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Starts and refutations of the Covid-19 rumors: Evidence from the reaction of the stock market

Zhe Li a, Zixi Ling a, Jian Sun a,*, Congjie Yun b

a School of Accountancy, Central University of Finance and Economics, Beijing, PR China
b Henan Audit Division, Bank of China, Zhengzhou, PR China

ABSTRACT

By manually collecting data on Internet-based rumors concerning COVID-19, we investigate the market reactions to the spread of such rumors and the government’s refutation of them. We find that frightening (reassuring) rumors have a negative (positive) impact on investors. The refutation of frightening rumors triggers a positive market response, whereas the refutation of reassuring rumors does not cause a significant market reaction. Further analysis shows that there is a stock price drift when frightening rumors are refuted by governments. Our conclusions remain robust after considering endogeneity. Our findings support the notion that epidemic-related rumors affect investors’ decisions, which add to literatures of the market responses of companies in the context of the COVID-19 pandemic and provide incremental evidence for the “the spiral of silence” theory.

1. Introduction

This study investigates how investors reacted to rumors related to COVID-19 at the height of the COVID-19 pandemic (hereafter the pandemic) in China in early 2020. We focus on rumors related to COVID-19 that were later confirmed to be false by government agencies (hereafter, we refer to these simply as COVID-19 rumors), in contrast to related research that examines company rumors and gossip in situations where it is difficult to distinguish true from false rumors (Difonzo, 2007). The COVID-19 rumors that arose during the pandemic were often deliberately fabricated, some with very serious effects, and Internet anonymity facilitated their spread. They are fundamentally different from the firm-related rumors that are extensively studied...
in the literature (Bordia et al., 2010; Schmidt, 2019; Jia et al., 2020). First, firm-related rumors are only related to a certain company, whereas the COVID-19 rumors (e.g., “Xinyang city is about to close”) often affect all companies in an entire region. Second, firm-related rumors often occur in a relatively ordinary context, whereas the COVID-19 rumors appear in a special or extraordinary environment, that of the pandemic, enabling us to study how investors reacted to rumors that may affect lives and safety in the context of a severe public health crisis.

From the end of 2019 to the beginning of 2020, the outbreak of the COVID-19 pandemic affected all aspects of the Chinese economy and society (Chen et al., 2020; Yang et al., 2020). Many cities implemented the central government’s pandemic prevention policy, and large-scale shutdowns began across the country, dealing a serious blow to physical industries as well as to the capital market. Simultaneously, a considerable number of online rumors related to the pandemic raged on Weibo, WeChat and other online platforms, misleading netizens concerned about the pandemic.

COVID-19 rumors related to some areas of China spread widely on the Internet from late January 2020. For example, rumors that a certain city was about to be isolated caused unnecessary panic in local areas, whereas rumors of some cities being reopened were falsely reassuring to the locals. Local government agencies worked diligently on network platforms to constantly refute all kinds of rumors. During the pandemic, great focus was placed on the impact of various rumors and regulating different rumors was a crucial governance matter.

In addition to influencing social stability and national governance, COVID-19 rumors cause volatility in the stock market. For example, on 10 February 2020, the Internet rumor that “Beijing is about to carry out a large-scale disinfection and sterilization activity” sent a false signal to the public that the pandemic situation in Beijing was not optimistic. Although the rumor was quickly refuted, in the meantime, local listed companies in Beijing were affected by investors’ negative perceptions of Beijing in response to the rumor. For instance, the stock prices of Shenzhou High-Speed Railway Technology (000008. SZ) and Shenzhou Digital (000034. SZ) fell after trending upward for several trading days before the rumor.

In this paper, we explore whether it is common for investors to be misled by COVID-19 rumors. We use manually collected data on COVID-19 rumors and their refutation to explore the abnormal market reactions caused by different types of rumors in company locations. Considering that governments in other countries seldom refute rumors in an authoritative and formal way, the refutation of COVID-19 rumors by Chinese government agencies provides a unique rumor refutation data set.

Based on the influence of rumors on investor sentiment, we divide COVID-19 rumors into frightening and reassuring rumors. Frightening rumors refer to false news and information that exaggerates the severity of the crisis and causes negative emotions among the public, such as statements that “many cases are confirmed” or “there has been a major spread of infections” in some particular locations. In contrast, reassuring rumors involve information that downplays the severity of the crisis and creates false optimism among the public, such as a certain area “is about to reopen” or “the pandemic control policies are about to be canceled” in some area. We conduct a series of tests based on this classification and find that frightening and reassuring rumors trigger negative and positive market reactions, respectively, and that the refutation of frightening rumors has a positive market response, whereas refuting reassuring rumors does not result in a significant market response. In further analysis, we show that there is a stock price drift after the refutation of frightening rumors. Finally, after controlling for potential endogeneity problems, our conclusions remain valid.

Our study makes three main contributions to the literature. First, by examining the market responses of listed firms to COVID-19 rumors, we improve understanding of the market responses of companies in the context of the COVID-19 pandemic. The literature explores the impact of news reports and other factors on corporate market responses during the pandemic from the perspective of companies (Baker et al., 2020; Chen et al., 2020). Conversely, we examine rumors and take the perspective of investors; although rumors as an alternative channel receive much less attention than news reports, they significantly affect the capital market during the COVID-19 pandemic.

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1 Information reported by official media can be seen via the below website [https://baijiahao.baidu.com/s?id=165813849681712872&wfr=spider&for=pc](https://baijiahao.baidu.com/s?id=165813849681712872&wfr=spider&for=pc).
Second, we confirm “the spiral of silence” theory from the perspective of investors by investigating the impact of rumor refutation on the stock market. Studies focus on the positive effect of refuting firm-specific gossip and rumors on firm recovery (Mathur and Waheed, 1995; Schmidt, 2019). Conversely, we find that the silent spiral effect means that investors are unwilling to spread disappointing information even when it refutes falsely reassuring rumors, resulting in a decline in the effectiveness of attempts to refute reassuring rumors.

Third, our study reveals that there is a stock price drift after the refutation of frightening rumors during a public crisis. We find that the refutation of frightening rumors does not immediately influence the market, and that Internet penetration improves the speed with which refutation becomes effective. This finding provides a theoretical basis for government agencies to improve the rumor management system. Our findings also have policy implications for capital market regulators regarding stabilizing the market during a public crisis.

2. Literature review and hypothesis development

2.1. Literature review

2.1.1. Sentiment, rumors and capital market reactions

Many studies demonstrate that investor sentiment affects investment decisions. Brown and Cliff (2004) find that investor sentiment influences stock prices, and Schmeling (2009) determines that, on average, investor sentiment inversely predicts the overall return of the stock market. Bollen, Mao and Zeng (2010) construct investor sentiment indicators by analyzing online language and verify the positive impact of investor sentiment on stock prices. Mendel and Shleifer (2012) find that investors’ irrational emotions affect stock price volatility. Therefore, emotion-related factors, such as reactions to weather or air quality (Hirshleifer and Shumway, 2003; Hu and Wang, 2012; Li et al., 2019) and beliefs and customs (Block and Kramer, 2009), influence stock prices.

During public crises, investors’ risk aversion tends to increase. Twemlow et al. (2003) find that terrorist attacks can change the mentality and emotions of residents, thereby changing their daily behaviors. These changes in mood and behavior are often reflected in the stock market, causing stock prices to fall (Jussi and Sami, 2010). Moreover, disasters such as earthquakes and hurricanes can cause negative emotions among investors and lead to irrational investment behavior (Carter and Simkins, 2004). Worthington and Valadkhani (2004) reveal that earthquakes and hurricanes bring about pessimism, which in turn causes negative market reactions. Moreover, research indicates that market anomalies reverse in the short term. Kaplanski and Levy (2010) find that the pessimism caused by air crashes in the US led to declines in the market value of aviation stocks. Overall, the literature emphasizes that investor sentiment tends to be affected by many factors, including the environment and customs, especially during public crises. However, studies seldom discuss the influence of other complex factors on market responses during public crises.

Investors are often disadvantaged by information asymmetry and have an urgent need for information (Davies and Canes, 1978; Dai et al., 2013). Therefore, when they find a simple, low-cost method of obtaining information, investors tend to overestimate its accuracy. To an extent, this explains the importance and reliance of investors on company rumors. In the era of advanced Internet technology and active social media, investors often fail to verify the authenticity of rumors (Toubia and Stephen, 2013). Mathur and Waheed (1995) find that rumors in business magazines affect investors’ decision-making, and Clarkson et al. (2006) determine that investors are highly sensitive to rumors of acquisitions on online platforms.

As a suggestive and communicative psychological factor (DiFonzo and Bordia, 2007), rumors related to certain companies often induce irrational decision-making by influencing the mood of the public. For instance, Rosnow (1991) finds that the spread of rumors is closely related to the anxiety and panic created in people. He considers that the spread of rumors leads to anxiety through the construction of scenarios. Schmidt (2019) finds that individual “rumor makers” make profits by creating rumors to affect stock prices. Jia et al. (2020) believe that rumors spread through social media have a misleading effect on market pricing. In summary, investors may not be able to rationally identify the authenticity of rumors, and they are often misled in their decision-making by false rumors. However, there is limited research on whether rumors related to a company affect that company’s stock price, and on whether regional rumors related to public crises influence
investors’ decision-making. Therefore, in this study, we analyze the impact of COVID-19 rumors on market responses in relation to local listed companies.

2.1.2. Impact of the COVID-19 crisis on market returns

Studies explore both the direct shock of the pandemic on the capital market and the impact of complex factors on the capital market in the context of the pandemic. In a time-series study, Kim and Thomas (2021) examine the impact of the pandemic in the US and Europe and determine that the first confirmed death had a negative impact on stock prices. Using data from multiple countries, He et al. (2020) find that the pandemic generally had a negative but short-term impact on the stock market. Baek et al. (2020) use negative news about the pandemic to represent its severity and study its impact on different industries, determining that stock prices are quite sensitive to pandemic news.

Alfaro et al. (2020) find that an increase in the number of new COVID-19 cases is related to a decline in overall stock market returns. Giglio et al. (2020) reveal that after the US stock market crashed due to the pandemic, investor confidence in the stock market declined even during the recovery period. Smales (2020) observes that investors’ attention to the pandemic is generally negatively correlated with market responses, but several industries may benefit from investors’ attention. Izzeldin et al. (2021) note that the market response of G7 countries to the pandemic was relatively synchronized, and that the stock price response was consistent with the financial crisis. As for the governance and prevention of the COVID-19 pandemic, Rui et al. (2020) consider that highly evaluated environmental and social policies help companies to recover from the stock price crash caused by the pandemic. Rouabhi et al. (2021) reveal that the development and uptake of COVID-19 vaccines stabilized global stock markets and reduced stock price volatility.

In China, Yang et al. (2020) observe that risks were transmitted between financial market entities during the pandemic, thereby increasing systemic financial risks. A number of studies analyze the impact of complex factors on the capital market. For example, Baker et al. (2020) find that news reports played a vital role in determining stock prices during the COVID-19 pandemic. Chen et al. (2020) reveal that in the context of the pandemic, the resumption of the pandemic control measures can bring a positive market response, specifically for smaller and growing companies. Liu and Wang (2020) consider that traditional irrational psychological factors, such as anchoring and herd effects, influence stock prices during the pandemic. Although many studies examine the factors influencing stock prices during the pandemic, knowledge about the effects of COVID-19 rumors on the stock market is limited.

2.2. Hypothesis development

2.2.1. Frightening and reassuring rumors during the COVID-19 crisis

In a public crisis, information asymmetry is likely to prevail between the public and authoritative organizations. The public’s desire for reasonable explanations results in unofficial speculation and gossip in an attempt to meet their psychological needs, which leads to the appearance of rumors (Popenoe, 1986; Sunstein, 2014). COVID-19 has inevitably led to the emergence of a considerable number of rumors, which have flooded major online platforms and received considerable attention from investors.

This study focuses on the impact of public opinion and rumors on the capital market during the public crisis. Investors tend to believe in unconfirmed rumors and, therefore, the positive or negative rumors concerning a company’s characteristics will affect stock prices (Schmidt, 2019). Investors with limited attention and professional ability are more inclined to use information common to a certain region or industry to make decisions rather than seeking specific information with higher professional and information content (Lin and Wei, 2006). Therefore, regional COVID-19 rumors can often influence the stock prices of local listed companies in a manner that is at least equivalent to rumors concerning specific companies.

To explore the relationship between the COVID-19 rumors related to a specific region and the stock prices of local listed companies, we must clarify two processes: first, why investors believe the rumors spread during the pandemic; and second, how their belief in the rumors influences the stock prices of local listed companies.

(1) Why do investors believe the rumors during the pandemic?
Investors potentially use two “thinking systems” to deal with received information: the intuitive system, which is related to intuition, instinct and emotions, and the rational system, which is related to caution, analysis and rationality (Wason and Evans, 1975). The intuitive system performs fast, superficial and intuitive heuristic processing of information, and consumes less resources than the rational system. The rational system performs slow, detailed and rational analytical processing of information, which requires much more resources (Kahneman, 2011). When the intuitive system is at work, investors exhibit lower discrimination and cognitive control abilities and produce more emotional and overly relevant cognitions than when the rational system is dominant (Maier et al., 2015). Often, the intuitive system responds first to new information, and then the rational system adjusts to the results of this first response. However, in stressful situations, cognition shifts more toward habit and intuition than toward rationality, and the reprocessing of results from the intuitive system diminishes (Schwabe and Wolf, 2013; Yu, 2016).

During the COVID-19 pandemic, investors’ perceptions of information asymmetry and uncertainty regarding the future increase. Under such circumstances, investors instinctively increase their reliance on the intuitive system and reduce the corrective effect of the rational system (Kassam et al., 2009; Schwabe and Wolf, 2013), which leads to a reduction in their cognitive control abilities (Maier et al., 2015) and more intense emotional responses than during normal times (Nolen-Hoeksema, 2012), making their cognition and behaviour tilt toward intuitive responses.

Therefore, during COVID-19, investors are more likely to believe rumors than to verify them in a rational manner. When investors use the intuitive system to judge rumors and information, they engage in discrimination and verification of that information to a lesser degree than when they think rationally, and they simultaneously make emotional and excessive correlations between the information on the local pandemic and a company’s business situation. Therefore, as investors’ thinking is skewed toward intuition, we expect (false) frightening and reassuring rumors to influence investors’ decision-making.

(2) The impact of rumors on local listed companies

Overestimation (underestimation) of the severity of the COVID-19 pandemic is often associated with more pessimistic (optimistic) judgments of local listed companies. On the one hand, in their consciousness, investors relate a worsening (improving) pandemic situation to stricter (looser) pandemic control and lower (higher) efficiency. On the other hand, investors expect other investors who invest in local listed companies to accept similar information and make similar decisions. When there are frightening (reassuring) rumors concerning the pandemic in a certain area, investors overestimate (underestimate) the severity of the local pandemic and are therefore overly pessimistic (optimistic) about the ability of local listed companies to resume work and production. These responses can lead investors to sell (buy) shares of local listed companies, leading to a negative (positive) market reaction. We therefore propose the following hypothesis:

H1: Frightening rumors result in negative market reactions to local listed companies, whereas reassuring rumors result in positive market reactions to local listed companies.

2.2.2. The refutation of frightening and reassuring rumors

According to the noise theory of Kyle (1985) and Black (1986), symmetrical noise cancels out each other’s impacts on the market. Rumors and anti-rumor information are symmetrical noises directed at the same event in opposite directions (Carlos et al., 2011). An announcement clarifying that prior information concerning a company was false is informational (Koller, 1992), which produces a market reaction opposite to the previous reaction. When rumors that led to abnormal returns are refuted, the abnormal returns are reversed (Bordia et al., 2010; Einwiller and Kamins, 2010). Therefore, we expect that when frightening or reassuring rumors concerning the local impacts of COVID-19 are refuted by relevant agencies, investors will revise their expectations about local pandemic conditions and the prospects of companies in that location. Thus, the market shock caused by the rumors will reverse.
When frightening rumors are refuted through online platforms, investors obtain accurate information about the local pandemic through these platforms. The provision of additional accurate rumor-clarifying information from official institutions often leads investors to increase their online tracking and attention to official information sources (Jia et al., 2020), and they thereby receive information more quickly and learn to behave more rationally than before. In the learning process, investors update their beliefs, gradually eliminate pessimistic expectations caused by frightening rumors and form relatively optimistic posterior expectations, thereby causing stock prices to rise. Moreover, the positive and accurate refutation of rumors eliminates negative investor sentiment and leads to a further positive market reaction.

Correspondingly, when falsely reassuring rumors are refuted, investors become better informed than before, engage in more rational learning and update their beliefs. Their overly optimistic expectations for the future prospects of local companies are adjusted downwards, resulting in relatively pessimistic posterior expectations, which cause stock prices to fall. The rational and accurate refutation of rumors eliminates investors’ previously optimistic sentiment, which leads to further negative market reactions. Therefore, we expect that the refutation of falsely reassuring rumors will lead to negative market reactions. Based on the analyses above for the refutation of frightening or reassuring rumors, we propose the following hypotheses:

H2a: Refuting frightening rumors leads to positive market reactions to listed companies.
H3a: Refuting reassuring rumors leads to negative market reactions to listed companies.

2.2.3. The role of trust and communication in the refutation of rumors

The analysis above establishes that the refutation of rumors influences market reactions. However, at least two factors may reduce this influence: (1) investors may not trust the refutation, particularly when frightening rumors are refuted; and (2) the silent spiral effect may lead investors to be irrationally enthusiastic (Huberman and Regev, 2001) and prevent them from reversing their investment decisions in the case of reassuring rumors.

Often, the effectiveness of rumor refutation depends on the authority of the refuting information (Bordia et al., 2010; Einwiller and Kamins, 2010). In the case of frightening rumors during the pandemic, investors may distrust the information provided and regard the release of the refuting information as merely a cover for bad news. In this case, the refutation of the rumors may not influence market reactions. Therefore, we propose the following hypothesis:

H2b: The refutation of frightening rumors does not cause a significant market reaction to listed companies.

Communication theory considers that people will actively speak out when they find that their viewpoints are consistent with the majority viewpoint of the public, whereas they will remain silent when their viewpoints and expectations are contrary to those of the public (Noelle-Neumann, 1991; Lars et al., 2002). This leads to the rapid spread of opinions in line with public expectations, whereas opinions that contradict public expectations gradually decline, forming an asymmetrical development process referred to as the “the spiral of silence” (Noelle-Neumann, 1974, page 43). This effect exists among investors, making them susceptible to strong opinions (Veldkamp, 2006; Tetlock, 2007; Engelberg and Parsons, 2011). “Irrational enthusiasm” is likely to arise when positive opinions become dominant through the silent spiral (Huberman and Regev, 2001). Particularly during the pandemic, when investors are eager for good news, reassuring rumors tend to disseminate and become strong opinions, which can limit the effectiveness of government departments in refuting such rumors. Therefore, we propose the following hypothesis:

H3b: The refutation of reassuring rumors does not cause a significant market reaction to listed companies.
3. Data and methodology

3.1. Data

Our sample includes all A-share non-special treatment public companies listed on the Shanghai and Shenzhen stock exchanges in China. We select the period from the outbreak of COVID-19 to the date when the initial controls were lifted in China, i.e., 20 January to 31 March 2020, as our period of analysis to collect rumors. To ensure that we do indeed focus on rumors, i.e., false and misleading information, we collect only rumors that were subsequently refuted by government agencies and certified as false. We collect market reaction data and other financial data from the China Stock Market and Accounting Research database. Our initial sample includes 131,712 firm-date observations from 20 January to 31 March 2020. After removing observations with missing data, we finally obtain 95,075 firm-date observations to conduct our baseline regression.

3.2. Empirical models and variable definitions

3.2.1. Model specification

We use Eq. (1) to examine the influence of frightening or reassuring rumors. The dependent variable \( \text{Car}_{[-1,1]} \) measures the reaction of the stock market and is calculated using two approaches, the market adjustment and market model approaches, denoted by \( \text{Car}_{\text{MA}}[-1,1] \) and \( \text{Car}_{\text{MM}}[-1,1] \), respectively. The independent variables are frightening rumors (Neg) or reassuring rumors (Pos), which are dummy variables that identify whether frightening or reassuring rumors influence a company’s location on a given day. The variable definitions are provided in Table 1 . Often, the severity of the pandemic has a systemic impact on stock prices (Baek et al., 2020). To control for this systemic impact and the impact of a company’s financial status during the sample period on market responses, we select the logarithm of total assets (Size), firm profitability (Roa), firm leverage (Lev), firm cash holdings (Cash) and firm revenue growth (Growth) as control variables. Moreover, we control for industry and city fixed effects and factors related to the pandemic (the number of COVID-19 cases, as explained below).

\[
\text{Car}_{\text{MA}}(\text{Car}_{\text{MM}})[-1,1] = \alpha + \beta_1 \text{Neg}(\text{Pos}) + \beta_2 \sum \text{Controls} + \sum \text{ind} + \sum \text{city} + \mu. \tag{1}
\]

We explore the impact of rumor refutation on the market by examining Eq. (2). \( \text{Car}_{\text{MA}}[-1,1] \) and \( \text{Car}_{\text{MM}}[-1,1] \) are the dependent variables, and Anti_Neg and Anti_Pos, which indicate the refutation of frightening and reassuring rumors, respectively, in a company’s location on a given day, are the independent variables.

\[
\text{Car}_{\text{MA}}(\text{Car}_{\text{MM}})[-1,1] = \alpha + \beta_1 \text{Anti_Neg}(\text{Anti_Pos}) + \\
\beta_2 \sum \text{Controls} + + \sum \text{ind} \sum \text{city} + \mu. \tag{2}
\]

3.2.2. Variables

Table 1 provides the definitions of the variables used in this study. The cumulative abnormal returns calculated using the market adjustment approach and market model approach (\( \text{Car}_{\text{MA}} \) and \( \text{Car}_{\text{MM}} \)) are the proxy variables for market reactions.

We use the market adjustment approach to calculate abnormal returns (\( \text{Ar}_{\text{MA}} \)), as shown in Eq. (3), where \( R_{it} \) is the return rate of individual stocks of company \( i \) on day \( t \), and \( R_{mt} \) is the market return on day \( t \).

\[
\text{Ar}_{\text{MA}} = R_{it} - R_{mt} \tag{3}
\]

\footnote{Our method for collecting rumors is detailed in the appendix.}
The market model approach regresses individual stock returns on market returns, as shown in Eq. (4). We estimate Eq. (4) and calculate the residual, which we define as abnormal returns \( Ar_{\text{MM}} \) under the market model approach. The economic meaning of the residual is that it is the part of individual stock returns that cannot be explained by market trends.

\[
R_{it} = a_i + \beta_i R_{mt} + \mu_{it}
\]

Then, we add \( Ar_{\text{MA}} \) and \( Ar_{\text{MM}} \) according to the window period and obtain the cumulative abnormal return rate, as shown in Eq. (5).

\[
Car_{MA_i}(Car_{MM_i})[-1, 1] = \sum_{t=1}^{i+1} Ar_{MA_i}(Ar_{MM_i})
\]

We define frightening rumors as rumors that exaggerate the severity of the crisis and can cause panic among investors, whereas reassuring rumors are those that dilute the impact of the crisis and can comfort investors. On this basis, we define our four main variables \( Neg \), \( Pos \), \( Anti Neg \) and \( Anti Pos \) as follows: \( Neg \) (\( Pos \)) takes a value of 1 when frightening (reassuring) rumors exist within the location of the company, and 0 otherwise, and \( Anti Neg \) (\( Anti Pos \)) takes a value of 1 if frightening (reassuring) rumors are refuted in the company’s location on a given day, and 0 otherwise. In addition to the control variables listed in Table 1, we control for pandemic-related influencing factors (i.e., the number of new cases in the company’s location the previous day). To avoid the influence of extreme values, we perform data cleaning on all continuous variables used in the main test.

4. Main results

4.1. Descriptive statistics

Table 2 shows the distribution of rumors based on our data collection. Hubei province is the most severely affected province of all provinces at the beginning of 2020, followed by Zhejiang and Hunan provinces. In total, we find that 143 rumors affect Chinese provinces during our study period, and Hubei province is affected by 34 of these rumors. In terms of the nature of the rumors, the majority (118) are frightening rumors, with only 25 being reassuring rumors.

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3 The Chinese Center for Disease Control and Prevention discloses the number of new cases of the previous day. Therefore, to control for the impact of the severity of the pandemic on the stock market, we control for the number of new cases with a lag period.
Table 3 shows the descriptive statistics of the main variables. The mean values of $Car_{MA}[-1,1]$ and $Car_{MM}[-1,1]$ are 0.002 and 0.001, respectively, and their medians are $-0.001$ and $-0.003$, respectively. On average, 3.3% and 1.4% of the firm-date observations in the sample are affected by frightening and reassuring rumors, respectively, and 1.4% and 0.5% of the firm-date observations experience a refutation of frightening and reassuring rumors, respectively. The mean values of $Size$, $Roa$, $Lev$, $Cash$, $Growth$ and $Newcases$ are 22.415, 0.046, 0.425, 0.161, 0.156 and 0.171, respectively.

In our sample, multiple rumors are refuted on the same day and hence the frequency of refuting rumors is lower than the frequency of the rumors themselves.
4.2. Baseline results

Table 4 reports market responses to different types of rumors. Columns (1) and (2) report the impact of frightening rumors on market reactions using the market adjustment and market model approaches, respectively. The coefficients of Neg are both \(-0.003\)***, which are both statistically significant, indicating that frightening rumors lead to negative market reactions to listed firms. The coefficients of Pos in Columns (3) and (4) are 0.007*** and 0.003**, respectively, indicating that reassuring rumors lead to significant positive market reactions. Thus, the results in Table 4 verify H1, proving that investors are affected by both types of COVID-19 rumors and that they change their expectations and judgments about the prospects of companies at the locality where a rumor is spread. Frightening rumors lead to negative abnormal returns, whereas reassuring rumors are associated with positive abnormal returns. The results of the main test show that Chinese investors experience difficulties in identifying and confirming the authenticity of unofficial information during the pandemic, which leads the stock market to fluctuate under the impact of COVID-19 rumors.

As a robustness test, we exclude all observations of listed companies in Hubei province from the H1 test. Hubei is the center of the pandemic and its high number of confirmed cases and high number of rumors compared with other provinces result in outliers and interference in our data analysis. Therefore, we remove all observations located in Hubei province and rerun the baseline regression. The results, shown in Table 5, indicate that our results remain robust after excluding all listed companies in Hubei province.

Table 6 reports the market reactions caused by the refutation of rumors. The coefficients of Anti_Neg in Columns (1) and (2) are positive and significant, which verifies H2a. When frightening rumors are refuted, investors revise their misjudgment of firms’ prospects, leading to a positive market reaction. However, the market response to the refutation of reassuring rumors does not meet the expectations of H3a. The coefficients of Anti_Pos in Columns (3) and (4) are not significant. Therefore, H3a is rejected and H3b is verified; that is, when investors are affected by reassuring rumors, even if the rumors are subsequently rejected, it is difficult for

| Variable | Car_MA[-1,1] | Car_MM[-1,1] | Car_MA[-1,1] | Car_MM[-1,1] |
|----------|--------------|--------------|--------------|--------------|
| Neg      | -0.003***    | -0.003***    | 0.007***     | 0.003**      |
|          | (–3.56)      | (–3.44)      | (5.22)       | (2.30)       |
| Pos      | -0.000**     | -0.001***    | -0.000**     | -0.001***    |
|          | (–2.48)      | (–3.79)      | (–2.48)      | (–3.79)      |
| Size     | 0.008***     | -0.007***    | 0.008***     | -0.007***    |
|          | (3.26)       | (–2.74)      | (3.26)       | (–2.73)      |
| Lea      | 0.001        | 0.002        | 0.001        | 0.002        |
|          | (0.95)       | (1.46)       | (0.95)       | (1.46)       |
| Cash     | -0.001       | 0.001        | -0.001       | 0.001        |
|          | (–0.91)      | (0.46)       | (–0.91)      | (0.47)       |
| Growth   | -0.000       | 0.000        | -0.000       | 0.000        |
|          | (–0.80)      | (0.05)       | (–0.80)      | (0.05)       |
| Newcases | -0.000       | -0.000*      | -0.000       | -0.000**     |
|          | (–1.06)      | (–1.65)      | (–1.43)      | (–2.02)      |
| Constant | 0.007*       | 0.012***     | 0.007*       | 0.012***     |
|          | (1.79)       | (3.04)       | (1.73)       | (3.00)       |

Industry fixed effects: \(\checkmark\) \(\checkmark\) \(\checkmark\) \(\checkmark\)
City fixed effect: \(\checkmark\) \(\checkmark\) \(\checkmark\) \(\checkmark\)

\(N\) = 95,075 \(R^2\) = 0.006

The table reports the coefficients, with the \(t\)-statistics shown in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.
### Table 5
Baseline regression without Hubei observations.

| Variable | Car_MA[-1,1] | Car_MM[-1,1] | Car_MA[-1,1] | Car_MM[-1,1] |
|----------|--------------|--------------|--------------|--------------|
|          | (1)          | (2)          | (3)          | (4)          |
| Neg      | -0.002**     | -0.002**     | 0.007***     | 0.004***     |
|          | (-2.32)      | (-2.53)      | (5.02)       | (2.76)       |
| Pos      | 0.000**      | 0.000***     | -0.000**     | -0.000***    |
|          | (-2.32)      | (-2.90)      | (-2.32)      | (-2.90)      |
| Size     | 0.008***     | -0.006**     | 0.008***     | -0.006**     |
|          | (3.27)       | (-2.28)      | (3.27)       | (-2.28)      |
| Roa      | -0.000**     | -0.000***    | 0.000        | 0.000        |
|          | (-2.48)      | (-9.55)      | (-6.29)      | (-9.62)      |
| Lev      | 0.000        | 0.000        | -0.000       | 0.000        |
|          | (-0.44)      | (0.46)       | (-0.44)      | (0.46)       |
| Cash     | -0.000       | 0.000        | -0.000       | 0.000        |
|          | (-0.70)      | (0.9)        | (-0.70)      | (0.9)        |
| Newcases | -0.017***    | -0.027***    | -0.017***    | -0.027***    |
|          | (-6.28)      | (-9.55)      | (-6.29)      | (-9.62)      |
| Constant | 0.007*       | 0.011***     | 0.007*       | 0.010***     |
|          | (1.74)       | (2.62)       | (1.69)       | (2.59)       |

Industry fixed effects | √ | | | | | City fixed effects | √ | | | | | N | 85,117 | 85,117 | 85,117 | 85,117 | | R² | 0.006 | 0.009 | 0.006 | 0.009 |

The table reports the coefficients, with the t-statistics shown in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

### Table 6
Impact of the refutation of rumors on market reactions.

| Variable | Car_MA[-1,1] | Car_MM[-1,1] | Car_MA[-1,1] | Car_MM[-1,1] |
|----------|--------------|--------------|--------------|--------------|
|          | (1)          | (2)          | (3)          | (4)          |
| Anti_Neg | 0.004***     | 0.005***     | -0.000       | -0.002       |
|          | (3.23)       | (3.91)       | (-0.10)      | (-0.43)      |
| Anti_Pos | -0.000**     | -0.001***    | -0.000**     | -0.001***    |
|          | (-2.48)      | (-3.79)      | (-2.48)      | (-3.79)      |
| Size     | 0.008***     | -0.007***    | 0.008***     | -0.007***    |
|          | (3.26)       | (-2.73)      | (3.26)       | (-2.74)      |
| Roa      | -0.000       | 0.000        | -0.000       | 0.000        |
|          | (-0.80)      | (0.05)       | (-0.80)      | (0.05)       |
| Lev      | 0.000        | 0.000        | -0.000       | 0.000        |
|          | (0.95)       | (1.47)       | (0.95)       | (1.46)       |
| Cash     | -0.000       | 0.000        | -0.000       | 0.000        |
|          | (-0.91)      | (0.47)       | (-0.91)      | (0.47)       |
| Growth   | 0.000        | 0.000        | 0.000        | 0.000        |
|          | (-0.80)      | (0.05)       | (-0.80)      | (0.05)       |
| Newcases | -0.000       | -0.000**     | -0.000       | -0.000**     |
|          | (-1.43)      | (-2.01)      | (-1.44)      | (-2.02)      |
| Constant | 0.007*       | 0.012***     | 0.007*       | 0.012***     |
|          | (1.74)       | (3.00)       | (1.76)       | (3.02)       |

Industry fixed effects | √ | | | | | City fixed effects | √ | | | | | N | 95,075 | 95,075 | 95,075 | 95,075 | | R² | 0.005 | 0.007 | 0.005 | 0.007 |

The table reports the coefficients for the impact of refuting frightening and reassuring rumors on market reactions. The t-statistics are shown in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.
them to rationally correct their overoptimistic expectations. Thus, the refutation of frightening and reassuring rumors has asymmetrical impacts on investors and the market.

The results indicate that investors respond to both types of rumors. However, the refutation of rumors is effective only in the case of frightening rumors; refuting frightening rumors causes market reactions and drives up stock prices, but investors do not react to the refutation of reassuring rumors. To an extent, this indicates that Chinese investors trust the information released by the government to refute rumors. However, because of the silent spiral effect during the pandemic, eradicating the impact of reassuring rumors remains difficult.

To verify the degree of investor trust in the government when it refutes frightening rumors, we further divide the sample into groups according to the level of trust of people in firms affected by rumors. We use regional trust data from the 2018 World Values Survey for mainland China as a measure of local people’s trust. In particular, we use the respondents’ confidence in the local government and trust in others to represent government and interpersonal trust. We divide the sample into two groups according to whether the level of government (interpersonal) trust is higher or lower than the median. Thus, we obtain a high government (interpersonal) trust group and a low government (interpersonal) trust group. If investors do not place sufficient trust in the government’s refutation of rumors in certain areas, then the anti-rumor information is likely to be less effective, such that it would only be effective in areas with a high level of trust. Table 7 shows the results of the cross-sectional tests.

Panel A of Table 7 shows the results of the group tests for the level of government trust. Suest test is an approach for testing between-group differences based on seemingly unrelated regression. The p values of Suest are 0.3487 in Columns (1) and (2) and 0.2640 in Columns (3) and (4). This result shows that whether Car\_MA\([-1,1]\) or Car\_MM\([-1,1]\) is used as the explained variable, no significant difference exists in the coefficient of Anti\_Neg between the high and low groups. Panel B shows the results of the group tests for interpersonal trust. The p values of Suest are 0.1199 in Columns (1) and (2) and 0.1547 in Columns (3) and (4). Therefore, no significant intergroup difference exists. In fact, the coefficient of Anti\_Neg is not significantly larger in the low than in the high interpersonal trust group, confirming that the government’s effectiveness in refuting frightening rumors is not related to investors’ level of trust in the government. The results indicate that investors trust the government’s refutation of rumors, and that neither the level of government trust nor the level of interpersonal trust has a significant influence on the effectiveness of the government’s refutation of frightening rumors.

5. Further analysis: Stock price drift of the refutation of frightening rumors

According to efficient market theory, the impact of any shock on the market forms in a very short period, and then stock prices stabilize at the adjusted position. However, investors’ lagging response and information limitations often cause stock price drifts (Bartov et al., 2000). Even when companies clarify unfavorable rumors about themselves, stock prices often cannot respond quickly (Huberman and Regev, 2001; Carlos et al., 2011). As mentioned above, the refutation of frightening rumors leads investors to correct their previous rumor-influenced misjudgments, leading to a positive market reaction, but we expect a drift after the refutation of frightening rumors. We use Eq. (6) to detect the influence of analysts on this drift.

$$Bhar_{1,15} = \alpha + \beta_1 Anti\_Neg + \beta_2 \sum Controls + \sum ind + \sum city + \mu \quad (6)$$

To capture the stock price drift, we used the dependent variable $Bhar_{1,15}$ in Eq. (6) to measure the long-term volatility of the stock market. $Bhar_{1,15}$ denotes the buy-and-hold abnormal returns of a firm during the [1,15] window period, which are calculated using Eq. (7).

$$Bhar_{it,1,15} = \prod_{t=1}^{t+15} R_{it} - \prod_{t=1}^{t+15} R_{mt} \quad (7)$$
Table 7
Cross-sectional tests according to the levels of government and interpersonal trust.

**Panel A: Government trust**

| Variable | Car_MA[-1,1] | Car_MM[-1,1] |
|----------|--------------|--------------|
|          | High (1)     | Low (2)      | High (3)     | Low (4)      |
| Anti_Neg | 0.008        | 0.003**      | 0.010*       | 0.003**      |
|          | (1.43)       | (2.07)       | (1.78)       | (2.28)       |
| Size     | -0.001**     | -0.000       | -0.001***    | -0.000**     |
|          | (-2.07)      | (-1.47)      | (-3.64)      | (-2.12)      |
| Roa      | 0.007        | 0.007**      | -0.007       | -0.009***    |
|          | (1.63)       | (2.34)       | (-1.57)      | (-2.83)      |
| Lev      | 0.003        | 0.000        | 0.003        | 0.001        |
|          | (1.57)       | (0.12)       | (1.38)       | (0.72)       |
| Cash     | -0.000       | -0.002       | -0.001       | 0.001        |
|          | (-0.02)      | (-1.21)      | (-0.23)      | (0.61)       |
| Growth   | -0.000       | 0.000        | -0.000       | 0.0001**     |
|          | (-1.10)      | (0.66)       | (-0.85)      | (2.39)       |
| Newcases | -0.000       | -0.036***    | -0.000*      | -0.054***    |
|          | (-1.28)      | (-11.06)     | (-1.78)      | (-16.16)     |
| Constant | 0.009        | 0.004        | 0.019**      | 0.007        |
|          | (1.29)       | (0.90)       | (2.54)       | (1.55)       |
| Bentler   | 0.3487       | 0.2640       |
| Industry fixed effects | √ | √ |
| City fixed effects | √ | √ |
| N         | 31,320       | 62,076       | 31,320       | 62,076       |
| R²        | 0.006        | 0.007        | 0.011        | 0.010        |

**Panel B: Interpersonal trust**

| Variable | Car_MA[-1,1] | Car_MM[-1,1] |
|----------|--------------|--------------|
|          | High (1)     | Low (2)      | High (3)     | Low (4)      |
| Anti_Neg | 0.002*       | 0.011**      | 0.003**      | 0.011**      |
|          | (1.90)       | (2.07)       | (2.23)       | (2.04)       |
| Size     | -0.000**     | -0.000       | -0.001***    | -0.000**     |
|          | (-2.24)      | (-1.03)      | (-3.24)      | (-2.42)      |
| Roa      | 0.005*       | 0.014***     | -0.010***    | 0.000        |
|          | (1.65)       | (2.90)       | (-3.50)      | (0.03)       |
| Lev      | 0.000        | 0.004        | 0.001        | 0.005**      |
|          | (0.22)       | (1.54)       | (0.61)       | (2.05)       |
| Cash     | -0.002       | 0.002        | 0.000        | 0.003        |
|          | (-1.27)      | (0.66)       | (0.23)       | (0.93)       |
| Growth   | 0.000        | -0.000*      | 0.001**      | -0.000       |
|          | (1.13)       | (-1.80)      | (2.52)       | (-1.54)      |
| Newcases | -0.037***    | -0.000       | -0.053***    | -0.000*      |
|          | (-11.67)     | (-1.27)      | (-16.42)     | (-1.79)      |
| Constant | 0.007        | -0.000       | 0.013***     | 0.003        |
|          | (1.64)       | (-0.03)      | (2.81)       | (0.37)       |
| Bentler   | 2.42         | 2.03         |
| Industry fixed effects | √ | √ |
| City fixed effects | √ | √ |
| N         | 69,399       | 23,997       | 69,399       | 23,997       |
| R²        | 0.006        | 0.009        | 0.009        | 0.015        |

This table presents the test results for the high and low government and interpersonal trust groups. Panel A (Panel B) reports the coefficients for the government (interpersonal) trust groups. The t-statistics are shown in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.
If $\text{Anti\_Neg}$ has explanatory power for the buy-and-hold abnormal returns during the $[1,15]$ window period, then investors continue to be affected by the frightening rumors in the long term after the rumors are refuted, which indicates the existence of a stock price drift. Column (1) of Table 8 reports the regression results and shows that the coefficient of $\text{Anti\_Neg}$ is positive and significant, confirming the existence of a stock price drift.

6. Endogeneity

There may be systemic differences between firm-date observations affected by rumors and those not affected by rumors. Therefore, we conduct an entropy balancing procedure (Hainmueller and Xu, 2013). The advantage of such a procedure is that it can eliminate the differences between the treated group and the control group in relation to various control variables under the premise of a full sample. This allows us to use the full sample for a post-matched regression. In Table 9 below, we report the results of the entropy balancing procedure (Panel A) and the results of rerunning the regression using this sample (Panel B). The results show that the signs of the coefficients on $\text{Neg}$ and $\text{Pos}$ are in the same direction as our baseline results and are statistically significant, suggesting that our baseline results are robust to the entropy balancing procedure.

The persuasiveness of the baseline test may be influenced by the severity of the pandemic nationally influencing the COVID-19 rumors and therefore the stock prices of all listed companies. To exclude any such interference, we conduct a placebo test. We replace the explanatory variables in the baseline regression with dummy variables for frightening rumors and reassuring rumors in regions other than the location of the firms influenced by rumors in the baseline results, and rerun the regression. $\text{Neg\_Othercity}$ ($\text{Pos\_Othercity}$) is a dummy variable that takes a value of 1 when frightening (reassuring) rumors exist outside the company’s location, and 0 otherwise. The results are shown in Table 10. It is evident that frightening and reassuring rumors in other cities do not influence the stock prices of local listed companies. Thus, our results remain robust after the placebo test.
Table 9
Entropy test results.

**Panel A: Summary of the distribution after entropy balancing**

### Matching results of frightening rumors

| Variable | Pre-matched | Post-matched | difference |
|----------|-------------|--------------|------------|
|          | Neg = 0     | Neg = 1      |            |
|          | (N = 91,929)| (N = 3,149)  |            |
| Size     | 22.41       | 22.61        | -0.207***  |
| Roa      | 0.046       | 0.041        | 0.006***   |
| Lev      | 0.425       | 0.438        | -0.013***  |
| Cash     | 0.161       | 0.171        | -0.010***  |
| Growth   | 0.156       | 0.152        | 0.004      |
| Newcases | 0.095       | 2.390        | -2.295***  |

### Matching results of reassuring rumors

| Variable | Pre-matched | Post-matched | difference |
|----------|-------------|--------------|------------|
|          | Pos = 0     | Pos = 1      |            |
|          | (N = 93,762)| (N = 1,313)  |            |
| Size     | 22.411      | 22.682       | -0.271***  |
| Roa      | 0.046       | 0.036        | 0.010***   |
| Lev      | 0.425       | 0.448        | -0.024***  |
| Cash     | 0.161       | 0.172        | -0.011***  |
| Growth   | 0.156       | 0.134        | 0.0230     |
| Newcases | 0.173       | 0.022        | 0.151*     |

**Panel B: Results after entropy balancing**

| Variable        | (1)          | (2)          | (3)          | (4)          |
|-----------------|--------------|--------------|--------------|--------------|
| Neg             | -0.005***    | -0.004***    |              |              |
| Pos             |              |              | 0.007***     | 0.007***     |
| Size            | -0.000       | -0.000       | -0.003***    | -0.003***    |
| Roa             | 0.005        | -0.014*      | -0.003       | -0.037*      |
| Lev             | 0.000        | -0.000       | 0.013**      | 0.017**      |
| Cash            | -0.000       | 0.003        | -0.004       | -0.006       |
| Growth          | -0.000       | -0.000       | -0.001       | -0.001       |
| Newcases        | 0.000        | -0.000       | -0.002***    | -0.002**     |
| Constant        | 0.007        | 0.006        | 0.060***     | 0.070***     |
| Industry fixed effects | ✓ | ✓ | ✓ | ✓ |
| City fixed effects  | ✓ | ✓ | ✓ | ✓ |
| N                | 95,075       | 95,075       | 95,075       | 95,075       |
| R²               | 0.017        | 0.015        | 0.028        | 0.011        |

Panel A reports the results of the entropy balancing procedure, whereas Panel B reports the main regression results after this procedure. The coefficients are reported with the t-statistics in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.
Conclusion

In this study, we investigate the impact of COVID-19 rumors on market reactions and find that when frightening (reassuring) rumors exist, they cause irrational pessimistic (optimistic) expectations of local companies and lead to negative (positive) market reactions. In the case of frightening rumors, investors correct their expectations after the rumors are refuted. However, in the case of reassuring rumors, even if the rumors are subsequently refuted, the expectations associated with them often remain and are difficult to correct. Thus, investors are not fully rational in the context of a public crisis, and they react asymmetrically to the refutation of different types of rumors. We find that the impact of the refutation of frightening rumors on the market causes a stock price drift. Finally, our conclusions remain stable after excluding Hubei firms and using an entropy balancing sample to control for endogeneity problems.

This study has several implications. First, in the digital era, the convenience of information transformation and the diversity of information sources make rumors a major hidden danger during a public crisis, and government agencies should be prepared to combat them. Second, during a public crisis, investors should accurately distinguish the quality of information, verify its authenticity and invest cautiously. They must acquire considerable official information from authoritative channels and make rational choices. Finally, for media organizations, information from online platforms and self-media should be strictly reviewed to avoid the spread of rumors.

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Table 10
Placebo test.

| Variable      | Car_M[-1,1] | Car_MM[-1,1] | Car_M[-1,1] | Car_MM[-1,1] |
|---------------|-------------|--------------|-------------|--------------|
|               | (1)        | (2)         | (3)         | (4)         |
| Neg_Othercity | 0.001      | –0.001      | –0.009      | –0.009      |
|               | (0.764)    | (–0.598)    | (–1.078)    | (–1.065)    |
| Pos_Othercity | –0.000**   | –0.001***   | –0.000**    | –0.001***   |
|               | (–2.483)   | (–3.794)    | (–2.484)    | (–3.795)    |
| Size          | 0.008***   | –0.007***   | 0.008***    | –0.007***   |
|               | (3.257)    | (–2.735)    | (3.257)     | (–2.735)    |
| Leverage      | 0.001      | 0.002       | 0.001       | 0.002       |
|               | (0.951)    | (1.464)     | (0.951)     | (1.465)     |
| Cash          | –0.001     | 0.001       | –0.001      | 0.001       |
|               | (–0.912)   | (0.465)     | (–0.913)    | (0.466)     |
| Growth        | –0.000     | 0.000       | –0.000      | 0.000       |
|               | (–0.796)   | (0.052)     | (–0.798)    | (0.053)     |
| New cases     | –0.000     | –0.000***   | –0.000      | –0.000**    |
|               | (–1.427)   | (–2.026)    | (–1.437)    | (–2.018)    |
| Constant      | 0.007*     | 0.012***    | 0.007*      | 0.012***    |
|               | (1.755)    | (3.020)     | (1.763)     | (3.017)     |
| Industry fixed effects | ✓ | ✓ | ✓ | ✓ |
| City fixed effects | ✓ | ✓ | ✓ | ✓ |
| N             | 95,075     | 95,075      | 95,075      | 95,075      |
| R²            | 0.005      | 0.007       | 0.005       | 0.007       |

The table reports the coefficients, with the t-statistics shown in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. A.1. Rumor collection and data selection

We manually collect the COVID-19 rumors circulating on online platforms (such as Sina Weibo) from 20 January to 31 March 2020, and collect the corresponding refutation from authoritative organizations (including provincial and municipal public security bureaus). Excluding rumors that affect Hong Kong, Macau and Taiwan, we identify 143 rumors for which we can identify the time of appearance and the city of effect; of these, 118 are frightening rumors and 25 are reassuring rumors. We obtain 34 rumors affecting cities in Hubei province, with the remaining rumors distributed across other cities in various provinces. The descriptive statistics in Section 4.1 show the distribution of rumors in detail. The selection period for the rumors is used as the sample period. Then, the financial indicators of each company at the end of 2019 are considered as the corresponding financial control variables.

To obtain and identify the rumors during our selected period, we apply the following four-step data collection method.

1. We search for “COVID-19” and “rumors” as keywords on Baidu and Weibo, China’s two main public network platforms, to collect all search results in the selected period (including rumors from Weibo, WeChat and Tieba).
2. For all search results, we check the source of the corresponding rumors to confirm their existence. We eliminate rumors for which we cannot determine a confirmed source.
3. Using the content of the rumor as keywords, we search for refuting information for all of the rumors, confirm the falseness of the rumors and eliminate any “rumors” that are subsequently realized.
4. We manually classify rumors based on their text. We divide rumors into frightening rumors and reassuring rumors. If a rumor exaggerates the severity of the local pandemic, for example, a report that “there is a COVID-19 case in a certain area” when one has not occurred in reality, we define it as a frightening rumor. If a rumor downplays the severity of the local pandemic, for example, a false report that a certain area “will resume work and production” on a certain day, then we define it as a reassuring rumor.

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