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A note on tweeting and equity markets before and during the Covid-19 pandemic

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ABSTRACT

We investigate the differential effects of a new index of Twitter-based market uncertainty (TMU) and variables for the US equity market before and during the Covid-19 pandemic. We find that markets are significantly more sensitive to the uncertainty contained in tweets during the pandemic, the TMU is a leading indicator of returns only during the pandemic, and the effect of the TMU on the volatility and liquidity of equity markets is greater during the pandemic compared to the pre-pandemic period. Our results show that the information contained tweets are having a much larger effect on equity markets during the pandemic.

“The Coronavirus is very much under control in the USA. We are in contact with everyone and all relevant countries. CDC & World Health have been working hard and very smart. Stock Market starting to look very good to me!” Tweet from @realDonaldTrump, February 24, 2020

1. Introduction

The Covid-19 pandemic is causing an unprecedented disruption to economic activities. Global travel restrictions and lockdowns have changed the way people work and interact with each other. Twitter has become one of the avenues through which world leaders, equity market professionals, and average citizens express their opinions. The number of “monetizable” daily users on Twitter increased 34% following the onset of the pandemic. This is the fastest growth in this metric since the company began keeping track of it Hutchinson (2020). In this note, we consider the following questions: (1) How is the uncertainty content of tweets related to equity market variables and vice versa. (2) Did the Covid-19 pandemic change the relations between tweets and equity market variables?

We use a new Twitter-based market uncertainty index (TMU). The index includes all tweets sent on Twitter that contain keywords related to “uncertainty” or related to “equity markets”. We examine the differential effects of the TMU and the following US equity market variables: S&P500 returns, Chicago board options exchange’s (CBOE) volatility index (VIX), and S&P500 liquidity as computed by the Amihud illiquidity measure (Amihud, 2002).

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We find that prior to the pandemic, the MKT and VIX are leading indicators of the TMU and the effect is stronger during the pandemic. If returns rise (volatility falls), TMU declines (rises). But the TMU did not contain information about the future path of the returns. However, following the onset of the pandemic, the returns on the S&P500 have become more sensitive to the uncertainty content of tweets that strengthens the TMU’s ability to predict them. Additionally, prior to the pandemic, we find that the effects of the TMU on the VIX and equity market liquidity were negligible. However, the VIX and S&P500 index liquidity have become much more sensitive to the uncertainty content of tweets during the pandemic. Our results are related to the literature on the effects of social media and the pandemic on equity markets.

Social media like Twitter connects people in a virtual community (Bukovina, 2016). Evidence from behavioral finance demonstrates that individual and group psychology is correlated or even predictive of financial market performance. Social media enable people to create, share, and respond to information. Such a combination of reactions is a valuable source of data about the opinions and emotions of the followers. The equity markets reflect the trading by institutional and retail investors; and if Twitter influences retail investors, then the stock prices may reflect this influence also. Portfolio managers and traders must therefore be cognizant of the increased influence of social media and retail investors on equity markets particularly in highly uncertain periods. A unique insight of this note is to show that the Covid-19 pandemic has accelerated the influence of social media on equity markets.

Several researchers have investigated the effect of Twitter-based sentiment on financial markets. Bollen et al. (2011) indicate that the “mood” of Twitter predicts the level of the Dow Jones industrial average (DJIA). Sprenger et al. (2014a) derive good and bad news from more than 400,000 tweets related to the S&P500 and find that this news has an effect on the market. Using company-specific news flows in Twitter, Sprenger et al. (2014b) find a relation between the stock returns and trading volume of the respective stock. You et al. (2017) use a daily happiness proxy extracted from Twitter and investigate whether investor sentiment has predictive power for stock returns in 10 international stock markets. They show that a causal relationship between happiness and stock returns only exists in high quartile of returns and conclude that happiness sentiment does not Granger cause stock returns. In a related study, Agrawal et al. (2018) use real-time data from StockTwits and Twitter to construct measures for extreme sentiment. Their results show that extreme sentiment corresponds to higher demand for and lower supply of liquidity. Furthermore, they show that negative sentiment has a larger effect on demand and the supply of liquidity than positive sentiment. While this note is related to the above papers, it differs in that the TMU is not a measure of sentiment but rather a measure of the level of market uncertainty contained in tweets.

This note is further related to the burgeoning literature on the effect of the Covid-19 pandemic on equity markets. Xu (2020) investigates the response of stock returns to unexpected changes in Covid-19 cases. Baker et al. (2020) analyze the effects of the pandemic on aggregate markets returns and other variables. Zhang et al. (2020) show that the pandemic has increased the volatility of global equity markets and that policy responses may have increased this uncertainty. Ramelli and Wagner (2020) show that the anticipated real effect of the pandemic was amplified by equity markets in the early stages of the pandemic. Cepoi (2020) shows that “fake news” and media coverage during the pandemic has had a negative effect on some countries’ stock market returns. However, to our knowledge no study has yet explored the effect of uncertainty measured through tweets on equity markets during the pandemic.

The remainder of this note proceeds as follows: We discuss the data and methods in Section 2. We present the empirical results in Section 3 and Section 4 concludes.

2. Data

The new Twitter-based market uncertainty index (TMU) is available at a daily frequency for the period from January 1, 2011, through August 31, 2020. We collect the TMU data from the policy uncertainty website at https://www.policyuncertainty.com. Fig. 1 plots the evolution of the TMU over the available sample period.

During uncertain periods, the TMU increases considerably. For example, the TMU spiked during the BREXIT referendum and the 2016 US election. To understand the relation between the information content of the TMU and the equity market variables before and during the Covid-19 pandemic, we need to have a breakpoint in the TMU. We use the Quandt-Andrew’s breakpoint test to identify one or more unknown structural breakpoints in the TMU time series. Unreported test results indicate that February 24, 2020, is a structural breakpoint. On this date the TMU rose from 149 to 345 and has remained elevated throughout the remainder of the sample, which can be observed from Fig. 1.

The TMU data are paired with the equity market data obtained from Bloomberg data services. We use the S&P500 as a proxy for the equity market. We examine the dynamic relation between the TMU and the following equity market variables: S&P500 returns (MKT), S&P500 index liquidity as measured by Amihud’s Illiquidity Ratio (ILR), and the Chicago Board Options Exchange’s CBOE Volatility Index (VIX).

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1. Morshet et al. (2021) show that large-scale Twitter data can be used as a source of information to understand the ride-hailing service users’ behavioral patterns by analyzing sentiment and emotions about a specific topic such as shared mobility or ridesharing. They show that due to the COVID-19 crisis, consumers’ sentiment measured through Twitter has become an essential requirement for understanding the behavioral patterns of ride-hailing service users.

2. The authors of policyuncertainty.com first extract all tweets sent on Twitter that contain keywords related to uncertainty as well as keywords related to equity markets. To construct the TMU index, the authors rescale each series to a mean of 100 from 2010 to 2015. A complete description of the construction of these data are also available on request. We thank the authors for making the data available.

3. Results are available on request.

4. The Amihud (2002) illiquidity ratio for the SP500 is defined as $ILR = |R|/VOLUME$, where $|R|$ is the absolute S&P500 returns in a day, and VOLUME is the dollar trading volume of the S&P500.

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Table 1 contains the summary statistics separately for the pre-pandemic period (January 3, 2011, to February 23, 2020) and the pandemic period (February 24, 2020, to August 31, 2020). The summary statistics clearly demonstrate that people have significantly increased their tweeting about uncertainty in the equity market during the pandemic. Mean and median values of the TMU are almost three times the pre-pandemic levels. Additionally, we find statistically significant increases in the averages of the VIX and ILR with mean values of the VIX increasing from 16.20% in the pre-pandemic period to 35.12% in the pandemic period. The summary statistics demonstrate that markets are more uncertain in the pandemic, and people are tweeting about it.

3. Empirical results

3.1. Univariate results

We begin our analysis with pairwise Granger causality tests. We select the optimal lag for the pairwise Granger causality based on the schwarz information criterion (SIC) to be two. Table 2 contains the results for the pre-pandemic period and the pandemic period separately. Most results are as expected and consistent with the literature. In the pre-pandemic period, the equity market returns and the VIX affect the amount that people tweet about the market’s uncertainty. If markets are up or if the VIX declines, then the uncertainty content of tweets also declines. However, in the pandemic period, the market returns lose their forecasting power on the TMU, while as expected the VIX still statistically affects the TMU. Interestingly, in the pre-pandemic period, the tweets are not a leading indicator of the market; however, in the highly uncertain pandemic period, the amount people tweet about uncertainty is a leading indicator of future returns.

Given the unique circumstances of the lockdowns and restrictions induced by the pandemic on social interactions, more people are seeking community through Twitter. Our results also show that during the pandemic period these interactions on social media are having a significant effect on the market. While pairwise Granger causality does not capture the underlying complex information exchange between the TMU and the equity market, the above analysis is informative in that it shows the endogenous relation among the variables.
3.2. Bayesian vector auto-regression analysis (BVAR)

We use a Bayesian vector autoregression (BVAR) with a “Minnesota prior” method to reduce over-parameterization. Koop and Korobilis (2010) argue that Bayesian methods are a superior way of dealing with the problem of over-parameterization when the length of a time-series is limited. In our analysis, the pandemic period is small relative to the full sample. Since each variable is related to other variables a possibility of over-parameterization exists in standard VAR analysis. The role of prior probabilities is important if the ratio of variables to observations increases and a Bayesian method is preferred.\(^5\)

![Fig. 2. Impulse Responses of MKT.](image)

**Notes:** Table 2 presents the results for the pairwise Granger causality test for the pre-pandemic period (01/03/2011–02/23/2020) and the pandemic period (02/24/2020–08/31/2020) separately. P-values are reported for each test. The ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

### Table 2

| Null Hypothesis                  | Pre-Covid | Covid  |
|---------------------------------|-----------|--------|
| TMU does not Granger cause MKT  | 0.11      | 0.01** |
| VIX does not Granger cause MKT  | 0.04**    | 0.04** |
| ILR does not Granger cause MKT  | 0.86      | 0.02** |
| MKT does not Granger cause TMU  | 0.00***   | 0.76   |
| VIX does not Granger cause TMU  | 0.01**    | 0.00***|
| ILR does not Granger cause VIX  | 0.1       | 0.11   |
| TMU does not Granger cause VIX  | 0.04**    | 0.18   |
| MKT does not Granger cause VIX  | 0.73      | 0.55   |
| ILR does not Granger cause VIX  | 0.69      | 0.00***|
| TMU does not Granger cause ILR  | 0.61      | 0.13   |
| MKT does not Granger cause ILR  | 0.00***   | 0.09*  |
| VIX does not Granger cause ILR  | 0.00***   | 0.00***|

Notes: Table 2 presents the results for the pairwise Granger causality test for the pre-pandemic period (01/03/2011–02/23/2020) and the pandemic period (02/24/2020–08/31/2020) separately. P-values are reported for each test. The ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

As a robustness check, we estimated models with standard unrestricted VAR models results are similar and available upon request.
We estimate a BVAR for the pre- and pandemic periods separately. Two lags are used in our BVARs based on the SIC criteria, and the endogenous variables are MKT, TMU, VIX, and ILR. The ordering of BVAR variables is always a concern. Thus, we investigate the generalized impulse responses where the ordering of the BVAR variables is unimportant (Pesaran and Shin 1998).

Figs. 2–5 show the IRFs. Panel A of each figure presents the impulse response functions (IRFs hereafter) for the pre-pandemic period, and Panel B presents the IRFs for the pandemic period. Our focus is the differential effects of the TMU on market variables and vice versa in the pre- and pandemic periods. Fig. 2 plots the IRF for the market return. A comparison of these periods shows that in general the market is more responsive to all shocks during the pandemic period. In the pre-pandemic period, the rate of change in the TMU has a very negligible effect on equity market returns of about 0.02% in the first day following a shock. In stark contrast, in the pandemic period, a generalized one standard-deviation shock to the rate at which people tweet about uncertainty strongly and negatively affects the market return by approximately 1.28% in the first day following a shock. This finding along with the earlier results support the idea that during the pandemic, people are relying on information from Twitter to make financial decisions.

Fig. 3 presents the IRFs for TMU. While in both the pre- and pandemic periods the equity market variables tend to affect the TMU, we observe that the effects are much stronger in the pandemic period. We suspect that this is because more people began trading stocks for leisure along with the fact that Twitter’s monetizable userbase increased by 34% during the initial stages of the pandemic. In the pre-pandemic period, a positive shock to the MKT decreased the TMU by 1.3%, while in the pandemic period a positive shock to the MKT decreased the TMU by over 10%. The same increased sensitivity of the TMU during the pandemic is also reported for the VIX and ILR. During the pre-pandemic period, the TMU was barely affected by shocks to the VIX or ILR. However, in the pandemic period a positive shock to the VIX and ILR elicited a 12% and 8% increase in the uncertainty content of tweets respectively.

Fig. 4 presents the IRFs for the VIX. In the pre-pandemic period, the TMU did not have a large effect on the VIX. However, in the pandemic period, a positive shock to the TMU resulted in a 2.33% increase in the VIX. These findings indicate that as the uncertainty reflected in the content of tweets increases during the pandemic, this is quickly translated into higher levels of implied market volatility. Fig. 5 presents the IRFs for the ILR. Like the other results, we show a much greater sensitivity of the ILR to a TMU shock in the pandemic period.
Fig. 4. Impulse Responses of VIX. This figure shows impulse responses of VIX to other variables in the endogenous Bayesian VAR. The endogenous variables are TMU, ILR, MKT, and VIX. The figure also shows the generalized impulse responses. Fig. 4A shows the 10-day responses of TMU to one standard-deviation positive shocks to other variables for the period from January 3, 2011, to February 23, 2020 (pre-pandemic). Fig. 4B shows the 10-day responses of TMU to one standard-deviation positive shocks to other variables for the period from February 24 to August 31, 2020 (pandemic).
4. Closing thoughts

The Covid-19 pandemic has changed the way people communicate and obtain financial information. The unique pandemic-induced lockdowns have increased the reliance on social media for communication and information sharing. Our results indicate that equity markets are becoming more sensitive to the uncertainty content contained in tweets. Prior to the pandemic, markets were a leading indicator of the uncertainty content of tweets; however, during the pandemic, the uncertainty content of tweets began to provide leading information about US equity markets. Taken together, these findings provide some evidence that the pandemic changed the way people invest. Amidst increased uncertainty, fear, and disruptions in leisure time, people are seeking community. Social media like Twitter provides this community virtually. Increased reliance and use of social media for information has led to an increase in the predictability of equity market variables from the information provided by this virtual society. The impacts of social media and retail investors on equity markets have grown since the onset of the Covid-19 pandemic. Therefore, it is critical for policy makers, portfolio managers, and traders to take into consideration the information contained in social media like Twitter.

Author Statement

I, Joseph J. French, certify that all authors have seen and approved the final version of the manuscript being submitted. I warrant that the article is the authors’ original work and has not received prior publication and is not under consideration for publication elsewhere.

Declaration of Competing Interest

None.

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References

Agrawal, S., Azar, P.D., Lo, A.W., Singh, T., 2018. Momentum, Mean-Reversion, and Social Media: evidence from Stock Twits and Twitter. J. Portfol. Management 44 (7), 85–95.

Amihud, Y., 2002. Illiquidity and stock returns: cross-section and time-series effects. J. Finan. Mark. 5 (1), 31–56.

Baker, S.R., Bloom, N., Davis, S.J., Kost, K.J., Sammon, M.C., Viratyosin, T., 2020. The Unprecedented Stock Market Impact of COVID-19. NBER Working paper 26945.

Bollen, J., Mao, H., Zeng, X.-J., 2011. Twitter mood predicts the stock market. J. Com- put. Sci. 2 (1), 1–8.

Bukovina, J., 2016. Social media big data and capital markets - an overview. J. Behav. Exp. Finance 11, 18–26.

Cepoi, Cosmin-Octavian, 2020. Asymmetric dependence between stock market returns and news during COVID-19 financial turmoil. Finan. Res. Lett. 36 (C). Elsevier.

Koop, G., Korobilis, D., 2010. Bayesian Multivariate Time Series Methods for Empirical Macroeconomics. Foundations and Trends® in Econometrics 3 (4), 267–358.

Morshed, S.A., Khan, S.S., Tanvir, R.B., Nur, S., 2021. Impact of COVID-19 pandemic on ride-hailing services based on large-scale Twitter data analysis. J. Urban Manage. in press.

Pesaran, H.H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. Econ Lett 58 (1), 17–29. Elsevier.

Ramelli, S., Wagner, A.F., 2020. Feverish stock price reactions to covid-19. The Review of Corporate Finance Studies 9 (3), 622–655. Pages.

Sprenger, T.O., Sandner, P.G., Tumasjan, A., Welpe, I.M., 2014a. News or noise? Using twitter to identify and understand company-specific news flows. J. Bus. Finance Account. 41, 791–830.

Sprenger, T.O., Sandner, P.G., Tumasjan, A., Welpe, I.M., 2014b. Tweets and trades: the information content of stock microblogs. Eur. Finan. Manage. 20 (5), 926–957.

Xu, L., 2020. Stock Return and the COVID-19 pandemic: evidence from Canada and the US. Finance Res. Lett., 101872.

You, W., Guo, Y., Peng, C. 2017. Twitter’s daily happiness sentiment and the predictability of stock returns. Finance Res. Lett. 23, 58–64.

Zhang, D., Hu, M., Ji, Q., 2020. Financial markets under the global pandemic of COVID-19. Finance Res. Lett., 101528

Hutchinson, Andrew. 2020. Twitter Adds More Users in Q2, but Sees Revenue Decline 19%. Available online: https://www.socialmediatoday.com/news/twitter-adds-more-users-in-q2-but-sees-revenue-decline-19/582222/ (accessed on 12 November 2020).