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Original Research

Jump Identification as a Proxy of Information Shocks, In Tehran Stock Exchange

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ABSTRACT

Using jumps in stock prices as a proxy for information shocks to examine investors' reactions to significant events is the most effective method for identifying information shocks. Compared to other studies, this method has advantages listed at the end of the literature review. We provide evidence consistent with short-term overreaction on the Tehran Stock Exchange. Thus, through the contrarian investment strategy, i.e., buying stocks with negative lagged jump returns and selling those with positive lagged jump returns, earn significantly positive returns over the next one- to three-month horizons. This research analyzed the adjusted daily closing prices of the top thirty stocks on the Tehran Stock Exchange in terms of market value and turnover during 2013-2020.

1 Introduction

The Securities Exchange continues to become increasingly influential as the core of the capital market and plays a crucial role in economic development. Hence, the securities market must be efficient. However, many studies reported inefficient markets and unreasonable investor reactions, leading to excess returns. Since most financial markets lack sufficient efficiency, they fail to communicate news/information extensively and rapidly. As a result of market inefficiency and irrational investor behavior, stocks are not priced rationally. This phenomenon increases investment risk, with investors uncertain about price fairness [15]. However, identifying investor behavior under information shocks and anticipating information shocks help avoid losses in such situations and obtain returns. Many researchers have conducted papers on identifying investor behavior under information shocks. Research has shown that Iran stock market investors overreact to information shocks. It is important to note that a reaction presupposes news. Therefore, it is necessary to identify such information to evaluate investor reactions to it. Earlier works investigated investor behavior by considering certain news about companies and political or economic events. They also focused on sanctions, booms, and recessions. Generalizing such results is not feasible as they restrict the scope of the news. Furthermore, due to market

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inefficiency, the impacts of many pieces of information on the market cannot be effectively identified. For example, some news parts impact the stock market before being communicated. Therefore, evaluating the market reaction after sharing such news leads to an inaccurate judgment of investor behavior as such notification has already impacted the market. Furthermore, many pieces of information contain no shocking words and have no impact on the market. Therefore, evaluating such news to identify the market reaction without knowing their insignificance would be inefficient and unreasonable.Actions have reactions, and reactions, reflected in jumps, follow the news. Our method differs from others conducted through the Iran Stock market in that we do not use the news to study investor behavior after publication. Instead, we identify price jumps as indicators of information shocks and assess how investors respond accordingly. A positive jump represents a positive information shock, while a negative jump indicates a negative information shock. This paper identifies significant discontinuous changes known as jumps in stock prices as a proxy for information shocks using the variance swap jump test [24], then assesses how markets react to information shocks to determine the best investment strategy.

2 Literature Review and Theoretical Framework

2.1 Role of Information Shocks

Information shocks constantly influence the stock market. In an efficient stock market, investors would respond correctly to new information, and stock prices would swiftly and impartially adjust to reflect realistic values.

As mentioned, most stock markets lack efficiency. In an inefficient stock market, information is not disseminated widely and promptly, and investors exhibit biased and inappropriate reactions to new information. They demonstrate under-reaction or overreaction to information about new events. [15]. Under-reaction and overreaction are discussed in detail below.

2.1.1 Over-Reaction

An overreaction occurs when investors’ reactions to information shocks are unreasonable and more than justified. As a result, stock prices go above or below the reasonable level. A positive information shock raises the stock prices more than what is expected (positive overreaction), while a negative shock reduces the stock prices below the realistic level (negative overreaction) [36].

2.1.2 Under-Reaction

An under-reaction occurs when investors’ reactions to information shocks are less intense than expected, leading to a change in the stock prices smaller than justified. Hence, underreacting investors increase the prices to a level lower than justified in reaction to a positive information shock and reduce the stock prices insufficiently in response to negative information shocks. [36].

2.2 Investment Strategies

2.2.1 Relative Strength Strategy (Momentum)

The relative strength strategy represents the market orientation and claims that the past positive or negative return will continue to occur for a certain period. In this strategy, excess returns could be achieved by purchasing the winners of the past and selling the losers of the past [23].

Levy [29] conducted pioneering work on momentum and reported interesting and controversial results. Conflicts between the contrarian and relative strength strategies led to more detailed research on the impacts of momentum. Jegadeesh and Titman [23] were pioneers in proving the ability of momentum to create a significant abnormal return. Their work was used as a basis for future research. The research in this field has increased significantly since the 1990s, and momentum has become more popular among institutional investors. [23].

2.2.2 Contrarian Investment Strategy

The contrarian investment strategy is based on the hypothesized overreaction of investors [30]. This strategy assumes that after overreacting to information on a short-term basis, investors acknowledge their mispricing in the long run and demand stocks at lower prices in the market. When they overreact to information on winners (losers), investors overprice (underprice) the stock. In such cases, prices return to the previous levels in the long run. Hence, the contrarian investment strategy proposes selling stocks that have exhibited high performance in the past and buying stocks that have exhibited poor performance, enabling investors to achieve significant excess returns [35].

2.3 Research Studies on the Iran Stock Market

Extensive research has been conducted to investigate the Iran stock market's reaction to news and information over different and specific periods.

The literature documents evidence of investor miss-reaction to information shocks, with a striking pattern of overreaction in Iran's stock market.

Nikbakht and Moradi [33] Collected data from daily, weekly, and monthly reports during 1992-2003. Drawing on the De Bondt-Thaler approach, they explored relative strength and contrarian strategies on stock price and turnover. They analyzed the data using the t-student test and concluded that Tehran Stock Exchange overreacted. They reported contrarian strategy success during 1992-1997 and failure during 1998-2003.

Ghalibaf-Asl and Naderi [15] Investigated investor overreaction under boom and recession conditions for companies listed on the Tehran Stock Exchange during 1998-2005. They used the Kolmogorov–Smirnov test and reported investor under-reaction to good news and short-term negative reactions to bad news under boom conditions, with a positive stock price change due to a market boom. However, investors overreacted to good and bad news in a recession.

Mehrani and Nonahalfar [30] Evaluated Jegadeesh and Titman's underreaction hypothesis [23] on the Tehran Stock Exchange. They studied stocks listed on the Tehran Securities Exchange during 1999-2006 and concluded that no under-reaction occurred in six-month periods, unlike many papers published elsewhere. The results implied that the return on investment in stocks could be increased on the Tehran Stock Exchange by adopting the contrarian investment strategy.

Damouri et al. [12] studied investor overreaction in firms listed on the Tehran Stock Exchange from 1999 to 2006 in two stages: (1) the uncontrolled investigation of the impacts of the price-to-book (P/B) ratio and firm size and (2) the controlled investigation of the impacts of the P/B ratio and firm size as risk criteria. They employed the portfolio test and analyzed the data via the t-student test. It was found that investors on the Tehran Stock Exchange overreacted to profit, sales, and stock return, while they did not overreact to firms' cash flows. It was also observed that a rise in the period of portfolio construction intensified overreactions.

Aghaei and Maleknejad [1] studied the short-term impacts of dividend announcements during a boom and a recession on the Tehran Stock Exchange during the boom period of 2003-2004 and the recession period of 2005-2006. They showed that investors reacted to dividend announcements negatively during a boom and positively in a recession. Overall, investors reacted more positively to dividend announcements in a recession than in a boom.

Saeedi and Bagheri [35] analyzed the profitability of the contrarian investment strategy on the Tehran

Stock Exchange for seventy firms that were selected using selective sampling. They found that the average return on losers changed significantly after twelve months and was higher than the average return on winners.

Heybati and Zandiyeh [19] studied investor overreactions to news on global financial crises in the stock market. They evaluated investor behavior based on overreaction and information uncertainty during 2008-2010. The findings demonstrated the consistency of stockholder returns with overreaction and information uncertainty. The results proved a rise in market uncertainty in some stocks and stockholder overreaction in some industries upon the release of up-to-date news or the end of global financial crises.

Ziaei and Bahrami [40] evaluated the adoption of the contrarian investment strategy in portfolio construction during 2005-2008. They showed no overreaction occurred in this period, and investors would not gain an abnormal return using the contrarian strategy.

Golarzi and Danaei [16] comparatively analyzed stockholder overreaction in large and small firms on the Tehran Stock Exchange and observed overreactions among the stockholders. Stockholders in large firms showed overreactions, while those in small firms showed no overreaction.

Talebi et al. [38] studied under-reaction and overreaction on the Tehran Stock Exchange following intensive events in the market. The results implied under-reaction after intensive events on the Tehran Stock Exchange. Under-reaction was, in particular, more significant on the initial days following negative intensive events. Adopting the momentum position could lead to excess returns. Moreover, short-term overreaction was not demonstrated.

2.4 Researches on Non-Iranian Stock Markets

Numerous investigations have been conducted on the market's reaction to information shocks. The first scholars who documented long-term reversals in stock returns in the equity market of the United States were De Bondt and Thaler [9]. In their investigation, stocks with poor performance over the previous 3-5 years showed higher returns over the next three to five-year holding periods compared to the stocks with a good performance over the mentioned period. Afterward, De Bont, W.F., Thaler, R.H. [10], and also Chopra et al. [6] documented additional pieces of evidence of long-run reversal patterns in stock returns. They ascribed these observed patterns to investors' overreactions to data in the equity market of the United States. The evidence obtained on under-reaction in the short run is predominantly based on special corporate events. The post-earnings announcement drift (PEAD) of Ball, R., Brown [3], Foster, et al., [14] and Bernard and Thomas [5] are one of the well-documented phenomena in which the corporates that report unexpected negative/positive earnings, on average, undergo negative/positive abnormal returns for up to three quarters following the announcements of earnings. Several investigations have also documented investor under-reaction to other corporate events.

Even with the reversal pattern documented by De Bondt and Thaler [9] for long-term stock returns, a comparatively mixed cross-sectional pattern has been documented for short-term stock returns. The famous investigation conducted by Jegadeesh, N., Titman [20] indicates that stocks featuring high past returns, on average, maintain their better performance compared to stocks featuring low past returns over intermediate horizons of 3-12 months. Such a pattern is called stock return momentum. From another perspective, apparent reversals are also reported by Lehmann [28] and N. Jegadeesh [22] in short-term (at weekly and monthly horizons) stock returns. They report that opposite strategies based on stock returns in the earlier month/week result in noticeable abnormal returns. While a potential cause suggested by Cooper [7] is an overreaction, as most investigations claim, the short-term price reversal is attributed to liquidity or market microstructure impacts, including bid-ask spreads ([21], [17]). Furthermore, Savor [37] Da, Z., Liu, Q., and Schaumburg [8] and Hameed and Mian [18] have shown that price reversal is more likely to occur in stock returns unassociated with firm fundamentals. These findings imply that, over short horizons, stock returns are affected by both information and liquidity effects.

In recent years, much research has been carried out to analyze price jumps whose jump measure is based mainly on the variance swap jump test proposed by Jiang, G.J., and Oomen [24]. Some of these studies are as follows: Kang and Kim [27] proposed an empirical analysis of bitcoin price jump risk, suggesting that considering jumps is essential for risk management and asset pricing. Zada et al. [39] examined whether jumps matter in equity market returns and integrated volatility. The results indicated that the average ratio of jump variations to total variation showed considerable variations due to jumps. Integrated volatility was high during negative jumps, and this pattern was consistent in both developed and emerging markets. Moreover, the peak volatility of stock markets was observed during crises.

Obaid et al. [34] compared the trading skill of institutions and individuals around information shocks. They found strong evidence that institutions possess information acquisition and processing advantages over individuals.The present study aims to identify significant discontinuous changes in stock prices, called jumps, to represent information shocks through a variance swap jump test suggested by Jiang and Oomen [24]. As Jiang and Zhu [26] suggest, this technique generally features the following advantages. Compared with the investigations carried out based on particular corporate events, our technique simplifies the demands on event dates, and, above all, it is not limited to the events announced publicly. This technique presents evidence of investors' reactions to information shocks beyond the ones associated with public events. Eventually, the news reports and corporate events may lack unexpected information regarding stock valuation. Jumps are defined as occasional significant changes in stock prices. As Fama [13] suggested, information surprises govern significant stock price changes during short event windows. Thus, relying on jumps helps improve our deduction about market reactions to significant information shocks. In addition, it can help to concentrate on miss-reaction rather than delayed reactions to information potentially neglected by previous investors.

3 Data

3.1 Statistical Population and Research Sample

The statistical population is the Tehran stock exchange. Furthermore, sample research is the top thirty companies on the Tehran Stock Exchange with the highest market value and turnover.

The companies included Aluminum of Iran, Bandar Abbas Oil Refining Co., Bank Mellat, Bank Pasargad, Bank Saderat Iran, Chadormalu Mining and Industrial Company, Civil Pension Fund Inv, Esfahan Steel Company, Fars & Khuzestan Cement, Ghadir Investment Company, Golgohar Sirjan Mining and Industrial Company, Informatics services, Iran Khodro, Iran Mobile Communications Company, Iran Telecom, IRISL Group, Isfahan Oil Co., Isfahan steel company, Khark Petrochemical Co., Khouzestan Steel Company Refinery, MAPNA Group, Middle East Bank, Mines and Metals Development Investment Company, National Development Investment Group, National Iranian Copper Industries Co., Omid Investment Management Group, Parsian Insurance, Parsian Oil and Gas Development Co., SAIPA and Tejarat Bank.

3.2 Sample Size and Research Period

According to the calculations made Based on the Standard Sample Size Formula (Cochran's formula) for large or unlimited statistical populations, we need a sample size of 1537 for each stock

As the error percentage is typically between one and five percent, we considered the middle of this interval, i.e., 2.5 percent, so the sample size of 1537, as shown below, is obtained with a 97.5% confidence level.

$$n = \frac{z^2\ (pq)}{e^2} = \frac{(1.96)^2\ (0.5 * 0.5)}{(0.025)^2} = 1537$$

n= Sample Size

z = Standard Error associated with the chosen level of confidence (Typically 1.96)

p = Variability / Standard Deviation (Typically 0.5)

q = 1-p

e = Acceptable sample error=0.025

Following the data-cleaning process of each sample stock's daily closing price from 2013 to 2020, we obtained 1624 daily closing prices.

In our sample period, the market trends, including the upward, downward, and neutral trends, must be covered so that we can make our assessment in different market conditions and states and be sure of the existence of both negative and positive jumps.

In this regard:

We examine the period from 2013 to 2020, in which:

2013 to 2014: Upside Trend

2014 to 2016: Sharp Downside Trend

2016 to 2017: Almost neutral

2017 to 2020: Sharp Upside Trend

Therefore, the sample period of 2013 _ 2020 covers both the sample size required based on Cochran's formula and different market trends.

Table 1: Summary statistics of daily returns of thirty sample companies in the Tehran Stock Exchange during 2013 – 2020.

Stock	N	Max(%)	Min(%)	0.25(%)	Mean(%)	Median(%)	0.75(%)	St. dev
Aluminum of Iran	1623	51.57	-68.67	-0.49	0.10	0.00	0.52	0.03
Bandar Abbas Oil Refining Co	1623	70.31	-57.96	-0.77	0.11	0.00	0.94	0.03
Bank Mellat	1623	46.31	-50.02	-0.54	0.14	0.00	0.67	0.03
Bank Pasargad	1623	32.93	-27.28	-0.29	0.06	0.00	0.09	0.02
Bank Saderat Iran	1623	7.88	-63.27	-0.44	0.03	0.00	0.46	0.03
Chadormalu Mining and Industrial Company	1623	10.09	-45.02	-0.57	0.00	-0.06	0.42	0.02
Civil Pension Fund Inv	1623	15.20	-50.40	-0.39	0.06	-0.04	0.43	0.02
Esfahan Steel Company	1623	10.17	-37.68	-0.70	0.03	-0.05	0.75	0.02
Fars & Khuzestan Cement	1623	10.11	-24.50	-0.93	0.14	-0.08	1.28	0.03
Ghadir Investment Company	1623	9.80	-45.21	-0.60	0.03	-0.07	0.63	0.02
Golgohar Sirjan Mining and Industrial Company	1623	10.17	-40.15	-0.55	0.03	-0.03	0.51	0.02
Informatics services	1623	14.10	-67.38	-0.16	0.08	0.00	0.20	0.03
Iran Khodro	1623	30.08	-13.55	-1.46	0.18	0.00	1.89	0.03
Iran Mobile Communications Company	1623	10.16	-56.05	-0.21	-0.01	-0.01	0.31	0.03
Iran Telecom	1623	10.19	-19.32	-0.36	0.07	0.00	0.36	0.02
IRISL Group	1623	218.79	-37.44	-0.44	0.20	0.00	0.24	0.06
Isfahan Oil Co	1623	12.60	-88.05	-0.68	0.06	0.00	0.79	0.04
Isfahan steel company	1623	131.39	-68.43	-1.44	0.11	0.00	1.70	0.05
Khark Petrochemical Co	1623	15.74	-64.77	-0.28	0.07	0.00	0.34	0.03
Khouzestan Steel Company Refinery	1623	12.05	-70.93	-0.46	0.01	-0.03	0.44	0.03
MAPNA Group	1623	26.62	-41.47	-0.68	0.14	0.00	0.88	0.03
Middle East Bank	1623	9.84	-29.57	-0.47	0.12	0.00	0.64	0.02
Mines and Metals Development Investment Company	1623	12.41	-56.45	-0.77	0.04	-0.04	0.58	0.03
National Development Investment Group	1623	23.63	-43.05	-0.44	0.10	0.00	0.72	0.03
National Iranian Copper Industries Co	1623	25.81	-45.20	-0.73	0.05	-0.04	0.73	0.02
Omid Investment Management Group	1623	9.82	-44.22	-0.24	0.06	-0.03	0.19	0.02
Parsian Insurance	1623	10.74	-29.23	-0.34	0.09	0.00	0.24	0.02
Parsian Oil and Gas Development Co	1623	10.17	-53.09	-0.63	0.05	0.00	0.77	0.02
SAIPA	1623	11.33	-42.13	-1.36	0.10	0.00	1.77	0.03
Tejarat Bank	1623	13.29	-73.59	-0.58	0.02	0.00	0.41	0.03

It is important to note that this research is based on adjusted prices, which cover the price gaps caused by corporate events, including capital increases and cash dividend distribution.

3.3 Data Collection and Analysis

The adjusted daily closing price of the thirty stocks selected as the research samples during 2013-2020 was collected using TSE Client. Furthermore, all processes described in the methodology section are implemented by MATLAB V.2019, using general MATLAB functions and statistical toolboxes.

4 Methodology

In this section, the empirical methodology employed for this study is described. Our jump measure is predominantly founded on the variance swap jump test suggested by Jiang, G.J., Oomen [24], and Barndorff-Nielsen and Shephard [4], who utilized Bi-power variation (BPV) minus realized variance (RV) in order to test for jumps over short intervals. Jiang and Yao [25] and Jiang and Zhu [26] employed the JO technique to express the cross-sectional stock returns. Recent years have witnessed continued follow-up research on the JO measure, making it highly relevant and applicable to stock market analysis.

Jumps are occasional significant changes in stock prices generally due to disclosing unanticipated information [26].

$$d\ln S_t = a_t dt + \sqrt{V_t}dW_t + J_t dq_t \tag{1}$$

Where a_t represents the instantaneous drift, S_t stands for the stock price at time t, J_t stands for jumps in asset prices, V_t represents the instantaneous variance in the absence of jumps, q_t stands for a counting process with finite instantaneous intensity λ_t, and W_t represents standard Brownian motion.

In particular, by applying Itô's lemma to Equation (1), followed by integrating over time, we can write:

$$2\int_0^T \left[\frac{dS_t}{S_t} - d\ln S_t\right] = V_{(0,T)} + 2\int_0^T (e^k - 1 - J_t)dq_t \tag{2}$$

Where $V_{(0,T)} = \int_0^T V_t dt$ is the integrated variance. Eq. (2) forms the basis of the jump test.

This characteristic is especially suitable for our investigation because we are focused on noticeable information shocks.

This investigation applies the jump test to the observed daily stock returns. In order to prevent potential look-ahead biases in empirical analyses, we determine the jumps based on a One-month rolling window. In such a way, the occurrence of stock price jumps in the previous months is examined at the beginning of every month. In the case of rejection of the null hypothesis of no jumps, a sequential process is resumed in order to find if the price change on a particular day indicates a jump or not.

4.1 Jump Test Formula

The set $\{St_0, St_1, \ldots, St_N\}$ stands for the stock prices witnessed within the [0, T] time interval, in which $t_0 = 0$, $t_N = T$. The equations below are associated with deciding the jump test equation.

$$R_{t_i} = S_{t_i} / S_{t_{i-1}} - 1 \tag{3}$$

$$r_{t_i} = \ln\left[S_{t_i} / S_{t_{i-1}}\right] \tag{4}$$

$$RV_N = \sum_{i=1}^N r_i^2, \tag{5}$$

$$SWV_N = 2\sum_{i=1}^N (R_i - r_i) = 2\sum_{i=1}^N R_i - 2\ln(S_T / S_0), \tag{6}$$

$$\Omega_{SWV} = \frac{1}{9}\mu_6 X_{(0,T)} \tag{7}$$

$$X_{(0,T)} = \int_0^T V_u^3 du, \tag{8}$$

$$\mu_p = 2^{\mu/2}\Gamma[(p+1)/2]/\sqrt{\pi}. \tag{9}$$

$$BPV_N = \frac{1}{\mu_1^2}\sum_{i=1}^{N-1}|r_i||r_{i+1}|. \tag{10}$$

$$\widehat{\Omega}_{SwV} = \frac{1}{9}\mu_6 \frac{N^3\mu_{6/p}^{-p}}{N-p+1}\sum_{i=0}^{N-p}\prod_{k=1}^{p}|r_{i+k}|^{6/p}, \text{ with p=6} \tag{11}$$

$$\frac{V_{(0,T)}N}{\sqrt{\Omega_{SWV}}} = (1-\frac{RV_N}{SW|V_N})^d \to N(0,1). \tag{12}$$

Among the abovementioned equations, Equations (3) and (4) present the logarithmic and simple returns, respectively. In the following, N represents the frequency of the observations sampled between zero, and T. Equation (12) indicates the jump test statistic introduced by Jiang, G.J., and Oomen [24]. In order to apply the test statistic in Equation (12), Barndorff-Nielsen and Shephard [4] suggested an appropriate estimator for V(0, T). They proved that BPV_N, shown in Equation (10), is an appropriate estimator for V (0, T). In addition, in order to apply the test statistics in Equation (12), Jiang and Zhu [26] developed a consistent estimator of Ω_{SWV} in Equation (11).

4.2 Jump Detection Procedure

The jump detection test presented above is carried out on the stock returns on a daily basis throughout the one-month rolling window**.** The null hypothesis assumes no jump in the desired one-month window. In the case of rejecting the null hypothesis of no jumps, in the one-month window, based on a sequential procedure, the days with a price jump are identified. Suppose $\{r_{t1}, r_{t2}, \dots, r_{tN}\}$ represents the daily stock returns over the $[t_1,t_N]$ period.

The sequential procedure of the identification of price jump is as follows:

Firstly, the jump test is carried out on daily returns over a one-month window $[t_1, t_N]$. If the jump test does not reject the null hypothesis of no jumps, no jump exists in this one month, and we progress toward the following months. However, in the case of rejecting the null hypothesis, the test statistic JS_0 is recorded, and we will proceed to the second step.

Secondly, the sample median (represented by r_{median}) replaces each daily return, and the jump test is conducted on the series. For instance, if the returns on the i[th] day are replaced, the jump test is conducted on the series $\{r_{t1}, ..., r_{ti-1}, r_{median}, r_{ti+1}, ..., r_{tN}\}$, and the test statistic JS_i is recorded for i = 1, …, N.

Thirdly, the series JS0–JSi is constructed for i = 1…N. +

If JS0–JSj has the maximum value of all days, the change in stock price on day j is then defined as a jump.

Finally, the r_{median} replaces the identified jump observation, and given the new sample of stock returns, the process is started again from Step 1.

5 Empirical Analysis

The main research question of our study is how the market reacts to large information shocks. To examine this question, at the beginning of each month, Jumps are identified using the variance swap jump test proposed by Jiang, G.J., Oomen [24] throughout the one-month rolling window. And then, stocks are sorted into deciles based on their lagged cumulative jump returns (CJR) over the past one month (D10 with the highest CJR and D1 with the lowest CJR). Moreover, the average monthly returns of each decile portfolio with one-, three-, six-, and 12-month investment horizons during 2013-2020 are calculated. Furthermore, market behavior under information shocks is analyzed. And Positive and negative jumps are analyzed independently.

5.1 Market Behaviour under Jumps and the Optimal Investment Strategy

After identifying jumps, the stocks are categorized into decile portfolios, D1 to D10, in each one-month rolling window. Then the average monthly return of decile portfolio D1 to D10 and the difference between the average monthly return of decile portfolio D1 and decile portfolio D10 (D10 – D1) for investment horizons of 1, 3, 6, and 12 months during 2013-2020 is calculated. The possible scenarios regarding positive price jumps include the following:

I) D10-D1>0

A D10-D1 return difference higher than 0 suggests that the portfolios that have recently had higher returns (D10 with the highest CJR) will have higher returns in the near future than those with lower recent returns (D1 with the lowest CJR); this indicates an under-reaction to information shocks in the market since the portfolios with a higher CJR are expected to have a higher CJR in the future consistent, with investors continuing to invest in the market; stocks experiencing positive jumps are purchased during the investment horizon, resulting in positive returns. Conversely, stocks with negative jumps are sold during the investment horizon, leading to negative returns. These findings indicate that information shocks causing jumps are not immediately incorporated into stock prices. Instead, investors adjust their price expectations over a longer timeframe than anticipated, implying an under-reaction of the market to these information shocks.

The relative strength (momentum) would be the optimal investment strategy in such a case. This strategy assumes that the positive or negative returns in the past continue for a certain period. An excess return can be obtained by buying winners and selling losers [23].

II) D10-D1<0

A D10-D1 return difference below 0 implies that portfolios that have recently had higher returns (portfolio D10 with the highest CJR) are expected to have lower returns in the near future compared to portfolios that recently had low returns (portfolio D1 with the lowest CJR); This suggests an overreaction to information shocks in the market. Investors overreact to information shocks concerning winners and increase their prices above the realistic level by increasing the demand for the winners. On the other hand, investors show a negative overreaction to losers and reduce their prices below the realistic level. In such a case, the prices rise/decline back to the realistic levels during the investment time horizon, providing an opportunity to gain returns. Thus, the contrarian investment strategy would be optimal; the stocks that have recently had positive returns are sold, and buying stocks that have recently had negative returns gain excess returns [35].

III) D10-D1=0

In an efficient stock market, one does not anticipate significant differences in returns between D10 and D1. As a result, it is not possible to obtain abnormal returns.

It is essential to note the reversal of the first and second scenarios regarding negative price jumps.

A summary of the procedure done through the one-month rolling window during 2013 – 2020 is shown below.

Fig.1: Illustrates a summary of the procedure conducted using a one-month rolling window from 2013 to 2020.

6. Empirical Results

As mentioned, we identified positive and negative jumps using the one-month rolling window, calculated positive and negative CJRs separately, and developed equally-weighted portfolios D1 to D10. Then, the average monthly returns of decile portfolios D1 to D10 were calculated in the 1, 3, 6, and 12 months investment horizons. Based on the D10-D1 return difference, we identified the market's (investors') reaction to information shocks and selected the optimal investment strategy.

As mentioned, the jump identification procedure was based on daily observations on the one-month rolling window. In particular, at the beginning of each month, it was tested whether a stock price had experienced a jump in the past month. If the null hypothesis (no jump) were rejected, a sequential process would be used to identify the day a jump occurred and measure that jump.

It is important to note that stocks may undergo both positive and negative jumps. Thus, positive and negative jumps neutralize each other when calculating the CJR, and the predictive power of negative and positive jumps cannot be investigated distinctly. Hence, the predictive power of positive and negative jumps was measured separately. This approach helped to detect potential asymmetric reactions to good and bad news separately. Tables 2 and 3 categorize stocks in each decile portfolio based on their one-month-lagged CJR during 2013-2020. D1 has the lowest CJR, whereas D10 has the highest CJR. Moreover, the average monthly returns of the equally weighted decile portfolios D1 to D10 for 1, 3, 6, and 12 investment horizons are reported after every one-month rolling window during 2013-2020.

Table 2: This table reports the average monthly return of equal-weighted portfolios (created based on positive cumulative jump returns) with one, three, six, and 12-month investment horizons.

Deciles	Raw Return (%) of each portfolio in each investment horizon			
	1M	3M	6M	12M
Sort on One Month Positive Cumulative Jump Returns				
D1	1.35	1.12	0.99	0.94
D2	1.22	0.97	0.98	0.96
D3	0.95	0.95	-0.99	0.96
D4	0.86	0.93	0.96	1.00
D5	0.87	0.90	0.96	0.97
D6	0.81	0.91	0.95	-0.97
D7	0.88	0.93	0.96	0.98
D8	0.83	0.93	1.00	0.98
D9	0.80	0.89	0.98	0.98
D10	0.70	0.88	0.99	1.04
D10 – D1	-0.65	-0.24	0	0.1

Table 2 (regarding positive jumps) indicates a D10-D1 return difference of -0.65 and -0.24 for the 1-month and 3-month investment horizons, respectively. These negative differences suggest that the prices declined over the short-term horizons of 1-3 months. Thus, the market showed an overreaction to positive shocks. As a result, the contrarian investment strategy would be optimal for short-term horizons of 1-3 months following information shocks.

Table 3 (regarding negative jumps) indicates a D10-D1 return difference of 0.62 and 0.36 for the 1-month and 3-month investment horizons, respectively, suggesting price rises. Therefore, the market showed an overreaction to negative information shocks over short-term horizons of 1-3 months. As a result, the contrarian investment strategy is recommended for a time horizon of 1-3 months after negative information shocks. Tables 2 and 3 show that the Tehran Stock Exchange overreacted to positive and negative information shocks. Therefore, the contrarian investment strategy would be optimal upon positive and negative information shocks for investment horizons of 1-3 months following information shocks.

Table 3: This table reports the average monthly return of equal-weighted portfolios (created based on negative cumulative jump returns) with one, three, six, and 12-month investment horizons.

Deciles	Raw Return(%) of each portfolio in each investment horizon			
	1M	3M	6M	12M
Sort on One Month Negative Cumulative Jump Returns				
D1	0.75	0.89	0.94	0.97
D2	0.80	0.89	0.95	0.96
D3	0.83	0.93	1.00	1.00
D4	0.88	0.93	0.96	0.95
D5	0.81	-0.91	-0.96	0.95
D6	0.87	0.90	0.90	0.97
D7	0.86	0.93	0.90	0.97
D8	0.95	0.97	0.92	0.96
D9	0.97	1.21	0.92	0.96
D10	1.37	1.25	0.93	0.95
D10 – D1	0.62	0.36	-0.01	-0.02

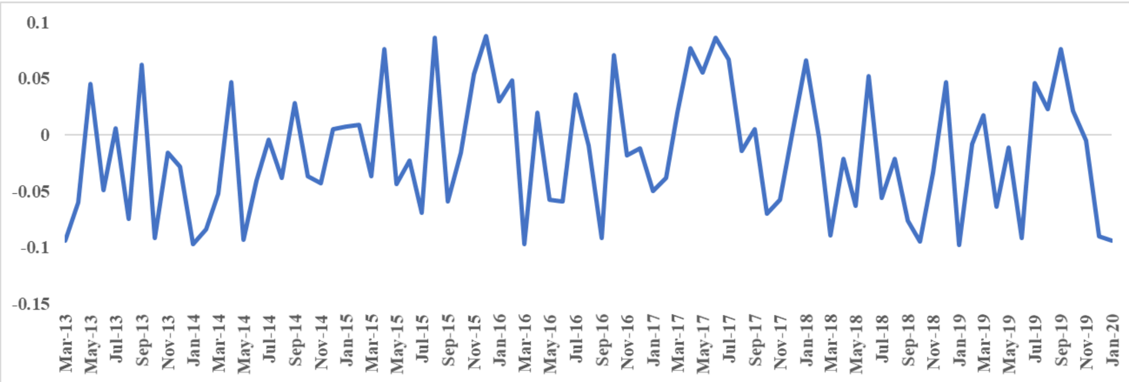

Fig. 2: Monthly decile portfolio's return difference of D10 and D1 (D10–D1) formed on past one-month cumulative positive jump returns (CJR) with one-month investment horizon.

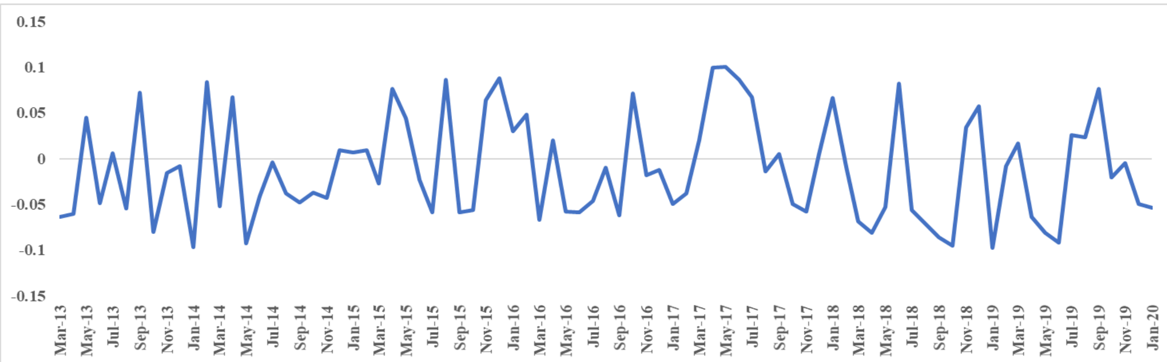

Fig. 3: Monthly decile portfolio's return difference of D10 and D1 (D10–D1) formed on past one-month cumulative positive jump returns (CJR) with three-month investment horizon.

Figs. 2 and 3 plot the monthly decile portfolio's return difference of D10 and D1 (D10–D1) formed on past one-month cumulative positive jump returns (CJR) with one-month and three-month investment horizons. The two time-series have a mean of -1.266% and -0.955%, respectively, for the whole sample period.

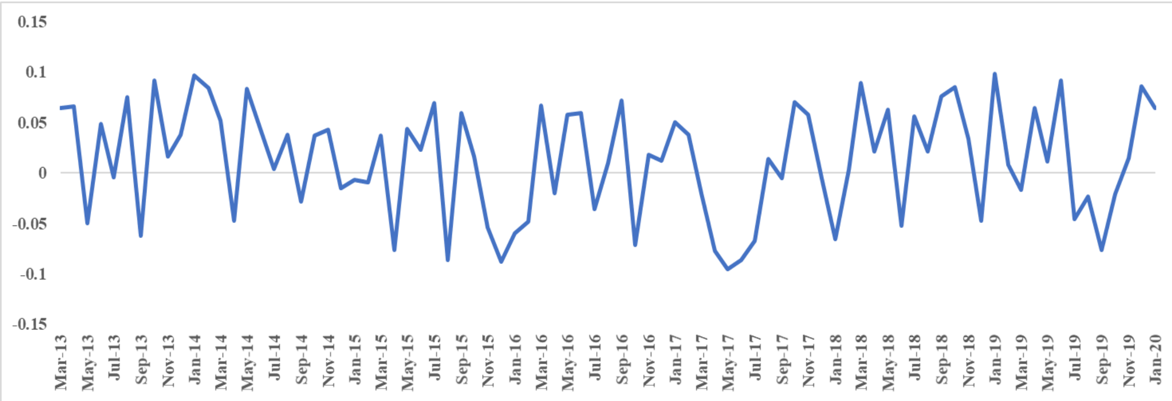

Fig. 4: Monthly decile portfolio's return difference of D10 and D1 (D10–D1) formed on past one-month cumulative negative jump returns (CJR) with one-month investment horizon.

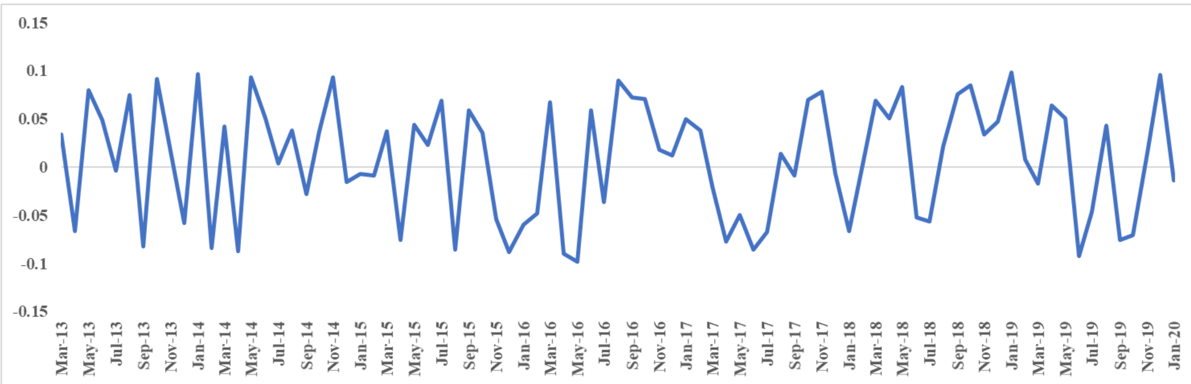

Fig. 5: Monthly decile portfolio's return difference of D10 and D1 (D10–D1) formed on past one-month cumulative negative jump returns (CJR) with three-month investment horizon.

Fig. 4 and 5 plot the monthly decile portfolio's return difference of D10 and D1 (D10–D1) formed on past one-month cumulative negative jump returns (CJR) with one-month and three-month investment horizons. The two time-series have a mean of 1.295% and 0.807%, respectively, for the whole sample period.

7 Conclusion

We use jumps in stock prices as a proxy for information shocks and examine market reactions to information shocks based on the adjusted daily closing price of the top thirty companies on the Tehran

Stock Exchange with the highest market value and turnover during 2013-2020. We provide evidence consistent with the short-term overreaction in the Tehran Stock Exchange.

Due to the overreaction to information shocks in the short run, the contrarian investment strategy is optimal on the Tehran Stock Exchange in the short run (over the next one- to three-month horizons) upon information shocks.

Regarding the practical application of the research, drawing on the variance swap jump test proposed by Jiang, G.J., and Oomen [24], stocks that have experienced lagged jump returns can be identified. As the research results, the Tehran Stock Exchange overreacts to information shocks in the short run, and the contrarian investment strategy could be adopted for short-term horizons (one- to three-month horizons); that is, buying stocks with negative lagged jump returns and selling those with positive lagged jump returns earn significantly positive returns over the next one- to three-month horizons.

7.1 Future Research Directions

1. Since this study adopted daily data, future works can exploit intraday data. Utilizing intraday data helps mitigate concerns about the accuracy of event dates or the time of information arrival.
2. The present study used equally-weighted portfolios (D1 to D10). A suggestion for future works is to employ value-weighted portfolios to enhance their results' accuracy.
3. This study focused on the top thirty companies with the highest market value and turnover on the Tehran Stock Exchange. In order to conduct a more comprehensive study, we suggest employing all the active stocks on the Tehran Stock Exchange.

Appendix

Implemented MATLAB codes of all processes related to the research methodology, including the Jump test and jump identification procedure, classifying stocks into D1 to D10 deciles (equal-weighted portfolios) based on their lagged cumulative jump returns (CJR) over the past month and calculating the average monthly return of decile portfolios D1 to D10 for 1,3,6 and 12-month investment horizons are entirely given below.

```
%%%%%%%%%%%%%%%Test%%%%%%%%%%%%%%%%%%
clc
clear
Prices=xlsread('prices.xlsx','sheet1','B2:ae1625');
% load Prices
R=price2ret(Prices,[],'periodic');
r=price2ret(Prices,[],'continuous');
w=1*30;     %one month
crVal=1.96; %critical value
for s=1:size(R,2)
   RR=R(:,s);
   rr=r(:,s);
   Rno=RR(1);
```

```
    rno=rr(1);
    for i=2:size(R,1)-w+1
        R0=RR(i:i+w-1,:);
        r0=rr(i:i+w-1,:);
        k0(i)=JS(V(r0),Q(r0),RV(r0),SWV(R0,r0));
        if k0(i) < crVal && k0(i) > -crVal %do not reject null hyp.
            jump(s,i)=0;
            Rno=[Rno(1:i-1);R0];
            rno=[rno(1:i-1);r0];
        else                                %reject null hyp.
            for j=1:w
                R1=R0;
                r1=r0;
                R1(j)=median(R1);
                r1(j)=median(r1);
                k1(j)=JS(V(r1),Q(r1),RV(r1),SWV(R1,r1));
                k2(j)=k0(i)-k1(j);
            end
            [~,ind]=max(k2);
            R0(ind)=median(R0);
            r0(ind)=median(r0);
            Rno=[Rno(1:i-1);R0];
            rno=[rno(1:i-1);r0];
            jump(s,i)=ind+i-1;
        end
    end
    RnoJump{s,:}=Rno;
    rnoJump{s,:}=rno;
end
%% %%%%%%%%%%%%%TABLE%%%%%%%%%%%%%%%

d1=(1:  30 : size(R,1));  %  for 1 month

for i=1:size(jump,1)
    jmp=jump(i,:);
    jmp(jmp==0)=[];
    JumpReturn{i,1}=unique(jmp');
```

```
    JumpReturn{i,2}=R(JumpReturn{i,1},i);
end
for i=1:size(Prices,2)
    JR1=JumpReturn{i,1};
    JR2=JumpReturn{i,2};

    ni=find(JR2 < 0);      %%%%%%  for negative return change to >



    JR1(ni)=[];
    JR2(ni)=[];
    for j=1:length(d1)-1
        in1=find(JR1 > d1(j));
        in2=find(JR1 < d1(j+1));
        in3=intersect(in1,in2);
        CJR1(i,j)=sum(JR2(in3));
    end
end
for i=1:size(CJR1,2) % month
    D0=sort(CJR1(:,i));
    D1=CJR1(:,i);
    D2=quantileranks(D1,10);
    for j=1:10 % decile
        stock{j,i}=find(D2==j);
    end
end
t=[30 90 120 360];
for i=1:size(stock,1) % deciles
    for j=1:size(stock,2) % month
        if t(1)*(j+1) < size(R,1);       T1(j,:)=mean(R(t(1)*(j):t(1)*(j+1),stock{i,j}));
        end
        if (t(2)*(j+1))-60 < size(R,1);  T2(j,:)=mean(R((t(2)*j)-60:(t(2)*(j+1))-60,stock{i,j}));
        end
        if (t(3)*(j+1))-90 < size(R,1);  T3(j,:)=mean(R((t(3)*j)-90:(t(3)*(j+1))-90,stock{i,j}));
        end
        if (t(4)*(j+1))-330 < size(R,1); T4(j,:)=mean(R((t(4)*j)-330:(t(4)*(j+1))-330,stock{i,j}));
```

```
        end
    end



    AllDEC1{i,:}={T1,T2,T3,T4}; %return of each portfolio (with each stock)for each month and for each decile
    AllDEC2{i,:}={mean(T1,2),mean(T2,2),mean(T3,2),mean(T4,2)}; %return of each portfolio for each month and for each decile
    DEC(i,:)=[mean(mean(T1)),mean(mean(T2)),mean(mean(T3)),mean(mean(T4))];
    clear T1 T2 T3 T4
end
DEC
D10_D1=DEC(1,:)-DEC(10,:)
%% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

%Function F

```
function f=JS(x,y,z,t)
I=1;
f=(x./(y).^1/2).*(I-(z./t));
end
```

%Function Q

```
function d=Q(x)
for i=1:85
    A(i,:)=prod(x(i:i+5,:));
end
d=5613.3.*sum(abs(A));
end
```

%Function RV

```
function a=RV(x)
a=sum(x.^2);
end
```

%Function SWV

```
function b=SWV(y,x)
b=2*sum(y-x);
```

```
end
```

%Function V

```
function c=V(x)
for i=1:89  %i=1:N-1
   A(i,:)=x(i,:).*x(i+1,:);
end
c=((2/pi)^1/2).*sum(abs(A));
end
```

%Function Y

```
function Y = quantileranks(X, q, permtie)
% return quantile ranks of the values in X based on
% their sorted order.
%
% X is a vector of values, possibly with NaNs.
% q determines quantile class i.e.
%   q =   4, quartiles   ( 4-quantile)
%   q =  10, deciles     (10-quantile)
%   q = 100, percentiles (100-quantile)
%   ...
% permties is a boolean flag to shuffle ranks over
% duplicate values, ties.
% Y is a vector of quantile ranks for the corresponding X values.
%
% notes:
% 1. as possible, the values in X are distributed evenly over quantile
% rank groups, could be verified using tabulate(Y).
% 2. NaNs are assigned the rank of zero.
% 3. duplicate values, ties, are distributed randomly over
% different groups (if assigned different ranks).
% 4. to find all values in the ith quantile group, e.x. the 5th decile,
% use X(Y==grp#), e.x. X(Y==5).
%
if nargin == 2
```

```
    permtie = true;
else if nargin ~= 3
    msg = 'ERROR: the function at least takes two inputs.';
    error('quantileranks:INPUT_ERROR', msg);
end

Y = zeros(size(X));
if ~isvector(X)
    msg = 'WARNING: first input must be a vector; returning ranks of zeros.';
    warning('quantileranks:INPUT_ERROR', msg);
    return;
end

non_nans_n = sum(~isnan(X)); % count of non-nans

% quantile rank positions in sorted X
q_pos = zeros(q,1);
for rank = 1:q
    q_pos(rank) = ceil(rank/q * non_nans_n);
end

[~,IX] = sort(X);

% initialize
rank = 1;
IX_first = 1;
IX_last = q_pos(rank);

% assign ranks
while (rank <= q)
    % Pick the highest possible rank (in case q > non_nans_n)
    while ( (rank < q) && (q_pos(rank+1) == IX_last) )
        rank = rank+1;
    end
    % assign ranks
    for k = IX_first:IX_last
        Y(IX(k)) = rank;
```

```
    end
    % next rank
    IX_first = IX_last + 1;
    rank = rank + 1;
    if (rank <= q)
        IX_last = q_pos(rank);
    end
end

% break ties
if permitted
    YT = Y(IX);
    k = 1;
    rank = YT(k);
    while (k <= non_nans_n)
        % find group boundary
        while (k < non_nans_n && YT(k+1) == rank)
            k = k + 1;
        end

        % if there is a tie at boundary then break
        % the tie by shuffling the ranks over tie values.
        if ( (k < non_nans_n) && (X(IX(k)) == X(IX(k+1))) )
            tie_value = X(IX(k));
            % find tie first occurrence, move backward
            bkw = k;
            while (bkw > 1 && X(IX(bkw-1)) == tie_value)
                bkw = bkw - 1;
            end

            % find tie last occurrence, move forward
            frw = k + 1;
            while (frw < non_nans_n && X(IX(frw+1)) == tie_value)
                frw = frw + 1;
            end
```

```
            % shuffle and reassign ranks
            IX_tie = IX(bkw:frw);
            shuffle = randperm(length(IX_tie));
            Y(IX_tie) = Y(IX_tie(shuffle));

            k = frw + 1;
        else
            k = k + 1;
        end

        if (k <= non_nans_n)
            rank = YT(k);
        end
    end
end

end
```

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