Live Streaming in A Long-term Uncertain Situation: Evidence from China's Listed Company

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Abstract. Since the outbreak of COVID-19 on December 2019, various industries have been affected to some extent. Due to the government's quarantine policy, much of the non-essential work has shifted from face-to-face to online, and more and more people are trapped at home. In the uncertain environment of the spread of COVID-19, the live streaming industry with many random factors is a suitable research object. This paper selects two well-known live streaming platforms in China, Douyu, and Huya. The stock data since January 20 and the new number of confirmed COVID-19 in China and overseas were captured. The ARMA-GARCH model is used to model and analyze the data to study how the yield and volatility of this kind of industry change in the long-term uncertain environment. By experimental comparison, in the long run, the spread of this epidemic in China still has a significant positive impact on this live streaming industry. While there is little impact by overseas outbreaks.

Keywords: Live streaming; COVID-19; ARMA-GARCH.

1. Introduction

With the popularity of the Internet, online activities, especially the live streaming industry, have gained a great deal of attention and are gradually understood by more and more people, becoming the main entertainment activities. For the streamers and the audience, the interaction in the form of live streaming is quite free. The audience can hear the voice of streamers they like and even see their behavior. At the same time, the audience can communicate with the streamers by typing in the chat box, and even send virtual gifts to express their affirmation and encouragement to the streamers. The content of live streaming has become more diversified, from the single talent show such as singing and audience chatting, to the live streaming of games, competitions, and e-commerce promotions. According to the data, by June 2021, the number of netizens in China was 1.011 billion, and the Internet penetration rate was as high as 71.6%, among which 888 million people watch short videos and 638 million people watch live streaming, which shows that short videos and live streaming are becoming the new lifestyle trend of the whole people (CNNIC, 2021) [1]. On November 22, 2021, the official Weibo account of Riot Games released the final viewing data of the Grand Finals Season 11 League of Legends World Championship. During the finals, the peak number of simultaneous viewers reached 73,860,742, which increased by 60.33% compared with the highest simultaneous viewers in 2020.

The two live streaming platforms mentioned in this article, Douyu, and Huya, were founded in January 2014 and November 2014 respectively. Known as China's "first game live streaming stock", HUYA, with the slogan of "Technology-Driven Entertainment -- Bullet Screen Interactive Live Streaming Platform", was officially listed on the NYSE of New York Stock Exchange in May 2018, with the ticker symbol of "HUYA", becoming the first listed game live streaming platform in China, with the opening stock price of $15.5. In addition, Huya has several top international games live streaming and exclusive broadcasting rights, such as the League of Legends World Championship, the Mid-Season Invitational, and the League of Legends Pro League (LPL) [2]. Secondly, Douyu, whose slogan is' Everyone's Live Streaming Platform ', officially filed for IPO with the SEC on April 19th and was listed on NASDAQ in July under the ticker symbol 'DOYU' at an opening stock price of $11.50 [3]. In terms of the live streaming themes of these two platforms, Huya's talent streamers

in terms of singing and dancing are more popular, while streamers on Douyu pay more attention to the live streaming of game themes.

The research purpose of this paper is to summarize the extent to which the live streaming industry is affected in the past two and a half years and simply analyze the reasons for the phenomenon based on the yield data of the two live streaming platforms and the increase in the number of COVID-19 patients. Due to the COVID-19 pandemic, the employment, financial and investment environment has been full of possibilities for a while. In this way, it's possible to infer the revenue impact of the live streaming industry under such an uncertain environment.

In this paper, the VAR model is constructed first, and the lag order of VAR is decided by using the unit circle test. The purpose of this step is to ensure that all points are in the circle under the determined order, otherwise, the order needs to be re-determined. Then the corresponding graphs of four impulse responses and the corresponding images of four cumulative impulses are drawn. These plots show the change of variables, the amount of change, and the duration of the impact by a shock. Then partial autocorrelation function (PACF) and autocorrelation function (ACF) are used to determine the lag order of the AR part and MA part of ARMA-GARCH model. Finally, the ARMA-GARCH model is established to predict the logarithmic rate of yield and the volatility of the two companies.

2. Literature Review

According to Meyer, for businesses, the coronavirus crisis is more on the demand side than the supply side [4]. And in the short term, most firms have responded to the crisis by lowering their short-term inflation expectations. Meanwhile, companies' expectations about the future of the pandemic have influenced their views on future market demand. And in Shen's study, by comparing the predicted value with the actual value, it was concluded that the performance of the industries severely affected by the pandemic decreased significantly and showed negative returns, such as the tourism and catering industry [5]. That's because the pandemic has reduced corporate revenues and investment. However, in Nhamo's book, due to the pandemic, movies and music festivals were canceled, actors and directors could not get together to shoot videos, and the stock value of entertainment companies fell extremely severely, which had a great negative impact [6]. At the same time, when people are being asked to reduce or even banned from going out, the demand for entertainment is increasing. As a result, companies in the streaming media industry, such as Netflix, have shown a relatively good trend.

Aqel says there are positive associations between net income, comprehensive income, and share price [7]. Ioana shows that both the net income and comprehensive income influence the value of the share price at a similar level [8].

For Douyu and Huya, the platforms' revenue sources include viewers' tipping and membership systems for their streamers. The platform gets benefits from the gifts received by streamers and extracts a portion as a share. In other words, when a streamer receives more virtual gifts, the platform will receive more income. At the same time, it will be graded according to the price of the gift, so as to ensure that audiences of different consumption levels can realize the purchase. In addition, when the audience sends the gift, the corresponding special visual effects are accompanied, which sets off the atmosphere of the streaming room and gives the audience incentive to consume. The second source of income is the member system, which refers to the differentiation of user types to guide user behavior. The classification of member users helps to provide different services based on ordinary users or customize concessions for ordinary users and member users. With the promotion of membership level, the platform provides users with corresponding identity characteristics and privileges, such as special effects coming with entering the steaming room, which can help users attract the attention of streamers faster. Its essence is to promote users' loyalty to the platform and encourage users to spend through a series of operating rules and exclusive rights and interests.

Taken together, these documents show that while the streaming industry is on the rise, the COVID-19 pandemic is hurting most businesses. At the same time, the relationship between company earnings and yield is analyzed to infer that the reason for this phenomenon is the increase in the number of users during the pandemic, which may have had a positive impact on yield. This paper focuses on the influence of Chinese or overseas epidemics on the development of this industry in China.

3. Research Design

3.1. Data Sources

The research data of this paper: the share price of two companies, Douyu and Huya, as well as the number of newly diagnosed COVID-19 cases each day in China and overseas, are from the website of Choice Financial terminal. After exporting into Excel files, the corresponding data since January 24, 2020, are screened out. However, due to the large difference between the number of the share price and that of new confirmed cases, the time series cannot match, it is necessary to delete the redundant data first to get the appropriate time series data. Take the log rate of yield, that is, the difference between every two data points after taking the log of the price. Formula is:

$$r_t = \frac{P_{t+1} - P_t}{P_t} \tag{1}$$

$$\log\ Yield_t = \ln\ (1 + r_t) \tag{2}$$

Where r_t is the yield, P_{t+1} and P_t are the closing prices for two consecutive days, and $\ln Yield_t$ is the log rate of yield. This can not only make the time series of data stable but also the biggest advantage of using a logarithmic yield is additive, which means that the logarithmic yield of a single period can be added to get the overall logarithmic yield. Similarly, the number of new confirmed from China and overseas should also be logarithmic.

3.2. Data Sources

Unit root test is used to test whether the panel regression data are stationary. This test uses the idea of cointegration to investigate whether there is a long-term equilibrium connection between variables. Stationarity tests for all variables are necessary tests before estimating econometric models. The null hypothesis of this test is that the original data series has a unit root, which means that the time series of the original data is not stationary. The relevant formula is:

$$x_t = c_t + \beta x_{t-1} + \sum_{i=1}^{p-1} \phi_i \Delta x_{t-i} + e_t \tag{3}$$

For this formula, the null hypothesis is $H_0: \beta = 1$ and the alternative hypothesis is$H_1: \beta < 1$.

Table 1. ADF test.

Variables	t-statistic	p-value
	Price	
Douyu	-2.0390	0.5800
Huya	-2.113	0.5389
	Yield	
Douyu	-18.323	0.0000***
Huya	-18.096	0.0000***
	New confirmed cases	
China	-10.281	0.0000****
Overseas	-6.684	0.0000***

From the results shown in Table 1, when 1% was chosen as the significance level, that is, when the P-value is less than 0.01, there is sufficient evidence to reject the null hypothesis. The test data of "Price" in the first two rows are the share prices of Douyu and Huya, and the P values obtained are

0.5800 and 0.5389 respectively, both greater than 1%. Therefore, the time series of the original share price data is non-stationary. The data labeled with 'Yield' refers to log yield calculated on the basis of share prices, and the data labeled with 'New confirmed cases' refers to the daily rise in the number of confirmed COVID-19 cases in China and overseas. The P-values obtained from these four data are 0.0000, less than 1%, which means that their time series are stationary and can be used for further research.

3.3. VAR specification

The vector autoregressive model (Var) was proposed by Sims [9]. The idea that all variables are regarded as endogenous variables is feasible for estimating macro models. VRA modeling is selected in this study because the VAR model does not need to distinguish variable types. Moreover, since the lagged variable is adopted by the explanatory variable, it means that the explanatory variable does not include the current period variable, and future data are easier to predict.

The purpose of the VAR model is variance decomposition and impulse response analysis. The pulse is used to study the impact of the shock on a variable in different periods. A four-element VAR model is established by integrating the logarithmic yield of Huya and Douyu and the logarithmic newly increased number of people in China and overseas. Its lag order is determined according to VAR lag order selection criteria. In Stata software, there are four statistics are reported, the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC). Then the impulse response function (IRF) can be established. The formula is as follows:

$$\frac{\delta y_{t+s}}{\delta \varepsilon_t'} = \psi_s \tag{4}$$

Consider $\frac{\delta y_{t+s}}{\delta \varepsilon_t'}$ as the time interval s. The meaning is that the effect of the ith variable of the value $y_{i,t+s}$ in period (t+s) whilst the jth variable increases by one unit at the perturbation term ε_{jt} in period t (while the other variables are unchanged with the perturbation terms in other periods).

3.4. ARMA-GARCH Specification

The generalized autoregressive conditional heteroskedasticity model (GARCH) is a generalization by Bollerslev based on the autoregressive conditional heteroskedasticity (ARCH) model by Engle, which is widely used to predict volatility in data [10,11]. For example, there were five studies based on the GARCH model by Almansour, Yunita, Ismail, Luo, and Ghani [12-16]. For the GARCH model, its variance error is considered to be serial autocorrelation, there are other different GARCH-type models, such as the exponential GARCH model (EGARCH), GARCH-in Mean (GARCH-M) Model, and so on. Autoregressive Moving Average (ARMA) model is divided into Autoregressive (AR) and moving average (MA). The ARMA-GARCH used in this paper is the hybrid model of ARMA and GARCH, it aims to predict the volatility of log returns of two firms simultaneously. For the GARCH (p, q) model, its model setting is

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 + \gamma_1 \sigma_{t-1}^2 + \ldots + \gamma_p \sigma_{t-p}^2 \tag{5}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma_1 \sigma_{t-1}^2 + \beta c_t \tag{6}$$

Where the ε_t is the disturbance term and σ_t is the variance. The first part of this formula is ARCH term and the second part is GARCH term. The sixth formula is about the common model GARCH (1, 1) adding a variable of confirmed cases, c_t with coefficient β.The design idea of ARMA-GARACH model is that the mean value equation of GARCH model is set as ARMA process. The formula of ARMA (P, Q) model is:

$$x_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i x_{t-i} + a_t - \sum_{i=1}^{q} \theta_i a_{t-i} \tag{7}$$

Where the $\{a_t\}$ is a sequence of white noise and both p and q are non-negative integers.

4. Empirical Results

4.1. VAR Lag Order Identification

According to Table 2, the minimum values of AIC and SBIC do not appear in the same lag order, which is 5 and 2 respectively. According to the study of Hatemi-J, when the maximum likelihood function value of the VAR model does not grow significantly when the lag period is increased, that is, when the LR statistic is smaller than the crucial value, the newly added lag variable is meaningless to the VAR model, the LR test is used. [17]. in this table, when the maximum lag order is 11, the corresponding P-value is 0.785 greater than 0.1, and the LL value does not increase significantly, so the maximum lag order is selected as 10. Test whether the VAR system satisfies the necessary and sufficient conditions for stationarity: all eigenvalues of the coefficient matrix fall inside the unit circle [18]. As can be seen in Figure 1, none of the black points exceed the range of the circle, which means that the necessary and sufficient conditions for judging stationarity are satisfied. Therefore, it is feasible to establish a VAR model with a lag order of 10.

Table 2. VAR model identification.

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-122.304				.000019	.491456	.504395	.524469
1	82.7925	410.19	16	0.000	9.2e-06	-.244329	-.179633	-.079262
2	151.169	136.75	16	0.000	7.5e-06	-.448127	-.331675	-.151006*
3	185.237	68.136	16	0.000	7.0e-06	-.51843	-.350222	-.089256
4	206.75	43.027	16	0.000	6.8e-06	-.539884	-.319919	.021344
5	298.673	183.85	16	0.000	5.1e-06*	-.835303*	-.563583*	-.142022
6	310.017	22.687	16	0.122	5.2e-06	-.817186	-.493708	.00815
7	317.542	15.05	16	0.521	5.4e-06	-.78421	-.408976	.173179
8	325.126	15.169	16	0.512	5.5e-06	-.751464	-.324474	.337978
9	346.232	42.211	16	0.000	5.4e-06	-.771329	-.292583	.450167
10	365.798	39.134*	16	0.001	5.4e-06	-.785208	-.254705	.568342
11	371.495	11.393	16	0.785	5.6e-06	-.745116	-.162857	.740487
12	378.695	14.4	16	0.569	5.8e-06	-.710876	-.07686	.906782

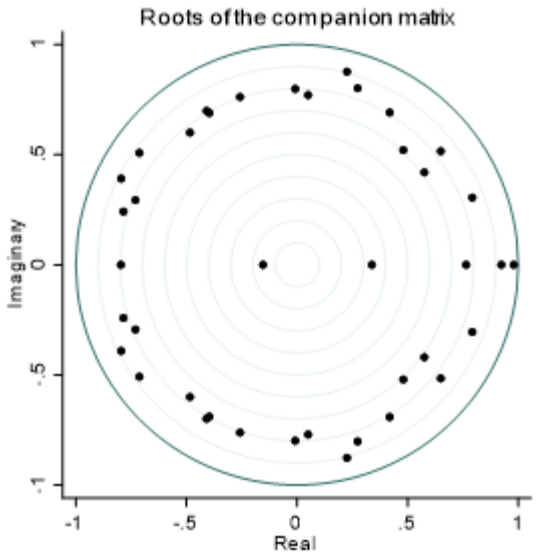


Figure 1. VAR stability.

4.2. Impulse Response Function

The impulse response function describes the reaction of endogenous variables to the change of error terms in the VAR model. In this paper, the pulse function values of 30 periods are calculated to draw images. Figure 2 shows the corresponding image of the obtained pulse.

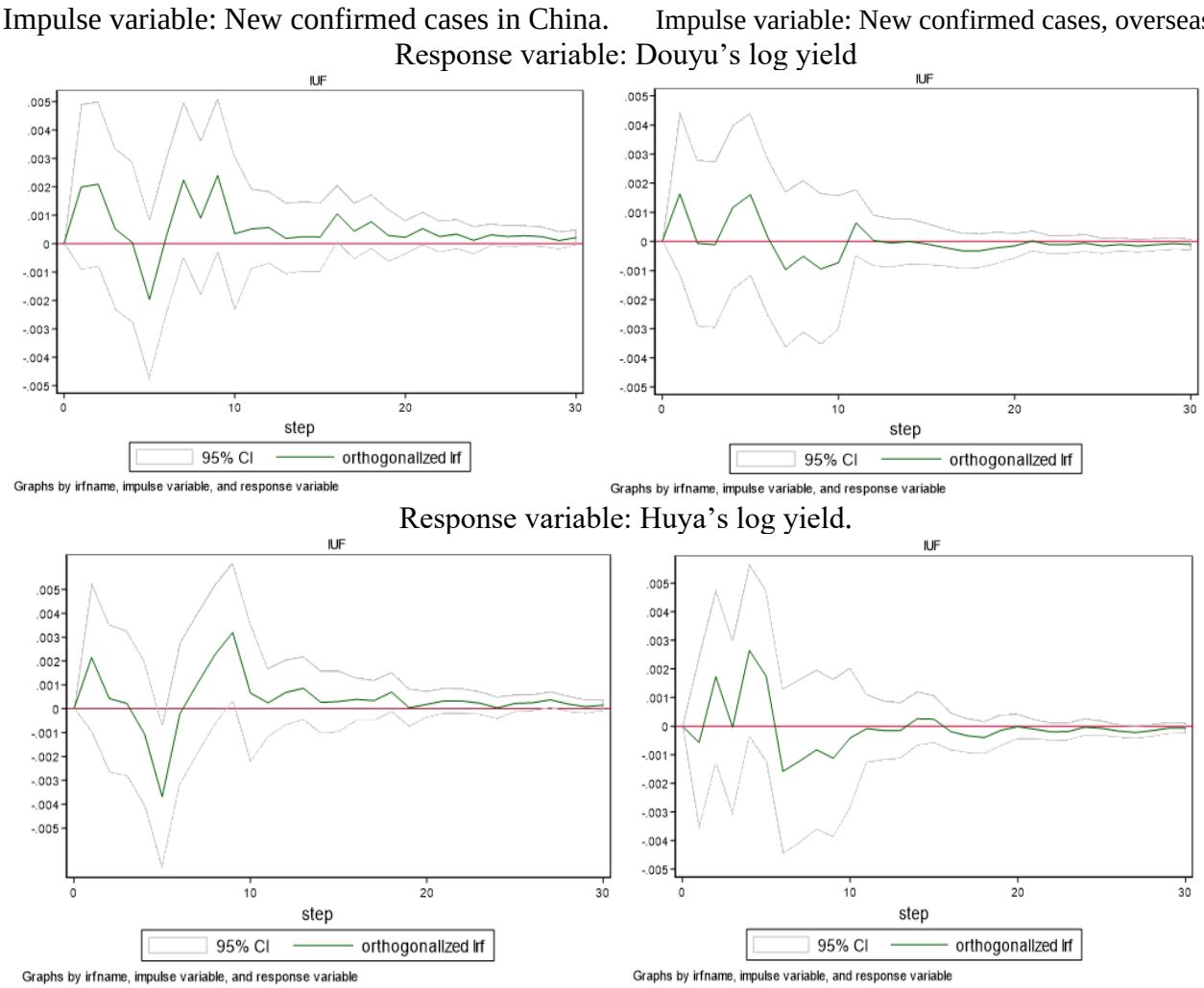
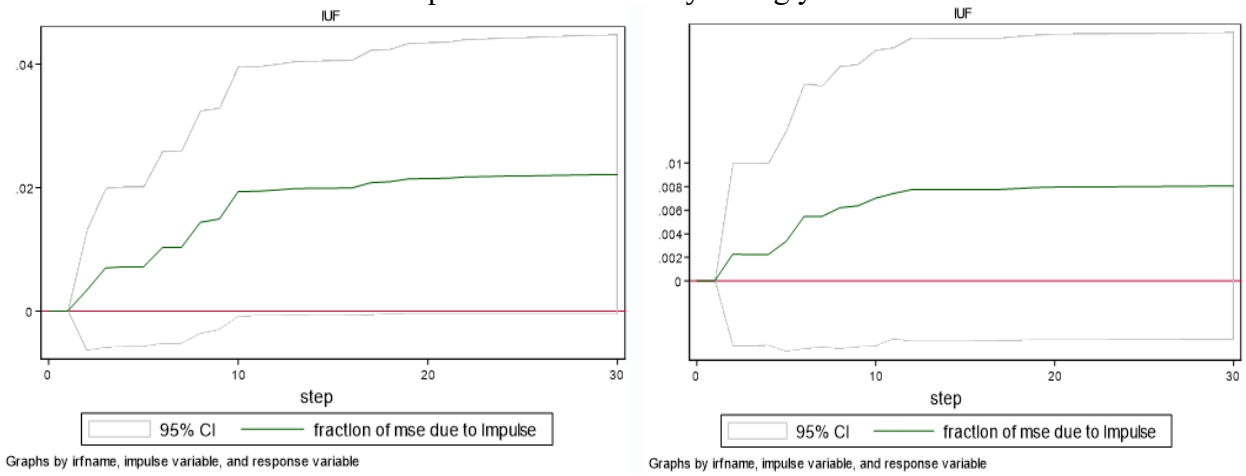


Figure 2. Impulse and response.

The image can be divided into two groups, by the pulse variable of the new confirmed cases in China and overseas respectively. Through comparison, it is found that although Douyu and Huya are two different companies, their response trends to the same impulse variable are very similar. The response trend for China first increases and decreases, and then rises again before becoming stable around 0. At this time, most of the values on the broken line are greater than 0. When turning to the overseas response trend, it shows a large fluctuation in the early stage and then converges to 0 after decreasing, but most of the broken lines are below the value of 0 at this time. Going back to the value of the corresponding estimation result of the pulse itself, the Douyu is first analyzed. When the number of new infected cases in China increases by 1% in the period t=0, the impact on the return rate of Douyu in the future period is basically positive, and the maximum positive effect is about 0.2%. The impact of 1 unit of overseas confirmed cases on Douyu was also positive, but the largest positive effect was 0.15%, which was 0.05% lower than that of the former. In terms of Huya, it is difficult to judge the net effect of a 1% growth in the number of new infected cases in China during the t=0 period on the return rate of Huya from the pulse diagram, but the impact of 1 unit of overseas shock can be basically concluded to be positive, with the largest positive effect between 0.2% and 0.3%, which is larger than the data of Douyu. As far as the time effect is concerned, in all four images, the shock of the current period gradually decays after 10 periods.

Impulse variable: New confirmed cases in China. Impulse variable: New confirmed cases, overseas.

Response variable: Douyu's log yield.



Response variable: Huya's log yield

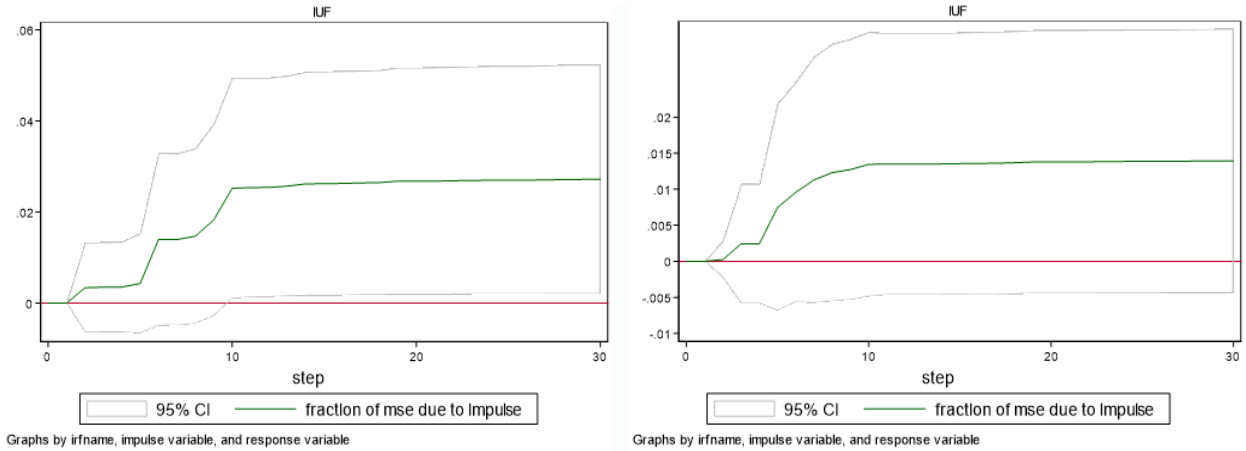


Figure 3. Cumulative response.

According to the cumulative response in Figure 3, the cumulative impact of new diagnosed cases in China in the present period on Douyu and Huya in the next 30 periods was slightly more than 2%, and Huya was more affected than Douyu. The cumulative impact of overseas epidemics was about 0.8% and 1.5%, respectively. Numerically, a one-unit shock in China is larger than the impact overseas. One possible reason is that active users of Douyu and Huya are concentrated in China. Secondly, it can be inferred that Huya has more active users than Douyu. The reason may be that Huya has a monopoly on the live streaming of international events, which can help the platform attract more viewers, both in China and overseas.

4.3. ARMA-GARCH Lag Order

The first part is AR, which is a time series model using the autocorrelation law of time series Xt for prediction. In simple terms, it is the use of past actual values to predict the future. For AR (P), his model is formulated as

$$x_t = \varphi_0 + \varphi_1 x_{t-1} + \cdots + \varphi_p x_{t-p} + a_t \tag{8}$$

Where φ_0 is a constant and φ_i for i =1, 2...p is the lag value. a_t Is the disturbance term of white noise? The second part, MA, is a time series model that uses shocks (past disturbances) to predict the future. For MA (q), his model is formulated as

$$x_t = c_0 + a_t - \theta_1 a_{t-1} - \cdots - \theta_q a_{t-q} \tag{9}$$

Where $q > 0$ and a_t is the disturbance term.

The partial autocorrelation function (PACF) and autocorrelation function (ACF) is used to determine the lag order for AR (P) and MA (Q), respectively. The determination is based on whether the upper limit of the 95% confidence interval is exceeded. The values of P and q are respectively the lag values when the two images cross the upper limit of the interval for the first time. The P value of logarithmic yield of Douyu is 9, and the Q value is 33 in Figure 4. The p-value and q value of the logarithmic yield of Huya are both 3. Therefore, the fitting models of Douyu and Huya are ARMA-GARCH (9, 33) and ARMA-GARCH (3, 3), respectively.

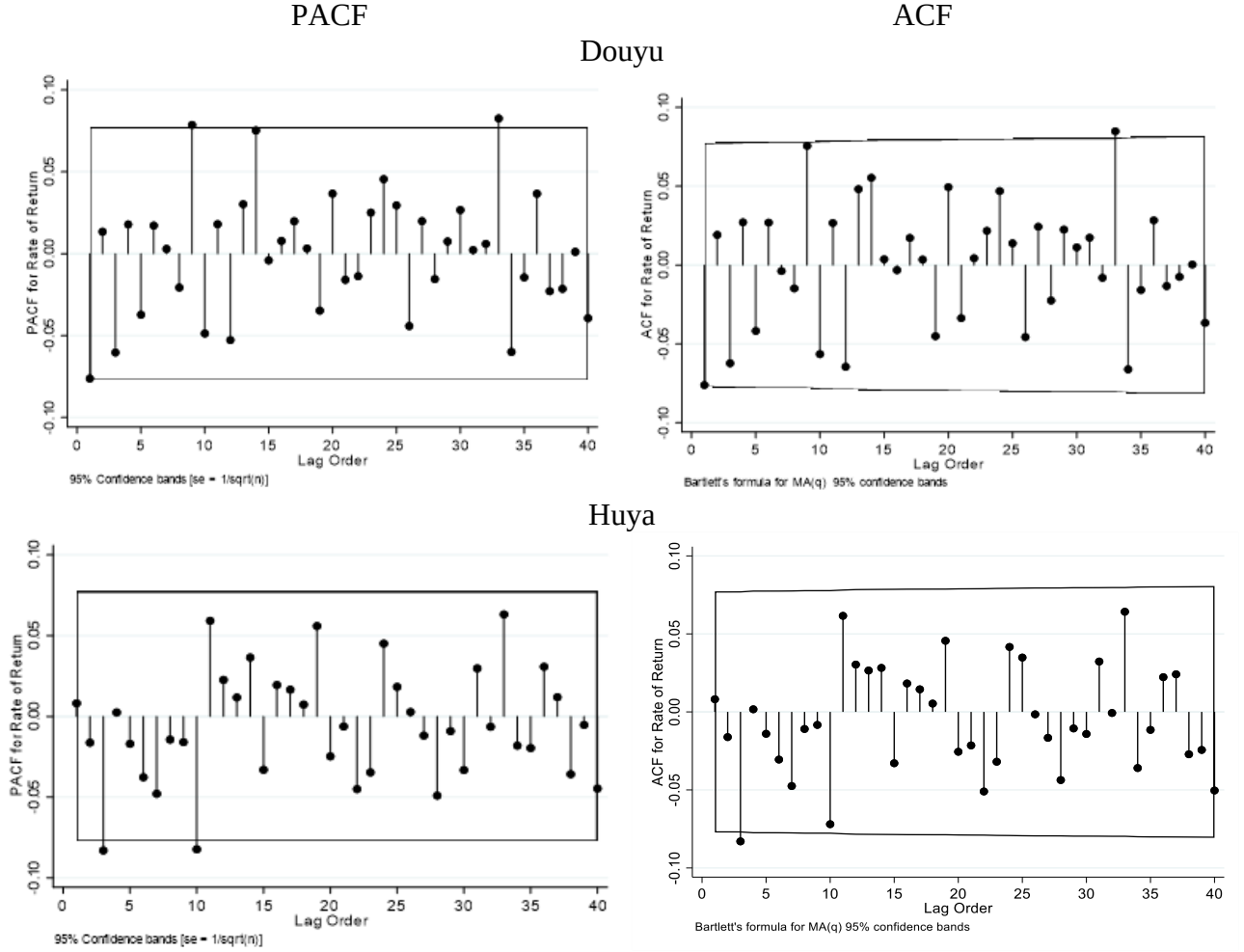


Figure 4. PACF and ACF.

Figure 5 shows the time series of logarithmic yield of Douyu and Huya. It can be found that the yields of the two companies have aggregation, and there have been three positive fluctuations of higher yields briefly. But it is still impossible to determine if it was statistically significant.

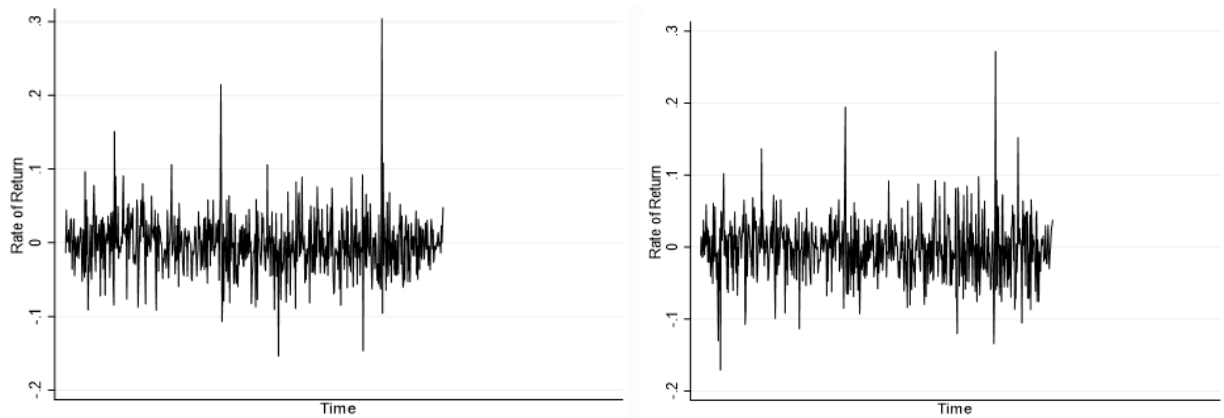


Figure 5. Yield.

4.4. ARMA-GARCH estimation results

As can be visible from the estimation outcomes in Table 3, in columns 1 to 4, although the significance levels of ARCH terms and GARCH terms are two levels, 1%, and 10%, both indicate the significance of the results. This shows that after the use of the mean equation to control the autocorrelation, there is still statistically significant conditional heteroscedasticity in the yields of Douyu and Huya, which can be used for GARCH modeling. From the estimation results of external explanatory variables, only the number of overseas confirmed cases has a obvious impact on the volatility of Douyu. Specifically, when the number of new overseas confirmed cases increases by 1%, the volatility of Douyu is expected to increase by 0.0936 units, and its coefficient is significant at the 5% level. For the other three cases, the effects of new confirmed cases in China on the volatility of Douyu, and the effects of China and overseas on Huya are all non-significant, with P values of 0.162, 0.611, and 0.888, respectively.

Table 3. ARMA-GARCHX estimation results.

Variables	(1)	(2)	(3)	(4)
	Douyu		Huya	
Mean equation				
AR, L9	.0894	.0894		
	(0.019)	(0.019)		
AR, L3			.6254	.4920
			(0.343)	(0.421)
MA, L3			-.6554	-.5337
			(0.301)	(0.363)
MA, L33	.08447	.0764		
	(0.028)	(0.047)		
Constant	-.0032	-.0030	-.0020	-.0022
	(0.058)	(0.065)	(0.138)	(0.1)
Variance equation				
New confirmed cases				
China	.0447		-.0183	
	(0.162)		(0.611)	
Overseas		.0936		.0064
		(0.017)		(0.888)
ARCH, L1	.2876	.2966	.1308	.1306
	(0.000)	(0.000)	(0.000)	(0.000)
GARCH, L1	.2488	.2081	.7526	.7468
	(0.051)	(0.073)	(0.000)	(0.000)
Constant	-7.661	-8.3428	-8.3629	-8.5506
	(0.000)	(0.000)	(0.000)	(0.000)

5. Discussion

To sum up, this paper establishes a connection between the number of new confirmed cases and yields of two companies, then models it to predict the yield and volatility. At the beginning of the outbreak of the epidemic, the live streaming industry showed an upward trend, while other industries were hit hard. In the long term, as people's awareness of COVID-19 increases, when national policies to manage the outbreak slow down, it means that people are no longer restricted from going outside. At this time, whether people's attitudes and behavior toward live streaming return to rationality and whether this effect still exists need to be empirically tested. For policymakers, the live streaming industry was one of the few industries that saw an increase in profits at the beginning of the pandemic,

easing the pressure on the country's economy. However, there are many volatile factors affecting the income fluctuation of the live streaming industry, such as the security of personal information in the online world and the quality assurance of third-party supply. When a streamer is found to have done something in the past or made a statement with moral problems on the Internet, the streamer will be resisted by the public and lose the job opportunity. Sometimes, the streamer may be found to have his home address and face personal safety problems. On the other hand, when the purpose of live streaming is to sell goods, if the quality of goods from the supplier goes wrong, the streamer promoting the product will also be questioned by the public. These turbulence factors will affect the reputation of the live streaming platform, people's perception of the platform, and other intangible assets. More policies can be used to improve this situation and bring good development prospects to the network broadcast industry. For investors, the live streaming industry is volatile, but it can also show sudden and large growth. Especially since the current outbreak is not exactly completely over, there may still be situations that require people to be asked to stay home. So, this is a worthwhile long-term investment.

6. Conclusion

From a fundamental point of view, the COVID-19 outbreak in early 2020 led to turmoil in worldwide economic markets. The speedy spread of the coronavirus caused investors to panic in the Chinese, U.S., and European markets in the short term, causing a large amount of capital to flee the financial markets, and leading to a precipitous drop in financial market indexes. For example, there was a huge fall in the FTSE at about 14% on stock markets in 2020.

Among them, a few industries have been spared, pharmaceutical and biological, online games and live streaming industries are one of them, in the short term there has been a great industry and good market, and the market will also reflect this information. The game industry soared for a short period but plummeted after 2021.

Policy in China says that confirmed cases must be in isolation. Under the environment, the reason for this phenomenon appears there may be two. One is younger students during the period of isolation may choose to watch e-sports games and streamers who stream games to spend leisure time. Secondly, it is a way for people who need money during the period of isolation to make a living. But as time goes on, people's lives gradually return to normal, so the number of people watching the live streaming will suddenly fall off. In short, the volatility of the live streaming industry in an uncertain environment is relatively unstable.

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