Liu *et al. Financial Innovation* (2024) 10:65
https://doi.org/10.1186/s40854-023-00587-y

Financial Innovation

RESEARCH Open Access

The game of lies by stock investors in social media: a study based on city lockdowns in China

Qing Liu[1,2], Hosung Son[2] and Woon-Seek Lee[2*]

*Correspondence:
iewslee@pknu.ac.kr

[1] College of Economics and Management, Huainan Normal University, West Dongshan Road, Huainan 232038, Anhui, China
[2] Graduate School of Management of Technology, Pukyong National University, 365, Sinseon_ro, Nam-Gu, Busan 48547, Republic of Korea

Abstract

The potential hypotheses for finance research based on social media sentiment revolve around the reliability of investor sentiment expressed on social media and the causal relationship between financial markets and this sentiment. The central hypothesis we focus on is derived from the "lie game" played by investors on social media. This study is the first to explore three states of this lie game in the context of the Chinese stock market: the "equilibrium state", the "confusion state", and the "subversion state". Our findings indicate that the "equilibrium" state is the typical state of the lie game, where increased investor sentiment results in more positive market behavior, and higher stock prices lead to increased investor sentiment. We also examine the effect of significant social events, such as the "lockdown in Wuhan" and the "lockdown in Shanghai", on the lie game's outcome. The successful lockdown in Wuhan and the public's opposition to the politicization of COVID-19 reinforced the "equilibrium" state of the game. However, the Shanghai lockdown's failure to promptly halt the spread of COVID-19 led to the intertwining of the economy and COVID-19 in public discourse, shifting the lie game's outcome from an "equilibrium state" to a "subversive state". We emphasize that the "confusion state" and "subversion state" outcomes of the lie game are concerning, and managing public opinion and the externalization of domestic conflicts can help reduce this risk. This study offers a fresh perspective on the traditional issues of investor sentiment reliability and the causal relationship between investor sentiment and stock markets.

Keywords: Lies, Social media, Investor sentiment, Public opinion, Lockdown

Introduction

In the age of big data and artificial intelligence, the sentiment expressed on social media serves as a valuable addition to traditional sentiment indicators derived from financial surveys, market signals, and search engines (Antweiler and Frank 2004; Da et al. 2015; Liu et al. 2022a, b, c). The question, "What do investors think?" which is inherent in social media sentiment, has numerous applications and is therefore intriguing (Pang and Lee 2008). Nevertheless, scholars have reported inconsistent results in related studies. For instance, some researchers have found no predictive value in the emotions expressed on social media (Antweiler and Frank 2004; Tumarkin and Whitelaw 2001), while others have identified weak or strong predictive capabilities (Liu et al. 2022a, b, c; Mao et al.

Springer Open

© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

2011). These inconsistent results have prompted scholars to reassess the reliability of investor sentiment on social media and the cause-and-effect relationship between the stock market and investor sentiment on social media.

This study highlights the causal link between stock market performance and investor sentiment on social media is the result of a game of lies by investors in social media. The trustworthiness of investor sentiment is contingent upon the potency of a positive outcome from this deceptive game. This study analyzes three potential outcomes of this deceptive strategy by stock investors on social media in the Chinese markets:

- "Equilibrium state": Investors' actions align with their words, resulting in a significant positive correlation between investment sentiment on social media and stock fundamentals. The strength of this correlation indicates the reliability of investor sentiment.
- "Confusion state": The lie tactics blur the cause-and-effect relationship, leading to no statistically significant correlation between social media sentiment and stock fundamentals.
- "Subversion state": The lie reverses the cause-and-effect relationship, resulting in a significant negative correlation between investment sentiment on social media and stock fundamentals.

This study provides a new perspective and theoretical reference for understanding social media sentiment, stock markets, and behavioral finance.

This study offers a multi-dimensional contribution. Researchers have thoroughly investigated how investor sentiment on social media affects various aspects of the stock market(Liu et al. 2023), including stock prices (Liu et al. 2022a, b, c), returns (Bollen et al. 2011; Oliveira et al. 2013), volatility (Sprenger et al. 2014), and price indices (Zheludev et al. 2014), among others. From these studies, researchers have verified a causal link between the stock market, investor sentiment, and social media. However, few describe the operational mechanism of the interaction between social media sentiment and the stock market. Therefore, this study offers a fresh theoretical explanation of the causal relationship between social media sentiment and the stock market.

The cause-and-effect relationship between investor sentiment and stock markets on social media is grounded in the fundamental assumptions of studies on social media investment sentiment (Liu et al. 2022a, b, c). However, these studies do not agree in terms of their findings (Nguyen et al. 2015). As previously mentioned, numerous studies suggest that investor sentiment can predict stock prices or returns (Bollen et al. 2011; Geva and Zahavi 2014; Sprenger et al. 2014; Vu et al. 2012). Conversely, other studies find little proof that sentiment can predict stock prices or returns (Brown and Cliff 2004; Nofer and Hinz 2015; Oliveira et al. 2013; Tumarkin and Whitelaw 2001). These conflicting results raise doubts about the reliability of investor sentiment on social media. This research suggests that there are multiple possible outcomes in the social media lie game, offering a comprehensive explanation for these varied findings.

Furthermore, our research pertains to COVID-19. It's widely recognized that COVID-19 has drastically affected our everyday lives and disrupted global trade and flows (Haleem et al. 2020). Numerous scholars have examined the intricate effect of

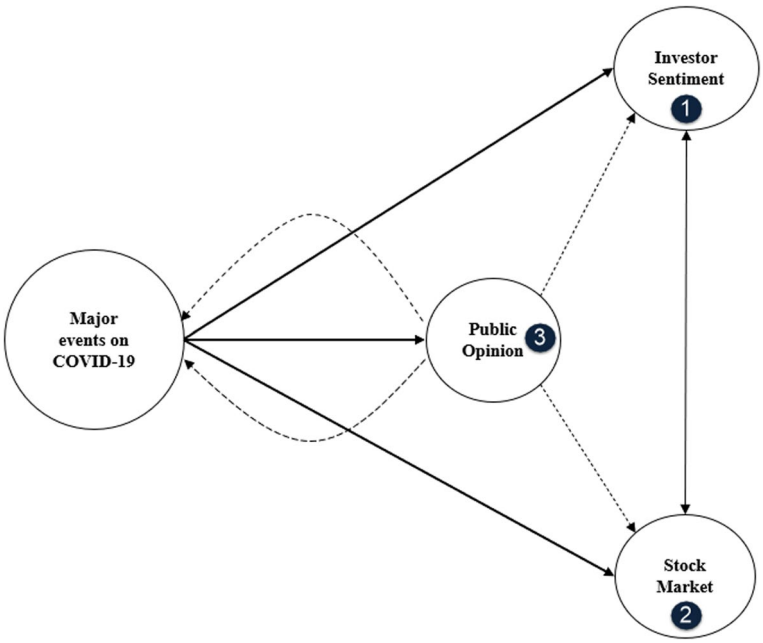

Fig. 1 Data logic of the study. The solid lines indicate causal influences, and the dashed lines indicate the perspective of observation

COVID-19 on stock markets and the sentiment of investors within these markets (Eachempati et al. 2021; Fallahgoul 2021; Hoang and Syed 2021; Naseem et al. 2021; Sun and Shi 2022). Typically, researchers use the onset of COVID-19 as a background event, and then observe the emergence and fluctuations of market, economic, and financial events within this context (Goodell 2020; Kumar et al. 2020). Given that over three years have passed since the COVID-19 outbreak, it is difficult to assume that its effect on financial markets has remained consistent over such an extended period (Szczygielski et al. 2023; Zaheer et al. 2022). This study explores the effect of COVID-19 on the stock market across various time frames, leveraging the capacity of public opinion to examine events retrospectively.

Figure 1 shows the data chain strip used in this study. The study applies the latent Dirichlet allocation (LDA) algorithm to topic-model news and self-published texts, thereby acquiring public opinion data (Data 3). It uses convolutional neural networks to measure investor sentiment (Data 1) in social media texts, and uses stock price data from the SSE Index as a proxy for stock prices (Data 2).

User-generated content in investor communities reflects individual investor views, and when these views are combined, they can effectively represent the overall sentiment of investors (Bollen et al. 2011). In an "honest" market, it is anticipated that public sentiment on social media corresponds with related shifts in financial markets (Liu et al. 2022a, b, c). Therefore, any discrepancies between investor sentiment on social media (Data 1) and stock indices (Data 2) may suggest "lies" in both social media and the stock market. Public sentiment (Data 3), conversely, can be seen as a compact representation of significant societal events, because financial markets are vulnerable

to macroeconomic conditions and key social incidents (Hong et al. 2023). Together, Data 1, Data 2, and Data 3 create the data linkage that underpins our research model.

Figure 1 illustrates our investigation into the outcome of the game of lies played by investors in social media and the effect of major social events on the game's outcome. We analyze three data strands: social media investor sentiment, stock market fundamentals, and public opinion. A recent study by Liu et al. (2022a, b, c) establishes the "equilibrium state" as the norm for the game of lies in social media. In this state, there is a significant positive correlation between investor sentiment in social media and stock prices, and the reliability of social media is contingent upon the strength of this correlation. However, major social events have the potential to disrupt this equilibrium:

1. Social events that generate positive public opinion, such as admiration and optimism, reduce lies on social media platforms that target investors. These events contribute to strengthening the equilibrium state of the lie game in the context of social media.
2. Social events that generate negative public opinion, such as worry or criticism, can disrupt the equilibrium of the game of lies on social media. For instance, during the Shanghai lockdown, the intertwining of COVID-19 and economic concerns in public discourse caused the outcome of investors' game of lies on social media to shift toward a state of confusion or even subversion.
3. In times of international conflict, the external transfer of domestic conflicts helps to reduce financial risks in the stock market.

Note that the significance lies not in the event itself but in the directions, outcomes, and contexts of major social events that affect the outcome of a game of lies by investors. Furthermore, the conclusion of an event does not signify the end of its effect. This study is the first to use the concept of the "lie game" to analyze investor sentiment, offering a fresh perspective on the reliability of investor sentiment and its relationship with stock markets.

The remainder of the paper is structured as follows. Sect. "Game model and hypothesis" defines the game model and outlines the research hypotheses. Sect. "Data and methodology" describes the data and methodology. Sect. "Empirical study" presents the empirical study and discussion. Sect. "Conclusion" concludes the paper.

Game model and hypothesis

Definition of a lie

False information on social media is commonly referred to as "rumors" or "lies" (Alhouti and Johnson 2022; Hameleers et al. 2020; Zubiaga et al. 2015). Distinguishing between lies and rumors is challenging, because both can incorporate elements of truth (Van Bommel 2003), and sometimes the distinction between falsehood and veracity is slim (Vrij 2008).

Several scholars have defined inconsistent information as a lie (Deeb et al. 2018; Han et al. 2020), while Clarkson et al. (2006) contend that in financial markets, any information that cannot be objectively verified falls into the category of a rumor or lie. In our study, we merge these perspectives and define "inconsistency in words and actions" as

a lie, embracing the notion that "people lie, actions don't!" (Raj and Meel 2022). On a micro level, "words" refer to social media texts, and "actions" refer to investors' transactions in the stock market; on a macro level, "words" represent investor sentiment on social media, and "actions" the stock market's performance. This framework allows us to assess whether an investor's message is truthful by comparing "words" and "actions" before and after the fact. Adhering to the assumption of safe chronological causality (i.e., the past precedes the future), we consider two scenarios: one where "words come first, followed by actions", and another where "actions come first, followed by words".

According to the principle that "words precede actions", an investor's behavior in the stock market should align with their prior social media statements. If an investor forecasts a stock's price increase on social media, but then sells or short sells that stock, they are being dishonest. Similarly, if an investor predicts a stock's decline, but proceeds to hold or buy the stock, they are not being truthful. Therefore, we can express an investor's statements and actions as a tuple: (words, actions). Excluding neutral opinions, there are four possible strategies (2×2). By assigning the number one to positive statements and actions and the number zero to negative ones, we can define the four strategies (G) as follows:

$$G(W, A) = \begin{vmatrix} 1 & 1 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{vmatrix}.$$

In the above combination of strategies, whether the investor is lying or not can be determined by the iso-or operation: $\boldsymbol{W} \oplus \boldsymbol{A} == 1$; then,

$$W \oplus A = \begin{vmatrix} 0 \\ 1 \\ 1 \\ 0 \end{vmatrix}.$$

According to the principle that "actions precede words", investors' posts on social media should align with prior stock market trends. If an investor shares negative comments following a stock price increase, or positive remarks after a decline, they are considered dishonest, because this contradicts the general investor-by-profit assumption that investors react positively to gains and negatively to losses (Kish and Fairbairn 2018). There are four possible combinations of market performance and investor sentiment. Assigning a score of one for positive market outcomes and investor sentiment, and zero for negative ones, these strategies can be categorized as

$$G(A, W) = \begin{vmatrix} 1 & 1 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{vmatrix}.$$

In the above combination of strategies, whether the investor is lying or not can be determined by the iso-or operation: $\boldsymbol{A} \oplus \boldsymbol{W} == 1$; then,

$$A \oplus W = \left| \begin{matrix} 0 \\ 1 \\ 1 \\ 0 \end{matrix} \right|.$$

We do not consider neutral emotions in the above analysis because Antweiler and Frank's (2004) findings suggest that considering neutral emotions introduces additional noise into the data. Based on the above, we define lies as follows.

Definition 1 Messages from investors in social media that meet conditions $\boldsymbol{W \oplus A == 1}$ or $\boldsymbol{A \oplus W == 1}$ are considered lies.

Game model

The preferred method for simulating natural phenomena involves a series of interconnected differential equations that capture the dynamics of temporal evolution (Schölkopf et al. 2021). These equations offer a deep understanding of the causal mechanisms governing a system's behavior. Consequently, we can depict the causal relationship between investor sentiment (*IS*) and the stock market (*SM*) as observed in social media by employing a set of differential equations:

$$\frac{\boldsymbol{dIS}}{\boldsymbol{dSM}} = \boldsymbol{f}(\boldsymbol{IS}), \boldsymbol{IS} \in \boldsymbol{R^d}, \tag{1}$$

$$\frac{\boldsymbol{dSM}}{\boldsymbol{dIS}} = \boldsymbol{f}(\boldsymbol{SM}), \boldsymbol{SM} \in \boldsymbol{R^d}, \tag{2}$$

where Eq. (1) describes how the stock market will change when investor sentiment changes, and Eq. (2) describes how investor sentiment will change when the stock market changes.

According to Eq. (1) and Definition 1, if an investor's message on social media is honest, the investor will act in accordance with the sentiment expressed in the message. Investor sentiment on social media emerges from the collective sentiments of numerous individuals (Deng et al. 2018; Wei et al. 2016). When investors collectively "match words with actions", this general personal honesty translates into overall honesty in social media sentiment, which, in turn, has a significant positive effect on the stock market:

$$\boldsymbol{if}\left(\frac{1}{\boldsymbol{n}}\sum_{\boldsymbol{i}=0}^{\boldsymbol{n}} \boldsymbol{W_n} \oplus \boldsymbol{A_n}\right) \sim 0, \boldsymbol{then IS} \rightarrow \boldsymbol{SM}. \tag{3}$$

At this point, $\frac{\boldsymbol{dIS}}{\boldsymbol{dSM}} = \boldsymbol{f}(\boldsymbol{IS}) > 0$.

In accordance with Eq. (2) and Definition 1, as a result of investors' inherent profit-seeking behavior, the sentiment expressed in their social media messages tends to align with preceding stock market fundamentals. A gloomy market climate fosters negative sentiment among investors, while a buoyant market does the opposite. This phenomenon suggests that individual perceptions often aggregate into a collective sentiment on social media, which in turn positively affects investor sentiment in relation to the stock market:

$$\boldsymbol{if}\left(\frac{1}{\boldsymbol{n}}\sum_{\boldsymbol{i}=0}^{\boldsymbol{n}}\boldsymbol{A_n}\oplus\boldsymbol{W_n}\right)\sim 0,\boldsymbol{then SM}\rightarrow\boldsymbol{IS}. \tag{4}$$

At this point, $\frac{\boldsymbol{dSM}}{\boldsymbol{dIS}}=\boldsymbol{f}(\boldsymbol{SM})>0$.

Thus, investors align their actions with their words. There is a positive causal relationship between investor sentiment expressed on social media and stock market performance, with

$$\frac{\boldsymbol{dIS}}{\boldsymbol{dSM}}=\boldsymbol{f}(\boldsymbol{IS})>0\text{and}\frac{\boldsymbol{dSM}}{\boldsymbol{dIS}}=\boldsymbol{f}(\boldsymbol{SM})>0.$$

Investor sentiment in social media is then credible, and the credibility of investor sentiment on social media is determined by the value of the differential equation. Credibility is a fundamental attribute that social media should possess (Alhouti and Johnson 2022). Arora and Sanni (2019) highlight that social media lacking credibility is practically ineffective. Van Bommel (2003) posited that a social media platform that consistently disseminates false information cannot sustain itself. These studies collectively imply that the credibility of social media represents the "equilibrium state" in the game of lies played by investors on these platforms.

"Equilibrium state": If $\frac{\boldsymbol{dIS}}{\boldsymbol{dSM}}>0$ and $\frac{\boldsymbol{dSM}}{\boldsymbol{dIS}}>0$ are statistically significant during the observation period, then investors are "consistent in words and actions", and the game of lies in social media leads to an "equilibrium state".

Social media is rife with falsehoods (Hameleers et al. 2020; Zubiaga et al. 2015), and when the ratio of these lies surpasses a certain threshold, the result of the investors' game of lies may deviate from the "equilibrium state". Furthermore, Eqs. (1) and (2), which represent natural phenomena, can have a range of potential values, such as the values of $\frac{\boldsymbol{dIS}}{\boldsymbol{dSM}}$ and $\frac{\boldsymbol{dSM}}{\boldsymbol{dIS}}$ being less than zero. Based on this, two additional potential outcomes of an investors' deception game are identified.

"Subversion state": If $\frac{\boldsymbol{dIS}}{\boldsymbol{dSM}}<0$ and $\frac{\boldsymbol{dSM}}{\boldsymbol{dIS}}<0$ are statistically significant during the observation period, then investors are "inconsistent between words and actions", and the game of lies in social media leads to a " subversive state".

"Confusion state": If the sign of the values of $\frac{\boldsymbol{dIS}}{\boldsymbol{dSM}}$ and $\frac{\boldsymbol{dSM}}{\boldsymbol{dIS}}$ cannot be in a steady state during the observation period, then the lies of investors in social media confuse cause and effect, and the result of this game of lies is a "confusion state".

In conclusion, the causal link between investor sentiment on social media and the stock market is shaped by a dynamic interplay of "truths" and "lies" among stock investors. The intensity of this interplay dictates the trustworthiness of the sentiment expressed on social media. Through ongoing observation, the results of this deceptive game played by investors on social media can be viewed as a probability distribution of "truths" and "lies", and can be estimated using Pearson's correlation coefficient (Benesty et al. 2009),

$$\boldsymbol{Gameresults}=\begin{cases}equilibriumstate\\confusionstate\\subversionstate\end{cases}\sim\begin{cases}correlation>0 and pValue<0.1\\correlation=0 or pValue\geq 0.1\\correlation<0 and pValue<0.1\end{cases}. \tag{5}$$

The Pearson correlation coefficient of investor sentiment in social media (*IS*) and stock market fundamentals (*SM*) can be considered as an integrity factor (*IF*) that we can use to determine the status of the game of lies by investors in social media:

$$IF = Pearson(IS, SM). \tag{6}$$

The integrity factor represents the correlation between investor sentiment (Data 1 in Fig. 1) and the stock market (Data 2 in Fig. 1). When investor sentiment and the stock market move significantly in the same direction, this signifies the market's integrity, which we refer to as the "equilibrium state". However, discrepancies between investor sentiment and the stock market suggest a state of confusion or even disruption. Numerous studies have recorded the existence of these states of confusion and disruption. In practical terms, this phenomenon is seen as the failure of social media investor sentiment to accurately forecast financial market results (Brown and Cliff 2005; Nofer and Hinz 2015), though the causes for this are still not fully understood. In our research, we incorporate public sentiment (Data 3 in Fig. 1) to encapsulate the wider societal context and the significant events it signifies. By creating an observational model based on the interaction of these three data sets, as shown in Fig. 1, we aim to better understand the dynamics of investor deception in social media.

Hypotheses

Several studies have established a cause-and-effect relationship between investor sentiment on social media and stock prices (Bollen et al. 2011; Oliveira et al. 2013; Renault 2017). Liu et al. (2022a, b, c) recently emphasized that there is, in general, a positive correlation between social media investor sentiment and stock prices. Arora and Sanni (2019) note that unreliable social media is practically ineffective, further affirming that investor sentiment on social media is, in general, dependable. The "equilibrium state" should be a general characteristic of social media. Social media for investors who have been untrustworthy cannot exist (Van Bommel 2003). Based on the above analysis, we propose the first hypothesis of this paper.

H1. In general, the outcome of the game of lies by investors in social media is an "equilibrium state", where investors' words (social media sentiment) align with their actions (stock market performance).

Statistics clearly demonstrate that overall figures do not necessarily reflect local characteristics (Green et al. 1982). Van Bommel (2003) identifies three forms of disinformation prevalent in investor social media. The first type involves lies that incorporate accurate information, the second type includes lies that lack any information, essentially bluffs, and the third type involves investors disseminating false rumors. Furthermore, Li et al. (2018) and Liu et al. (2022a, b, c) describe certain aimless lies that may not be evenly distributed over short time spans, but that they neutralize each other in the long term. A surge of lies within a specific timeframe could disrupt the equilibrium of the deception game, altering the game's outcome to a state of "confusion" or even "subversion". Based on these observations, we propose our second hypothesis.

H2. At a specific time, the outcome of the game of lies played by investors in social media may appear to be in a state of "confusion" or "subversion". Investors' words (social media sentiment) may not align with their actions (stock market performance), resulting in no significant correlation between social media sentiment and the stock market, or even a significant negative correlation.

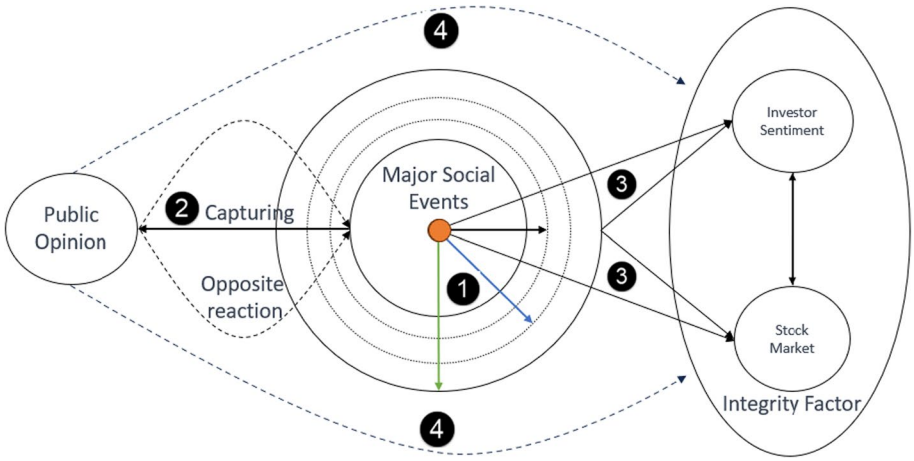

Fig. 2 A mechanism map of how major social events influence the game of lies in social media

The COVID-19 pandemic has significantly altered our daily routines and disrupted global trade (Haleem et al. 2020). The effects of COVID-19 on stock markets and investor sentiment have been well-documented (Cox et al. 2020; Fernandez-Perez et al. 2021; Wagner 2020). The extensive influence of COVID-19 globally illustrates the wide-ranging effects of a significant societal event, either directly or indirectly. Many studies have confirmed the direct or indirect effects of COVID-19 on financial markets and investor sentiment (Goel and Dash 2022; Loang 2022). These effects are likely to result in changes to the integrity factor, subsequently affecting the outcomes of the game of lies among investors on social media. Although it may be difficult to directly observe the effects of major societal events on the game of lies among social media investors, public opinion can fortunately capture these events and their ripple effects (Hu et al. 2021). Therefore, by examining differences in these outcomes within various states of public opinion during major societal events, we can indirectly observe the effects of these events on the outcomes of the game of lies among social media investors.

Figure 2 clarifies the process through which significant societal events affect the results of deception games among investors. Step 1 outlines the broad diffusion effects of notable events. Step 2 demonstrates the ability of public sentiment to recognize significant societal events and their effects. Step 3 provides details on how major societal events and their subsequent effects influence investor sentiment and stock markets. Step 4 emphasizes the way public sentiment indirectly monitors or evaluates the Integrity factor in reaction to significant societal events. Based on this analysis, we propose Hypothesis 3.

H3. Major social events may influence the outcome of the game of lies played by investors in social media.

The Chinese government's most extreme reaction to COVID-19, the city lockdown, has also had significant effects on the economy and finances. For instance, You et al. (2020) calculated the monthly economic losses during Wuhan's lockdown. Over three years have passed since the COVID-19 outbreak, and the human response to the virus has drastically changed, shifting from an initial severe lockdown to learning to coexist with COVID-19 (Zhang et al. 2021). It seems illogical that the effect of COVID-19 on financial markets has remained consistent throughout these three years. Similarly,

NAME	Self-Media A
DATE	2022-12-24
ACCREDITATION	Senior Media Person
CONTENT	On December 24, the Nara Prefecture District Prosecutor's Office in Japan said that, according to the results of the mental identification, the suspect who previously shot and killed former Japanese Prime Minister Shinzo Abe, Toru Yamayama, also has the ability to be criminally responsible. The Nando reporter noted that the Nara Prefecture District Prosecutor's Office also said it expects to formally charge Tetsuya Yamama with murder on January 13, 2023.
LIKE	150
COMMENTS	20

Fig. 3 Sample of micro headlines

it seems unlikely that the financial effects of the 2022 Shanghai lockdown and the 2020 Wuhan lockdown were identical. Based on this explanation, we propose hypothesis H4.

H4. The effects of the lockdowns on the outcomes of the game of lies by investors in social media vary between Wuhan, which occurred in the pre-COVID-19 era, and Shanghai, which occurred in the post-COVID-19 era.

COVID-19's effects on financial markets are multifaceted. Researchers often use the emergence of COVID-19 as a proxy for investor sentiment (Liu et al. 2022b), and they measure its effect by comparing financial markets before and after its onset (Chen et al. 2020; Huynh et al. 2021). However, the severity of COVID-19's effect is continually evolving (Zhang et al. 2021), as are the strategies for managing COVID-19. It is challenging to define COVID-19's current role in society and, therefore, to predict its potential economic effect. Nevertheless, as a significant societal event, COVID-19 plays a crucial role in shaping public opinion (Maeda 2022; Malecki et al. 2021; Yu et al. 2020). By examining the relationship between the topics of "COVID-19" and "economy" in public opinion, we can hypothesize about COVID-19's possible economic effect. Based on this discussion, we propose hypothesis H5.

H5. COVID-19 has a greater impact on the outcome of the game of lies in social media when the topic of "COVID-19" is intertwined with the topic of "economy" in public opinion.

Data and methodology

Data

Figure 1 illustrates the three data channels used in this study: public opinion, investor sentiment on social media, and stock market prices. The LDA algorithm is used to extract public opinion from news and self-published texts. Convolutional neural networks are employed to gauge investor sentiment on social media. Stock price data from the SSE serve as a proxy for stock prices.

(A) Public opinion data

We gathered news and commentary data from Micro Headlines, a product of Today's Headlines.[1] This platform allows users to share graphics, short videos, and live streams,

[1] https://www.toutiao.com

Table 1 Statistics of news and comments

Media No.	Number of followers (ten thousand)	No. of news (Nov 2019–Dec 2022)	Media category
1	922.8	2,759	Self-Media
2	550.7	5,195	Self-Media
3	301.2	6,384	Self-Media
4	270.9	2,995	Self-Media
5	563.1	5,195	Newspapers
Mean	521.74	4505.6	
Total	2,608.7	22,528	

TITLE	Insufficient downward momentum. Maybe stock index will be dominated by the horizontal accumulation of downward momentum
NAME	Cat catching mouse
DATE	2021-05-10 13:46:28
READERS	221
COMMENTS	112
TEXT	Because of the sharp decline some time ago, many chips have been missed. Stop losing money at first. Coupled with the recent emergence of several slogan-style stabilization of stock measures, stock indices are expected to continue to fall in mid to late June.

Fig. 4 Sample of investor message

fostering relationships over time. As per the official website, Micro Headlines generates over 20 million user interactions daily, with nearly 10 million posts.[2] Figure 3 shows the text structure and style of Micro Headlines. For our research, we collected texts posted by a mainstream news outlet and four senior media professionals on Micro Headlines from November 2019 to December 2022 to gauge public sentiment. We have chosen not to reveal the identities of the news media and self-publishers to protect their privacy. As Table 1 indicates, the average follower count for these five sources is 5,217,400, demonstrating their significant influence.

(B) Social media texts from investors

Social media data was gathered from the "SSE Index Bar" within the "Stock Bar", the most significant stock and fund exchange community in China. This community is a hub where numerous investors and investment institutions daily share and comment on the "SSE Index". As shown in Fig. 4, each post includes a title, author, date, number of reads, number of comments, and text.

We gathered media texts posted by investors from January 2019 to December 2022 using crawler technology. The total number of messages from investors was around 3,562,000, with a readership of 2,245 million and a total of 8,395,200 comments. The daily message volume varied, with a maximum of 19,204, a minimum of 13, and an average of 2,442, as outlined in Table 2.

(C) Stock price data

[2] https://www.toutiao.com/about/

Table 2 Statistical description of social media texts

Indicators	Daily messages	Daily reading	Daily comments
count	1,459	1,459	1,459
mean	2,442	1,539,014	5,754
std	2,047	1,815,480	3,930
min	13	24,426	22
25%	590	702,471	3,197
50%	2,228	1,172,903	5,006
75%	3,353	1,825,842	7,065
max	19,204	44,924,350	43,562

25%, 50%, and 75% are quartiles, and the subsequent tables are consistent

Table 3 Statistical description of stock price

Indicators	Opening price	Closing price	Highest price	Lowest price	Previous closing price
count	972.00	972.00	972.00	972.00	972.00
mean	3,200.54	3,202.98	3,221.62	3,179.91	3,202.36
std	279.39	278.44	279.19	277.15	279.34
min	2,446.02	2,464.36	2,488.48	2,440.91	2,464.36
25%	2,964.98	2,968.31	2,984.44	2,940.19	2,967.67
50%	3,224.66	3,223.95	3,249.79	3,201.29	3,223.95
75%	3,445.50	3,449.68	3,465.89	3,422.75	3,449.68
max	3,721.09	3,715.37	3,731.69	3,692.82	3,715.37

Prices are in CNY. Except for the "count" indicator, the value of stock returns is a percentage

Because the subject of messages in social media is "SSE Index", we use the SSE Composite Index as a proxy for the composite stock price. We gathered data on metrics such as the opening price, closing price, highest share price, and lowest share price, aligning the time frame with the investor message, spanning 972 trading days from 2019 to 2022. In line with Mallikarjuna and Rao (2019) and Nimal (1997), this study uses closing prices to define stock market returns:

$$\boldsymbol{R_t} = \frac{(\boldsymbol{P_t} - \boldsymbol{P_{t-1}})}{\boldsymbol{P_{t-1}}} * 100. \tag{7}$$

Statistical descriptions of the stock price data are shown in Table 3.

News topic modelling

We used the LDA technique for topic modeling to examine the evolution of public opinion, focusing on news and comments. The process of textual topic modeling typically involves three key stages: data pre-processing, the creation of TF-IDF word vectors, and news topic modeling (Zhou et al., 2023). This process is illustrated in Fig. 5.

Step 1. Text pre-processing

The process of text pre-processing starts with the removal of numbers, punctuation, unnecessary spaces, and unreadable special characters, such as "(", "[", "{", and "&", from the text. These characters, although commonly found in news articles, do not aid in text topic mining and are therefore considered noise (Uysal and Gunal 2014).

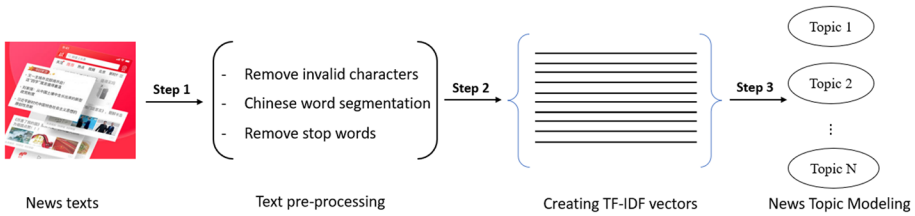

Fig. 5 Flowchart of news topic mining

The second step in pre-processing is Chinese word separation. Unlike English sentences, which are sequences of words separated by spaces, Chinese sentences are represented as strings of characters without any mandatory separation. Therefore, the first hurdle in processing Chinese is to identify the sequence of words in a sentence and denote the appropriate boundary positions (Ma et al. 2018; Xue 2003).

The last step in data pre-processing involves the removal of stop words. These are words that frequently occur in text, but do not aid in text classification or topic mining (Baradad and Mugabushaka 2015). Removing stop words improves the efficiency of natural language processing and is a crucial part of text data preprocessing (Anandarajan et al. 2019). Therefore, we use a list of stop words at the end of data preprocessing to enhance data quality (Hao and Hao 2008).

Step 2. Creating TF-IDF vectors

The "term frequency-inverse document frequency (TF-IDF)" is a prevalent word weighting strategy in current information retrieval systems (TF-IDF)" (Aizawa 2003). The "TF" (term frequency) in "TF-IDF" signifies the frequency of specific terms within a document. Terms with a high TF value are deemed significant in a manuscript. Conversely, the DF represents the frequency of a particular term across a collection of documents. It measures how often a term appears in multiple documents, not just one. Terms with a high DF value are considered less significant due to their common occurrence across all documents. Therefore, the IDF, the inverse of the DF, is employed to assess the significance of terms across all documents. High IDF values suggest that terms are rare across all documents, thus increasing their importance (Kim and Gil 2019). The formula for calculating TF is as follows:

$$\boldsymbol{TF_{i,j}} = \frac{\boldsymbol{n_{i,j}}}{\sum_k \boldsymbol{n_{k,j}}}. \tag{8}$$

In Eq. (8), $\boldsymbol{n_{i,j}}$ indicates the number of occurrences of the word $\boldsymbol{t_i}$ in document j, and $\boldsymbol{TF_{i,j}}$ indicates the frequency of the word $\boldsymbol{t_i}$ in document j. The formula for calculating the IDF is as follows:

$$\boldsymbol{IDF_i} = \boldsymbol{log}\frac{|\boldsymbol{D}|}{1 + \left|\boldsymbol{j} : \boldsymbol{t_i} \in \boldsymbol{d_j}\right|}. \tag{9}$$

In Eq. (9), $|\boldsymbol{D}|$ denotes the number of all documents, and $\left|\boldsymbol{j} : \boldsymbol{t_i} \in \boldsymbol{d_j}\right|$ denotes the number of documents containing the term $\boldsymbol{t_i}$. The denominator in Eq. (9) is added to one to prevent the denominator from being zero. The TF-IDF is calculated as

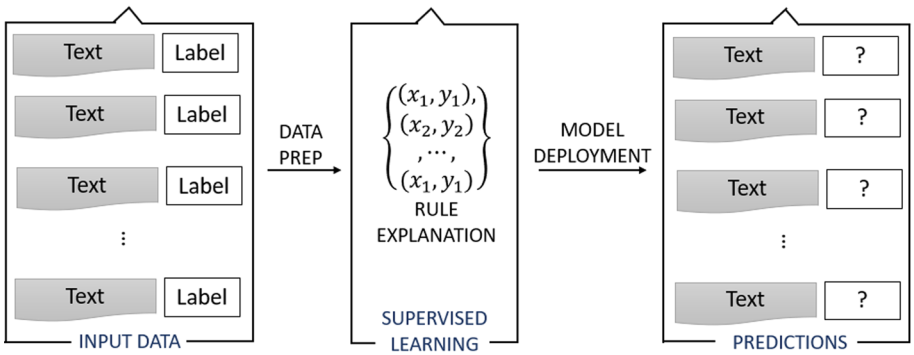

Fig. 6 Diagram of supervised learning

$$\boldsymbol{TF-IDF} = \boldsymbol{TF} \times \boldsymbol{IDF}. \tag{10}$$

Step 3. Topic Modeling

The LDA algorithm, as indicated by the research, is applicable for news topic modeling. The LDA topic model can effectively reduce the dimensionality of text in semantic space, modeling the text based on the probability of vocabulary, which somewhat mitigates the issue of data sparsity (Yu and Qiu 2019; Zhang et al. 2015). In terms of text modeling, each document is constructed as a blend of themes, with the proportions of this continuous-valued blend distributed as a latent Dirichlet random variable (Blei et al. 2001).

LDA is a three-tiered hierarchical Bayesian model. In this model, each item in a collection is depicted as a finite mixture over a foundational set of topics. Following this, each topic is modeled as an infinite mixture of underlying topic probabilities (Blei et al. 2003).

Constructing investor sentiment

The process of gauging investor sentiment on social media typically involves two stages: sentiment mining and sentiment aggregation (Pang and Lee 2008). We follow Antweiler and Frank (2004) to categorize investor messages into "positive", "neutral", and "negative" based on the degree of market confidence expressed in these messages. These individual investor sentiments are then compiled over time to generate a comprehensive investor sentiment. Given the sheer volume of investor social media texts, which can reach up to 3,561,200, manually classifying the sentiment in these comments is challenging. To address this, we employ supervised learning. The defining characteristic of supervised learning is the presence of annotated training data (Hinz et al. 2011). The name refers to a "supervisor", who instructs the learning system on which labels to associate with training data (Cord and Cunningham 2008). Supervised learning methods use this training data to develop models, which can then be applied to classify further unlabeled data (Hastie et al. 2009). Figure 6 provides a visual representation of the fundamental supervised learning process.

In their recent study, Liu et al. (2022a, b, c) employed a convolutional neural network to categorize investor messages as "bullish", "neutral", or "bearish" in their examination of the interplay between investor sentiment and stock prices. The network model's

Table 4 Performance of model classification

True classification	Prediction classification			
	Positive	Negative	Neutral	Accuracy (%)
Positive	1010	79	21	90.99
Negative	21	880	29	94.62
Neutral	24	154	802	81.83
Total				89.14

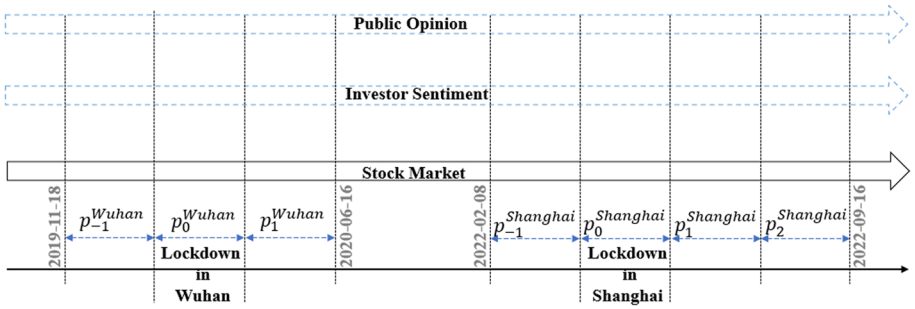

Fig. 7 Research framework. *Note*: p_{-1}^{wuhan} denotes the 47 trading days before the lockdown in Wuhan. p_0^{wuhan} denotes the 47 trading days during lockdown in Wuhan. p_1^{wuhan} denotes the 47 trading days after the end of the lockdown in Wuhan. $p_{-1}^{Shanghai}$ denotes the 38 trading days before the lockdown in Shanghai. $p_0^{Shanghai}$ denotes the 38 trading days during the lockdown in Shanghai. $p_1^{Shanghai}$ denotes the 38 trading days after the end of the lockdown in Shanghai. $p_2^{Shanghai}$ denotes the second 38 trading days after the end of lockdown in Shanghai

classification accuracy was 89.14%, surpassing the 88.1% accuracy of Antweiler and Frank (2004). Our research uses the same data source as Liu et al. (2022a, b, c), which is why we have adopted their sentiment classification model for this study. Table 4 displays the model's classification performance.

Based on text sentiment mining, investor sentiment (*IS*) is constructed by referring to Antweiler and Frank's (2004) definition of a bullish index:

$$IS = ln\left[\frac{1+N_t^p}{1+N_t^n}\right], \tag{11}$$

where N_t^p and N_t^n denote the number of messages expressing positive and negative sentiments, respectively, about the stock market on day t. A higher investor sentiment (*IS*) indicates a higher proportion of investors in social media who are confident about the stock market. Following Liu, Zhou, et al. (2022), we do not have a concurrently constructed protocol index to analyze investor sentiment in this study.

Empirical study

Our research framework is depicted in Fig. 7. We begin our study by examining the overall outcomes of the investors' game of lies on social media, taking into account investor sentiment and stock market fundamentals from 2019 to 2022. We then select three periods surrounding the Wuhan lockdown (denoted by p_0^{Wuhan}, p_{-1}^{Wuhan}, and p_1^{Wuhan}, respectively) and four periods around the Shanghai lockdown (denoted by

Table 5 Integrity factors for 2019 to 2022

	OP	CP	HP	LP	PCP	Overall
IS	0.343*****	0.377*****	0.355*****	0.362*****	0.347*****	0.357*****

*, **, ***, ****, and ***** represent significance levels of 0.1, 0.05, 0.01, 0.001, and 0.0001, respectively. OP, CP, HP, and LP represent the opening, closing, highest, and lowest prices of the day, respectively. PCP represents the previous day's closing price. The overall column uses the mean of OP, CP, HP, LP, and PCP as price proxies for calculating correlations

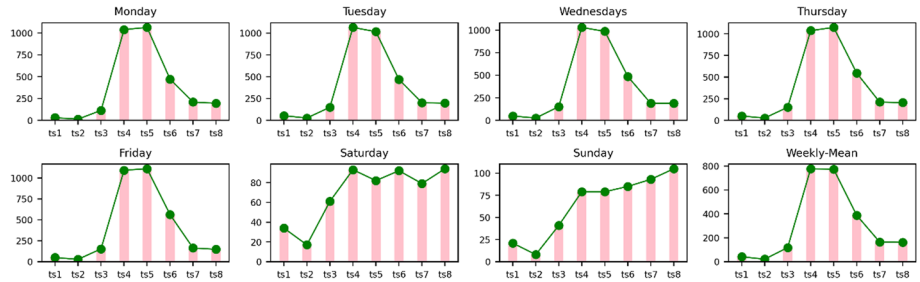

Fig. 8 Intraday message distribution of "SSE Index Bar"

$p_0^{Shanghai}$, $p_{-1}^{Shanghai}$, $p_1^{Shanghai}$ and $p_2^{Shanghai}$) as our study intervals. Then we further explore how major social events affect the results of the game of lies.

Analysis of the overall game outcome

Table 5 presents the results of the game of lies employed by investors on social media from 2019 to 2022. A weak, but highly significant positive correlation exists between the stock market's opening price (OP), closing price (CP), highest price (HP), lowest price (LP), the previous day's closing price (PCP), and investor sentiment (IS). There is consistency between investor sentiment (expressed in words) on social media and stock market performance (reflected in actions). The deceptive tactics used by investors on social media result in a state of "equilibrium", confirming H1. In general, an increase in sentiment leads to a rise in stock prices, and higher stock prices, in turn, lead to an increase in sentiment.

Figure 8 presents the intra-day data of messages posted on the "SSE Index Bar". The day is divided into eight time segments, labeled as ts1, ts2, through to ts8, with trading periods happening at ts4 and ts5. The segments ts1, ts2, and ts3 are times before trading begins, and the investor sentiment (expressed in words) on social media can be analyzed by the market performance (actions) at ts4 and ts5 (IS $\rightarrow$ SM). The segments ts6, ts7, and ts8 take place after the market closes, and the investor sentiment (words) during this time should reflect the stock market fundamentals (actions) for ts4 and ts5 (SM $\rightarrow$ IS). The data in Fig. 8 indicates that on trading days, most investor messages are posted during ts4 and ts5, when investor sentiment (words) and stock market fundamentals (actions) interact frequently (IS $\leftrightarrow$ FM).

Based on the above, we segmented the day into three intervals: 00:00 a.m.–09:30 a.m. (period A), 09:30 a.m.–15:00 p.m. (period B), and 15:00 p.m.–24:00 p.m. (period C). This segmentation allowed us to examine the overall outcomes of the game of lies used by investors on social media. As Table 6 shows, there is a strong positive

Table 6 Analysis of the integrity factor for three intra-day periods from 2019 to 2022

	OP	CP	HP	LP	PCP	Overall
IS^A	0.385*****	0.384*****	0.381*****	0.388*****	0.373*****	0.383*****
IS^B	0.270*****	0.297*****	0.283*****	0.282*****	0.278*****	0.282*****
IS^C	0.198*****	0.241*****	0.208 *****	0.223*****	0.196*****	0.213*****

*, **, ***, ****, and ***** represent significance levels of 0.1, 0.05, 0.01, 0.001, and 0.0001, respectively. The overall column uses the mean of OP, CP, HP, LP, and PCP as price proxies for calculating correlations

IS^A, IS^B, and IS^C represent investor sentiment for time periods 00:00 a.m.–09:30 a.m.; 09:30 a.m.–15:00 p.m.; and 15:00 p.m.–24:00 p.m., respectively, within a day

correlation between investor sentiment during the pre-market opening (period A), the trading session (period B), and the post-market break (period C), and the fundamentals of the stock market. This suggests that in the pre-market opening (period A), the game of lies on social media result in an "equilibrium", where "positive" or "negative" investor messages before the market opens elicit "positive" or "negative" responses during the trading session (period B). Similarly, after the market break (period C), the game of lies on social media result in an "equilibrium", where "positive" or "negative" stock market fundamentals during period B lead to "positive" or "negative" investor messages on social media during the market break (period C). The high-frequency interaction between investor sentiment and stock market fundamentals during the trading session (period B), where positive messages correspond with positive market behavior and negative messages correspond with negative market behavior, also results in an "equilibrium" in the game of lies used on social media during the trading session (period B).

In summary, from 2019 to 2022, the general result of investors' game of lies on social media consistently reached a state of "equilibrium", whether evaluated over the course of an entire day or during the three distinct periods before, during, and after a trading session. Data indicate that investors' actions align with their stated intentions, thus confirming H1.

Analysis of the game surrounding the lockdown in Wuhan

In an effort to curb the spread of COVID-19, the Chinese government enforced a city-wide lockdown in Wuhan for 76 days, from January 23 to April 7, 2020 (Cao et al. 2020). This period encompassed 47 trading days. We examine the outcomes of the "game of lies" for three separate 47-day trading periods: before (p_{-1}^{wuhan}), after (p_1^{wuhan}), and during (p_0^{wuhan}) the lockdown. Our aim is to understand how the Wuhan lockdown affected the results of the game of lies.

Survey of public opinion surrounding the lockdown in Wuhan

This study uses the LDA algorithm to independently model public sentiment during the p_{-1}^{wuhan}, p_0^{wuhan}, and p_1^{wuhan} stages. Text modeling analysis enhances our comprehension of Wuhan's closure and its effects by enabling us to retrospectively examine public opinion. The number of topics to be modeled must be predetermined when modeling textual topics. If the number of topics is too small, it diminishes the analysis's credibility, while too many topics complicate the analysis. After numerous trials, we finally settled on a

Table 7 Public opinion modeling concerning the lockdown in Wuhan

Panel A: p_{-1}^{Wuhan}		
Topic No.	**Share of news (%)**	**Topic description**
Topic 01	34.70	Corruption, crime, and high-impact criminal cases
Topic 02	27.30	International competition and conflicts: US-China competition, international economy, Iranian issues, etc.
Topic 03	20.70	Domestic economic, business, and social issues
Topic 04	9.20	COVID-19 appeared in the news.
Topic 05	6.10	Hong Kong Issues
Topic 06	2	Cases of crime against women
Panel B: p_{0}^{Wuhan}		
Topic No.	**Share of news (%)**	**Topic description**
Topic 01	51.90	From COVID-19 to resuming work and production
Topic 02	34.10	The politicization of COVID-19 and the international dissemination of COVID-19
Topic 03	10.30	Out-of-country imported COVID-19-infected patients
Topic 04	2.70	International assistance against COVID-19
Topic 05	0.70	The spread of COVID-19 in Korea and Italy
Topic 06	0.30	International epidemic topics
Panel C: p_{1}^{Wuhan}		
Topic No.	**Share of news (%)**	**Topic description**
Topic 01	24.40	Major social news and crime
Topic 02	18.70	US-China Competition and Hong Kong Issues
Topic 03	15.50	International dissemination of COVID-19
Topic 04	14.90	Economy, corruption, and crime
Topic 05	14.00	Resumption of work and production after COVID-19
Topic 06	12.50	Out-of-country imported COVID-19-infected patients

The "share of news" represents the popularity of the topic.

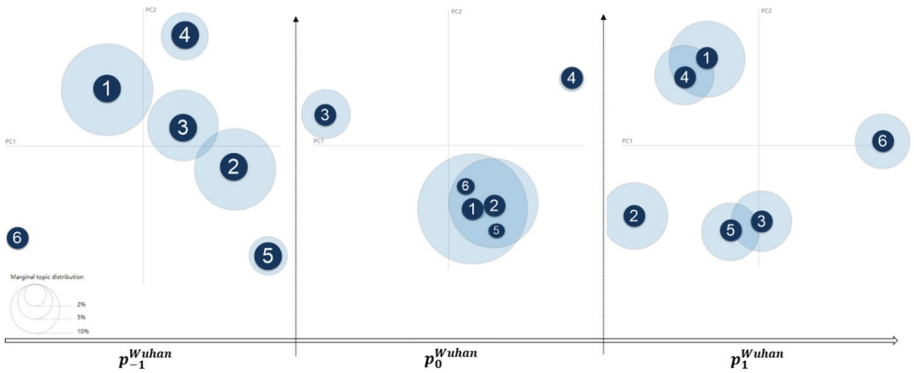

Fig. 9 Inter-topic distance map for the lockdown in Wuhan. *Note*: The size of the circle represents the popularity of the topic

total of six topics. Table 7 offers a succinct overview of the opinion modeling. Detailed data for the opinion modeling is available in Appendix A, and a description of the news data used for the opinion modeling is in Appendix B.

Understanding the relationships between various topics can enhance our comprehension of public sentiment. Here, the principal component analysis (PCA) is an important method in data analysis (Abdi and Williams 2010; Bro and Smilde 2014). In Fig. 9, we apply PCA to scale the public opinion data multidimensionally. This approach aims to represent multiple themes within a two-dimensional image, thereby facilitating a clearer inspection of the public opinion theme modeling results. By merging the information from Table 7 and Fig. 9, we can provide a continuous narrative of public sentiment before, during, and after the Wuhan lockdown.

(A) Analysis of public opinion prior to the lockdown in Wuhan

Before the Wuhan lockdown, the most prevalent topics in public opinion were societal corruption and crime (Topic 01, 34.70%), China-US competition (Topic 02, 27.30%), and domestic economic concerns (Topic 03, 20.70%). There is an overlap between Topic 02 and Topic 03, suggesting that economic issues are a part of the discourse on Sino-US competition. Note that Topic 04 (9.20%) pertains to COVID-19, showing that the subject of COVID-19 had already surfaced in Chinese public opinion prior to the Wuhan lockdown, although it was not yet a mainstream topic.

(B) Analysis of public opinion during the lockdown in Wuhan

During the Wuhan lockdown, the keywords "Wuhan" and "COVID-19" rapidly emerged as the most prevalent topic (Topic 01, 51.9%). Four specific aspects of public sentiment during this lockdown period warrant consideration:

1. Topic 02 overlaps significantly with Topic 01, both discussing the epidemic in the United States and globally. Noteworthy keywords, such as "human", "political", and "world" are incorporated, signaling the onset of the international COVID-19 pandemic. Concurrently, the Chinese public perceived COVID-19 as a global issue, despite the efforts of Western countries to politicize the disease.
2. Topic 01 discussed the resumption of work and production, as well as the issue of COVID-19. Amid the Wuhan lockdown in 2020, the Chinese government effectively contained the country's COVID-19 spread within two months (Lau et al. 2020) and began to restart work and production. The domestic public response was positive and hopeful, filled with pride and admiration (Cao et al. 2021).
3. Topics 04, 05, and 06 outline the aid China extended to Italy in response to COVID-19 (Chen 2021). These topics also highlight China's concern about the global outbreak. This shows that the Chinese government was not only able to swiftly control the outbreak domestically, but also had the ability to offer help internationally.
4. Topic 03 discusses the prevention of COVID-19 cases being imported into the country. This suggests that the Chinese government's approach to managing COVID-19 is gradually transitioning from curbing domestic transmission to thwarting foreign importation.

In summary, the Wuhan lockdown proved to be highly effective. Amidst the city's lockdown, the Chinese government swiftly managed to control the spread of COVID-19

Table 8 Statistics of IF for the periods around the lockdown in Wuhan

	OP	CP	HP	LP	PCP	Overall
IS in p_{-1}^{wuhan}	0.293**	0.373***	0.290**	0.291**	0.337**	0.318**
IS in p_{0}^{wuhan}	0.427***	0.610*****	0.380****	0.499****	0.530*****	0.501****
IS in p_{1}^{wuhan}	0.195	0.400**	0.236*	0.305**	0.317**	0.297**

p_{-1}^{wuhan} denotes the 47 trading days before the lockdown in Wuhan

p_{0}^{wuhan} denotes the 47 trading days during the lockdown in Wuhan

p_{1}^{wuhan} denotes the 47 trading days after the end of the lockdown in Wuhan

*, **, ***, ****, and ***** represent significance levels of 0.1, 0.05, 0.01, 0.001, and 0.0001, respectively. The overall column uses the means of OP, CP, HP, LP, and PCP as price proxies for calculating correlations

within the country and initiated international aid. The government also started to focus on resuming production. The emphasis of outbreak prevention and control gradually transitioned from halting internal spread to averting external importation. As underscored by Cao et al. (2021), there was a rise in the levels of pride and admiration at each phase of the Wuhan lockdown, whereas fear showed a contrasting trend.

(C) Analysis of public opinion after the end of lockdown in Wuhan

The effectiveness of the Wuhan lockdown is further demonstrated by the swift shift in social opinion back to pre-lockdown issues once the lockdown ended. Here, Topic 01 and Topic 04 intersect, highlighting significant social events, economic challenges, corruption, and crime within the nation. The rivalry between the United States and China, along with the Hong Kong issue, have also regained their positions at the forefront of public opinion (Topic 02).

The effect of the Wuhan lockdown on the game of lies

Table 8's statistics reveal that the results of the game of lies played by social media investors are in a state of "equilibrium" during the Wuhan lockdown periods. This "equilibrium" intensifies significantly during the lockdown, with the overall integrity factor markedly higher than before and after the lockdown. Figure 10, based on the data in Table 8, shows the relationship between investor sentiment and stock market fundamentals (OP, CP, etc.), with darker points indicating more statistically significant data. Figure 10 clearly displays these findings. The "equilibrium" in the game of lies played by social media investors strengthens significantly during the Wuhan lockdown, and social media sentiment exhibits a stronger positive correlation with stock market fundamentals. Note that once the city lockdown ends, the game of lies reverts to its pre-lockdown state, indicating the lockdown event's direct effect on the game's outcome.

By analyzing public opinion surveys conducted during the Wuhan lockdown, we can gain a clearer understanding of how the lockdown affected the game of lies played by investors on social media. Table 9 illustrates that the lockdown significantly strengthened the "equilibrium state" of this game on social media, leading to a notable rise in the positive synergy between investor sentiment on social media and the stock market. Investors became more truthful, enhancing the credibility of social media. In terms of shifts in public opinion, the Chinese government's successful containment of COVID-19

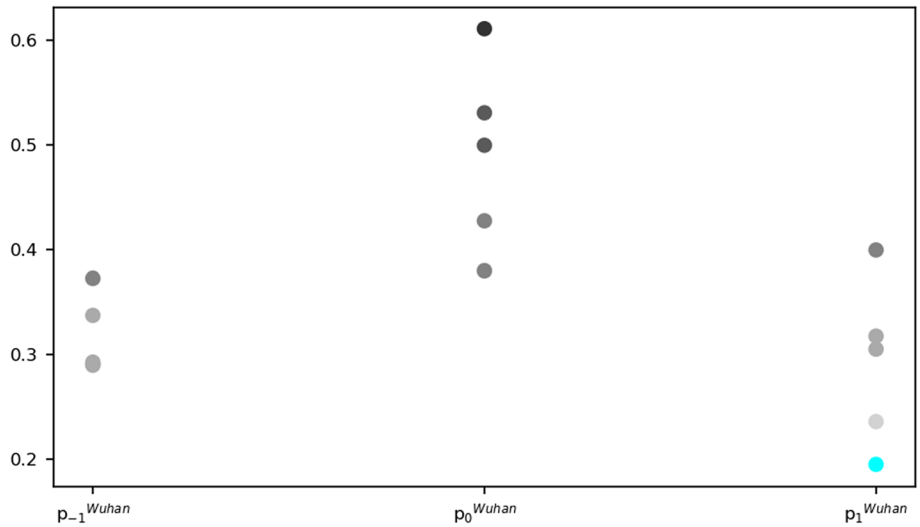

Fig. 10 Diagram of the integrity factor around the lockdown in Wuhan. Note. Aqua dots indicate statistically insignificant values, while gray dots indicate statistically significant data. The darker the gray, the more significant the data. Data with similar values and levels of significance are overwritten

Table 9 Public opinion modeling concerning the lockdown in Wuhan

Time period	Game results	Public opinion
p_{-1}^{Wuhan}	Equilibrium state, 0.318**	- Corruption, crime, and social issues - US-China competition - Domestic Economy
p_0^{Wuhan}	Equilibrium state, 0.501**** (strengthen)	- Rapidly stopping the spread of COVID-19 and providing assistance to the international community - Public sentiment resists the politicization of COVID-19 in the international community
p_1^{Wuhan}	Equilibrium state, 0.297** (Back to pre-lockdown)	- Social issues, economic issues, corruption, and crime - US-China competition - The international proliferation of COVID-19

The integrity factor data is taken from the data in the overall column in Table 8

during the Wuhan lockdown boosted national pride and unity, significantly elevating the "equilibrium state" of the social media game of lies.

Following the shutdown of Wuhan, mainstream public sentiment shifted back to social, economic, and criminal corruption issues, as well as Sino-US competition. Consequently, the balance in the social media game of lies reverted to its pre-closure state. It is clear that examining the event from a public opinion standpoint appears more advantageous than directly explaining the event's cause and effect.

Analysis of the game surrounding the lockdown in Shanghai

The lockdown in Shanghai, which lasted from April 1 to June 1, 2022,[3] is the second major city lockdown adopted by the Chinese government in response to COVID-19. We examine the outcomes of the game of lies conducted by investors on social media during

[3] https://m.gmw.cn/baijia/2022-04/03/1302880724.html

Table 10 Public opinion modeling concerning the lockdown in Shanghai

Panel A: $p_{-1}^{Shanghai}$		
Topic No.	**Share of news (%)**	**Topic description**
Topic 01	24.20	Russia–Ukraine War and NATO
Topic 02	22.70	Discussion on the spread of COVID-19 in Shanghai
Topic 03	21.60	International competition, conflict and diplomacy
Topic 04	17.80	Airliner accident of Eastern Airlines
Topic 05	11.80	General public opinion in society
Topic 06	1.90	China's concerns over Russia and Ukraine
Panel B: $p_{0}^{Shanghai}$		
Topic No.	**Share of news (%)**	**Topic description**
Topic 01	30.30	Shanghai implements a strict COVID-19 clearance policy
Topic 02	28.20	Economy, US-China competition
Topic 03	19.40	Self-built house collapse in Changsha
Topic 04	12.50	Production, work in the context of COVID-19
Topic 05	6.30	Taiwan issue, Russia-Ukraine issue
Topic 06	3.30%	Corporate, Internet
Panel C: $p_{1}^{Shanghai}$		
Topic No.	**Share of news (%)**	**Topic description**
Topic 01	31.60	Society, Epidemic and Economy
Topic 02	23.10	US-China competition and the economy
Topic 03	17.00	Public opinion centered on the Tangshan beating incident
Topic 04	15.00	Public opinion centered on the Tangshan beating incident
Topic 05	10.20	Public opinion centered on the Tangshan beating incident
Topic 06	3.10	Assassination of Shinzo Abe
Panel D: $p_{2}^{Shanghai}$		
Topic No.	**Share of news (%)**	**Topic description**
Topic 01	34.80	COVID-19 control and nucleic acid detection
Topic 02	27.50	Pelosi's visit to Taiwan and PLA exercises around Taiwan
Topic 03	19.90	Social events and journalist investigations
Topic 04	6.70	Geological disasters and rescue in Sichuan
Topic 05	6.30	International political events
Topic 06	4.80%	International opinion

The "share of news" represents the popularity of the topic.

four periods ($t_0^{Shanghai}, t_{-1}^{Shanghai}, t_1^{Shanghai}, t_2^{Shanghai}$) aro surrounding the city's lockdown. Each of these periods encompasses 38 trading days. We analyze the effects of the game of lies by investors over a more extended period following the Shanghai lockdown ($, t_1^{Shanghai}, t_2^{Shanghai}$) rather than that of the Wuhan lockdown, because we have observed that the Shanghai lockdown has a more prolonged effect.

Survey of public opinion surrounding the lockdown in Shanghai

Here, as in the examination of the Wuhan lockdown, we explore public sentiment regarding the Shanghai lockdown using the LDA algorithm. Table 10 presents a summary of the public opinion model's results, while Appendix C provides a detailed

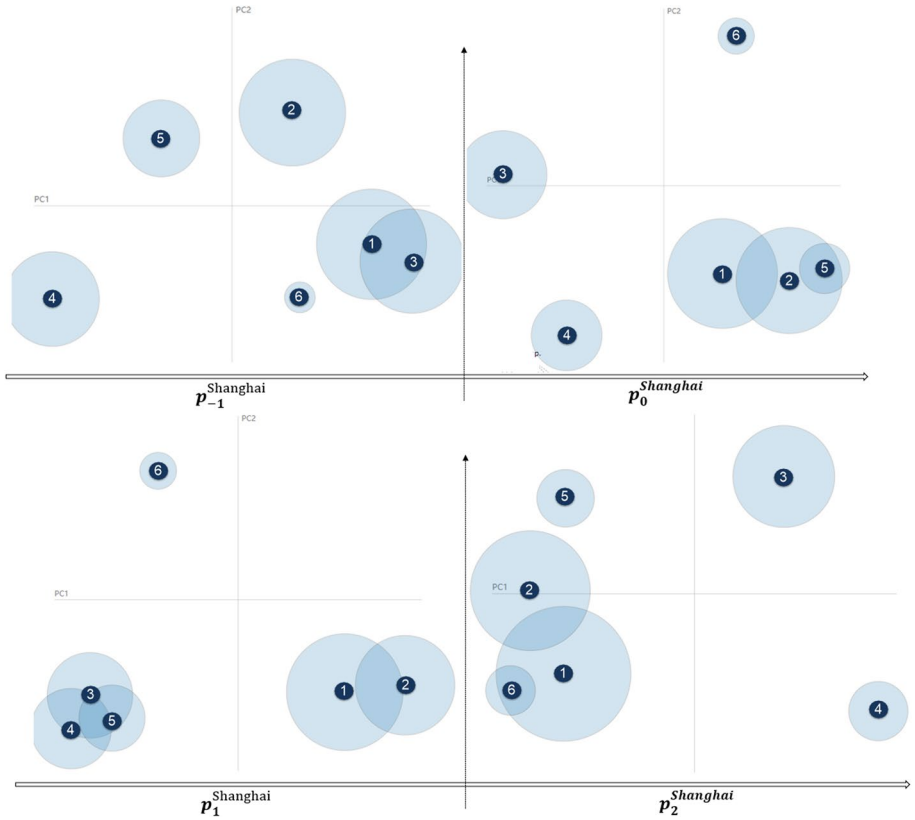

Fig. 11 Inter-topic distance map about lockdown in Wuhan

breakdown. Figure 11 illustrates the relationships and gaps among the various topics. Appendix B contains a description of the news data used in the public opinion model. By integrating the information from Table 10 and Fig. 11, we can clearly articulate public sentiment during the Shanghai lockdown period, thereby gaining a more profound understanding of the lockdown's effect.

(A) Analysis of public opinion prior to the lockdown in Shanghai

Table 10 reveals that before the Shanghai lockdown ($p_{-1}^{Shanghai}$), the dominant news topics were the Russo-Ukrainian war[4] and the North Atlantic Treaty Organization (NATO) support for the war (Topic 01, 24.20%). Topic 03, which made up 21.60% of the conversation, largely overlapped with Topic 01 (as seen in Fig. 11), but it also included broader keywords related to the US-China rivalry and international diplomacy. Topic 02 focused on the spread of COVID-19 in Shanghai, indicating that the Shanghai outbreak was a widely discussed topic even before the city's lockdown. The most frequently used keywords in Topic 02 were "believe" and "think", suggesting that the general public in Shanghai believed the epidemic was under control before the city was shut down.

[4] https://en.wikipedia.org/wiki/Russo-Ukrainian_War

(B) Analysis of public opinion during the lockdown in Shanghai

During the lockdown in Shanghai ($p_0^{Shanghai}$), the prevailing subject was the city's epidemic prevention measures, accounting for 30.30% of the news. This is unsurprising. However, as shown in Fig. 11, Topic 02, which overlaps significantly with Topic 01, focuses on the economy and the US-China rivalry, making up 28.2% of the news. The keywords in Topic 02 reveal a widespread worry that the lockdown in Shanghai, China's financial hub,[5] could significantly affect the national economy. This marks the first time the themes of COVID-19 and "economy" have become intertwined during the Shanghai lockdown. Other secondary topics include Topics 05 and 02, which intersect to discuss the US and China's positions on Russia and Ukraine, and Topic 03, which describes a serious housing collapse in China during the Shanghai lockdown.

(C) Analysis of public opinion after the end of lockdown in Shanghai

Following the Shanghai lockdown ($p_1^{Shanghai}$), public sentiment did not revert to its pre-lockdown state. Topic 01, accounting for 31.6% of the discussion, centered on "social" issues, with the epidemic remaining a significant keyword. The themes of Topic 01 and Topic 02 continue to be interrelated, with "economy" persisting as a crucial keyword in their intersection (see Appendix C). As shown in Fig. 11, Topics 03, 04, and 05, which partially overlap, detail a grave social event that transpired during this period: the Tangshan beating incident.[6]

We continued to investigate public sentiment during the second period after the lockdown ended in Shanghai ($p_2^{Shanghai}$). In the $p_2^{Shanghai}$ period, Topic 01 remains centered on COVID-19. Observing the ongoing trend of public opinion from the $p_{-1}^{Shanghai}$ period to $p_2^{Shanghai}$, it appears that since the onset of COVID-19 in Shanghai, the enforcement of China's COVID-19 clearance policy has started to face challenges. The lockdown in Shanghai has not achieved the intended effect.

During the $p_2^{Shanghai}$ period, Topic 02 shifts its focus from the anxiety surrounding the US-China rivalry and economic worries to an unexpected event: Pelosi's visit to Taiwan.[7] The Chinese Foreign Ministry expressed that "Pelosi's visit to Taiwan seriously infringed on China's sovereignty and security, seriously undermined China's territorial integrity, and seriously jeopardized peace and stability in the the Taiwan Strait".[8] Reacting to this provocative incident, the Chinese government conducted a military exercise around Taiwan, crossing the Strait's center line for the first time. The Western world, led by the United States, did not react aggressively, seemingly accepting this reality.[9] The People's Liberation Army's (PLA) assertive response showcased its robust military strength and boosted national pride domestically.[10] As shown in Fig. 11, during $p_2^{Shanghai}$, the topics of domestic epidemics and social issues (Topic 01) and Pelosi's visit to Taiwan and

[5] https://en.wikipedia.org/wiki/Shanghai

[6] https://en.wikipedia.org/wiki/2022_Tangshan_restaurant_attack

[7] http://www.news.cn/world/2022-08/06/c_1128893882.htm

[8] http://mo.ocmfa.gov.cn/xwdt/wjbt/202208/t20220825_10753381.htm

[9] https://en.wikipedia.org/wiki/2022_Chinese_military_exercises_around_hong

[10] https://www.zhihu.com/topic/25993105/hot

Table 11 Statistics of IF for the periods around the lockdown in Shanghai

	OP	CP	HP	LP	PCP	Overall
IS in $p_{-1}^{Shanghai}$	0.467***	0.595*****	0.491***	0.565****	0.457***	0.524****
IS in $p_{0}^{Shanghai}$	− 0.310**	− 0.115	− 0.295*	− 0.207	− 0.354**	− 0.261*
IS in $p_{1}^{Shanghai}$	0.115	0.318**	0.219	0.171	0.111	0.189
IS in $p_{2}^{Shanghai}$	0.225	0.607****	0.339***	0.501****	0.262*	0.422***

$p_{-1}^{Shanghai}$ denotes the 38 trading days before the lockdown in Shanghai
$p_{0}^{Shanghai}$ denotes the 38 trading days during the lockdown in Shanghai
$p_{1}^{Shanghai}$ denotes the 38 trading days after the end of the lockdown in Shanghai
$p_{2}^{Shanghai}$ denotes the second 38 trading days after the end of lockdown in Shanghai
*, **, ***, ****, and ***** represent significance levels of 0.1, 0.05, 0.01, 0.001, and 0.0001, respectively
The overall column uses the mean of OP, CP, HP, LP, and PCP as price proxies for calculating correlations

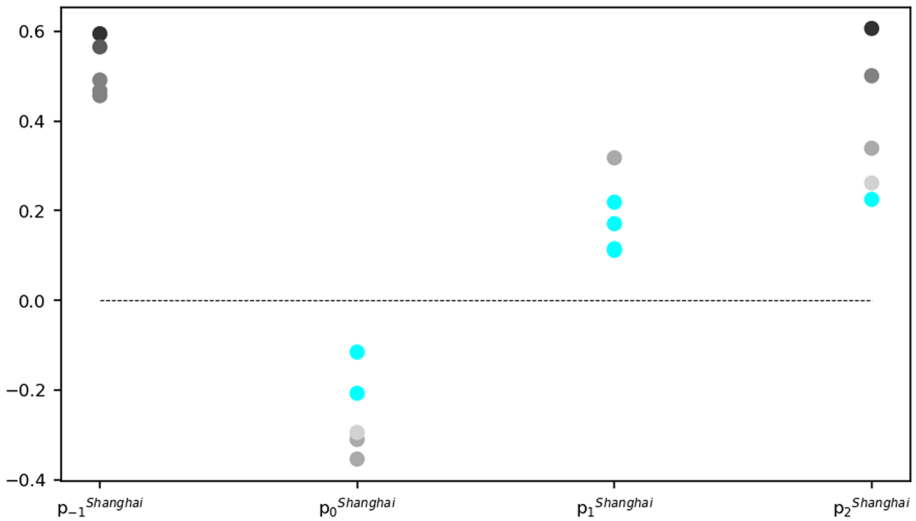

Fig. 12 Diagram of the integrity factor before, after, and during the lockdown in Shanghai. *Note*: Aqua dots indicate statistically insignificant values, while gray dots indicate statistically significant data. The darker the gray, the more significant the data. Data with similar values and levels of significance are overwritten

PLA exercises (Topic 02) were intermingled, accounting for more than 62% of the public opinion topics.

The effect of the Shanghai lockdown on the game of lies

Table 11 shows the findings from the game of lies on social media during Shanghai's lockdown. The analysis reveals that the outcome of this game prior to the city's shutdown ($p_{-1}^{Shanghai}$) is an "equilibrium state". In this state, investors' actions align with their words, meaning that a higher sentiment corresponds to higher stock prices, and the reverse is also true. However, during the lockdown in Shanghai ($p_{0}^{Shanghai}$), the results of the "game of lies" on social media shifted primarily to a "subversion state". In this state, there is no longer a significant positive correlation between investor sentiment and stock market fundamentals. In fact, the cause-and-effect relationship has reversed, with higher stock prices leading to lower investor sentiment.

Table 12 Public opinion modeling concerning the lockdown in Shanghai

	Game results	Public Opinion
$p_{-1}^{Shanghai}$	Equilibrium State, 0.524****	- The Russo-Ukrainian War - Proliferation of COVID-19 in Shanghai - The Russian-Ukrainian Question and Diplomacy
$p_{0}^{Shanghai}$	Subversion State, − 0.261*	- Blockade of Shanghai to curb the spread of COVID-19 - US-China competition and the economy
$p_{1}^{Shanghai}$	Confusion state (corr: 0.189, pValue 0.255)	- Social issues and efforts to stop the spread of COVID-19 - US-China competition and the economy
$p_{2}^{Shanghai}$	Equilibrium State, 0.422*** (Back to Equilibrium State)	- COVID-19 and social issues - Pelosi's visit to Taiwan and PLA exercises around Taiwan - Pride of military power

The integrity factor data is taken from the data in the overall column in Table 11

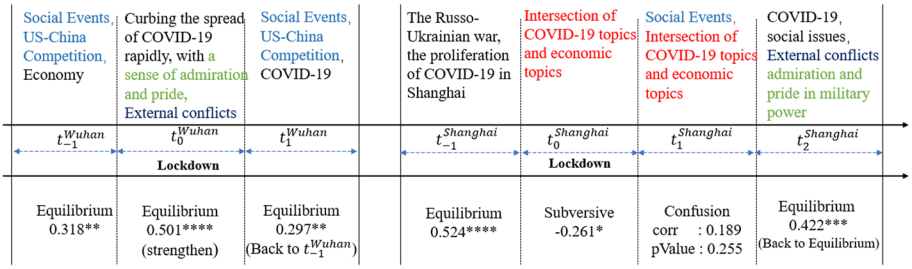

Fig. 13 The comparison of public opinion and game outcome switching

Following the conclusion of the Shanghai lockdown ($p_{1}^{Shanghai}$), the aftermath of the game of lies played by investors on social media did not revert to an "equilibrium state" as it did post-Wuhan lockdown. Instead, a "confusion state" dominated, with most stock price indicators showing no significant statistical correlation with investor sentiment. In the subsequent phase ($p_{2}^{Shanghai}$) after Shanghai's lockdown ended, the game of lies' results on social media returned to the "equilibrium state". Fig. 12, which draws on the data in Table 11, provides a clearer view of the transition process of the game of lies' state from an "equilibrium state" to a "subversion state", "confusion state", and ultimately back to "equilibrium state".

By analyzing shifts in public sentiment during the Shanghai lockdown, we can fully understand how this event affected the outcome of the game of lies among investors, as shown in Table 12. During the lockdown in Shanghai ($p_{0}^{Shanghai}$), public opinion for the first time linked COVID-19 and the economy, suggesting a significant macroeconomic effect of the virus. Consequently, the game of lies on social media entered a "subversion state". After the lockdown in Shanghai ended ($p_{1}^{Shanghai}$), despite some improvement, the intertwining of COVID-19 and the economy persisted. The game of lies then transitioned into a "confusion state", and the correlation between investor sentiment and stock prices became statistically insignificant. This indicates that the effects of the lockdown did not vanish once it ended, contradicting the results observed post-lockdown. In the second phase following the end of the Shanghai lockdown, Pelosi's visit to Taiwan shifted domestic public opinion, even though COVID-19 remained a dominant topic. The PLA's positive response to Pelosi's visit

enhanced national pride, and the game of lies on social media returned to a "state of equilibrium".

Discussion

We confirmed Hypothesis H1 on two scales: a complete trading day and three intervals within a trading day. In general, the result of the game of lies that investors play on social media is in an "equilibrium state". We examined three possible states of the game of lies on social media by investors during the city's lockdown: the "equilibrium state", the "confusion state", and the "subversion state". This results support Hypothesis H2 that, at a specific moment, the outcome of the game of lies by investors on social media could shift from the "equilibrium state" to either the "confusion state" or the "subversion state".

Figure 13 demonstrates the shift in public sentiment and the resulting changes in the game of lies across various time frames during the two lockdowns. The Wuhan and Shanghai lockdowns may seem like two identical events, both being severe responses to the COVID-19 spread. However, their effects on the game of lies were starkly different. The Wuhan lockdown reinforced the "equilibrium state", making social media sentiment more trustworthy, while the Shanghai lockdown led to a "confusing" or even "subversive" game outcome. This observation validates hypotheses H3 and H4. It also indicates that we cannot predict an event's effect based solely on the action itself. Instead, we must consider the event's direction, result, and context.

Public opinion analysis allows us to retrospectively assess the effects of significant events. This study analyzes public sentiment regarding the lockdowns in Wuhan and Shanghai, using news topic modeling to reveal the essence of these events. Specifically, during $p_0^{Shanghai}$ and $p_1^{Shanghai}$, when opinions about "COVID-19" and "economy" intertwine, the "equilibrium state" in the investor's game of lies collapses. Deception becomes the prevailing sentiment among investors on social media. This observation validates the H5 hypothesis, demonstrating that the effect of COVID-19 on the economy varies over time. We can also observe this effect through opinion analysis, offering a fresh theoretical reference for studying the economic effects of COVID-19.

From Fig. 13, we derive the following insights:

- Similar events can have varying effects on the stock market, contingent on the context and the result. Through opinion modeling, we can examine the circumstances and narrative logic in which these events transpire, providing a more transparent understanding of their influence on the stock market.
- The "equilibrium state" typically characterizes the game of lies on social media, implying that social media sentiment often provides a reliable basis for conducting financial research. However, significant social events have the potential to disrupt this "equilibrium state".
- Social occasions that foster positive feelings, such as pride and admiration, can effectively enhance the balance in the game of lies or even convert a state of imbalance into a state of "equilibrium".

- When the subject of an event becomes intertwined with the concept of "economy" in public perception, this signifies that the event has a substantial effect on the economy. Consequently, the result of the game of lies could potentially be altered.
- External conflicts are conducive to attracting domestic public opinion and defusing domestic conflicts, thus defusing domestic financial risks.

Note that lies on social media can create confusion or even distort cause and effect when the result of the investors' game of lies enters a "confusion state" or a "subversion state". There are costs and risks involved in betting against sentimental market participants (Shleifer and Vishny 1997), and the risks of betting against deceitful traders are challenging to evaluate. Moreover, Van Bommel (2003) suggests that if social media messages consistently spread false rumors, no followers would be willing to trade based on them, leading to the demise of investor social media. Therefore, "confusion" and "disruption" are not the typical states of the investors' game of lies on social media. The "confusion state" and the "subversion state" indicate that the market is in a non-optimal state, which should raise concerns for investors and policymakers.

To the best of our knowledge, no existing research connects the game of lies to investor sentiment. Nevertheless, our study aligns with much of the current research, as the core principle of the "game of lies" in social media is the cause-and-effect relationship between social media investor sentiment and the stock market. The result of this game signifies the trustworthiness of social media investor sentiment. For instance, numerous studies affirm the causal link between social media sentiment and stock markets (Renault 2017; Sun et al. 2016), which, in our theoretical framework, signifies an "equilibrium state" in the outcome of the "game of lies" on social media. Another instance is the discrepancy noted by researchers concerning the positive (Hengelbrock et al. 2013; Perez-Liston et al. 2016) or negative (Grigaliūnienė and Cibulskienė, 2010; Schmeling 2009) effect of investor sentiment on stock market returns. These inconsistencies in our theoretical framework can be clarified by the varying outcomes of the social media game of lies. Moreover, our study, which is based on public opinion, provides fresh perspectives and findings to the traditional single-context COVID-19 research.

Conclusion

This study first introduces the concept of the game of lies into the analysis of social media investor sentiment, examining the three potential outcomes in the Chinese market: the "equilibrium state", the "confusion state", and the "subversion state". The results indicate that the "equilibrium state" is the typical outcome of the game of lies on social media. In this state, there is a significant positive correlation between social media sentiment and the stock market, making social media investor sentiment trustworthy. However, significant social events can disrupt this relationship, leading to a "confusion state" or even a "subversion state". We observe the transitions between these three states by examining how the Wuhan and Shanghai lockdowns in China affected the game of lies. The Wuhan lockdown, which elicited positive public sentiment (such as "admiration", "pride", etc.), strengthened the "equilibrium state" of the game of lies. Conversely, the Shanghai lockdown, which sparked discussions about COVID-19 and the economy, led the game of lies to a "confusion state" or "subversion state".

Our findings suggest that the effects of COVID-19 on financial markets have varied over time. Furthermore, this study offers a comprehensive explanation for some of the conflicting results found in previous research. For instance, some scholars have found that social media sentiment does not have predictive power (Antweiler and Frank 2004; Tumarkin and Whitelaw 2001), while others have reported weak or strong predictive power (Liu et al. 2022a, b, c; Mao et al. 2011). Our findings suggest that inconsistent results may occur when the outcomes of the game of lies are in different states.

This research carries significant policy implications. The "equilibrium state" represents the typical outcome of the game of lies on social media. Policymakers should be aware that when the game's outcome reaches a "confusion state" or even a "subversion state", lies on social media can muddle or even invert cause and effect. Our study indicates that during major social events, a positive public sentiment can help mitigate the event's negative effect on financial markets. We also discovered that when COVID-19 and economic matters become intertwined in public opinion, lies tend to dominate investor sentiment on social media. Additionally, our research reveals that shifting conflicts and contradictions to foreign countries aids in mitigating financial risks.

This research provides fresh insights into the understanding and identification of investor social media, investor sentiment, and behavioral finance, carrying significant theoretical and policy implications. There are three avenues for further exploration in this study. First, by corroborating our findings across more financial markets. Second, in our study, when the outcomes of the game of lies on social media are in a "subversion state" or a "confusion state", we are unable to determine if these falsehoods originate from individual investors or the market. Third, the "equilibrium state" represents the typical outcome of the "game of lies". In this state, higher stock prices correspond to increased investor sentiment. The question then arises: is this a case of marginal increase or marginal decrease?

Appendix A: Keywords for public opinion surrounding the lockdown in Wuhan

Panel A: p_{-1}^{wuhan}

Topic No.	Share of news (%)	Top 40 topic keywords
Topic 01	34.70	Police, notification, investigation, man, reporter, found, woman, public security bureau, officer, Guangzhou, video, suspected, family, currently, local, supervisory committee, occurred, a, news, death, suspect, disciplinary committee, said, serious, conducted, crime, secretary, husband, police, organization, time, scene, indiscipline, illegal, work, a, killed, lawyer, reported, double-opening
Topic 02	27.30	China, America, comment, Iran, a, society, country, issue, read, work, some, need, media, development, world, opinion, British, time, Western, economy, already, business, it, thing, this, government, important, maximum, today, kind, president, culture, hope, appear, know, report, become, deceased, situation, video
Topic 03	20.70	Company, request, triggered, a, response, social, public, situation, concern, issue, netizen, video, legal, conducted, employee, related, network, said, need, incident, conduct, should, evidence, regulation, safety, whether, management, teacher, microblogging, exposure, media, regulation, appear, use, involved, information, exist, apologize, dispute, handle

Panel A: p_{-1}^{wuhan}

Topic No.	Share of news (%)	Top 40 topic keywords
Topic 04	9.20	Wuhan, new, patient, pneumonia, platform, coronavirus, hospital, infection, Shenzhen, reporter, situation, outbreak, currently, citizen, service, report, Beijing, found, said, exist, response, treatment, Shanghai, official, article, carried, release, staff, related, now, death, news, handle, Guangzhou, government, such, personnel, from, understand, part
Topic 05	6.10	Hong Kong, student, child, mother, school, father, a, body, now, some, today, together, parents, political, become, willing, situation, hope, a, last, believe, Beijing, should, teacher, social, already, violent, know, over, law, become, maximum, resolute, contact, this, is, deal, future, office, serious, later
Topic 06	2.00	Court, sentenced, sentenced, imprisonment, rape, first, trial, verdict, man, found, victim, case, act, occurred, guangzhou, took, relationship, violence, considered, apology, compensation, woman, first, a, thing, between, a, family, time, finally, similar, education, minute, positive, harm, believed, a, website, long, content, media

Panel B: p_{0}^{wuhan}

Topic No.	Share of news (%)	Top 40 topic keywords
Topic 01	51.90	Wuhan, social, problem, opinion, Hubei, public, situation, national, people, emerged, can, this, local, anti-epidemic, occur, comment, think, prevention and control, thing, should, now, today, see, believe, serious, this, case, new, crown, hope, officials, resumed, already, work, formed, this, is, sealed, city, should, everywhere, read, need
Topic 02	34.10	America, COVID-19, antiviral, virus, world, death, new, Europe, already, pneumonia, Trump, case, President, Italy, comment, society, global, infection, now, confirmed, media, number, serious, Korea, international, able, political, hope, today, data, interest, take, become, said, reading, being, this, human, West, huge
Topic 03	10.30	quarantine, cases, people, import, prevention, control, abroad, all, concentrated, entry, local, measures, home, have, taken, South Korea, entry, support, situation, prevent, vulnerability, risk, local, anti-epidemic, local, resolute, government, new, restriction, area, must, Beijing, system, national, UK, security, need, Iran, current, carry, domestic
Topic 04	2.70	Aid, Italy, medical, help, western, material, humanitarian, anti, epidemic, provide, difficulties, should, force, such, should, support, hospital, active, powers, whole, opinion, society, local, US, political, system, keep, apparently, action, new, crown, made, surging, request, take, need, after, human, able, already, common, think
Topic 05	0.70	Someone, Korea, really, happened, Italy, online, comment, hope, million, local, a, high, do, global, related, information, anti-epidemic, suggest, opinion, feel, positive, ability, read, under, today, big, country, really, reality, special, see, concern, first, easy, collective, cause, worth, express, person, region, important
Topic 06	0.30	America, government, problem, society, infection, death, Trump, Wuhan, really, has, imported, situation, quarantine, serious, interest, reported, constantly, announced, such, see, know, day, someone, hope, self, Beijing, world, carry, presence, official, national, under, believe, president, seal, western, criticism, prevention, control, public opinion, anti-epidemic

Panel C: p_{1}^{wuhan}

Topic No.	Share of news (%)	Top 40 Topic Keywords
Topic 01	24.40	Reporter, police, said, man, video, currently, child notification, guangzhou, suspect, a, a, told, investigation, found, a, details, occurred, conducted, hospital, incident, local, student, woman, shenzhen, mother, officer, netizen, live, concern, scene, school, release, lady, triggered, related, being, staff, a, previously, involved

Panel C:p_1^{wuhan}		
Topic No.	**Share of news (%)**	**Top 40 Topic Keywords**
Topic 02	18.70	China, American, society, a, country, Hong Kong, need, issue, some, opinion, adult, already, media, such, become, think, western, law, should, develop, suggest, capacity, support, political, world, market, which, protect, must, be, able, government, exist, public, system, relationship, now, should, situation, occur, carry
Topic 03	15.50	America, COVID-19, virus, outbreak, death, Trump, infection, pneumonia, said, mask, China, time, reported, patient, president, treatment, research, hospital, vaccine, anti-epidemic, UK, number, global, local, France, one, already, protest, doctor, country, expert, found, Germany, serious, accepted, being, case, currently, Zhong Nanshan, announced
Topic 04	14.90	Company, work, secretary, details, alleged, express, investigation, issue, feng nao, mayor, serious, violation, supervisory, committee, charge, news, regulations, related, district, cadre, discipline, director, enterprise, issued, currently, accepted, show, court, punishment, notice, discipline, reporter, information, violation, position, conducted, decision, application, case, investment, period
Topic 05	14.00	Epidemic, Wuhan, prevention and control, work, national, Zhang Wenhong, unsealing, prevention, measures, pneumonia, new crown, area, economy, national, city, Hubei, data, recovery, Beijing, risk, back to work, anti-epidemic, period, personnel, India, current, time, seal, students, China, said, situation, masks, news, opening, government, back to school, details, flights, open
Topic 06	12.50	Case, confirmed, new, imported, detection, infected, asymptomatic, outbound, outbreak, isolation, cumulative, Harbin, hospital, nucleic acid, infection, reported, new crown, pneumonia, personnel, native, patient, entry, Russia, Guangzhou, notification, conducted, discharged, associated, Suifenhe, found, Heilongjiang, emerged, Harbin, Health and Welfare Commission, Jilin, positive, Heilongjiang Province, transmission, treatment, port

Note: The "share of news" represents the popularity of the topic. In public opinion in China, COVID-19 is often referred to simply as an "epidemic", "new crown", or "new crown virus".

Appendix B: Statistics of news used in news topic modelling

News statistics for public opinion modeling concerning the lockdown in Wuhan				
Media No	**Media category**	p_{-1}^{Wuhan}	p_0^{Wuhan}	p_1^{Wuhan}
1	Self-Media	112	231	186
2	Self-Media	339	196	239
3	Self-Media		531	409
4	Self-Media	118	256	140
5	Newspapers	481	1815	1507
Total		1050	3029	2481

News statistics for public opinion modeling concerning the lockdown in Shanghai

Media No	Media category	$p_{-1}^{Shanghai}$	$p_{0}^{Shanghai}$	$p_{1}^{Shanghai}$	$p_{2}^{Shanghai}$
1	Self-Media	102	107	115	324
2	Self-Media	332	341	338	811
3	Self-Media	321	375	346	1042
4	Self-Media	102	47	40	189
5	Newspapers	133	305	215	653
Total		990	1175	1054	3019

Appendix C: Keywords for public opinion surrounding the lockdown in Shanghai

Panel A: $p_{-1}^{Shanghai}$

Topic No.	Share of news (%)	Top 40 Topic Keywords
Topic 01	24.20	Ukraine, Russia, West, war, Putin, country, United States, already, NATO, a, world, political, Europe, said, this, sanctions, think, Russia-Ukraine, attitude, economic, support, both, declared, situation, government, whole, mobilization, now, need, goal, society, strategy, present, this, Beijing, join, interest, end, able, hope
Topic 02	22.70	Epidemic, Shanghai, public opinion, some, prevention and control, problem, one, society, event, thing, believe, think, report, economy, city, need, public, country, information, should, must, place, investigation, already, hope, official, government, media, this is, this, continuously, national attitude, comment, now, happen, form, sure, play, situation
Topic 03	21.60	America, Russia, strategy, West, Ukraine, country, president, war, diplomacy, support, relations, Washington, become, sanctions, power, great power, today, interests, politics, a, full, confrontation, military, development, this, capacity, world, important, Europe, strength, certain, conflict, Chinese, provide, keep, all, security, now, insist, demand
Topic 04	17.80	China Eastern Airlines, accident, airliner, aircraft, flight, occurrence, reporter, crash, scene, flight, personnel, present, Boeing, Guangxi, news, confirmation, company, press conference, Wuzhou, emergency, time, investigation, discovery, Guangzhou, hour, one, display, being, disposing, related, information, command, work, country, informed, afternoon, expressing, data, carrying out, and reporting
Topic 05	11.80	advice, journalist, work, country, national, said, Hong Kong, netizen, problem, related, currently, time, conducted, release, news, impact, concern, development, serious, investigation, detailed, headline, appeared, details, director, health, accept, aspect, already, understand, continue, video, life, safeguard, pressure, news, attention, request, against, need
Topic 06	1.90	China, relations, end, parties, release, briefing, United States, situation, video, shows, officials, express, Ukraine, support, formation, keep, journalists, issue, attitude, continue, conditions, influence, direction, provide, information, know, war, strategy, West, participate, important, confrontation, media, first, further, normal, decision, request, present, Russia

Panel B: $p_{0}^{Shanghai}$

Topic No.	Share of news (%)	Top 40 Topic Keywords
Topic 01	30.30	epidemic, nucleic acid, Shanghai, anti-epidemic, clearance, prevention and control, detection, dynamic, infected, social, transmission, prevention, city, case, situation, new crown, need, measures, isolation, local, already, citywide, positive, containment, work, infection, standing, believe, new, management, national, virus, news, Guangzhou, control, situation

Panel B: $p_0^{Shanghai}$

Topic No.	Share of news (%)	Top 40 Topic Keywords
Topic 02	28.20	China, America, economic, social, country, problem, development, need, such, constant, strategy, western, has, important, force, announced, business, should, become, this, is, policy, political, situation, thing, now, see, support, public opinion, solve, greatest, hope, confidence, growth, epidemic, increasingly, international, provide, increase, keep, university
Topic 03	19.40	reporter, occurred, Changsha, person, accident, collapsed, self-built, house, rescue, local, scene, found, trapped, Sichuan, time, details, learned, incident, situation, safety, lost, report, died, staff, resident, news, appeared, hospital, notification, Hunan, released, hour, use, this, Chinese, attention, understand, injured, told, show, police
Topic 04	12.50	work, release, issue, safeguard, investigation, response, epidemic, law, ensure, service, serious, part, prevention, conference, production, accept, suspected, request, concern, presence, news, organisation, strengthen, study, life, information, market, national, reporter, national, triggered, area, controversy, director, regulation, notification, handle, do, detailed, control
Topic 05	6.30	Taiwan, Russia, NATO, Ukraine, West, United States, risk, this, decision, country, region, now, entire, action, into, outbreak, security, between, people, today, held, need, believe, target, directly, against, declared, fully, support, route, political, implementation, mobilization, already, time, government, ready, become, joint, against
Topic 06	3.30	Guangzhou, product, Guangdong, citizen, buy, participate, choose, internet, participate, future, adjust, before, enterprise, long-term, development, formal, people, notice, enter, market, site, expected, this, time, news, risk, which, this, policy, completely, range, process, institution, has, sustained, strategy, million, situation, see, specific, aspect

Panel C: $p_1^{Shanghai}$

Topic No.	Share of news (%)	Top 40 Topic Keywords
Topic 01	31.60	society, issue, epidemic, opinion, situation, prevention, Beijing, need, Beijing, government, China, thing, country, internet, local, localities, economic, think, hope, people, believe, should, this, already, public, sure, this, city, law, now, should, risk, serious, appear, online, constantly, request, subject, comment, officials
Topic 02	23.10	China, America, country, Taiwan, economic, development, world, western, society, issue, relationship, strategic, political, constantly, capacity, international, maximum, between, force, already, market, information, need, continue, support, conflict, become, important, see, period, after, now, this, should, today, achieve, increasingly, been, this is, gradually
Topic 03	17.00	Tangshan, Sichuan, nuclear acid, journalist, work, personnel, Shanghai, rescue, outbreak, occurred, scene, prevention and control, hours, meeting, injured, Hebei, details, time, hours, hospital, currently, caused, Xinguan, carried, news, local, found, carried, report, issued, action, request, health, Public Security Bureau, department, part, suspect, Tangshan, crime, continued
Topic 04	15.00	woman, response, investigation, Tangshan, incident, related, reporter, police, is, man, briefing, video, conducting, concern, Tangshan, currently, this, matter, net, staff, information, triggered, case, according to law, situation, details, handling, multiple, public security bureau, occurred, a, beating, health, media, crime, society, accept, said, child, law, request
Topic 05	10.20	reporter, guangdong, investigation, company, said, related, netizen, told, currently, notification, safety, accident, work, national, has, conducted, situation, released, time, emergency, found, appeared, end, response, problem, impact, further, cause, occurred, personnel, centre, history, part, afternoon, incident, presence, department, video, official, details
Topic 06	3.10	Abe, scene, man, suspect, time, reporter, around, report, has, CCTV, currently, police, attention, then, Taiwan, control, completely, video, subsequently, a, citizen, local, directly, morning, day, public, cause, caused, use, keep, conscious, public opinion, occurred, usually, met, place, show, details, together, said

Panel D: $p_2^{Shanghai}$		
Topic No.	**Share of news (%)**	**Top 40 topic keywords**
Topic 01	34.80	epidemic, country, society, problem, nucleic acid, prevention, situation, China, prevention and control, public, support, local, city, government, national, risk, need, development, feel, risk, measures, believe, already, management, should, everywhere, life, serious, policy, able, people, now, hope, public opinion, people, appear, interest, comment, this, law
Topic 02	27.50	China, America, Taiwan, Pelosi, mainland, PLA, issue, country, Taiwan Strait, Taiwan Island, has, long, such, exist, action, today, means, interest, believe, business, carry, think, occur, time, affect, become, constantly, implement, need, war, this, is, relevant, now, know, official, since, strategy, measure, increase, force
Topic 03	19.90	reporter, response, investigation, details, accident, concern, related, local, conducted, man, show, news, request, triggered, staff, learned, previously, link, cause, page, currently, China, understand, occurred, reported, told, ongoing, being, incident, attention, proof, to, this, work, announced, illegal, impact, department, situation, afternoon, information
Topic 04	6.70	Sichuan, briefing, rescue, currently, occurred, death, scene, is, further, found, hour, emergency, personnel, reporter, force, caused, country, carry, work, safety, people, all, control, effective, understand, according, carry, CCTV, local, deal, strong, tell, page, link, staff, network, should, part, centre, news
Topic 05	6.30	British, time, a, issue, history, end, become, western, accept, Beijing, political, this, national, continue, aspect, world, this, after, today, first, details, country, appear, management, both, sides, war, opinion, present, including, local, being, last, capacity, situation, afternoon, carry, hope, action, show, rapid
Topic 06	4.80	war, this, opinion, western, information, unification, occur, region, report, support, form, force, media, China, strategy, need, special, domestic, thing, able, plan, gradually, online, between, actual, comment, before, whether, play, local, interest, this, now, comprehensive, common, specific, point, important, maximum, first

Note: The "share of news" represents the popularity of the topic. The "share of news" represents the popularity of the topic. In public opinion in China, COVID-19 is often referred to simply as an "epidemic", "new crown", or "new crown virus".

Abbreviations

IS	Investor sentiment
IS^A	Investor sentiment for the period 00:00 a.m. to 09:30 a.m.
IS^B	Investor sentiment for the period 09:30 a.m. to 15:00 p.m.
IS^C	Investor sentiment for the period 15:00 p.m. to 24:00 p.m.
OP	The opening price of the day
CP	The closing price of the day
HP	The highest share price of the day
LP	The lowest share price of the day
PCP	Previous closing price
p_{-1}^{wuhan}	The 47 trading days before the lockdown in Wuhan
p_0^{wuhan}	The 47 trading days during lockdown in Wuhan
p_1^{wuhan}	The 47 trading days after the end of the lockdown in Wuhan
$p_{-1}^{Shanghai}$	The 38 trading days before the lockdown in Shanghai
$p_0^{Shanghai}$	The 38 trading days during the lockdown in Shanghai
$p_1^{Shanghai}$	The 38 trading days after the end of the lockdown in Shanghai
$p_2^{Shanghai}$	The second 38 trading days after the end of lockdown in Shanghai

Acknowledgements
The authors express their gratitude for the hard work of the editorial team and language editing team.

Author contributions
QL: manuscript writing; bibliography; data analysis. HS: supervision, review, and editing. W-SL: paper structure, review. All author(s) read and approved the final manuscript.

Funding
Not applicable.

Availability of data and materials
Available via email contact.

Declarations

Competing interests
The author declare that they have no competing interests.

Received: 30 January 2023 Accepted: 18 December 2023
Published online: 02 April 2024

References

Abdi H, Williams LJ (2010) Principal component analysis. Wiley Interdiscip Rev Comput Stat 2(4):433–459. https://doi.org/10.1002/wics.101
Aizawa A (2003) An information-theoretic perspective of tf–idf measures. Inf Process Manage 39(1):45–65. https://doi.org/10.1016/S0306-4573(02)00021-3
Alhouti S, Johnson CM (2022) Web of lies: drivers and consequences of social media (in)authenticity. J Promot Manag 28(8):1129–1164. https://doi.org/10.1080/10496491.2021.1955077
Anandarajan M, Hill C, Nolan T, Anandarajan M, Hill C, Nolan T (2019) Text preprocessing. In: Practical text analytics: Maximizing the value of text data (pp. 45–59). https://doi.org/10.1007/978-3-319-95663-3_4
Antweiler W, Frank MZ (2004) Is all that talk just noise? The information content of internet stock message boards. J Financ 59(3):1259–1294. https://doi.org/10.1111/j.1540-6261.2004.00662
Arora AS, Sanni SA (2019) Ten years of 'social media marketing' research in the journal of promotion management: research synthesis, emerging themes, and new directions. J Promot Manag 25(4):476–499. https://doi.org/10.1080/10496491.2018.1448322
Baradad VP, Mugabushaka AM (2015) Corpus specific stop words to improve the textual analysis in scientometrics. In: ISSI
Benesty J, Chen J, Huang Y, Cohen I (2009) Pearson correlation coefficient. Noise Reduction Speech Process. https://doi.org/10.1007/978-3-642-00296-0_5
Blei DM, Ng AY, Jordan MI (2003) Latent dirichlet allocation. J Mach Learn Res 3(Jan):993–1022
Blei D, Ng A, Jordan M (2001) Latent dirichlet allocation. In: Advances in neural information processing systems, vol 14
Bollen J, Mao H, Zeng X (2011) Twitter mood predicts the stock market. J Comput Sci 2(1):1–8. https://doi.org/10.1016/j.jocs.2010.12.007
Bro R, Smilde AK (2014) Principal component analysis. Anal Methods 6(9):2812–2831. https://doi.org/10.1002/wics.101
Brown GW, Cliff MT (2004) Investor sentiment and the near-term stock market. J Empir Financ 11(1):1–27. https://doi.org/10.1016/j.jempfin.2002.12.001
Brown GW, Cliff MT (2005) Investor sentiment and asset valuation. J Bus 78(2):405–440. https://doi.org/10.1086/427633
Cao G, Shen L, Evans R, Zhang Z, Bi Q, Huang W, Yao R, Zhang W (2021) Analysis of social media data for public emotion on the Wuhan lockdown event during the COVID-19 pandemic. Comput Methods Programs Biomed 212:106468. https://doi.org/10.1016/j.cmpb.2021.106468
Cao S, Gan Y, Wang C, Bachmann M, Wei S, Gong J et al (2020) Post-lockdown SARS-CoV-2 nucleic acid screening in nearly ten million residents of Wuhan, China. Nat Commun 11(1):1–7. https://doi.org/10.1038/s41467-020-19802-w
Chen C, Liu L, Zhao N (2020) Fear sentiment, uncertainty, and bitcoin price dynamics: the case of COVID-19. Emerg Mark Financ Trade 56(10):2298–2309. https://doi.org/10.1080/1540496X.2020.1787150
Chen WA (2021) COVID-19 and China's changing soft power in Italy. Chinese Political Science Review. https://doi.org/10.1007/s41111-021-00184-3
Clarkson PM, Joyce D, Tutticci I (2006) Market reaction to takeover rumour in Internet Discussion Sites. Acc Finance 46(1):31–52. https://doi.org/10.1111/j.1467-629X.2006.00160.x
Cox J, Greenwald DL, Ludvigson SC (2020) What explains the COVID-19 stock market? (No. w27784). Natl Bureau Econ Res. https://doi.org/10.3386/w27784
Cord M, Cunningham P (eds) (2008) Machine learning techniques for multimedia: case studies on organization and retrieval. Springer, Berlin, pp 21–49. https://doi.org/10.1007/978-3-540-75171-7
Da Z, Engelberg J, Gao P (2015) The sum of all FEARS investor sentiment and asset prices. Rev Financ Stud 28(1):1–32
Deeb H, Vrij A, Hope L, Mann S, Granhag PA, Strömwall LA (2018) Police officers' perceptions of statement inconsistency. Crim Justice Behav 45(5):644–665
Deng S, Huang ZJ, Sinha AP, Zhao H (2018) The interaction between microblog sentiment and stock return: an empirical examination. MIS Q 42(3):895–918
Eachempati P, Srivastava PR, Panigrahi P (2021) Sentiment Analysis of COVID-19 Pandemic on the Stock Market. Am Bus Rev. https://doi.org/10.37625/ABR.24.1.141-165
Fallahgoul H (2021) Inside the mind of investors during the COVID-19 pandemic: evidence from the StockTwits data. J Financ Data Sci 3(2):134–148. https://doi.org/10.3905/jfds.2021.1.058
Fernandez-Perez A, Gilbert A, Indriawan I, Nguyen NH (2021) COVID-19 pandemic and stock market response: A culture effect. J Behav Exp Financ 29:100454. https://doi.org/10.1016/j.jbef.2020.100454
Geva T, Zahavi J (2014) Empirical evaluation of an automated intraday stock recommendation system incorporating both market data and textual news. Decis Support Syst 57:212–223. https://doi.org/10.1016/j.dss.2013.09.013
Goel G, Dash SR (2022) Investor sentiment and government policy interventions: evidence from COVID-19 spread. J Financ Econ Policy 14(2):242–267. https://doi.org/10.1108/JFEP-02-2021-0038

Goodell JW (2020) COVID-19 and finance: agendas for future research. Financ Res Lett 35:101512. https://doi.org/10.1016/j.frl.2020.101512
Green SB, McCoy JF, Burns KP, Smith AC (1982) Accuracy of observational data with whole interval, partial interval, and momentary time-sampling recording techniques. J Behav Assess 4(2):103–118. https://doi.org/10.1007/BF01321385
Grigaliūnienė Ž, Cibulskienė D (2010) Investor sentiment effect on stock returns in Scandinavian stock market. Econ Manag 15:929–940
Haleem A, Javaid M, Vaishya R (2020) Effects of COVID-19 pandemic in daily life. Curr Med Res Pract 10(2):78–79. https://doi.org/10.1016/j.cmrp.2020.03.011
Hameleers M, Powell TE, Van Der Meer TG, Bos L (2020) A picture paints a thousand lies? The effects and mechanisms of multimodal disinformation and rebuttals disseminated via social media. Polit Commun 37(2):281–301. https://doi.org/10.1080/10584609.2019.1674979
Han S, Li G, Lubrano M, Xun Z (2020) Lie of the weak: Inconsistent corporate social responsibility activities of Chinese zombie firms. J Clean Prod 253:119858. https://doi.org/10.1016/j.jclepro.2019.119858
Hao L, Hao L (2008) Automatic identification of stop words in Chinese text classification. In: 2008 International conference on computer science and software engineering, vol 1, pp 718–722. https://doi.org/10.1109/CSSE.2008.829
Hastie T, Tibshirani R, Friedman J, Hastie T, Tibshirani R, Friedman J (2009) Overview of supervised learning. In: The elements of statistical learning: Data mining, inference, and prediction, pp 9–41. https://doi.org/10.1007/978-0-387-84858-7_2
Hengelbrock J, Theissen E, Westheide C (2013) Market response to investor sentiment. J Bus Financ Acc 40(7–8):901–917. https://doi.org/10.1111/jbfa.12039
Hinz O, Skiera B, Barrot C, Becker JU (2011) Seeding strategies for viral marketing: an empirical comparison. J Mark 75(6):55–71
Hoang T, Syed Q (2021) Investor sentiment and volatility prediction of currencies and commodities during the COVID-19 pandemic. Asian Econ Lett 1:4. https://doi.org/10.46557/001C.18642
Hong W, Gu Y, Wu L, Pu X (2023) Impact of online public opinion regarding the Japanese nuclear wastewater incident on stock market based on the SOR model. Math Biosci Eng 20(5):9305–9326. https://doi.org/10.3934/mbe.2023408
Hu T, Wang S, Luo W, Zhang M, Huang X, Yan Y, Liu R, Ly K, Kacker V, She B (2021) Revealing public opinion towards COVID-19 vaccines with Twitter data in the United States: spatiotemporal perspective. J Med Internet Res 23(9):e30854. https://doi.org/10.2196/30854
Huynh TLD, Foglia M, Nasir MA, Angelini E (2021) Feverish sentiment and global equity markets during the COVID-19 pandemic. J Econ Behav Organ 188:1088–1108
Kim S-W, Gil J-M (2019) Research paper classification systems based on TF-IDF and LDA schemes. HCIS 9(1):30. https://doi.org/10.1186/s13673-019-0192-7
Kish Z, Fairbairn M (2018) Investing for profit, investing for impact: moral performances in agricultural investment projects. Environ Plann a Econ Space 50(3):569–588. https://doi.org/10.1177/0308518x17738253
Kumar S, Maheshwari V, Prabhu J, Prasanna M, Jayalakshmi P, Suganya P, Jothikumar R (2020) Social economic impact of COVID-19 outbreak in India. Int J Pervasive Comput Commun 16(4):309–319. https://doi.org/10.1108/IJPCC-06-2020-0053
Lau H, Khosrawipour V, Kocbach P, Mikolajczyk A, Schubert J, Bania J, Khosrawipour T (2020) The positive impact of lockdown in Wuhan on containing the COVID-19 outbreak in China. Travel Med 27(3):taaa037. https://doi.org/10.1093/jtm/taaa037
Li T, van Dalen J, van Rees PJ (2018) More than just noise? Examining the information content of stock microblogs on financial markets. J Inf Technol 33(1):50–69
Liu Q, Huang M, Zhao L, Lee W-S (2023) The dispositional effects of holidays on investor sentiment: therapeutic and hygienic. J Innov Knowl 8(2):100358. https://doi.org/10.1016/j.jik.2023.100358
Liu Q, Lee W-S, Huang M, Wu Q (2022a) Synergy between Stock Prices and Investor Sentiment in Social Media. Borsa Istanbul Rev. https://doi.org/10.1016/j.bir.2022.09.006
Liu Q, Wang X, Du Y (2022b) The weekly cycle of investor sentiment and the holiday effect—An empirical study of Chinese stock market based on natural language processing. Heliyon. https://doi.org/10.1016/j.heliyon.2022.e12646
Liu Q, Zhou X, Zhao L (2022c) View on the bullishness index and agreement index. Front Psychol. https://doi.org/10.3389/fpsyg.2022.957323
Loang OK (2022) Overreaction, investor sentiment and market sentiment of COVID-19. Vis J Bus Perspect. https://doi.org/10.1177/0972262922108
Ma J, Ganchev K, Weiss D (2018) State-of-the-art Chinese Word Segmentation with Bi-LSTMs. https://doi.org/10.48550/arXiv.1808.06511
Maeda Y (2022) Public Opinion and COVID-19. Japan Decides 2021: The Japanese General Election. Springer, Cham, pp 167–182
Malecki KM, Keating JA, Safdar N (2021) Crisis communication and public perception of COVID-19 risk in the era of social media. Clin Infect Dis 72(4):697–702. https://doi.org/10.1093/cid/ciaa758
Mallikarjuna M, Rao RP (2019) Evaluation of forecasting methods from selected stock market returns. Financ Innov 5(1):1–16. https://doi.org/10.1016/j.cor.2004.03.016
Mao H, Counts S, Bollen J (2011) Predicting financial markets: comparing survey, News, Twitter and Search Engine Data (arXiv:1112.1051). arXiv. https://doi.org/10.48550/arXiv.1112.1051
Naseem S, Mohsin M, Hui W, Liyan G, Penglai K (2021) The investor psychology and stock market behavior during the initial era of COVID-19: a study of China, Japan, and the United States. Front Psychol 12:16. https://doi.org/10.3389/fpsyg.2021.626934
Nguyen TH, Shirai K, Velcin J (2015) Sentiment analysis on social media for stock movement prediction. Expert Syst Appl 42(24):9603–9611. https://doi.org/10.1016/j.eswa.2015.07.052
Nimal PD (1997) Relationship between Stock Returns and Selected Fundamental Variables; Evidence from Sri Lanka. Sri Lankan J Manag 2(3):268–286

Nofer M, Hinz O (2015) Using twitter to predict the stock market. Bus Inf Syst Eng 57(4):229–242. https://doi.org/10.1007/s12599-015-0390-4
Oliveira N, Cortez P, Areal N (2013) On the predictability of stock market behavior using stocktwits sentiment and posting volume. In: Portuguese conference on artificial intelligence, pp 355–365. https://doi.org/10.1007/978-3-642-40669-0_31
Pang B, Lee L (2008) Opinion mining and sentiment analysis. Found Trends Inf Retr 2(1–2):1–135. https://doi.org/10.1561/1500000011
Perez-Liston D, Huerta D, Haq S (2016) Does investor sentiment impact the returns and volatility of Islamic equities? J Econ Finance 40(3):421–437
Raj C, Meel P (2022) People lie, actions Don't! Modeling infodemic proliferation predictors among social media users. Technol Soc 68:101930. https://doi.org/10.1016/j.techsoc.2022.101930
Renault T (2017) Intraday online investor sentiment and return patterns in the U.S. stock market. J Bank Finance 84:25–40. https://doi.org/10.1016/j.jbankfin.2017.07.002
Schmeling M (2009) Investor sentiment and stock returns: some international evidence. J Empir Financ 16(3):394–408. https://doi.org/10.1016/j.jempfin.2009.01.002
Schölkopf B, Locatello F, Bauer S, Ke NR, Kalchbrenner N, Goyal A, Bengio Y (2021) Toward causal representation learning. Proc IEEE 109(5):612–634. https://doi.org/10.1109/JPROC.2021.3058954
Shleifer A, Vishny RW (1997) The limits of arbitrage. J Financ 52(1):35–55. https://doi.org/10.1111/j.1540-6261.1997.tb03807.x
Sprenger TO, Tumasjan A, Sandner PG, Welpe IM (2014) Tweets and trades: the information content of stock microblogs. Eur Financ Manag 20(5):926–957. https://doi.org/10.1111/j.1468-036X.2013.12007.x
Sun L, Najand M, Shen J (2016) Stock return predictability and investor sentiment: a high-frequency perspective. J Bank Finance 73:147–164. https://doi.org/10.1016/j.jbankfin.2016.09.010
Sun L, Shi W (2022) Investor sentiment and stock market reactions to COVID-19: evidence from China. Discret Dyn Nat Soc 2022:e8413916. https://doi.org/10.1155/2022/8413916
Szczygielski JJ, Charteris A, Bwanya PR, Brzeszczyński J (2023) Which COVID-19 information really impacts stock markets? J Int Financ Mark Inst Money 84:101592. https://doi.org/10.1016/j.intfin.2022.101592
Tumarkin R, Whitelaw RF (2001) News or noise? Internet postings and stock prices. Financ Anal J 57(3):41–51. https://doi.org/10.2469/faj.v57.n3.2449
Uysal AK, Gunal S (2014) The impact of preprocessing on text classification. Inf Process Manage 50(1):104–112. https://doi.org/10.1016/j.ipm.2013.08.006
Van Bommel J (2003) Rumors. J Finance 58(4):1499–1520. https://doi.org/10.1111/1540-6261.00575
Vrij A (2008) Detecting lies and deceit: Pitfalls and opportunities. Wiley, Hoboken
Vu TT, Chang S, Ha QT, Collier N (2012) An experiment in integrating sentiment features for tech stock prediction in twitter. In: Proceedings of the workshop on information extraction and entity analytics on social media data, pp 23–38
Wagner AF (2020) What the stock market tells us about the post-COVID-19 world. Nat Hum Behav 4(5):5. https://doi.org/10.1038/s41562-020-0869-y
Wei W, Mao Y, Wang B (2016) Twitter volume spikes and stock options pricing. Comput Commun 73:271–281. https://doi.org/10.1016/j.comcom.2015.06.018
Xiong X, Chunchun LUO, Ye Z (2017) Stock BBS and trades: the information content of stock BBS. J Syst Sci Math Sci 37(12):2359. https://doi.org/10.12341/jssms13312
Xue N (2003) Chinese word segmentation as character tagging. In: International journal of computational linguistics & Chinese language processing, vol 8(1), February 2003: Special issue on word formation and chinese language processing, pp 29–48
You S, Wang H, Zhang M, Song H, Xu X, Lai Y (2020) Assessment of monthly economic losses in Wuhan under the lockdown against COVID-19. Human Soc Sci Commun 7(1):1–12. https://doi.org/10.1057/s41599-020-00545-4
Yu J, Qiu L (2019) ULW-DMM: an effective topic modeling method for microblog short text. IEEE Access 7:884–893. https://doi.org/10.1109/ACCESS.2018.2885987
Yu X, Zhong C, Li D, Xu W (2020) Sentiment analysis for news and social media in COVID-19. In: Proceedings of the 6th ACM SIGSPATIAL international workshop on emergency management using GIS, pp 1–4. https://doi.org/10.1145/3423333.3431794
Zaheer K, Aslam F, Tariq Mohmand Y, Ferreira P (2022) China Finance Rev Int 13(1):23–45. https://doi.org/10.1108/CFRI-07-2021-0137
Zhang Y, Chen M, Liu L (2015) A review on text mining. In: 2015 6th IEEE international conference on software engineering and service science (ICSESS), pp 681–685. https://doi.org/10.1109/ICSESS.2015.7339149
Zhang Y, You C, Gai X, Zhou X (2021) On coexistence with COVID-19: estimations and perspectives. China CDC Weekly 3(50):1057. https://doi.org/10.46234/ccdcw2021.245
Zheludev I, Smith R, Aste T (2014) When can social media lead financial markets? Sci Rep 4(1):1–12. https://doi.org/10.1038/srep04213
Zubiaga A, Liakata M, Procter R, Bontcheva K, Tolmie P (2015) Towards detecting rumours in social media. Workshops at the 29th AAAI conference on artificial intelligence. https://doi.org/10.48550/arXiv.1504.04712

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.