study between before and after the five great events in Table 5, this study finds that the mean-reverting speeds of commercial paper rates across frequencies after the first two (the Taiwan Strait missile crisis and the Asian financial crisis) and the last three (the Taiwan 921 earthquake, the 2000 Presidential election, and the 911 terrorist attacks) are slower and faster than before, respectively. This not

Table 5

The Poterba and Summers' (1988) Variance Ratios of Commercial Paper Rates across Frequencies for the Periods before and after the Five Great Events

	1 Day	1 Week	1 Month	1 Quarter	2 Years	4 Years	6 Years	8 Years
Panel A: Daily Returns								
Before Missile Crisis (Before Five Great Events) (1982/01/05 to 1996/03/07)	0.005	0.032	0.124	0.333	1.581	1.821	1.305	0.236
After Missile Crisis (1996/03/08 to 2012/02/22)	0.004	0.023	0.089	0.264	1.798	2.406	2.058	1.411
Before Financial Crisis (1982/01/05 to 1997/06/30)	0.005	0.033	0.126	0.338	1.543	1.736	1.242	0.458
After Financial Crisis (1997/07/02 to 2012/02/22)	0.004	0.027	0.106	0.310	1.533	1.685	1.157	0.903
Before 921 Earthquake (1982/01/05 to 1999/09/20)	0.006	0.033	0.129	0.346	1.512	1.659	1.150	0.451
After 921 Earthquake (1999/09/23 to 2012/02/22)	0.005	0.027	0.108	0.313	1.102	0.480	0.330	0.577
Before Presidential Election (1982/01/05 to 2000/03/17)	0.006	0.033	0.128	0.344	1.481	1.623	1.119	0.445
After Presidential Election (2000/03/20 to 2012/02/22)	0.005	0.033	0.129	0.368	0.957	0.327	0.233	0.489
Before 911 Terrorist Attacks (1982/01/05 to 2001/09/11)	0.006	0.033	0.128	0.343	1.488	1.564	1.097	0.499
After 911 Terrorist Attacks (After Five Great Events) (2001/09/12 to 2012/02/22)	0.005	0.031	0.121	0.343	1.160	0.403	0.086	0.091
Panel B: Weekly Returns								
Before Missile Crisis (Before Five Great Events) (1982/01/05 to 1996/03/07)	—	0.030	0.116	0.313	1.571	1.786	1.263	0.214
After Missile Crisis (1996/03/08 to 2012/02/22)	—	0.021	0.082	0.241	1.794	2.441	2.221	1.647
Before Financial Crisis (1982/01/05 to 1997/06/30)	—	0.030	0.118	0.318	1.533	1.701	1.205	0.432
After Financial Crisis (1997/07/02 to 2012/02/22)	—	0.024	0.096	0.281	1.547	1.821	1.309	1.020
Before 921 Earthquake (1982/01/05 to 1999/09/20)	—	0.031	0.121	0.326	1.497	1.618	1.107	0.430
After 921 Earthquake (1999/09/23 to 2012/02/22)	—	0.024	0.097	0.282	1.217	0.636	0.331	0.507
Before Presidential Election (1982/01/05 to 2000/03/17)	—	0.031	0.120	0.324	1.466	1.580	1.075	0.424

After Presidential Election (2000/03/20 to 2012/02/22)	—	0.028	0.112	0.323	1.055	0.452	0.194	0.468
Before 911 Terrorist Attacks (1982/01/05 to 2001/09/11)	—	0.031	0.119	0.321	1.476	1.515	1.065	0.499
After 911 Terrorist Attacks (After Five Great Events) (2001/09/12 to 2012/02/22)	—	0.027	0.106	0.302	1.256	0.673	0.011	0.155
Panel C: Monthly Returns								
Before Missile Crisis (Before Five Great Events) (1982/01/05 to 1996/03/07)	—	—	0.133	0.340	1.574	1.826	1.327	0.239
After Missile Crisis (1996/03/08 to 2012/02/22)	—	—	0.089	0.261	1.793	2.436	2.217	1.645
Before Financial Crisis (1982/01/05 to 1997/06/30)	—	—	0.135	0.345	1.534	1.736	1.261	0.467
After Financial Crisis (1997/07/02 to 2012/02/22)	—	—	0.104	0.302	1.544	1.808	1.291	1.013
Before 921 Earthquake (1982/01/05 to 1999/09/20)	—	—	0.138	0.354	1.500	1.656	1.164	0.465
After 921 Earthquake (1999/09/23 to 2012/02/22)	—	—	0.103	0.301	1.232	0.649	0.340	0.522
Before Presidential Election (1982/01/05 to 2000/03/17)	—	—	0.137	0.352	1.470	1.616	1.128	0.456
After Presidential Election (2000/03/20 to 2012/02/22)	—	—	0.119	0.342	1.056	0.456	0.200	0.478
Before 911 Terrorist Attacks (1982/01/05 to 2001/09/11)	—	—	0.136	0.351	1.489	1.556	1.117	0.527
After 911 Terrorist Attacks (After Five Great Events) (2001/09/12 to 2012/02/22)	—	—	0.115	0.325	1.255	0.666	0.010	0.161
Panel D: Quarterly Returns								
Before Missile Crisis (Before Five Great Events) (1982/01/05 to 1996/03/07)	—	—	—	0.368	1.524	1.728	1.239	0.201
After Missile Crisis (1996/03/08 to 2012/02/22)	—	—	—	0.264	1.811	2.469	2.298	1.729
Before Financial Crisis (1982/01/05 to 1997/06/30)	—	—	—	0.374	1.479	1.631	1.152	0.402
After Financial Crisis (1997/07/02 to 2012/02/22)	—	—	—	0.304	1.529	1.774	1.266	1.005
Before 921 Earthquake (1982/01/05 to 1999/09/20)	—	—	—	0.382	1.442	1.556	1.070	0.400
After 921 Earthquake (1999/09/23 to 2012/02/22)	—	—	—	0.299	1.298	0.725	0.387	0.546
Before Presidential Election (1982/01/05 to 2000/03/17)	—	—	—	0.378	1.412	1.516	1.037	0.397
After Presidential Election	—	—	—	0.322	1.091	0.500	0.233	0.486

(2000/03/20 to 2012/02/22)								
Before 911 Terrorist Attacks (1982/01/05 to 2001/09/11)	—	—	—	0.376	1.439	1.455	1.028	0.487
After 911 Terrorist Attacks (After Five Great Events) (2001/09/12 to 2012/02/22)	—	—	—	0.333	1.218	0.635	0.013	0.211

Note: "—" refers to the uncountable variance ratio because of the different data types.

only indicates an important impact of great events on the commercial paper rate behavior across frequencies but also implies a possible structure change in commercial paper rate behavior during 1996-2001 that is the period of the occurrence of the five great events. In addition, Table 5 reveals the slight differences of mean-reverting speeds across frequencies between before and after the Asian financial crisis, which are consistent with the findings of Pilbean (2001): Taiwan's economy experienced less of an impact during the Asian financial crisis.

When the five great events are viewed as a single event, the first three lines and the last three lines in Panels A-D of Table 5 present that the commercial paper rates across frequencies before and after the "whole" five great events are negatively autocorrelated after lagging 8 and 4 years, respectively. Moreover, the variance ratios of Poterba and Summers (1988), which lag more than two years, become lower after the "whole" five great events occurred (as shown in the first three lines and the last three lines in Panels A-D of Table 5). This suggests that after the "whole" five great events happened, the negative autocorrelation of long-term holding period returns on commercial papers increased.

4.5. The Random Walk Behavior of Commercial Paper Rates across Frequencies

This study applies the variance ratio test of Lo and MacKinlay (1988) to investigate the random walk behavior of commercial paper rates across the four frequencies. Although Lo and MacKinlay (1988) suggested that a weekly observation interval yields a large number of observations while minimizing the biases inherent in daily data (*e.g.*, bid-ask spread, asynchronous prices, *etc.*), the adoption of monthly and quarterly return data is appropriate because the over-30-year research period of this study is longer than the research period of Lo

and MacKinlay (1988). Additionally, in order to compare the difference of random walk testing results of commercial paper rates between high and low frequency data this study tests the random walk null hypothesis for daily returns. Table 6 reports the testing results of random walk hypotheses for the four frequencies.

Like the presentation of Lo and Mackinlay (1988), the variance ratios and standard test statistic, $1+M_r(q)$ and $Z^*(q)$, are also reported in Table 6. Due to the above design, $Z^*(q)$ is a negative value as the $1+M_r(q)$ is less than 1. From Table 6, the *Mr(4)*, *Mr(12)*, and *Mr(16)* for the daily returns on commercial papers are significantly different from zero while $Z^*(12)$ and $Z^*(16)$ for the weekly returns on commercial papers show the statistical significance. In addition, the variance ratios of Lo and Mackinlay (1988) in all cases for the monthly and quarterly returns on commercial papers all reject the null hypothesis of random walk at the 10% or 5% significance levels. The above results indicate that the commercial paper rates across the four frequencies do not follow random walk and the statistical significance of rejecting the random walk null hypothesis for low frequency data (*i.e.*, monthly and quarterly return data) is stronger than that for high frequency data (*i.e.*, daily and weekly return data).

Table 6

The Lo and Mackinlay's (1988) Variance Ratios of Commercial Paper Rates across the Four Frequencies

	Number q of Base Observations Accumulated to Compute Variance Ratio				
	2	4	8	12	16
Daily Returns	0.994 (-0.252)	1.056 (1.884)*	1.042 (1.393)	1.051 (1.784)*	1.083 (2.964)**
Weekly Returns	0.964 (-0.803)	1.023 (0.367)	0.989 (-0.169)	0.868 (-2.155)**	0.719 (-4.745)**
Monthly Returns	0.834 (-1.790)*	0.585 (-3.768)**	0.472 (-4.811)**	0.406 (-5.613)**	0.450 (-5.290)**
Quarterly Returns	0.812 (-2.168)**	0.601 (-2.776)**	0.516 (-2.873)**	0.459 (-3.154)**	0.435 (-3.358)**

Note: Lo and Mackinlay's (1988) variance ratios used by this study, $1+M_r(q)$, are reported in the main rows. Figures in parentheses are the standardized test statistic of $M_r(q)$ [*i.e.*, $Z^*(q)$]. "*" and "**" refer to significant at the 10 and 5 percent level, respectively.

Lo and Mackinlay (1988) argued that $M_r(2)$ is the first-order autocorrelation coefficient estimator. According to the $1+M_r(2)$ across frequencies in Table 6, the first-order autocorrelation coefficients for the daily, weekly, monthly, and quarterly returns on commercial papers are -0.006, -0.036, -0.166, and -0.188, respectively. This indicates the negative autocorrelation for the commercial paper rates across frequencies and is consistent with the parameter β in Table 2. Additionally, Table 6 displays that because the $1+Mr(q)$ in all cases for the monthly and quarterly returns on commercial papers are significantly less than 1 [$Mr(q)$ are significantly less than zero] as well as the absolute $Z^*(q)$ increases with q for the quarterly returns on commercial papers, this study finds the strong evidence of mean reversion for the monthly and quarterly returns on commercial papers. In the end, from Table 6, the significant positive and negative $Mr(12)$ [and $Mr(16)$] for the daily and weekly returns on commercial papers respectively indicate that the daily returns on commercial papers do not fit a mean reversion process and there is a weak mean-reverting pattern for the weekly returns on commercial papers. The above results again support the argument that it is easier to detect the mean reversion when adopting low frequency data.

As shown in Tables 2, 4, and 6, empirical results of mean reversion in Tables 2 and 6 are similar but differences are identified in Table 4. Differences among the methods explain the inconsistency in empirical findings because Chan *et al.* (1992), Koutmos (1998) and Lo and MacKinlay (1988) used the autocorrelation of the returns on commercial papers to estimate parameter β and variance ratios. As a result, both provided similar conclusions but the variance ratios of Poterba and Summers (1988) were calculated with the ratio of the variance on the k-year holding period returns divided by k to the variance on the one-year holding period returns. The method of Poterba and Summers (1988) requires a longer holding period to detect the mean-reverting tendency. In general, the results of the three methods are shown with limited differences while the mean reversion tendency is found in data with the four different frequencies.

4.6. The Random Walk Behavior of Commercial Paper Rates across Frequencies for the Periods before and after the Five Great Events

Section 4.5 concludes the rejection of the random walk null hypothesis for the four frequencies and provides the supporting evidence of mean reversion for low frequency data. In Section 4.6, this study investigates whether the great events contaminate the above conclusion in Section 4.5 and compares the differences of the influences among the five great events. The empirical results are reported in Table 7.

Panels C and D of Table 7 present that the majority of $1+Mr(q)$ for the monthly and quarterly returns on commercial papers surrounding the five great events are significantly different from 1, indicating the rejection of random walk null hypothesis. The majority of $1+Mr(12)$ [and $1+Mr(16)$] for the daily and weekly returns on commercial papers around the five great events, as shown in Panels A and B in Table 7, are also significantly from 1. The above results reveal that both before and after the five great events the four frequencies of commercial paper rates do not follow random walk, which is consistent with the testing results of random walk hypothesis in Table 6. That is, the five great events do not contaminate the conclusion regarding random walk in Section 4.5.

In contrast to the findings of mean reversion in Table 6, the majority of $1+Mr(2)$ after the five great events in Table 7 are larger than 1 even for the low frequency data, indicating the positive first-order autocorrelation coefficients for the commercial paper rates across frequencies after the five great events. Moreover, Table 7 presents that the differences of Lo and Mackinlay's (1988) variance ratios between before and after the five great events are numerically significant. When the five great events are viewed as a single event, the first three lines and the last three lines in Panels A-D of Table 7 reveal similar results with those of five individual great events. Therefore, as the findings in Tables 3 and 5, the great events have a big impact on the tendency of mean reversion.

Table 7

Lo and Mackinlay's (1988) Variance Ratios of Commercial Paper Rates across Frequencies for the Periods before and after the Five Great Events

	Number q of Base Observations Accumulated to Compute Variance Ratio				
	2	4	8	12	16
Panel A: Daily Returns					
Before Missile Crisis	0.961	1.030	1.053	1.085	1.136
(Before Five Great Events)	(-1.506)	(0.929)	(1.624)	(2.709)**	(4.432)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	1.194	1.202	0.945	0.821	0.755
(1996/03/08 to 2012/02/22)	(3.846)**	(2.991)**	(-0.721)	(-2.423)**	(-3.444)**
Before Financial Crisis	0.974	1.046	1.067	1.092	1.139
(1982/01/05 to 1997/06/30)	(-1.040)	(1.472)	(2.128)**	(3.045)**	(4.704)**
After Financial Crisis	1.174	1.190	0.996	0.900	0.824
(1997/07/02 to 2012/02/22)	(2.312)**	(1.997)**	(-0.040)	(-1.053)	(-1.947)*
Before 921 Earthquake	0.994	1.054	1.037	1.046	1.078
(1982/01/05 to 1999/09/20)	(-0.268)	(1.798)*	(1.227)	(1.560)	(2.721)**
After 921 Earthquake	1.021	1.141	1.271	1.358	1.378
(1999/09/23 to 2012/02/22)	(0.811)	(4.152)**	(6.277)**	(7.352)**	(7.530)**
Before Presidential Election	0.993	1.053	1.036	1.044	1.076
(1982/01/05 to 2000/03/17)	(-0.296)	(1.772)*	(1.184)	(1.508)	(2.661)**
After Presidential Election	1.068	1.213	1.401	1.516	1.552
(2000/03/20 to 2012/02/22)	(2.651)**	(6.136)**	(8.562)**	(9.611)**	(9.898)**
Before 911 Terrorist Attacks	0.993	1.054	1.036	1.044	1.076
(1982/01/05 to 2001/09/11)	(-0.279)	(1.800)*	(1.192)	(1.512)	(2.662)**
After 911 Terrorist Attacks	1.063	1.247	1.599	1.791	1.860
(After Five Great Events)	(2.436)**	(6.284)**	(9.524)**	(10.442)**	(10.784)**
(2001/09/12 to 2012/02/22)					
Panel B: Weekly Returns					
Before Missile Crisis	0.983	1.082	1.068	0.925	0.752
(Before Five Great Events)	(-0.359)	(1.221)	(0.952)	(-1.078)	(-3.699)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	0.830	0.669	0.497	0.497	0.465
(1996/03/08 to 2012/02/22)	(-1.232)	(-2.101)**	(-3.505)**	(-3.847)**	(-4.370)**
Before Financial Crisis	0.957	1.035	1.014	0.877	0.715
(1982/01/05 to 1997/06/30)	(-0.913)	(0.553)	(0.210)	(-1.877)*	(-4.505)**
After Financial Crisis	1.055	0.844	0.616	0.661	0.658
(1997/07/02 to 2012/02/22)	(0.436)	(-1.035)	(-2.647)**	(-2.512)**	(-2.686)**
Before 921 Earthquake	0.960	1.019	0.986	0.860	0.707
(1982/01/05 to 1999/09/20)	(-0.873)	(0.312)	(-0.217)	(-2.223)**	(-4.847)**
After 921 Earthquake	1.145	1.183	1.141	1.209	1.274
(1999/09/23 to 2012/02/22)	(1.916)*	(1.769)*	(1.238)	(1.937)*	(2.693)**
Before Presidential Election	0.960	1.019	0.985	0.859	0.706
(1982/01/05 to 2000/03/17)	(-0.882)	(0.302)	(-0.233)	(-2.248)**	(-4.866)**
After Presidential Election	1.181	1.233	1.206	1.295	1.361

(2000/03/20 to 2012/02/22)	(2.187)**	(2.047)**	(1.654)*	(2.494)**	(3.260)**
Before 911 Terrorist Attacks	0.960	1.017	0.985	0.862	0.711
(1982/01/05 to 2001/09/11)	(-0.899)	(0.284)	(-0.228)	(-2.224)**	(-4.828)**
After 911 Terrorist Attacks	1.325	1.424	1.208	1.212	1.221
(After Five Great Events)	(2.794)**	(2.646)**	(1.183)	(1.291)	(1.461)
(2001/09/12 to 2012/02/22)					
Panel C: Monthly Returns					
Before Missile Crisis	0.862	0.583	0.447	0.373	0.425
(Before Five Great Events)	(-1.362)	(-3.468)**	(-4.612)**	(-5.423)**	(-5.058)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	0.591	0.590	0.644	0.657	0.650
(1996/03/08 to 2012/02/22)	(-3.094)**	(-2.720)**	(-2.316)**	(-2.254)**	(-2.356)**
Before Financial Crisis	0.855	0.582	0.458	0.389	0.436
(1982/01/05 to 1997/06/30)	(-1.490)	(-3.605)**	(-4.692)**	(-5.494)**	(-5.157)**
After Financial Crisis	0.643	0.651	0.698	0.774	0.854
(1997/07/02 to 2012/02/22)	(-2.544)**	(-2.113)**	(-1.772)*	(-1.339)	(-0.851)
Before 921 Earthquake	0.830	0.573	0.453	0.383	0.427
(1982/01/05 to 1999/09/20)	(-1.810)*	(-3.817)**	(-4.910)**	(-5.739)**	(-5.418)**
After 921 Earthquake	1.086	1.263	1.575	1.777	1.860
(1999/09/23 to 2012/02/22)	(0.913)	(2.390)**	(5.284)**	(7.215)**	(8.132)**
Before Presidential Election	0.830	0.574	0.453	0.383	0.426
(1982/01/05 to 2000/03/17)	(-1.813)*	(-3.818)**	(-4.909)**	(-5.744)**	(-5.435)**
After Presidential Election	1.121	1.303	1.626	1.816	1.889
(2000/03/20 to 2012/02/22)	(1.238)	(2.659)**	(5.585)**	(7.388)**	(8.228)**
Before 911 Terrorist Attacks	0.832	0.578	0.459	0.388	0.430
(1982/01/05 to 2001/09/11)	(-1.804)*	(-3.799)**	(-4.882)**	(-5.725)**	(-5.422)**
After 911 Terrorist Attacks	1.023	1.090	1.315	1.514	1.626
(After Five Great Events)	(0.169)	(0.601)	(2.366)**	(4.226)**	(5.548)**
(2001/09/12 to 2012/02/22)					
Panel D: Quarterly Returns					
Before Missile Crisis	0.774	0.529	0.469	0.433	0.387
(Before Five Great Events)	(-2.429)**	(-3.055)**	(-2.932)**	(-3.078)**	(-3.391)**
(1982/01/05 to 1996/03/07)					
After Missile Crisis	1.289	1.516	1.015	0.772	0.929
(1996/03/08 to 2012/02/22)	(2.815)**	(3.808)**	(0.091)	(-1.185)	(-0.338)
Before Financial Crisis	0.794	0.564	0.489	0.437	0.403
(1982/01/05 to 1997/06/30)	(-2.319)**	(-2.956)**	(-2.946)**	(-3.186)**	(-3.443)**
After Financial Crisis	1.316	1.804	2.024	2.128	2.384
(1997/07/02 to 2012/02/22)	(3.070)**	(5.717)**	(6.705)**	(6.985)**	(8.243)**
Before 921 Earthquake	0.800	0.575	0.488	0.425	0.388
(1982/01/05 to 1999/09/20)	(-2.232)**	(-2.875)**	(-2.960)**	(-3.265)**	(-3.535)**
After 921 Earthquake	1.260	1.675	1.883	1.819	1.571
(1999/09/23 to 2012/02/22)	(2.118)**	(4.057)**	(4.992)**	(4.381)**	(2.982)**

Before Presidential Election (1982/01/05 to 2000/03/17)	0.801 (-2.237)**	0.575 (-2.887)**	0.483 (-2.998)**	0.420 (-3.298)**	0.386 (-3.555)**
After Presidential Election (2000/03/20 to 2012/02/22)	1.296 (2.344)**	1.700 (4.101)**	2.002 (5.462)**	2.140 (5.696)**	2.078 (5.214)**
Before 911 Terrorist Attacks (1982/01/05 to 2001/09/11)	0.803 (-2.225)**	0.576 (-2.898)**	0.482 (-3.024)**	0.421 (-3.315)**	0.393 (-3.542)**
After 911 Terrorist Attacks (After Five Great Events) (2001/09/12 to 2012/02/22)	1.307 (2.365)**	1.827 (5.142)**	2.142 (6.524)**	2.086 (5.606)**	1.923 (4.632)**

Note: Lo and Mackinlay's (1988) variance ratios, $1+M_r(q)$, are reported in the main rows. Figures in parentheses are the standardized test statistic of $M_r(q)$ [*i.e.*, $Z^*(q)$]. "*" and "**" refer to significant at the 10 and 5 percent level, respectively.

5. Conclusions

To get a more complete picture of the behavior of commercial paper rates, this study investigates the influence of data frequencies and great events on commercial paper rate behavior. The empirical results show that first, the levels of commercial paper rates across the four different frequencies are all crucial to the determination of their volatility, and that the commercial paper rate process is stationary. Second, the double exponential or Laplace is a more suitable density function for the daily and weekly returns on the commercial papers. Third, the commercial paper rates across the four different frequencies all reject the null hypothesis of random walk. Finally, the commercial paper rates across the four different frequencies all exhibit mean reversion over a "very" long period of time, and a contrarian strategy will gain excess returns. This study believes that the reason for the mean reversion process of commercial paper rates comes from incorrect expectations of noise traders regarding the fair price of commercial papers when they encounter an information shock. Specifically, noise traders usually cannot make a correct valuation when faced with information shocks, or without the ability to predict the fair price of a commercial paper. Therefore, when a noise trader does business in the commercial paper market frequently, it may lead to a deviation between the market price of a commercial paper and its fair price, and result in a mean reversion.

In terms of the effect of data frequencies on commercial paper rate behavior, the exhibition of mean reversion tendency and the rejection of the random walk null hypothesis for low frequency data are stronger than those for high frequency data. However, the data frequencies have a limited impact on the sensitivity of commercial paper rate volatility to its level and the shape of the distribution of commercial paper rates. The findings across the four frequencies give us a more complete picture of commercial paper rate behavior.

For the impact of great events on commercial paper rate behavior, the empirical evidence across frequencies indicates that there is an obvious difference of mean-reverting speed between before and after the five great events. In addition, the Taiwan Presidential election in 2000 had the weakest effect on the commercial paper rate behavior among the five great events. This study concludes that because the result of the presidential election in 2000 did not deviate from the expectation of investors in the money market, this political event had less impact on commercial paper rate behavior than the other four. This suggests that the variation of commercial paper rates depends on fundamental economic factors and investor sentiment changes, and the investors in the Taiwan's commercial paper market should pay more attention to the events causing a substantial economic loss and over-pessimistic sentiments.

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