



“Gold, crude oil and the weekend effect: a probability distribution approach”

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Gold, crude oil and the weekend effect: a probability distribution approach

Abstract

Using probability distribution approach, the results show that the traditional weekend effect no longer exist in either the gold or oil markets. Friday does not show the highest return and Monday does not show the lowest return. Instead, a Thursday effect seems to appear in the gold market, while a Wednesday effect is in the oil market. Results of these findings imply that the trading behavior and investors' beliefs change with the passing of time. These beliefs change may result from the changes in information opaqueness, the completeness of markets, internet trading and the settlement procedure also find that the traditional holding period in the gold market has been lengthened, from Thursday (one day earlier than the traditional Friday) to the following Tuesday (one day later than the traditional Monday). As for the oil, a shortening holding period from Wednesday to Friday and a leftward return distribution is found. The plausible interpretation for the longer investors' holding period in regard to gold may relate to that gold is value-preserving. In the case of oil, the shortened period may be due to its larger volatility. The results of this study provide some implications of risk management for both policy-makers and investors who trade the commodity markets on a frequent basis or a long-term view.

Keywords: weekday effect, probability distribution, volatility, gold, crude oil.

JEL Classification: G14, G19, Q48, G10, C13.

Introduction

An extensive literature documents that weekday returns vary with the days of the week across various types of assets and markets (see, for example, Pettengill, 2003)¹. However, most of these works focus on debt- and equity-related securities. In the last two decades, weekday effects have been observed in other types of debt- or equity-related securities and FX (foreign exchange) markets as well², suggesting different conclusions based on various markets or countries. Some of these studies find that Monday does not appear to have the lowest negative return, and Friday no longer provides the highest returns. Instead, these two effects have been replaced by the rest of the weekdays.

Although these issues are continuously being reexamined and explored using different methodologies³, most works focus on financial markets instead of commodity markets. The gold price, however, plays two roles, namely, that of the price of a financial asset as well as the price of a commodity asset. This dual role with one price thus facilitates a more powerful test of the day-of-the-week effect through the impacts of both markets. While some related works have examined the gold market, the method-

ology they use or the time period they investigate is insufficiently up-to-date to provide information on the current patterns of behavior of investors in the market. For example, Ball, Torous, and Tschogl (1982) and Ma (1986) find that weekday effects exist in the gold market, but they use data that is now more than twenty years old. There was then little research in this area until Coutts and Sheikh (2000), who find that there is no longer evidence of a January effect in the gold index.

With the passing of time, institutional factors such as the settlement procedure, or arbitrage opportunities afforded by institutional rules, change, and perhaps a number of the aforementioned anomalies also change. Fortunately, over time sufficient data are also generated that enable us to test this conjecture at the current moment. As gold demonstrates, the mean and variance governing its return are not sufficiently specified, and an approach that explains the behavior of other moments of distributions is required. Besides this, some studies show that weekday effects exist in real estate markets, which is evidence that weekday effects appear to occur over a wide spectrum of asset and commodity markets⁴.

Since the 1970s, and at least until recently, macroeconomists have viewed the price of oil as one of the important sources of economic fluctuations, and a driver of global economic shocks. Since the late 1990s, the global economy has experienced two oil shocks of a sign and magnitude comparable to those

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We appreciate the helpful and suggestive comments from the participants at the Taiwan Finance Association annual meeting in Taichung, Taiwan.

¹ Pettengill (2003) presents a complete literature review on this issue.

² See, for example, Gibbons and Hess (1981), Flannery and Protopadakis (1988), Griffiths and Winters (1995), Johnston, Kracaw, and McConnell (1991), Jordan and Jordan (1991), Ma and Goebel (1991), Singleton and Wingender (1994).

³ For example, Yu et al. (2008), using the panel probability distribution approach, examine the FX markets in Tokyo, London, and New York.

⁴ Redman, Manakyan, and Liano (1997) analyze calendar anomalies for real estate investment trusts and common stocks from 1986 through 1993, finding that REIT returns tend to be higher in January, on Friday, on turn-of-the-month trading days, and on pre-holiday trading days.

of the 1970s. The dramatic surges in oil prices have had a significant impact on the global economy making these disruptions particularly worth analyzing. As far we know, no extant literature has as yet investigated the weekend effect in the oil market.

Gold has been seen as historically having a close relationship with oil – when oil prices soar, gold prices simultaneously rise. Cashin et al. (1999) employ a concordance approach to examine the relationships among different commodities and find that the concordance is highest between oil and gold with a coefficient of 0.69 over the 1957-1999 period. This finding motivates us to further explore whether there exists a similarity or diversity in the distribution of returns and volatility between them. If a regular pattern can be found through distribution, this information may provide investors with a better understanding of trading timing and strategy in both commodities. Moreover, gold is a commodity that is widely held and continuously traded around the world, so that gold is a suitable hedging instrument against currency and stocks. Nikos (2006) and Baur et al. (2007) provide examples of these findings demonstrating that it is beneficial for investors to better understand the relationship between the distributions of these two commodities before including them in their portfolio.

Recently, Roache and Rossi (2009) provide a summary of earlier gold studies based on sample periods in the 1980s and 1990s, confirming the conventional wisdom that gold serves as a hedge against higher inflation and economic uncertainty. Besides, gold also appears sensitive to news related to supply and demand. For example, Cai, Cheung, and Wong (2001) indicate that central bank announcements regarding sales of gold reserves have tended to cause price declines. Other studies have found that gold's sensitivity to news varies with time. Hess, Huang, and Niessen (2008) provide evidence that gold's sensitivity to news is dependent upon the state of the economy, with sensitivity increasing during recessions. So far, the extant studies do not examine whether gold has weekday or weekend effects.

Our paper differs from the extant literature in a number of respects. First, we use the probability distribution technique, which has never been used as far as we know, to analyze the calendar anomaly in the commodity markets of oil and gold. Second, based on the characteristic of the return distribution being symmetric and bell-shaped, the Gaussian function is utilized to fit the return distribution from Monday to Friday in both markets, and the parameters are subsequently estimated. This approach can avoid potential biases resulting from focusing on the

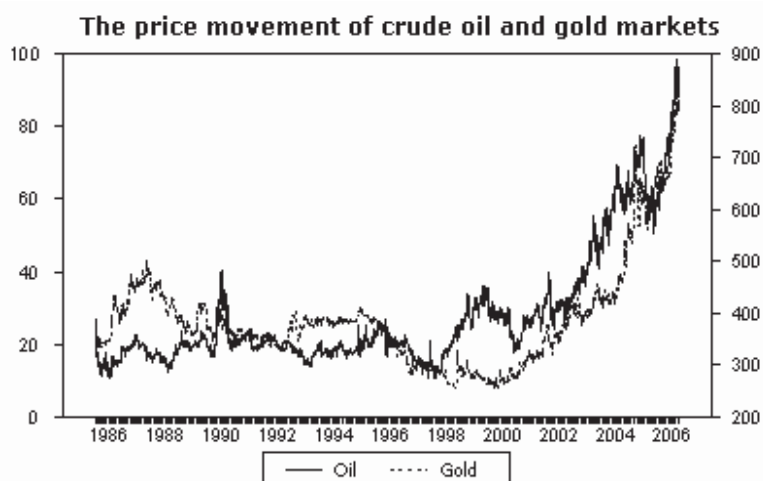
two moments of the mean and standard deviation, and neglecting other moments of the distribution. Third, based on the asymmetric and right-skewed characteristics of the volatility of returns, we use the log-normal function to fit the distribution of volatility from Monday to Friday in both the oil and gold markets, and the coefficients of parameters are estimated. These estimates help us explore in greater detail the micro behavior of weekday returns. Fourth, we conclude that some similarity and diversity in weekday behavior exists between the two markets.

We find that the traditional weekend effect disappears in both the gold and oil markets. Instead, a pre-weekend effect and a mid-weekend effect seem to appear in the gold and oil markets, respectively. A possible interpretation may be due to the different price determination regimes between commodity and financial assets. We also find that the traditional holding period is lengthened from Thursday to the following Tuesday in the gold market, whereas the holding period for oil shortens from Wednesday to Friday. We interpret this lengthening phenomenon in the case of gold as gold is having the dual characteristics of being a commodity and serving as money, it being value-preserving. The shortening of the period for holding oil may be due to oil serving a crucial resource and commodity, whose price is both sensitive and volatile and a shorter holding period can help reduce risk.

The paper is organized as follows. Section 1 presents the data and methodology. Section 2 shows the estimated results of the probability distributions of returns and volatility and reports the estimates of the panel probability distributions from Monday to Friday. Finally, the last Section provides a brief discussion and conclusion.

1. Data and methodology

The daily closing price of crude oil and gold are obtained from the AREMOS database from January 1, 1986 to December 31, 2007 for a total of 5,165 observations. The West Texas Intermediate crude oil price is chosen to represent the oil spot market, and the London 99.5 percent fine afternoon fixing is chosen for the gold spot market, respectively. Figure 1 displays the price movements of the oil and gold markets. As shown in Figure 1 during our sample period, gold traded between a low of \$252 (August 1999) and a high of \$836 (December 31, 2007) per ounce at the fixing; while oil traded between a low of \$10 (in late 1998, in the wake of the Asian financial crisis and the United Nations' oil-for-food program) and a high of \$99.3 (Nov. 2007) per barrel. The wide variance in the price reflected in the probability distribution technique is a better approach for detecting the trading pattern of investors.



Note: The sample period extends from January 1, 1986 to December 31, 2007 for a total of 5,405 observations.

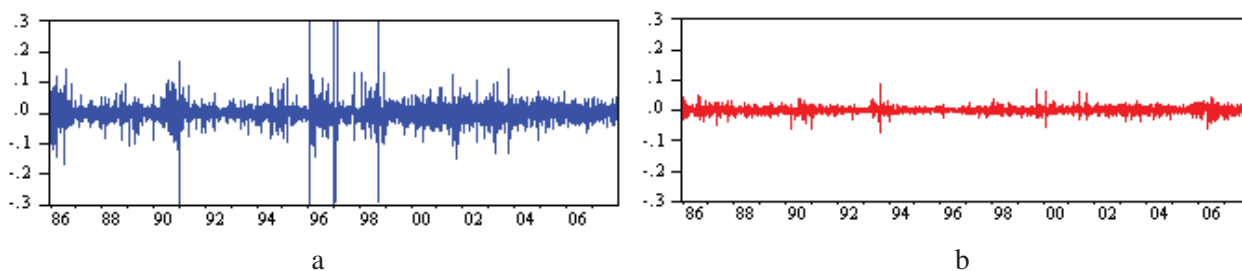
Fig. 1. The price movement of the West Texas Intermediate crude oil and gold markets.

1.1. Quantifying intraday returns and the probability distribution. A few studies have investigated the returns on varying time scales, δt , in probing the nature of the stochastic process (Gopikrishnan et al., 1999; Yu and Huang, 2004). In order to construct the necessary time series of returns, we use the daily prices of crude oil and gold, represented by $Z_i(t)$ $i = 1, 2$, 1 for oil, and 2 for gold, as well as

the price change, represented by $R_i(t)$. $R_i(t)$ is defined as the change in the logarithm of the daily price as expressed in equation (1):

$$R_i(t) = \ln Z_i(t + \delta t) - \ln Z_i(t), \tag{1}$$

where δt denotes the time interval of the sampling with $\delta t = 1$ day. Figure 2 displays the daily returns of the oil and gold markets.



Note: The sample period extends from January 1, 1986 to December 31, 2007 for a total of 5,405 observations.

Fig. 2. The time series of daily returns for the (a) West Texas Intermediate crude oil and (b) gold markets

To construct the probability distribution, we first employ the histogram method to separate the total sample into 100 equal intervals with each interval having the average return as expressed in equation (2):

$$\Delta R = \frac{R^{\max} - R^{\min}}{100}. \tag{2}$$

In equation (2), ΔR is the average return range in each interval, and R^{\max} and R^{\min} are the maximum and minimum intraday returns, respectively. We then calculate the number of intervals, $N(R_n)$, ranging between $R_{n-1} = R^{\min} + (n-1) \cdot (\Delta R)$ and $R_n = R^{\min} + n \cdot (\Delta R)$. Here, n is an integer ranging from 1 to 100. Therefore, the probability of the in-

traday returns ${}_{n-1}R_n$ between R_{n-1} and R_n can be expressed as equation (3):

$$P_r({}_{n-1}R_n) = \frac{N({}_{n-1}R_n)}{\sum_{n=1}^{100} N({}_{n-1}R_n)}. \tag{3}$$

The probability P_r satisfies

$$\sum_{n=1}^{100} P_r({}_{n-1}R_n) = 1. \tag{4}$$

To further analyze the characteristics of the probability distribution, the Gaussian function is chosen to fit the original intraday returns because of its ability to capture the symmetry and shape of the distribution. The Gaussian function is defined as shown in equation (5):

$$f(R) = y_0 + \frac{A}{w \times \sqrt{\pi/2}} e^{-\frac{2(R-R_0)^2}{w^2}}, \quad (5)$$

where y_0 is the baseline, R_0 is the center of the peak, A is the total area under the curve from the baseline, and w equals to the width of the peak at half height.

1.2. Quantifying intraday volatility and the probability distribution. The volatility is measured as the local average of absolute price changes over a specified period of intervals T , where T is an adjustable parameter. We use $T = 5$ days to construct the time series of the volatility of returns. Volatility $V(t)$ is defined as the average of absolute value of $G(t)$ over a time window of $T = 5\delta t$, so the intraday volatility can be specified as in equation (6),

$$V(t) = \frac{1}{5} \sum_{n=0}^4 |G(t + n\delta t)|. \quad (6)$$

Next, we use the probability distribution to fit the volatility. We divide the total sample of observations into 100 equal intervals and calculate the frequency in each interval to estimate the shape of the probability distribution. The volatility in each interval is shown as equation (7):

$$\Delta V = \frac{V^{\max} - V^{\min}}{100}, \quad (7)$$

where the V^{\max} and V^{\min} represent the global maximum and minimum intraday volatility, respectively. We then count the number in each interval of $N(V_n)$ ranging from $V_{n-1} = V^{\min} + (n-1) \cdot (\Delta V)$ to $V_n = V^{\min} + n \cdot (\Delta V)$. In addition, n is an integer ranging from 1 to 100. The estimated probability of the volatility in each interval of $_{n-1}V_n$ (between V_{n-1} and V_n) can be expressed as in equation (8):

$$P_r(_{n-1}V_n) = \frac{N(_{n-1}V_n)}{\sum_{n=1}^{100} N(_{n-1}V_n)}. \quad (8)$$

The normalization of equation (8) can be formulated by equation (9):

$$\sum_{n=1}^{100} P_r(_{n-1}V_n) = 1. \quad (9)$$

To further display the distribution of volatility more clearly, we construct the probability distribution of the volatility of returns. The preliminary distributions for the sample markets are observed to have long tails and to be asymmetrical across the peak so that a log-normal distribution is employed to fit these distributions as shown in equation (10):

$$P(V) = \frac{1}{wV(2\pi)^{1/2}} \exp\left[-\frac{1}{2w^2} \left(\ln \frac{V}{V_c}\right)^2\right], \quad (10)$$

where the parameters V_c and w represent the peak and width of the distribution, respectively¹; μ and σ represent the average intraday volatility and global standard deviation of the volatility in equation (11), respectively. Furthermore,

$$\begin{aligned} \mu &= \exp\left[\ln V_c + \frac{w^2}{2}\right] \text{ and} \\ \sigma &= \sqrt{\exp(2\ln V_c + w^2) \times (\exp(w^2) - 1)} \end{aligned} \quad (11)$$

Be setting $P'(V) = 0$, we can get the peak V as shown in equation (12):

$$V = e^{-w^2} V_c. \quad (12)$$

2. Probability distributions from Monday to Friday in the oil and gold markets

2.1. Descriptive statistics of intraday returns from Monday to Friday. After reshaping the data into a panel style from Monday to Friday, the descriptive statistics from Monday to Friday are presented in Table 1.

Table 1. Summary statistics of panel intraday returns from Monday to Friday in the crude oil and gold markets

	Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera
Monday returns					
Crude oil market	-0.0004	0.0316	0.5020	56.6169	42645.41
Gold market	-0.0001	0.0093	0.9486	14.3703	3210.88
Tuesday returns					
Crude oil market	0.0006	0.0275	3.0769	41.5066	67984.40
Gold market	-0.0002	0.0085	-0.6735	7.2965	298.02
Wednesday returns					
Crude oil market	0.0011	0.0264	-1.3991	21.7203	20229.69
Gold market	0.0004	0.0082	-0.3778	5.9057	1466.06
Thursday returns					
Crude oil market	0.0010	0.0258	-1.3567	19.0074	15420.83
Gold market	0.0006	0.0090	-0.1159	4.1786	734.13
Friday returns					
Crude oil market	-0.0010	0.0323	-0.8643	37.3760	13802.04
Gold market	0.0001	0.0099	0.1448	7.3023	2015.15

Note: This table summarizes the panel intraday returns from Monday to Friday for the West Texas Intermediate crude oil and gold markets. The sample covers the period from January 1, 1986 through December 31, 2007 for a total of Monday (1014 observations), Tuesday (1105 observations), Wednesday (1103 observations), Thursday (1067 observations), and Friday (986 observations).

¹ Width (w) is calculated at half the height of the distribution.

The statistics in Table 1 shows that Friday does not have the highest return in either the oil or gold market, as suggested by the equity returns in the extant research. Instead, Wednesday and Thursday exhibit the most significantly positive and highest returns in the oil (0.0011) and gold (0.0006) markets, respectively. This result implies that a mid-weekday effect exists in the commodity market. Most noticeably, Monday no longer exhibits the most negative and lowest returns. Instead, Friday and Tuesday provide the most negative and lowest returns in the oil (-0.001) and gold (-0.0002) markets, respectively. A preliminary interpretation for the disappearance of

the traditional weekend effect in commodity markets may due to the different price determination regimes between commodities and financial assets. Investors who buy commodities are guided by the macro demand and supply, while investors who buy financial assets are guided by both macro and micro information, which may provide investors with different expectations and beliefs on how to outperform the markets in the short term. Figure 3 displays the average returns among weekdays in the oil and gold markets. The highest (lowest) return, as shown, no longer appears on Friday (Monday), which suggests that no evidence was found for the weekend (Monday) effect.

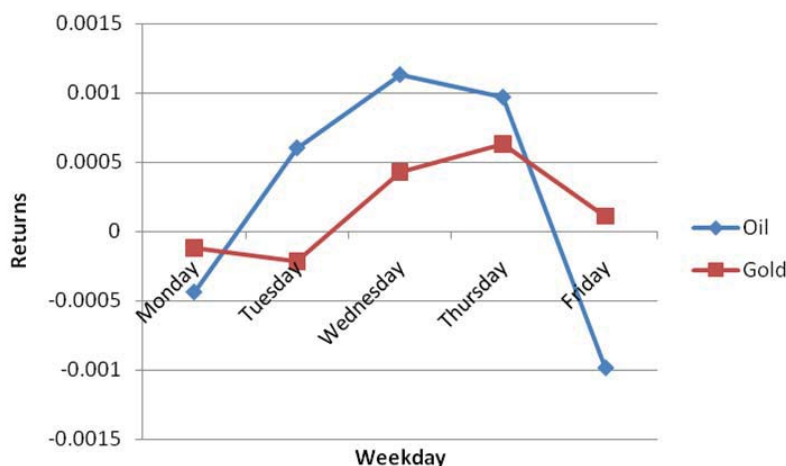


Fig. 3. Weekday returns from Monday to Friday in the oil and gold markets

2.2. Results of estimated parameters in the return distribution. Graphs of the probability distributions of return from Monday to Friday in the oil market are displayed in Figures 4(a)-(f). The returns for the oil distribution indicate that Wednesdays have the highest peak associated with an average width, implying that Wednesdays may have the highest probability of earning abnormal returns. Figures 5(a)-(f) then display the returns for the gold distribution and show that Thursdays have the highest peak associated with an average width, suggesting that the highest probability of earning abnormal returns may occur on Thursday. Both findings compensate for the previous results.

The results in Table 1 show that neither the oil nor gold return satisfies the normality assumptions. Therefore, a Gaussian function was fitted to measure the parameters of the distribution. The estimated coefficients in Table 2 show that Thursdays (Wednesdays) have the greatest peak of 24.49 (71.83) for the crude oil (gold) market. The widest width, at 0.033 (0.0118), appears on Tuesday (Friday) for the crude oil (gold) market; the narrowest width, at 0.0277 (0.0095), is shown on Thursday (Wednesday) for the crude oil (gold) market.

Table 2. Parameter estimates of weekday returns of Gaussian function for the crude oil and gold markets

	Center (R_0)	Width (w)	Height
Monday returns			
Crude oil market	-0.0036098	0.0298	23.586
Gold market	-6.9882E-4	0.0107	66.871
Tuesday returns			
Crude oil market	-0.0019647	0.0330	21.903
Gold market	-4.2028E-4	0.0103	66.733
Wednesday returns			
Crude oil market	8.6570E-4	0.0302	22.807
Gold market	-2.8902E-4	0.0095	71.828
Thursday returns			
Crude oil market	-0.0012900	0.0277	24.490
Gold market	-1.6132E-4	0.0108	62.545
Friday returns			
Crude oil market	-0.0042636	0.0328	20.954
Gold market	-6.9238E-4	0.0118	58.696

Notes: In this table, the Gaussian function was used to fit the

$$\text{original distribution: } f(R) = y_0 + \frac{A}{w \cdot \sqrt{\pi/2}} e^{-\frac{2(R-R_0)^2}{w^2}}$$

where y_0 is the baseline, R_0 is the center of the peak, w is equal to the width of the peak at half height, and h is the height of the fitted distribution.

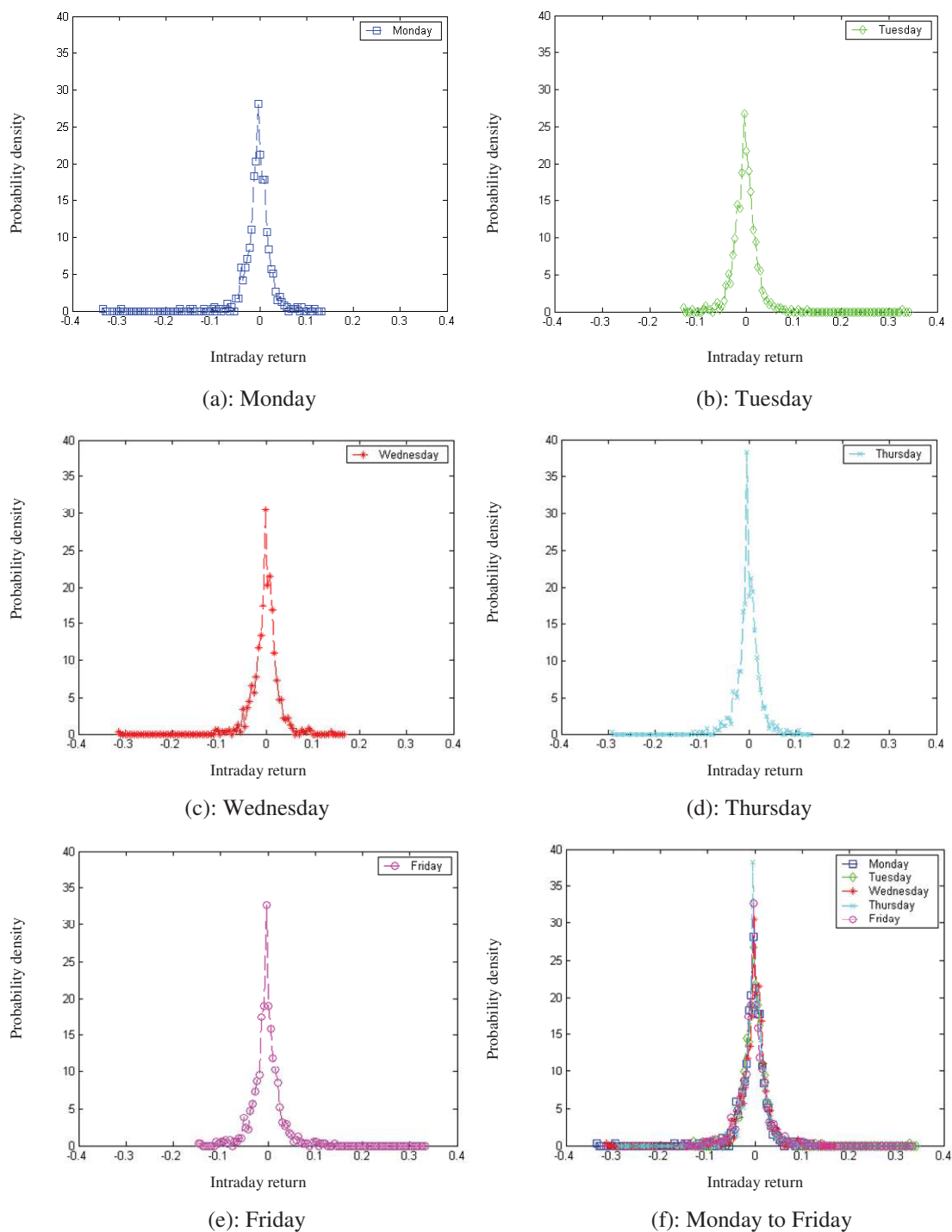


Fig. 4. Probability distributions of returns from Monday to Friday in the oil market

To sum up, we find that the traditional weekend effects have been lengthened in the gold market. Specifically, the Friday effect has been replaced by the Thursday (or pre-weekend) effect, and the Monday effect has recently been replaced by the Tuesday effect. In other words, in order to earn excess returns, it is now likely that investors will buy gold on Thursday and hold it until the following Tuesday. We interpret this from the point of view of a rational market: if investors know that the return on gold will be better on Friday than on the

other days, they should start buying gold on Thursday and shift the positive returns earlier to the other days. Similarly, if investors know that the gold price is likely to be marked down on Monday, they are likely to avoid having their own gold marked down on Monday and so that they can either sell it on Friday or later on Tuesday. Given that gold has the unique characteristic of preserving value, a holding period with a longer term is better and hence can shift the negative returns to the next day.

Apart from that, the settlement effects may also drive this phenomenon in the gold market. For example, the instant market adjusts the returns to reflect the passage of time between striking the bargain and the completion of the transaction. Thus, this particular

operational procedure can partially explain why negative returns do not often appear on Mondays. Our findings differ from the previous findings of Ball, Torous, and Tschoegl (1982)¹ and Ma (1986)², who demonstrate that a weekend effect exists in the gold market.

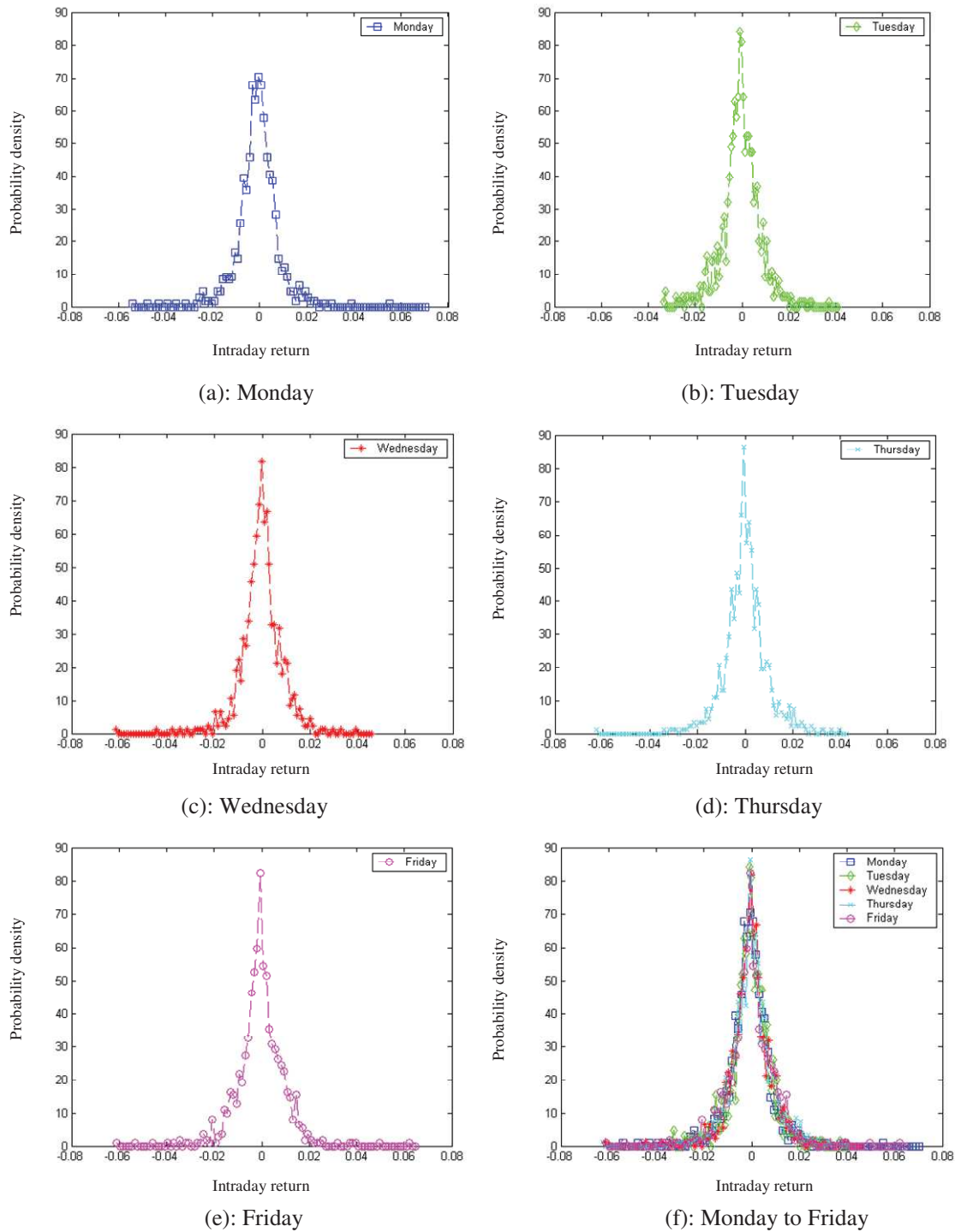


Fig. 5. Probability distributions of returns from Monday to Friday in the gold market

¹ Ball, Torous, and Tschoegl (1982) investigated the morning and afternoon fixings of gold on the London Metal Exchange over the period of 1975-1979, and find the evidence of negative Monday return.

² Ma (1986) analyzed the afternoon fixings of gold price and found that although the pre-1981 and post-1981 periods exhibited daily seasonality, the nature of the seasonality changed. A negative return on Tuesday and a positive return on Wednesday are found in pre-1981; while the negative return disappeared on Tuesday and a negative return on Monday were found in post-1981.

Of course, it is also possible that the investors' behaviors or beliefs may have changed over the last two decades. Apart from that, internet trading with its lower costs and time may change investors' trading behavior to weekdays due to more profitable trading opportunities.

As for the oil market, we find that the traditional weekend effect disappears and the holding period shifts leftward, suggesting that investors buy oil earlier on Wednesdays (or mid-weekday) and sell it earlier on Fridays. We interpret this finding from the same point of view as for gold: if investors know that excess returns on oil may appear on Friday, they will start buying oil on Thursday or even earlier on Wednesday and shift the positive returns leftward. Similarly, when Monday is expected to result in negative (or lower) returns, investors are likely to mark the price of oil down earlier on Friday based on the volatility of oil. All these beliefs thus shift the distributions of the traditional weekend and Monday effect leftward. Apart from that, this behavior may also imply information flows reflecting investor's behavior that is faster than on a daily basis.

This result also possibly relates to the announcement effect: an announcement by the American Petroleum Institute regarding the price of crude oil regularly occurs on Tuesdays, which thus discounts the crude oil price on Wednesday. Other relevant reasons can be broadly summed up as the news to/in the market (e.g., Steeley, 2001; Pettengill and Buster, 1994), and news release impact (e.g., Singleton and Wingender, 2003). Our findings complement these findings from a news release point of view and add an extra dimension in the form of a probability distribution to explain the leftward-shifting weekday effect for crude oil.

2.3. Results of the estimated parameters of the volatility distribution. In Table 3, we compute the average return, standard deviation, skewness, kurtosis, and J-B value of returns for both gold and oil. Results of both gold and oil show that the volatility distribution of gold is slightly right-skewed (with skewness larger than 0) and leptokurtic (with kurtosis larger than 3). However, no significant difference on volatility is found across the five days of the week. Besides, the skewness and kurtosis for oil are significantly larger than those for gold, implying that oil has a much higher risk than gold across the weekdays.

Table 3. Summary statistics of panel intraday volatility from Monday to Friday in the crude oil and gold markets

	Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera
Monday volatility					
Crude oil market	0.01754	0.0131	3.8187	27.8238	19268.53
Gold market	0.00619	0.0038	1.9895	6.7878	1134.86
Tuesday volatility					
Crude oil market	0.01757	0.0129	3.7989	26.7448	8964.78
Gold market	0.00618	0.0039	2.5275	12.5588	2331.95
Wednesday volatility					
Crude oil market	0.01775	0.0137	4.3900	34.1207	13740.46
Gold market	0.00616	0.0040	2.6371	13.7308	4237.16
Thursday volatility					
Crude oil market	0.01771	0.0143	4.5066	34.0445	15457.59
Gold market	0.00619	0.0040	2.6339	13.5126	4646.99
Friday volatility					
Crude oil market	0.01766	0.0132	3.3539	18.8566	9020.83
Gold market	0.00620	0.0039	2.1937	8.7531	1958.21

Notes: This table summarizes the volatility of returns from Monday to Friday for the West Texas Intermediate crude oil and gold markets. The sample covers the period from January 1, 1986 through December 31, 2007 for a total of Monday (1014 observations), Tuesday (1105 observations), Wednesday (1103 observations), Thursday (1067 observations), and Friday (986 observations).

When comparing both markets, the oil market exhibits higher volatility than gold for all of the weekdays in Figure 6(b), implying that oil prices reflect most of the economic instability and expectations. Furthermore, as shown in Figure 6(a), the highest (lowest) volatility in the oil market appears on Wednesday (Monday), whereas the highest (lowest) volatility in the gold market appears on Friday

(Wednesday). If volatility is related to trading volume, these results imply some positive relationship between returns and trading volume¹ and a discrepancy among investors in terms of their beliefs. We discuss it in the next section.

¹ The highest return also appears on Wednesdays in the oil market.

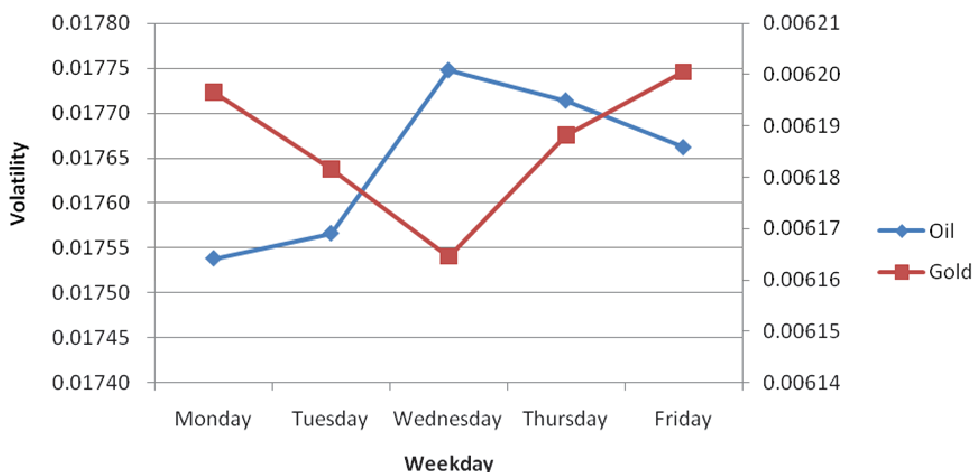


Fig. 6(a). Weekday volatility from Monday to Friday in the oil and gold markets

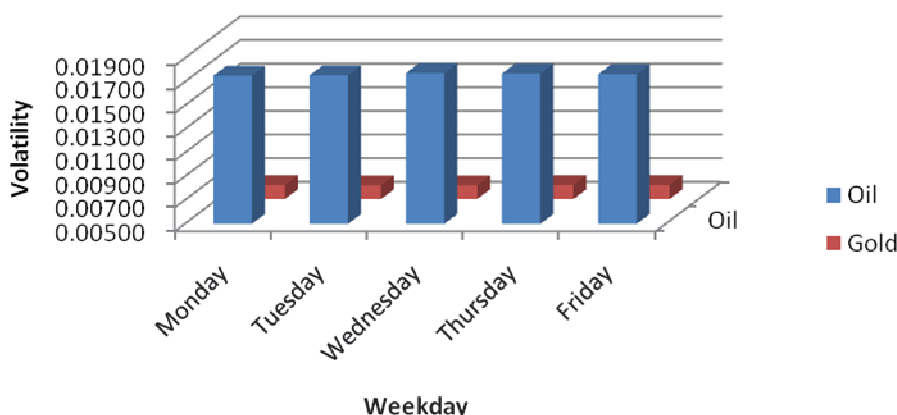


Fig. 6(b). Three-dimensional weekday volatility from Monday to Friday in the oil and gold markets

To better understand the detailed characteristics of volatility, the parameters of the peak and width of the volatility function are estimated. The corresponding graphs of the volatility distributions from Mondays to Fridays for the oil and gold markets are displayed in Figures 7(a)-(f) and Figures 8(a)-(f), respectively. Results are presented in Table 4. Table 4 shows that Mondays have the highest peak of 0.0356 (0.0128) associated with a width of 0.5539

(0.5721) in the oil (gold) market. Results of both markets suggest that the biggest discrepancy in terms of the investors' beliefs occurs in the beginning of the week (Monday), and Wednesdays (Tuesdays) show the lowest peak of 0.0308 (0.0116) in the oil (gold) market. Given that the range of peak and width ($V_c \pm w$) represents the volatility area, the oil market is obviously more volatile than the gold market and has larger discrepancy in terms of investors' beliefs.

Table 4. Estimated coefficients of the volatility of the log-normal function in the crude oil and gold markets

	Mean (μ)	Std. dev. (σ)	Peak (V_c)	Width (w)	Volatility area ($V_c \pm w$)
Monday volatility					
Crude oil market	0.01754	0.0131	0.0356	0.5539	-0.5183-0.5895
Gold market	0.00619	0.0038	0.0128	0.5721	-0.5593-0.5849
Tuesday volatility					
Crude oil market	0.01757	0.0129	0.0339	0.5122	-0.4783-0.5460
Gold market	0.00618	0.0039	0.0116	0.5295	-0.5179-0.5411
Wednesday volatility					
Crude oil market	0.01775	0.0137	0.0328	0.5436	-0.5108-0.5764
Gold market	0.00616	0.0040	0.0119	0.5052	-0.4934-0.5171
Thursday volatility					
Crude oil market	0.01771	0.0143	0.0331	0.5614	-0.5283-0.5945
Gold market	0.00619	0.0040	0.0116	0.5167	-0.5050-0.5283

Table 4 (cont.). Estimated coefficients of the volatility of the log-normal function in the crude oil and gold markets

	Mean (μ)	Std. dev. (σ)	Peak (V_c)	Width (w)	Volatility area ($V_c \pm w$)
Friday volatility					
Crude oil market	0.01766	0.0132	0.0340	0.5211	-0.4871~0.5551
Gold market	0.00620	0.0039	0.0117	0.5367	-0.5251~0.5484

Notes: In this table, the log-normal function is specified as:

$$P(V) = \frac{1}{Vw\sqrt{2\pi}} \exp\left[-\frac{1}{2w^2}\left(\ln\frac{V}{V_c}\right)^2\right], \text{ where } \mu = \exp\left[\ln V_c + \frac{w^2}{2}\right] \text{ and } \sigma = \sqrt{\exp(2 \ln V_c + w^2) (\exp(w^2) - 1)}.$$

The parameters V_c and w represent the peak and width of the distribution, respectively; μ and σ represent the average intraday volatility and standard deviation of the intraday volatility, respectively.

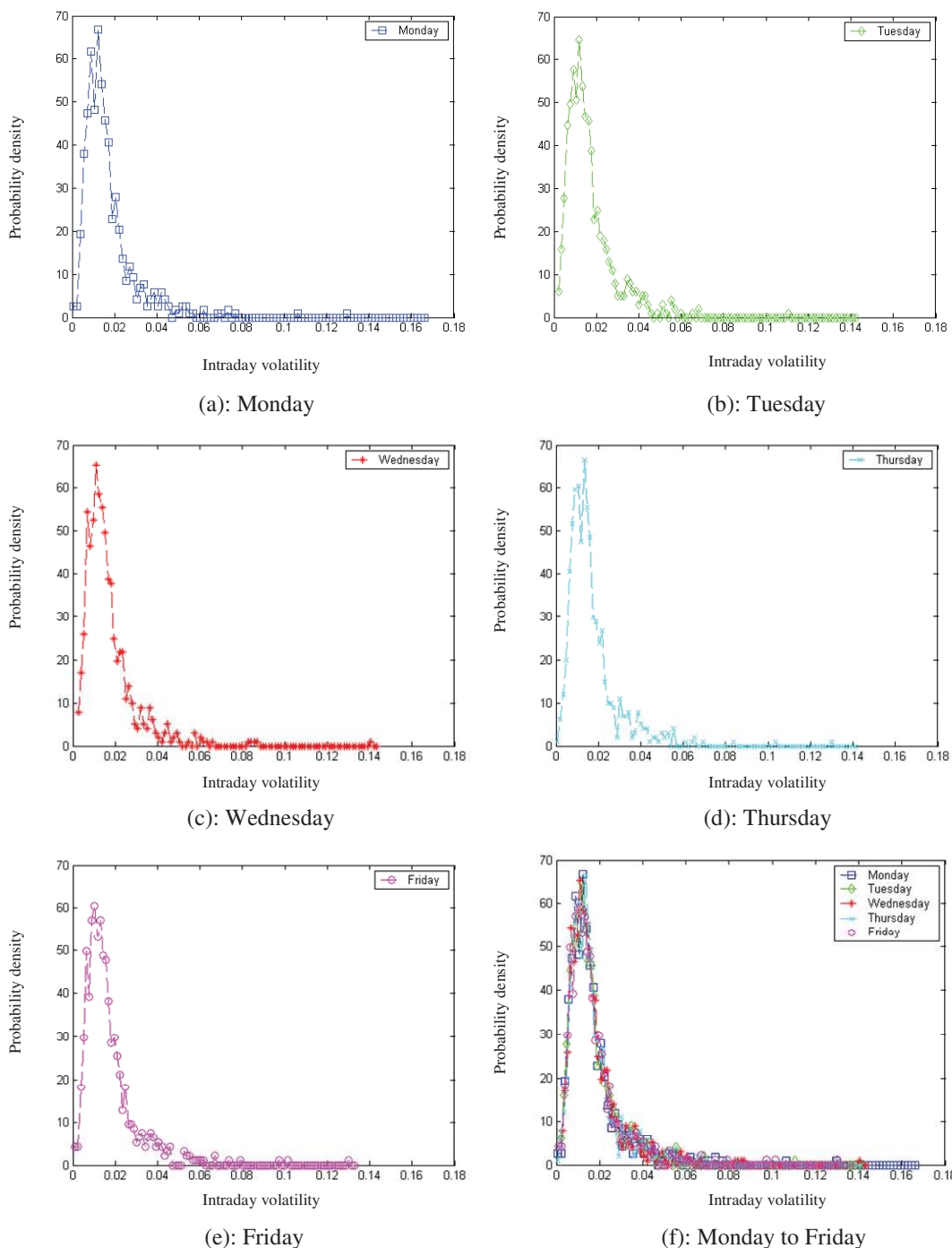


Fig. 7. Probability distributions of volatility from Monday to Friday in the crude oil market

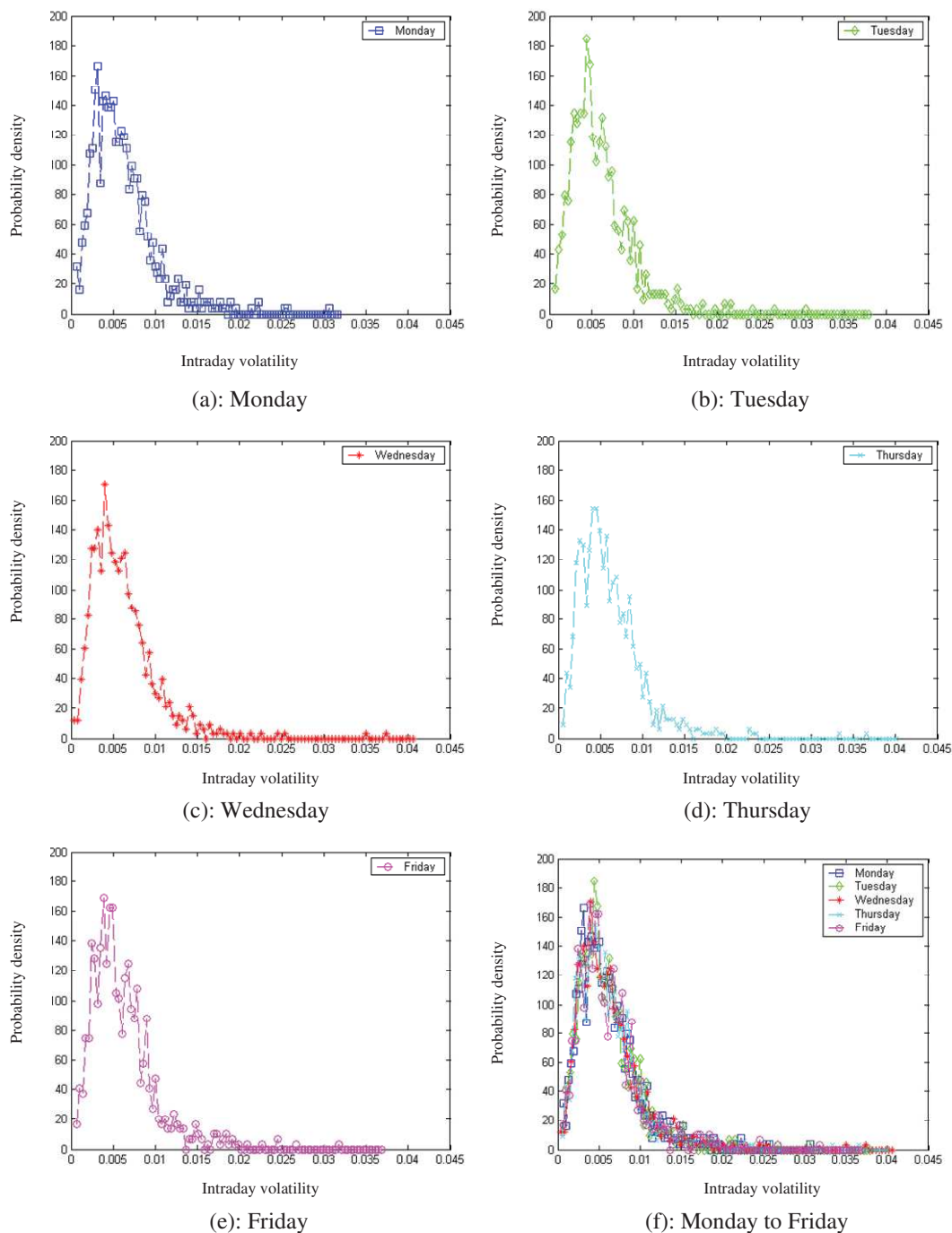


Fig. 8. Probability distributions of volatility from Monday to Friday in the gold market

Conclusions and discussion

Using an approach of probability distribution, we find that the traditional weekend effect no longer exists in gold and oil markets. Instead, a pre-weekend (Thursday) effect seems to appear in the gold market, while a mid-weekend (Wednesday) effect seems to occur in the oil market. The result whereby the weekend effect disappears in the case of gold is different from the report of Ball et al. (1982), implying that the trading behavior and investors’ beliefs change with the passing of time. These beliefs change may result from the changes in

settlement procedure, information opaqueness, the completeness of markets, and internet trading.

We also find that the holding period for gold lengthens from Thursday in the current week to the following Tuesday, whereas the holding period for oil shortens from Wednesday to Friday. We interpret this lengthening phenomenon in the case of gold as having the dual characteristics of being a commodity and serving as money, it being value-preserving. The shortening of the period for holding oil may due to oil serving a crucial resource and commodity, whose price is both sensitive and volatile.

We find that the mean returns of gold vary substantially among the days of the week, with prices reacting to specific scheduled announcements or settlement effects in the United States in a manner consistent with gold's traditional role as a store of value. The essence of the settlement effects is that the market adjusts returns to reflect the passage of time between the striking and completion of the transaction.

We also find that crude oil is more volatile than gold within the volatility distribution as a whole, as shown by the lower peak and the larger width based on the parameters of the volatility function. The results of distribution analysis reveal that innovations in the oil market are faster transmitted than in the gold market. For gold, the lowest volatility appears on Wednesdays, while the highest volatility and peak appear on Fridays, showing that larger trading volume appears on Fridays while thinner trading may occur on Wednesdays. As for oil, the lowest volatility occurs on Mondays, while the highest volatility occurs on Wed-

nesdays. Since these commodities have become increasingly financialized, these results are important for those trading in the commodity markets on a frequent basis and for long-term market participants that make trading decisions based on the release of potentially price-sensitive information or announcements.

Our findings have a number of implications. First, to reduce the uncertainty surrounding the return on gold transactions, traders may wish to time their order flows so as to avoid the release of information that has been shown to affect prices. Second, for longer-term market participants, these results provide confirmation of the pro-cyclical bias of both commodities during periods of economic uncertainty. Third, for policy-makers, the results provide fiscal and exchange rate-related information that enables them to better capture trading times and assess the ability of the policies to respond to the impact that the oil will have on the economy.

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