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Day-of-the-week effect in the Taiwan foreign exchange market

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Abstract

This study uses stochastic dominance with and without risk-free assets to examine whether trading days can affect patterns of the day-of-the-week effect in the Taiwan foreign exchange market. Our results generally indicate that higher returns appear on the first three days of the week across different trading-day regimes in the Taiwan foreign exchange market, confirming day-of-the-week effect. Allocating part of investors' assets in risk-free assets is useful in distinguishing returns among weekdays for all currencies.

JEL classification: F31; G14; G15

Keywords: Day-of-the-week effect; Stochastic dominance theory; Efficient set

1. Introduction

In the last three decades of financial research, one of the distinctive return patterns of financial assets is the day-of-the-week effect. That is, returns of equity assets appear to be lower on Monday as compared to other days of the week (Cross, 1973; French, 1980;

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Harris, 1986). Ritter and Chopra (1989), Lakonishok and Maberly (1990), DeFusco et al. (1993), Al-Loughani and Chappell (2001) and Tonchev and Kim (2004) find the average Monday return of stocks is negative in the US and some emerging stock markets. Similarly, Stickel (1982) and Roll (1983) document the day-of-the-week effect in futures prices and Gibbons and Hess (1981) in Treasury bills returns.

McFarland et al. (1982) have first documented the day-of-the-week effect in the foreign exchange market. Their empirical results show that Monday and Wednesday offer higher average returns than Thursday and Friday, a finding also later confirmed by So (1987) and Cornett et al. (1995). Aydoğan and Booth (2003) reveal that returns in the Turkish foreign exchange markets are generally higher on Tuesday and Wednesday and lower on Friday. Recently, Yamori and Kurihara (2004) find that the day-of-the-week effect exists in the 1980s for some currencies, but disappears for almost all currencies in the 1990s in the New York foreign exchange market.

The goal of the study is to investigate if there is day-of-the-week effect in the Taiwan foreign exchange market. We use daily data on eight currencies with respect to New Taiwan dollar: Australia dollar, Canada dollar, Euro, Hong Kong dollar, Japan yen, Swiss franc, United Kingdom pound, and US dollar from 1992 through 2006.[1] The Taiwan market offers several interesting features for our examination as follows.

First, our data enable us to examine if changes of trading-day regimes affect the potential day-of-the-week effect. Prior to 1952, the New York Stock Exchange (NYSE) conducted six-day trading in a week (i.e., one-day weekend). Since 1952, it has been only five-day trading in a week (i.e., two-day weekend). Keim and Stambough (1984) find a higher return on the last trading day of the week, no matter whether it was Friday or Saturday. The six-day trading (one-day weekend) was in effect before 1998 in the Taiwan foreign exchange market. In addition, an ‘‘alternative two-day’’ weekend was implemented during 1998–2000.[2] Since 2001, the two-day weekend has been adopted in the Taiwan financial market in order to align with the global practice. Thus, the change of trading-day regimes in the Taiwan foreign exchange market provides us a unique opportunity to examine if the pattern of day-of-the-week effect changes.

Second, we are the first to study and employ the stochastic dominance (SD) theory to examine day-of-the-week effect in the foreign exchange market. An important and useful feature of SD is that it is distribution-free, allowing the distribution of returns to be continuous, discrete or any mix of the two. It does not require the normality assumption, which is obviously inappropriate for exchange rate. In addition, the advantage of SD imposes fewer restrictive assumptions regarding the investor utility function. For example, the first-degree stochastic dominance (FSD) makes only one assumption on investor utility that investors prefer more returns to less. Thus, the investor utility function can be concave, linear, or convex. In contrast, many asset pricing models, like the well-known capital asset pricing model (CAPM), are derived on the assumption that the investor utility function must be concave or on the normality assumption of returns.

[1] The authors thank the suggestions of the anonymous referee for considering the new Euro currency in comparison to the other currencies taken into account; therefore, Euro is added during the 2001–2006 period in this study.

[2] The ‘‘alternate two-day’’ weekend means that one week has six-trading days and that the following week has only five.

Finally, our methodology is enticing as it allows part of investors' money to be invested in the foreign currency (risky assets) and part of their money to be invested in the risk-free assets.[3] Earlier studies use the regression model to test whether the day-of-the-week effect exists in the foreign exchange market (e.g., Aydoğan and Booth, 2003; Yamori and Kurihara, 2004). Our methodology utilizing SD theory enables investors to have a better tool for assets allocation. That is, investors can decide an optimal proportion of investment in risky assets and risk-free assets.

Eight currencies, Australia dollar, Canada dollar, Euro, Hong Kong dollar, Japan yen, Swiss franc, United Kingdom pound and the US dollar, are examined in this study during the 1992–2006 period. The exchange rates of eight currencies against New Taiwan dollar are referred as *AUD*, *CAD*, *EUR*, *HKD*, *JPY*, *SWF*, *UKP* and *USD*, respectively. Our study offers two interesting results. First, we demonstrate that higher returns appear on the first three days of the week (Monday through Wednesday) for the six-day trading regime covering the 1992–1997 period (one-day weekend) for all currencies. It seems no clear pattern for day-of-the-week effect over 1998–2000. During recent five-day trading regime from 2001 to 2006 period (two-day weekend), the returns of six currencies on Monday through Wednesday are also higher than the other days except the *EUR* and *UKP*. These findings indicate there are day-of-the-week effects in the Taiwan foreign exchange market and higher returns generally appear on the first three days of the week across different trading-day regimes. Our results are similar to earlier literature, such as McFarland et al. (1982), So (1987) and Cornett et al. (1995). But, it obviously differs from the results of Yamori and Kurihara (2004) which have documented that the day-of-the-week effect disappears in the New York foreign exchange market after 1990s. The second important finding is that allocating part of investors' assets in risk-free assets can help distinguish the relative performance among weekdays for all currencies, which is also supported by the simulation test. This finding can enable investors to better design their international investment strategy.

The rest of this paper is organized as follows: Section 2 introduces the foreign exchange market in Taiwan. Section 3 describes the data and methodology. Section 4 presents and explains the empirical results. The final section is the conclusions.

2. Foreign exchange market in Taiwan

The New Taiwan Dollar (NTD) was issued in 1949 when the Republic of China moved from mainland China to Taiwan. Since then, Taiwan adopted a fixed exchange rate system, and the exchange rate was fixed at NTD 40 to one USD. Taiwan changed to the floating exchange rate system since the Taiwan foreign exchange market was established in 1979. Initially, the daily central exchange rate and the daily upper and lower exchange rate limits were determined both by the central bank and five-appointed foreign exchange banks. The daily central exchange rate was determined by supplies and demands in the inter-bank foreign exchange market. The daily upper and lower exchange rate limits still existed.

The liberalization of the Taiwan foreign exchange market began in 1990. The regulations of the daily central exchange rate and daily upper and lower exchange rate limits

[3] The example in Appendix shows that 60% of investor money is invested in risky assets (buying Australia dollar), while 40% is lent at the risk-free rate of 5%.

were removed. The exchange rate was then allowed to fluctuate freely according to supplies and demands in the foreign exchange market. According to the statistics of *Foreign Exchange Bureau* in Taiwan, the transaction value in the Taiwan foreign exchange market has increased dramatically in the past several years, and the daily average trading value has increased from USD 2964 million in 1994 to USD 16,090 million in 2006.

3. Data and methodology

Currency returns are defined as $R_t = (P_t - P_{t-1})/P_{t-1}$, where P_t is the New Taiwan dollar per unit of the foreign currency. Daily data of eight currencies against NTD consisting of Australia dollar (*AUD*), Canada dollar (*CAD*), Euro (*EUR*), Hong Kong dollar (*HKD*), Japan yen (*JPY*), Swiss franc (*SWF*), United Kingdom pound (*UKP*), and US dollar (*USD*) are taken from the *Taiwan Economic Journal Data Bank* (*TEJDB*). The sample period contains 3886 trading days from January 1992 to April 2006. As noted earlier, in the Taiwan foreign exchange market, the one-day weekend was in effect before 1998, the "alternative two-day" weekend was implemented during the 1998–2000 period, and the two-day weekend has been in place since January 2001.

Table 1 shows the mean returns on the various currencies by day of the week. In the 1992–1997 period, the highest returns appear on first three days of the week for all currencies, and the lowest returns appear on Friday for most currencies. In addition, the highest standard deviation appears on Friday for all currencies, and the lowest on Monday or Saturday for all currencies. During 1998–2000, there is no significant pattern. However, over 2001–2006, the highest returns appear on Monday through Wednesday for all currencies again except *EUR* and *UKP*, a result implying day-of-the-week effect in the Taiwan foreign exchange market.

We also investigate the normality of the daily returns assumption for the various currencies using the Kolmogorov–Smirnov (K–S) test. The results show that the daily returns within the week do not follow a normal distribution.[4] As a result, it is more appropriate to use the SD theory to examine the day-of-the-week effect.

The stochastic dominance (SD) theory provides a simple method of selecting risky alternatives.[5] Suppose an investor has to choose between two risky assets, X_1 and X_2, and the return on asset X_1 always exceeds that on asset X_2. Then, as long as investors prefer more returns to less, no investor would choose asset X_2 because asset X_1 would always provide a higher return. This illustration is a special case of the first-degree stochastic dominance (FSD). Generally, asset X_1 dominates asset X_2 by FSD, if the cumulative density function (CDF) of X_1 lies, roughly speaking, to the right of the CDF of X_2. That is, with the distribution of G_1 (asset X_1), the chance of earning a higher return is always greater than with the distribution of G_2 (asset X_2), regardless of whether investors like or dislike risks. Formally, an asset X_1 with the CDF of G_1 dominates an asset X_2 with the CDF of G_2 by the

[4] In order to save space, we omit the table expression.

[5] The stochastic dominance rules given here are slightly modified from Hadar and Russell (1969), Hanoch and Levy (1969), Levy and Kroll (1979), Seyhun (1993), Liao and Chou (1995), Levy (1998) and Best et al. (2000). Readers interested in the SD theory should refer to Levy and Kroll (1976, 1978), Kroll and Levy (1980), Levy and Sarnat (1985) and Levy (1992).

Table 1
Mean returns on the various currencies by day of the week

Period[a]	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
AUD[c]						
1992–1997	−0.0117%	−0.0022	0.0708	0.0012	−0.0266	0.0360
	(0.4020%)[b]	(0.4931)	(0.5873)	(0.5070)	(0.6484)	(0.4483)
1998–2000	−0.0820	−0.0934	0.0299	−0.0542	0.1275	−0.0258
	(0.5554)	(0.6469)	(0.7125)	(0.8162)	(0.6771)	(0.6647)
2001–2006	0.0665	0.0317	−0.0081	−0.0672	0.0508	
	(0.6994)	(0.5840)	(0.6974)	(0.6621)	(0.5842)	
CAD						
1992–1997	0.0218	0.0212	0.0364	−0.0131	−0.0391	−0.0168
	(0.2571)	(0.3722)	(0.3835)	(0.3934)	(0.4984)	(0.3348)
1998–2000	0.0483	−0.0174	0.0036	−0.0285	0.0122	−0.0144
	(0.3761)	(0.4244)	(0.3822)	(0.4727)	(0.4565)	(0.4260)
2001–2006	0.0737	−0.0270	0.0396	−0.0100	0.0108	
	(0.5105)	(0.4493)	(0.4373)	(0.4995	(0.4569)	
EUR[d]						
2001–2006	0.03600	−0.0130	0.0376	−0.0308	0.0403	
	(0.6695)	(0.5347)	(0.5843)	(0.5674)	(0.5644)	
HKD						
1992–1997	0.0323	0.0204	0.0428	0.0080	−0.0079	0.0014
	(0.2253)	(0.2538)	(0.2856)	(0.2396)	(0.3542)	(0.1983)
1998–2000	0.0399	0.0263	0.0173	−0.0113	−0.0083	−0.0313
	(0.2961)	(0.2889)	(0.2571)	(0.2985)	(0.3459)	(0.3076)
2001–2006	−0.0019	0.0269	−0.0007	−0.0252	0.0220	
	(0.2789)	(0.2269)	(0.2269)	(0.2809)	(0.2550)	
JPY						
1992–1997	0.0956	0.0997	0.0193	−0.0430	−0.0264	−0.0032
	(0.4465)	(0.5918)	(0.7421)	(0.5951)	(0.7473)	(0.6154)
1998–2000	0.018	−0.0300	0.1170	−0.0360	0.0490	−0.1250
	(0.6171)	(0.6078)	(0.6231)	(0.7967)	(0.6879)	(0.7376)
2001–2006	0.0028	0.0071	0.0496	−0.0280	−0.0428	
	(0.5497)	(0.4538)	(0.4875)	(0.4933)	(0.5022)	
SWD						
1992–1997	0.0355	0.0761	−0.0231	0.0122	0.0308	−0.0100
	(0.5454)	(0.7770)	(0.7635)	(0.6445)	(0.8647)	(0.7521)
1998–2000	−0.0440	−0.0410	0.0910	−0.0720	0.0970	−0.1150
	(0.7446)	(0.6415)	(0.6497)	(0.6391)	(0.7554)	(0.8032)
2001–2006	0.0440	−0.0343	0.0466	−0.0002	0.0362	
	(0.6797)	(0.5981)	(0.6425)	(0.6051)	(0.5890)	
UKP						
1992–1997	−0.0218	0.0844	−0.0025	−0.0400	0.0200	−0.0069
	(0.4807)	(0.5789)	(0.5694)	(0.6475)	(0.6833)	(0.6370)
1998–2000	−0.0167	0.0005	0.0266	−0.0697	0.0827	−0.0221
	(0.5972)	(0.4781)	(0.4694)	(0.4834)	(0.5691)	(0.5164)
2001–2006	0.0385	−0.0070	0.0359	−0.0070	0.0559	
	(0.5142)	(0.4360)	(0.5123)	(0.5130)	(0.4227)	

(*continued on next page*)

Table 1 (*continued*)

Period[a]	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
USD						
1992–1997	0.0427	0.0272	0.0412	−0.0011	−0.0131	0.0018
	(0.2067)	(0.2417)	(0.2635)	(0.2251)	(0.3105)	(0.1965)
1998–2000	0.0454	0.0423	−0.0180	0.0087	−0.0137	−0.0307
	(0.3360)	(0.3728)	(0.2844)	(0.3194)	(0.2632)	(0.2498)
2001–2006	−0.0152	0.0396	0.0082	−0.0124	−0.0008	
	(0.3504)	(0.3102)	(0.2050)	(0.2296)	(0.1971)	

[a] The one-day weekend was in effect before 1998, the "alternate two-day" weekend was in force during the 1998–2000 period, and the two-day weekend was phased in starting in January 2001.

[b] The standard deviation of returns is reported in parentheses.

[c] The exchange rates of Australia dollar, Canada dollar, Hong Kong dollar, Japan yen, Swiss franc, United Kingdom pound and US dollar against New Taiwan dollar are referred as *AUD*, *CAD*, *HKD*, *JPY*, *SWF*, *UKP* and *USD*, respectively.

[d] Based on the anonymous referee's suggestion, Euro (*EUR*) currency is also considered for comparison to the other currencies during the 2001–2006 period.

first-degree stochastic dominance if and only if:

$$G_1(r) \leqslant G_2(r), \text{ for all possible } r \tag{1}$$

The preference is obvious as in the case where G_1 lies entirely to the right of G_2. When two CDFs cross, the other factor has to be considered to establish the successive dominance. If investors are risk averse, second-degree stochastic dominance (SSD) can be employed. Formally, an asset X_1 dominates an asset X_2 by the second-degree stochastic dominance if and only if:

$$\int_{-\infty}^{r} [G_2(t) - G_1(t)]\mathrm{d}t \geqslant 0 \text{ for all possible } r \tag{2}$$

where $\int_{-\infty}^{r} G_2(t)\mathrm{d}t$ and $\int_{-\infty}^{r} G_1(t)\mathrm{d}t$ denote the areas under G_2 and G_1, respectively. Hence, SSD allows two CDFs to cross by some amounts as long as the area under G_1 is always less than G_2. Fig. 1 shows that when the condition of Eq. (2) is met, G_1 lies far enough to the right of G_2 that asset X_1 is preferred to asset X_2 because the expected utility gain from the positive area to the left of r_0 exceeds the reduction in the expected utility loss between r_0 and r_1.[6]

When borrowing and lending at the risk-free rate are permitted, a much stronger rule, called stochastic dominance with risk-free asset rules (SDR), can be used. Consider a portfolio containing one risky asset and one risk-free asset, with $(\beta \cdot 100)\%$ of investor's money invested in the risky asset X_1, and $(100 - \beta \cdot 100)\%$ of investor's money borrowed or lent at the risk-free rate.[7] The portfolio return, R_p, is then computed as the weighted sum of two assets: $R_\mathrm{p} = (1 - \beta)r_\mathrm{f} + \beta X_1$, where r_f is the risk-free interest rate. Additionally, let F_β denote the cumulated distribution function of R_p. Next, we can compare the two distributions G_1 and G_2, as illustrated in Fig. 2. Clearly, neither G_1 nor G_2 dominates the other by FSD. Nevertheless, it is possible to rotate G_1 about the point $(r_\mathrm{f}, G_1(r_\mathrm{f}))$ and obtain $G_{1\beta}$, which dominates G_2 by FSD; hence, G_1 dominates G_2 by first-degree stochastic

[6] Figs. 1 and 2 are taken and slightly modified from Levy (1998).

[7] Please refer to Footnote 3 and Appendix in details.

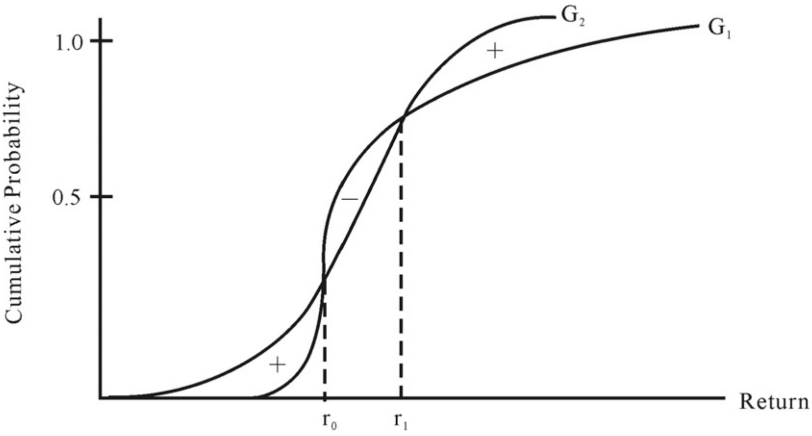

Fig. 1. G_1 preferred to G_2 with risk aversion.

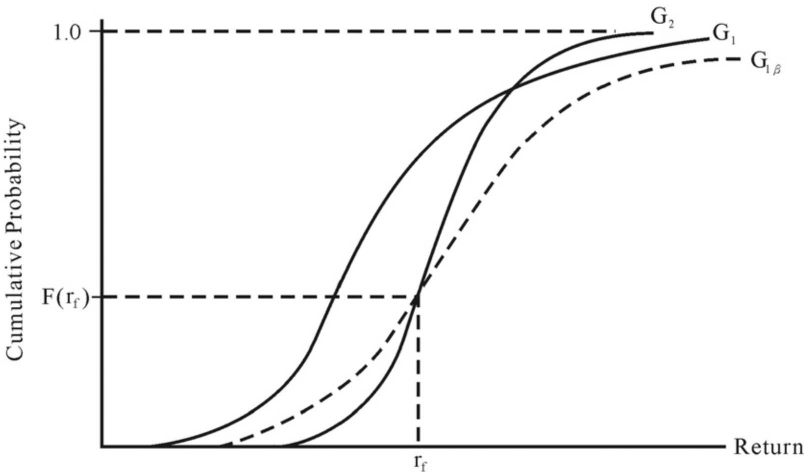

Fig. 2. G_1 and G_2 intersect but $G_{1,\beta}$ dominate G_2.

dominance with a risk-free rate (FSDR). Formally, let G_1 and G_2 be the CDFs of two risky assets, X_1 and X_2. Also let $G_{1\beta}$ be the CDF of R_p, where $R_p = (1 - \beta)r_f + \beta X_1$ and β is a constant. Then G_1 dominates G_2 by FSDR if and only if:

$$G_{1\beta}(r) \leqslant G_2(r) \text{ for all possible } r \tag{3}$$

Similar to SSD, G_1 dominates G_2 by the second-degree stochastic dominance with a risk-free rate (SSDR) if and only if:

$$\int_{-\infty}^{r} [G_2(t) - G_{1\beta}(t)]\mathrm{d}t \geqslant 0 \text{ for all possible } r \tag{4}$$

4. Empirical results

Our study period is divided into three sub-periods: (1) the 1992–1997 period (six-day trading per week), (2) the 1998–2000 period (i.e., the ‘‘alternative two-day’’ weekend, i.e., one week has six-trading days, and the next has five), and (3) the 2001–2006 period (five-day trading per week). This study uses SD rules to examine the day-of-the-week effect. That is, we test the null hypothesis that returns on all weekdays are equal.

The empirical study uses a version of the stochastic dominance algorithm introduced and developed by Levy and Kroll (1979), Levy and Sarnat (1985) or Levy (1992). That is, the FSD, SSD, FSDR and SSDR criteria are employed to test the day-of-the-week effect.[8] The annual risk-free assets return during our study period was ranging from 1.05% to 8.30%, which is used to conduct the FSDR and SSDR tests.[9]

Fig. 3 illustrates the application of the stochastic dominance rules and presents the cumulative distribution curves of Wednesday and Saturday for *AUD* during the 1992–1997 period. Generally, the cumulative distribution curve of Wednesday lies to the right of that of Saturday, a sign indicating that whether Wednesday dominates Saturday is questionable. The two cumulative distribution curves do, however, cross each other about at 0.09% of return. According to the FSD rule, Wednesday does not dominate Saturday.[10] The only restriction on the risk preference structure is that the investor utility function is non-decreasing (the first derivative of the utility function is positive). In addition, the SSD test also fails since the expected utility gain from the positive area to the left of −0.0912% does not exceed the reduction in the expected utility losses between −1.9634% and −0.0964%.[11]

If investors are allowed to borrow and lend money at a risk-free interest rate; i.e, the Wednesday curve can be mixed with a risk-free asset (for risk-free asset return rate $r_f = 5\%$, for example)[12] in such proportions that the cumulative distribution of the mixture starts rising to the right of the Saturday distribution. The cumulative area between the two curves remains positive. Consequently, for $r_f = 5\%$, Wednesday returns outperform Saturday returns. The detailed calculations of the stochastic dominance tests for two weekdays are provided in Appendix.

4.1. One-day weekend

Table 2 identifies those weekdays that appear in the stochastic dominance efficient sets for the various currencies during the 1992–1997 period (i.e., six-day trading in a week). Several conclusions can be drawn.

[8] Because some technical errors appear in the third stochastic dominance (TSD) and third stochastic dominance with risk-free asset (TSDR) algorithms, these algorithms are not discussed here. (For more details, see Levy (1992).)

[9] The risk-free interest rate is taken from Financial Statistics Monthly, Taiwan District, Republic of China (2006).

[10] Please see the columns of (3) and (7) of Appendix at C.D.F. of 82/222 and 83/222. Two curves cross each other about at 0.09% of return.

[11] The expected utility gain or loss can also consult the columns of (3) and (7) of Appendix.

[12] The annual risk-free rate fluctuated between 4.94% and 8.30% during the 1992–1997 period, therefore, we use $r_f = 5\%$ to test dominance relationship between Wednesday and Saturday.

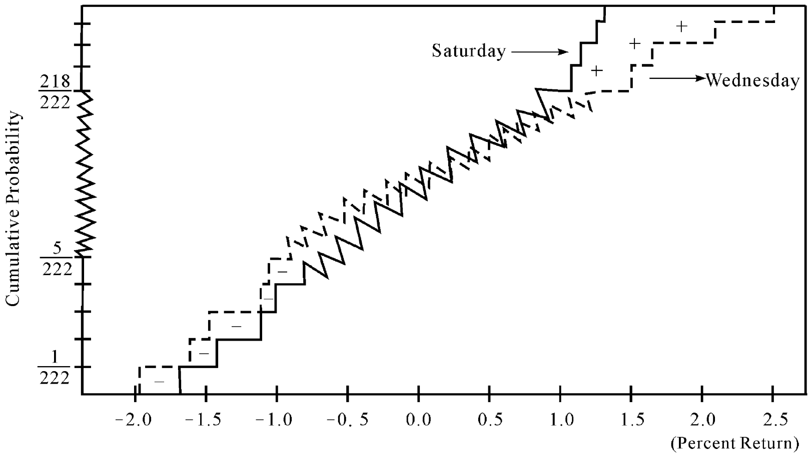

Fig. 3. Cumulative return distribution of Wednesday and Saturday for *AUD*.

(1) Using the weak assumption ($U' > 0$) on investors' preferences, the performance of the weekdays cannot be distinguished, i.e., the FSD (without lending and borrowing at a risk-free interest rate) efficient sets include six weekdays for all seven currencies. Allowing investors to borrow and lend money at a risk-free interest rate also does not reduce the size of the FSDR efficient sets. Thus, sharper decision rules are required to distinguish among weekdays for the various currencies. In order to save space, only the FSD and FSDR efficient sets of *AUD* are shown in Table 2.
(2) Assuming risk aversion ($U' > 0$ and $U'' < 0$), which most economists accept, different findings are revealed: the performance of Monday, Wednesday and Saturday dominate returns on all the other trading days of the week for the *AUD* efficient set when the SSD rule is used to examine the dominance relationship among weekdays. The other currencies also show the similar results. For example, the returns on Monday, Tuesday and Saturday as well as Monday through Wednesday returns also dominate the returns on all the other trading days of the week for the SSD efficient sets of the *JPY* and *UKP*, respectively.
(3) The results are much stronger when investors are allowed to borrow and lend money at a risk-free interest rate. As noted above, r_f denote the risk-free interest rate. The results of the SSDR efficient set for the *AUD* exhibit that Wednesday's returns outperform the returns on all the other trading days of the week. The findings of the SSDR efficient set also show that the performance of Tuesday for the *SWD* and *UKP* beat the returns on all the other trading days of the week. However, the performance of Monday and Tuesday still cannot be distinguished when the SSDR rule is used to test the dominance relationship between them for the *JPY*. Note that the size of SSDR efficient set is a function of risk-free interest rate. For $1.5\% \leqslant r_f < 4.94\%$, the SSDR efficient sets of the *CAD* and *HKD* display that Monday's and Wednesday's returns, respectively, outperform the returns on all the other trading days of the week, and the efficient sets of these two currencies only include Wednesday when the risk-free interest rate is greater than 5.0%.

Table 2
The day-of-the-week effect for the various currencies during the 1992–1997 period[a]

	AUD[b]				*CAD*			*HKD*		
	FSD[c]	SSD	FSDR	SSDR[e]	SSD	SSDR		SSD	SSDR	
			$r_f \geqslant 4.94\%$	$r_f \geqslant 4.94\%$		$1.5\% \leqslant r_f \leqslant 4.94\%$	$r_f \geqslant 5.0\%$		$1.5\% \leqslant r_f \leqslant 4.94\%$	$r_f \geqslant 5.0\%$
Monday	+[d]	+	+	–	+	+	–	+	+	–
Tuesday	+	–	+	–	–	–	–	–	–	–
Wednesday	+	+	+	+	+	+	+	+	+	+
Thursday	+	–	+	–	+	–	–	+	–	–
Friday	+	–	+	–	–	–	–	–	–	–
Saturday	+	+	+	–	+	–	–	+	–	–

	JPY		*SWD*		*UKP*		*USD*	
	SSD	SSDR	SSD	SSDR	SSD	SSDR	SSD	SSDR
		$r_f \geqslant 4.94\%$		$r_f \geqslant 4.94\%$		$r_f \geqslant 4.94\%$		$r_f \geqslant 4.94\%$
Monday	+	+	+	–	+	–	+	+
Tuesday	+	+	+	+	+	+	–	–
Wednesday	–	–	+	–	+	–	–	–
Thursday	–	–	+	–	–	–	–	–
Friday	–	–	–	–	–	–	–	–
Saturday	+	–	–	–	–	–	+	–

[a] In order to save space, only the results of the FSD and FSDR efficient sets for *AUD* are presented in the table.

[b] The exchange rates of Australia dollar, Canada dollar, Hong Kong dollar, Japan yen, Swiss franc, United Kingdom pound and US dollar against New Taiwan dollar are referred as *AUD*, *CAD*, *HKD*, *JPY*, *SWF*, *UKP* and *USD*, respectively.

[c] FSD: first-order stochastic dominance, SSD: second-order stochastic dominance, FSDR: first-order stochastic dominance with risk-free assets, SSDR: second-order stochastic dominance with risk-free assets.

[d] Efficient weekdays marked by "+", inefficient weekdays marked by "–".

[e] From the report of Financial Statistics Monthly, Taiwan District, Republic of China (1998), the annual risk-free rate fluctuated between 4.94% and 8.30% during 1992–1997 period.

Our findings indicate that Wednesday's returns outperform the returns on all the other trading days of the week for the *AUD*, *CAD* and *HKD*, and the performance of Monday and/or Tuesday outperform the returns on all the other weekdays for the *USD*, *JPY*, *SWD* and *UKP*. Therefore, our results imply that the day-of-the week effect exists in the Taiwan foreign exchange market during the period, 1992–1997.

4.2. "Alternate two-day" weekend

Table 3 shows the results for the "alternate two-day" weekend (i.e., one week has six-trading days, while the next week has five-trading days) during the 1998–2000 period. When the weak assumption ($U' > 0$) on investors' preferences is used, the performance of the weekdays still cannot be definitively distinguished for all currencies; that is, all the FSD or FSDR efficient sets include five or six weekdays. In order to save space, we also do not show the results of FSD and FSDR results. More convincing results are obtained when the SSD or SSDR rule is applied to test the dominance relationship among weekdays for all currencies. Panel (a) of Table 3 shows that only Friday or Wednesday is, respectively, included in the SSD efficient set of *AUD* and *JPY*; that is, all the other weekdays are excluded from the SSD efficient set. The SSDR efficient sets of *CAD*, *UKP* and *USD* also display that Tuesday's or Wednesday's returns dominate the performance of all the other trading days of the week. The results of the SSDR efficient set of *HKD* show that Monday's and Tuesday's returns dominate the performance of the other weekdays for $4.68\% \leqslant r_f < 6.89\%$ as well. It is also notable that the SSDR efficient set of *HKD* only includes Tuesday when the risk-free rate is greater than 8.0%.

Panel (b) of Table 3 shows that Friday's returns are superior to the returns on the other weekdays for the *AUD*, *SWD* and *UKP* when the SSDR rule is applied to test the dominance relationship among the weekdays for $r_f \geqslant 4.68\%$. For the *CAD* and *USD*, the results show that the performance of Monday and Thursday outperform the returns on Tuesday, Wednesday and Friday; i.e., Tuesday, Wednesday and Friday are, respectively, excluded from their SSD efficient sets. Finally, we find that Monday's or Wednesday's returns are, respectively, higher than all the other weekday's returns for the *HKD* and *JPY* when the SSDR rule is used to test the dominance relationship among the weekdays for $r_f \geqslant 4.68\%$.

Briefly, the analytical results of the one-day and two-day weekends show the different pattern of the day-of-the-week effect for the *CAD*, *HKD*, *SWD*, *UKP* and *USD* during the 1998–2000 period. However, the efficient sets of *AUD* and *JPY* exhibit the similar pattern for the one-day and two-day weekends; i.e., Friday's or Wednesday's returns, respectively, dominate the returns on all the other weekdays in their efficient sets.

4.3. Two-day weekend

Since January 2001, the two-day weekend has been in effect in the Taiwan foreign exchange market. Table 4 reports the results of the day-of-the-week effect over 2001–2006. Several results are found.

First, with the weak assumption ($U' > 0$) on investors' preferences, the performance of the weekdays still cannot be distinguished for all currencies; i.e., the FSD or FSDR efficient sets include five weekdays for all currencies.

Second, when we apply the SSD or SSDR rule to examine the dominance relationship among the weekdays, robust results are also obtained. The findings of the SSD efficient

Table 3
The day-of-the-week effect for the various currencies during the 1998–2000 period[a]

(a) Trading six days a week (Monday through Saturday)

	AUD	*CAD*		*HKD*			*JPY*	*SWD*		*UKP*		*USD*	
	SSD	SSD	SSDR $r_f \geqslant 7.0\%$[b]	SSD	SSDR $4.68\% \leqslant r_f < 6.89\%$	SSDR $r_f \geqslant 8\%$[b]	SSD	SSD	SSDR $r_f \geqslant 4.68\%$	SSD	SSDR $r_f \geqslant 4.68\%$	SSD	SSDR $r_f \geqslant 4.68\%$
Monday	−	+	−	+	+	−	−	−	−	−	−	+	−
Tuesday	−	−	−	+	+	+	−	+	−	+	+	+	+
Wednesday	−	+	+	+	−	−	+	+	+	+	−	−	−
Thursday	−	−	−	−	−	−	−	+	−	−	−	−	−
Friday	+	−	−	−	−	−	−	+	−	+	−	+	−
Saturday	−	−	−	−	−	−	−	−	−	−	−	−	−

(b) Trading five days a week (Monday through Friday)

	AUD		*CAD*	*HKD*		*JPY*		*SWD*		*UKP*		*USD*
	SSD	SSDR $r_f \geqslant 4.68\%$	SSD[c]	SSD	SSDR $r_f \geqslant 4.68\%$	SSD	SSDR $r_f \geqslant 4.68\%$	SSD	SSDR $r_f \geqslant 4.68\%$	SSD	SSDR $r_f \geqslant 4.68\%$	SSD[c]
Monday	+	−	+	+	+	+	−	+	−	+	−	+
Tuesday	−	−	−	+	−	+	−	−	−	−	−	−
Wednesday	−	−	−	−	−	+	+	+	−	+	−	−
Thursday	−	−	+	−	−	−	−	−	−	−	−	+
Friday	+	+	−	−	−	+	−	+	+	+	+	−

[a] The meanings of the symbols are the same as Table 2. In order to save space, the results of the FSD and FSDR efficient sets for all currencies are not presented in the table.

[b] From the report of Financial Statistics Monthly, Taiwan District, Republic of China (2001), the annual risk-free rate fluctuated between 4.68% and 6.89% during the 1998–2000 period. Though 7.0% or 8% is not at intervals of [4.685%, 6.89%], we still examine whether some weekdays dominate all the other day of the week.

[c] For $r_f = 12.0\%$, the returns of Monday and Thursday still cannot distinguish between them for *CAD* and *USD*, therefore, the results of SSDR is not shown in the table.

Table 4
The day-of-the-week effect for the various currencies during the 2001–2006 period[a]

	AUD		*CAD*		*EUR*[c]		*HKD*	*JPY*		*SWD*			*UKP*		*USD*
	SSD	SSDR $r_f \geqslant 7.0\%$[b]	SSD	SSDR $r_f \geqslant 1.5\%$	SSD	SSDR $r_f \geqslant 1.5\%$	SSD	SSD	SSDR $r_f \geqslant 1.5\%$	SSD	SSDR $1.5\% \leqslant r_f \leqslant 6\%$	SSDR $r_f \geqslant 7.0\%$[b]	SSD	SSDR $r_f \geqslant 1.5\%$	SSD
Monday	+	+	+	+	–	–	–	–	–	+	–	–	–	–	–
Tuesday	–	–	–	–	+	–	+	+	–	–	–	–	+	–	+
Wednesday	–	–	+	–	+	–	–	+	+	+	+	+	+	–	–
Thursday	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Friday	+	–	–	–	+	+	–	–	–	+	+	+	+	+	–

[a] The meanings of the symbols are the same as Table 2. In order to save space, the results of the FSD and FSDR efficient sets for all currencies are not presented in the table.

[b] From the report of Financial Statistics Monthly, Taiwan District, Republic of China (2006), the annual risk-free rate fluctuated between 1.05% and 4.94% during the 2001–2006 period. Though 7.0% is not at intervals of [1.05%, 4.94%], the results show that returns on Monday or Wednesday tend to dominate all the other trading days of the week for *AUD* and *SWD*.

[c] Based on the anonymous referee's suggestion, Euro (*EUR*) currency is also examined during the 2000–2006 period.

sets of the *HKD* and *USD* only include Tuesday; i.e., Monday and Wednesday through Friday are excluded from their SSD efficient sets. The SSDR efficient sets of the *AUD*, *CAD*, *JPY* and *SWD* only include Monday or Wednesday; that is, Monday's or Wednesday's returns are superior to all the other weekday's returns. Finally, the analytical results of the *EUR* and *UKP* show that Friday's returns dominate all the other trading days of the week for $r_f \geqslant 1.5\%$, which is an interesting finding; i.e., the same pattern of the day-of-the-week effect exists in European currencies.

Our findings for all currencies (except European currencies) show that higher returns appear on the first three days of the week during the 2001–2006 period, which is similar to the results of the one-day weekend for all currencies during the 1992–1997 period.

4.4. Discussion

Table 5 shows the summary of weekdays in the SSD or SSDR efficient sets for our sample currencies in each sub-period. During 1992–1997, higher returns appear on the first three days of the week (Monday through Wednesday) for all currencies, which results are almost the same as previous studies. For example, McFarland et al. (1982), So (1987) and Cornett et al. (1995) document that returns on foreign currencies to American investors are high on Monday and Wednesday and Aydoğan and Booth's (2003) results also reveal that returns are generally high on Tuesday and Wednesday in the Turkish foreign exchange market.

From 1998 to 2000, Tuesday or Wednesday is included in the SSD or SSDR efficient set for all currencies (except *AUD*) for one-day weekend. Friday of *AUD*, *SWD* and *UKP*, and Monday or Monday and Thursday of *CAD*, *HKD* and *USD* are included in the SSD or SSDR efficient set for two-day weekend. There is no significant pattern in this period. The reasons may be that it is a transition period from one-day weekend to two-day weekend and this period covers the Asian financial crisis. Finally, our findings during the 2001–2006 period generally indicate that the returns on Monday through Wednesday have been higher than those of the other weekdays for all currencies except European currencies.

Over the two trading regimes (the 1992–1997 period and 2001–2006 period), we conclude that higher returns generally appear on the first three days of the week (Monday through Wednesday) for almost all currencies, indicating that the pattern of the day-of-the-week effect is not influenced by the change of trading days during the week, a result different from Yamori and Kurihara (2004). Our results show that the day-of-the-week effects are persistent in the Taiwan foreign exchange market. Although Taiwan has gradually liberalized restrictions on capital flows from 1990s, its foreign exchange market is still immature or inefficient.

To examine the power of SD approach, we simulate a trading strategy by buying the amount of 100,000 units for all currencies at the closing price on day $t-1$ and selling them at the closing price on day t for two years from April 2004 to April 2006. The purpose of the test is to see if there are potential profits to be made by such a trading rule.

We calculate the profits or losses (in NT$ unit) by day of the week and then sum them up over the two years. Table 6 reports the results. Several results are noted. First, we observe that Monday of the *AUD*, Friday of *EUR*, Tuesday of the *HKD*, Wednesday of the *SWD* and Tuesday of the *USD*, respectively, gain the most profits within the week. These results are consistent with the findings in the last column of Table 5. Second, although Monday of the *CAD* and Wednesday of the *JPY* do not, respectively, gain the most profit within the week, their performance still rank the second place, respectively. Third, the most profitable weekday for almost all currencies appears on the first three days

Table 5
Summary of winning weekdays for all currencies in each sub-period

Currencies	1992–1997	1998–2000		2001–2006
	One-day weekend	One-day weekend	Two-day weekend	Two-day weekend
AUD	Wednesday	Friday	Friday	Monday
CAD	Wednesday	Wednesday	Monday and Thursday	Monday
HKD	Wednesday	Tuesday	Monday	Tuesday
EUR	–	–	–	Friday
JPY	Monday and Tuesday	Wednesday	Wednesday	Wednesday
SWD	Tuesday	Wednesday	Friday	Wednesday
UKP	Tuesday	Tuesday	Friday	Friday
USD	Monday	Tuesday	Monday and Thursday	Tuesday

Table 6
Testing results for all currencies during the April 2004 to April 2006 Period[a]

	Monday	Tuesday	Wednesday	Thursday	Friday
AUD	NT$ 79,353**[b]	53,200	−90,300	−95,400	−67,100
CAD	143,728*	−82,800	158,300	−11,900	−22,100
EUR	−125,400	49,800	205,600	−89,100	50,099*
HKD	−3,448	7,650**	6,000	−12,400	1,600
JPY	1,470	50	213*	−2,095	−1,930
SWD	−24,190	−55,300	97,357**	75,700	−85,400
UKP	304,100	21,800	236,000	−334,000	−40,080
USD	−46,481	129,500**	50,405	−38,205	−2,885

[a] Assume that investors buy the amount of 100,000 unit for all currencies at the closing price on day $t-1$ and sell them at the closing price on day t during the April 2004 to April 2006 Period. The profit or loss (in NT$ unit) sums up by day of the week. According to the results in Table 4, our trading strategy, of course, is that part of investors' money is invested in risky assets (buying currency), while part of their money is invested in risk-free assets for some weekdays. There are no transaction costs in the Taiwan foreign exchange market, therefore, we ignore the effect of transaction cost.

[b] "**" indicates that it gains the most profit within the week and is the "winner" in the last column of Table 5. In addition, "*" represents that its performance ranks the second within the week and is the "winners" in the last column of Table 5.

of the week, a result consistent with the previous ones. Finally, an important implication of our simulation analysis is that allocating part of investors' assets in risk-free assets can help distinguish the relative performance among weekdays; i.e. SD approach can provide an effective method of choosing risky alternatives. Thus, the SD method is useful to investors in designing their international investment strategies for assets allocation.

5. Conclusions

This study employs the distribution-free stochastic dominance theory to examine the day-of-the-week effect of eight daily exchange rates in the Taiwan foreign exchange market for the period, 1992–2006. Our study period covers three trading regimes: six-trading days, alternative trading days, and five-trading days. Our findings can be summarized as follows.

First, we observe the day-of-the week effect across different trading-day regimes in our sample period. During the first trading regime, 1992–1997 (one-day weekend) and the third trading regime, 2001–2006 period (two-day weekend), higher returns appear on the first three days of the week (Monday through Wednesday) for almost all currencies, implying that the pattern of the day-of-the-week effect is not influenced by the change of trading days during the week.

Second, Yamori and Kurihara (2004) document the day-of-the-week effect exists in the 1980s for some currencies, which later disappear for almost all currencies in the 1990s in the New York foreign exchange market. The day-of-week effect persists in the Taiwan foreign exchange market even in recent years. This persistence may be explained by the immaturity or inefficiency of the Taiwan foreign exchange market, despite the fact that capital flows have been gradually liberalized from 1990s.

Finally, our important finding is that allocating part of investors' assets in risk-free assets can help distinguish the relative performance among weekdays for the various currencies, which is also supported by the simulation test. This finding enables investors to structure their investment strategies for better assets allocation.

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Appendix

SD and SDR tests

Comparison of Wednesday's and Saturday's returns for *AUD* during the 1992–1997 period (refer to the following table)

(1) *FSD test*:

$$Q_S(p) > Q_W(p) \quad \text{for } 0 < p \leqslant 82/222,$$
$$Q_S(p) < Q_W(p) \quad \text{for } 83/222 \leqslant p \leqslant 1$$

(see columns (3) and (7)). No FSD between Wednesday and Saturday returns.

(2) *SSD test*:

$$\int_0^p Q_S(p)\mathrm{d}t > \int_0^p Q_W(p)\mathrm{d}t \quad \text{for } 0 < p \leqslant 87/222,$$
$$\int_0^p Q_S(p)\mathrm{d}t < \int_0^p Q_W(p)\mathrm{d}t \quad \text{for } 218/222 \leqslant p \leqslant 1.$$

(see columns (4) and (8)). No SSD between Wednesday and Saturday returns.

Comparison of Q_β with Saturday returns:

(1) *FSDR test*:

$$Q_\beta(p) > Q_S(p) \quad \text{for } 0 < p \leqslant 87/222,$$
$$Q_\beta(p) < Q_S(p) \quad \text{for } 218/222 < p \leqslant 220/222$$

(see columns (5) and (7)). No FSDR between Wednesday and Saturday returns.

(2) *SSDR test*:

$$\int_0^p Q_\beta(p)\mathrm{d}t > \int_0^p Q_{\mathrm{S}}(p)\mathrm{d}t \quad \text{for } 0 < p \leqslant 1$$

(see columns (6) and (8)). Mixture Q_β dominates Saturday returns by SSD; hence Wednesday returns dominate Saturday returns by SSDR for $r = 5\%$.

Step No.	C.D.F.[a]	Wednesday		Mixture Wednesday With risk-free rate		Saturday	
		$Q_{\mathrm{W}}(p)$	$\int_0^p Q_{\mathrm{W}}(t)\mathrm{d}t$	$Q_\beta(p)$[b]	$\int_0^p Q_\beta(t)\mathrm{d}t$	$Q_{\mathrm{S}}(p)$	$\int_0^p Q_{\mathrm{S}}(t)\mathrm{d}t$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	1/222	−0.019634	−0.019634	−0.011726	−0.011726	−0.017272	−0.017272
2	2/222	−0.016783	−0.036417	−0.010015	−0.021741	−0.014681	−0.031953
3	3/222	−0.014925	−0.051342	−0.008900	−0.030641	−0.010983	−0.042937
4	4/222	−0.010933	−0.062276	−0.006505	−0.037146	−0.009936	−0.052873
5	5/222	−0.010641	−0.072916	−0.006330	−0.043476	−0.009687	−0.062560
6	6/222	−0.010323	−0.083239	−0.006139	−0.049615	−0.007762	−0.070322
7	7/222	−0.009755	−0.092994	−0.005798	−0.055413	−0.007599	−0.077921
8	8/222	−0.009577	−0.102571	−0.005691	−0.061104	−0.007299	−0.085221
9	9/222	−0.009467	−0.112038	−0.005625	−0.066730	−0.007061	−0.092282
10	10/222	−0.009386	−0.121424	−0.005577	−0.072306	−0.006775	−0.099057
11	11/222	−0.009174	−0.130598	−0.005450	−0.077756	−0.006476	−0.105533
12	12/222	−0.009141	−0.139739	−0.005430	−0.083186	−0.006098	−0.111630
13	13/222	−0.008471	−0.148210	−0.005028	−0.088213	−0.006094	−0.117725
14	14/222	−0.008463	−0.156673	−0.005023	−0.093236	−0.005817	−0.123542
15	15/222	−0.008197	−0.164869	−0.004863	−0.098100	−0.005688	−0.129230
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
80	80/222	−0.001095	−0.384738	−0.000602	−0.226459	−0.000955	−0.314599
81	81/222	−0.001078	−0.385816	−0.000592	−0.227051	−0.000932	−0.315530
82	82/222	−0.000964	−0.386780	−0.000524	−0.227575	−0.000930	−0.31646
83	83/222	−0.000912	−0.387692	−0.000493	−0.228067	−0.000922	−0.317382
84	84/222	−0.000829	−0.388521	−0.000442	−0.228510	−0.000918	−0.31830
85	85/222	−0.000810	−0.389330	−0.000431	−0.228941	−0.000917	−0.319218
86	86/222	−0.000807	−0.390137	−0.000429	−0.229370	−0.000913	−0.320130
87	87/222	−0.000770	−0.390908	−0.000407	−0.229777	−0.000832	−0.320962
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
218	218/222	0.013507	0.0769616	0.0081590	0.058122	0.010609	0.030337
219	219/222	0.015524	0.0924852	0.0093689	0.067491	0.011009	0.041346
220	220/222	0.016843	0.1093283	0.0101607	0.077652	0.011665	0.053010
221	221/222	0.022791	0.1321189	0.0137291	0.091381	0.013327	0.066337
222	1	0.025153	0.1572718	0.0151466	0.106528	0.013571	0.079908

[a] C.D.F. represents cumulative probability. A similar calculation can be found in Levy and Lerman (1985) and Chou and Liao (1996).

[b] The mixture quantile $Q_\beta(p) = \alpha Q_{\mathrm{W}}(p) + (1-\alpha)r_{\mathrm{f}}$ calculated for $r_{\mathrm{f}} = 0.0137\%$ and $\alpha = 0.47$ as $Q_\beta(p) = 0.47Q_{\mathrm{W}}(p) + 0.53 \times 0.0137\%$. In this example, annually risk-free rate is equal to 5.0%. Therefore, daily risk-free rate is equal to 0.0137% (0.05/365).

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