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Shall the winning last? A study of recent bubbles and persistence.

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Abstract

In this study, we analyze stock market performance of 43 firms that show very large price rises in COVID-19 times for the period 21/11/2019 – 20/1/2021. These cover 6 industries - work-from-home companies, stay-at-home companies, Cryptocurrency companies, Bitcoin companies, Coronavirus Vaccine companies and Coronavirus therapeutics companies. Our results demonstrate the presence of bubbles and persistence patterns.

Keywords: COVID19, bubble, persistence.

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Abstract

In this study, we analyze stock market performance of 43 firms that show very large price rises in COVID-19 times for the period 21/11/2019 – 20/1/2021. These cover 6 industries - work-from-home companies, stay-at-home companies, Cryptocurrency companies, Bitcoin companies, Coronavirus Vaccine companies and Coronavirus therapeutics companies. Our results demonstrate the presence of bubbles and persistence patterns.

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1. Introduction

Financial markets experienced significant price rises after the initial fall in response to the COVID pandemic. Gharib, Mefteh-Wali, & Jabeur (2021) document contagion effects of bubbles from oil to gold markets during the 2014/2015 crash and the COVID-19 outbreak¹. It is possible that similar contagion effects have generated price bubbles on multiple stocks in the sectors that were poised to benefit the most from the economic conditions caused by the pandemic, especially tech companies, companies with exposure to cryptocurrencies (particularly Bitcoin), pharmaceutical companies. This prompted us to investigate the possibility that price bubbles formed for stocks in these sectors. To the best of our knowledge, we are the first to investigate the bubble phenomenon in the context of these industries.

Consistent with the above reasoning, we chose to focus on companies with stocks from the six sectors that exhibited the most significant price rises as a consequence of the COVID pandemic i.e., Work-from-home product/service companies, Stay-at-home product/service, cryptocurrency related companies, and Coronavirus Vaccine and therapeutics companies. We hand-select the 43 companies that are most representative of the 6 industries that benefitted the most from the unprecedented COVID-19 crisis owing to the nature of their product/service offered (Table 1).

We also sought guidance from the TipRank.com classification of companies/markets. This service evaluates public stock recommendations made by financial analysts. TipRank also classifies companies that we use in our study in the same way as we did.

The literature provides several approaches to detect bubbles, such as the Residual Augmented Least Square Dickey-Fuller test of Taylor & Peel (1998), or the Log-Periodic Power Law method (Sornette, 2003; Jiang et al. 2010). Gürkaynak (2008) shows that econometric detection of asset price bubbles should be taken with some degree of caution. Phillips et al. (2011) propose a SADF test method based on the supremum of a set of forward recursive right-tailed ADF tests. Zhang et al. (2018) document that, in identifying multiple bubbles, the SADF method is less effective than extant

¹ Effects of the COVID-19 outbreak on different markets are discussed, for instance, in Jalan et al. (2021), Yarovaya et al. (2021), Le et al. (2021), Corbet et al. (2021), Aziz et al. (2020), Yarovaya et al. (2020a,b), among others.

alternatives. Phillips, Shi & Yu (2015a,b; 2017) extend the SADF to enhance test performance in identification of multiple bubbles.

The main favorable properties relate to the bootstrap procedure targeted at mitigating the potential impact of heteroskedasticity. The recursive evolving algorithm is more efficient compared to the forward expanding and rolling window algorithms in bubble identification, especially if the selected sample period contains multiple bubbles, as in our case. Phillips and Shi (2017) document consistency of the estimated switch date for crises under various data generating processes. While this method has been tested on different data (Harvey et al.2015; Zhang et al. 2018; Sharma & Escobari 2018; Zhao et al. 2021 etc.), Pavlidis et al. (2018) confirm favorable properties.

We apply this approach for the date stamping of bubbles in our sample and then go on to investigate the persistence of the price spikes using the Yang & Zhao (2020) quantile unit-root test to identify mean-reverting behaviour across quantiles. The unusual conditions that have been experienced in equity markets over our sample period due to the onset of the global pandemic have led to a fattening of the tails of the return distribution for several stocks in our sample. Also, fat tails are typical of cryptocurrencies, to which some of our stocks are exposed. Yang and Zhao (2020) show that their proposed test is more powerful than conventional unit root tests, especially in the presence of heavy tailed distributions, that is mainly the case for the crypto currency market. Furthermore, their test allows testing of the unit root hypothesis against the mean reversion alternative on a quantile-by-quantile basis, which is not possible with conventional tests.

Our results indicate the presence of price bubbles in almost all markets analyzed. In terms of persistence, 24 of our 43 companies demonstrate complete absence of mean reversion, implying higher risk in the long run. Several firms in the work-from-home, cryptocurrency and coronavirus-vaccine groups show reversion in higher quantiles.

The rest of this paper is organized as follows. Section 2 introduces the data and the methodology while Section 3 presents the empirical results. Section 4 summarizes our paper and provides conclusions.

Table 1. Selected companies by market classification

	<i>Group 1</i>		<i>Group 2</i>		<i>Group 3</i>		<i>Group 4</i>		<i>Group 5</i>		<i>Group 6</i>	
	Work-from-home product/service companies (companies that provide products and technological services related to continuity of business in the new COVID-19 conditions)		Stay-at-home product/service companies		Cryptocurrency companies (companies that provide products/services related to cryptocurrency market)		Bitcoin companies (companies that provide products/services linked bitcoin market or invested into bitcoin)		Coronavirus Vaccine companies		Coronavirus therapeutics companies	
1	LOGI	Logitech	ROKU	Roku, Inc.	NVDA ²	Nvidia Corporation	MSTR	Microstrategy Incorporated	PFE	Pfizer Inc	REGN	Regeneron, Inc
2	BOX	Box, Inc.	NFLX	Netflix	AMD	Advanced micro Devices	OSTK	Overstock.com Inc	MRNA	Moderna, Inc	GILD	Gelead Sciences, Inc.
3	ZM	Zoom video communication.	DOCU	DocuSign, Inc.	SQ	Square, Inc	HVBTF	HIVE Blockchain Technologies Ltd	BNTX	BioNTech SE	SRNE	Sorrento Therapeutics, Inc.
4	TWLO	Twillio	PTON	Pelaton Interactive, Inc.	IBKR	Interactive Brokers Group, Inc. (IBG, Inc.)	RIOT	Riot blockchain Inc.	JNJ	Johnson and Johnson	AMGN	Amgen Inc.
5	ESTC	Elastic	PINS	Pinterest	CME	CME group	MARA	Marathon Patent Group Inc	AZN	AstraZaneca PLC	ABBV	AbbVie Inc.
6	VNWX	Vmware	CHWY	Chewy, Inc.	V ³	Visa Inc.	CAN	Canaan Inc	NVAX	Novavax, Inc	GSK	GlaxoSmithKline PLC
7	UPLD	Upland software			PYPL	PayPal holdings, Inc.	GBTC	Grayscale Bitcoin Trust	INO	Inovio Pharmaceuticals, Inc.	LLY	Eli Lilly and Company
8	MSFT	Microsoft										
9	GOOGL	Alphabet										

² While it is hard to trace how its graphical processors are employed by end-users (i.e., whether they are used in gaming and cryptocurrency mining), an NVIDIA report shows that the demand for GeForce RTX was “incredible” in 2020 (<https://nvidianews.nvidia.com/news/nvidia-announces-financial-results-for-fourth-quarter-and-fiscal-2021>). The company asserts that the significant increase in the Ethereum network hash rate was driven by their GPUs and ASICs. Also, NVIDIA at the beginning of the sample period launched the crypto-mining processors for professional cryptocurrency mining (Source: <https://finance.yahoo.com/news/edited-transcript-nvda-oq-earnings-220000362.html>)

³ Visa launched a pilot program for payment with cryptos. On account of the project’s scalability and Visa’s large market share and dominant position in the payment business, the potential growth from the project can be immense. This provides us a major reason to believe that Visa’s stock price is significantly exposed to fluctuations in cryptocurrency prices.

2. Data and methodology

We collect daily close-price observations for the selected 43 companies over the period 21/11/2019 – 20/1/2021 (Thomson-EIKON). The length of our time series is defined by data availability. General statistics are provided in Appendix Tables A1-A2. To detect bubbles, we use the Phillips, Shi & Yu (2015a,b; 2017) approach. The test is designed to make inference on the $\delta_{r_1 r_2}$ coefficient of the following recursive regression:

$$\Delta x_t = \alpha_{r_1 r_2} + \delta_{r_1 r_2} x_{t-1} + \sum_{k=1}^K \beta_{r_1 r_2}^k \Delta x_{t-k} + u_t. \quad (1)$$

Here, x_t denotes the natural log of the asset price, $\alpha_{r_1 r_2}$ is the constant intercept, $\delta_{r_1 r_2} = 1 - \rho_{r_1 r_2}$ ($\{x_t\}$ is a random walk with drift when $\rho = 1$, and an explosive process when $\rho > 1$ meaning a departure from an efficient market, $u_t \sim NID(0, \sigma_{r_1 r_2}^2)$), and K is the lag order from minimizing the BIC, and r_1 and r_2 are the start and end points of the regression sample.

A rolling version of the ADF statistic is used with a rolling window. As an extension, Phillips, Shi & Yu (2015a,b; 2017) introduced the SADF test (supremum ADF), that uses recursive calculations of the ADF statistics by applying a fixed starting point and an expanding window. The SADF statistic is defined as the supremum value of the ADF_{r_2} sequence for $r_2 \in [r_0, 1]$ in the form of $ADF(r_0) = \sup_{r_2 \in [r_0, 1]} \{ADF_{r_2}\}$ (r_0 represents the minimum window width).

The generalized SADF (GSADF) statistic is defined as the supremum of the ADF statistics sequence over all feasible ranges of r_1, r_2 , allowing for changes in end-point fraction r_2 from r_0 to 1 and in the starting point fraction r_1 from 0 to $r_2 - r_0$, ensuring discriminatory power if more than one speculative bubble happens:

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \{ADF_{r_1}^{r_2}\} = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ \frac{\hat{\delta}_{r_1 r_2}}{se(\hat{\delta}_{r_1 r_2})} \right\}. \quad (2)$$

Thus, although the SADF and GSADF tests share a common testing variable, they differ in the rolling window setting. The SADF test requires a repeated ADF test on a forward expanding

sample sequence. The GSADF test differs from the SADF test in terms of variability of the starting and end point that can be changed simultaneously.

Following Phillips, Shi & Yu (2015a,b; 2017) approach, we locate specific start and end points of bubbles by calculating and comparing *the backward SADF and BSADF* statistics with the 95% SADF finite sample critical value sequence:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \{ADF_{r_1}^{r_2}\} \quad (3)$$

If $BSADF_{r_2}(r_0)$ is greater than the corresponding critical value of the standard ADF statistic at time Tr_2 , this time point is set as the start date of a bubble. Under the null hypothesis, $\{x\}$ is a random walk with an asymptotically negligible drift and the limit distributions of SADF and GSADF test statistics are defined as:

$$\frac{\frac{1}{2}[B(1)^2 - 1] - B(1) \int_0^1 B(s) ds}{\left\{ \int_0^1 B(s)^2 ds - \left[\int_0^1 B(s) ds \right]^2 \right\}^{\frac{1}{2}}} \quad (4)$$

$$\sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left(\frac{\frac{1}{2}r_w[B(r_2)^2 - B(r_1)^2 - r_w] - \int_{r_1}^{r_2} B(r) dr [B(r_2) - B(r_1)]}{r_w^{1/2} \left\{ r_w \int_{r_1}^{r_2} B(r)^2 dr - \left[\int_{r_1}^{r_2} B(r) dr \right]^2 \right\}^{\frac{1}{2}}} \right) \quad (5)$$

where $r_w = r_2 - r_1$, B is a standard Brownian motion. Critical values are derived using Monte Carlo simulations.

To investigate the potential of a market to bounce back to recovery after the initial shock, we apply quantile unit root tests. Following Galvao (2009) and Yang & Zhao (2020), the quantile nonlinear unit root test statistic with covariates is:

$$t(\tau) = \frac{f(F^{-1}(\tau))}{\sqrt{\tau(1-\tau)}} (Y'_{-1} M_Z Y_{-1})^{\frac{1}{2}} \hat{\delta}(\tau), \quad (6)$$

where $f(F^{-1}(\tau))$ is a consistent estimator of $f(F^{-1}(\tau))$, with f and F representing the density and distribution function of u_t , Y_{-1} is the vector of the values taken in the sample period by the lagged dependent variable y_{t-1} , M_Z is the projection matrix onto the space orthogonal to $z =$

$(1, \Delta y_{t-1}, \dots, \Delta y_{t-p}, x'_{t-q_1}, x'_{t+q_2})$. The test statistic $t(\tau)$ under the null converges to (Yang & Zhao 2020 and Koenker & Xiao 2004):

$$\xi(\tau) = \lambda \frac{\int_0^1 W_1 dW_1}{\sqrt{\int_0^1 W_1^2 dr}} + \sqrt{1 - \lambda^2} \frac{\int_0^1 W_1 dW_2}{\sqrt{\int_0^1 W_1^2 dr}}, \quad (7)$$

where $\underline{W}_1 = W_1^3 - \int_0^1 W_1^3 dr$; W_1, W_2 are standard Brownian motions, independent of one

another, $\lambda = \lambda(\tau) = \frac{\sigma_u \psi(\tau)}{\sigma_u \sigma_\psi(\tau)} = \frac{\sigma_u \psi(\tau)}{\sigma_u \sqrt{\tau(1-\tau)}}$, $\psi_\tau(u) = \tau - I(u < 0)$, $e_{t\tau} = \Delta y_t - z'_t \beta(\tau)$,

$E[\psi_\tau(e_{t\tau}) | \mathbb{F}_{t-1}] = 0$. The asymptotic theory for near-integrated processes utilizes the Ornstein-Uhlenbeck process (Chan & Wei, 1987).

We compute these statistics for the distance of the log-price to the stationary mean of each asset, $y_t = x_t - \mu$, where $x_t = \log(p_t)$, and μ is its sample mean. The lag orders are chosen using the BIC. For estimating long-run variance and covariance parameters, we use the Bartlett-Parzen kernel and Quadratic Spectral windows in the kernel estimators following Galvao (2009) and Yang & Zhao (2020). We compare obtained results with pre-calculated critical values at several significance levels.

3. Results

Univariate results suggest that mean return is the highest for the Bitcoin companies' group (0.0094), followed by coronavirus vaccine companies (0.0061). Average median for returns is lower than average mean, indicating that the data is skewed to the right. The highest maximum return for the whole sample is observed for Sorrento (1.58), a coronavirus therapeutic company. The highest standard deviation and variance is noted for Marathon (0.117), a Bitcoin company, while the lowest for Johnson&Johnson (0.076), a coronavirus vaccine company (Tables A1-A2 in appendix).

Bubble estimates show that bitcoin and stay-at-home companies dominate in terms of bubble length (Tables A3-A8), while Coronavirus-Vaccine and Cryptocurrency companies have the lowest average bubble length. March 2020 represents the most common bubble period for most

companies. For Bitcoin companies, bubbles are observed mainly at end-2020-start-2021, while for COVID-vaccine companies, this period is March and July 2020.

Persistence results are presented in Fig.1 and Tables A9-A14 in Appendix. Rejecting the null hypothesis of a unit root implies that shocks are not accumulated over time. Mean reversion also implies that stocks become less risky in the long run, making them more attractive for long-term investors.

HO (unit root) rejected	BOX RIOT GILD ZM MARA CAN						BOX CME PFE AMGN VNW V JNJ UPLD AZN MSFT NVAX GOOGL			
	HO (unit root) not rejected	LOGI ROKU NVDA MSTR PFE REGN TWLO NFLX AMD OSTK MRNA SRNE ESTC ZM SQ HVBTF BNTX AMGN VNW DOCU IBKR JNJ ABBV UPLD PTON CME AZN GSK MSFT PINS V NVAX LLY GOOGL CHWY PYPL INO						LOGI ROKU MRNA REGN ZM NFLX BNTX GILD TWLO ZM SRNE ESTC DOCU ABBV PTON GSK PINS LLY CHWY		
		Lower quantiles						Higher quantiles		

Fig. 1. Persistence results grouped by quantiles and presence of mean reversion (details in Appendix Tables A9-A14).

For our selected work-from-home companies, mean reversion is observed only for 6 companies, of which 4 provide evidence of reversion only in higher quantiles of the shock. Interestingly, all our stay-at-home companies demonstrate complete absence of mean reversion, making them potentially risky for long-term investment. Of our 7 cryptocurrency companies, only CME and Visa demonstrate mean reversion in higher quantiles. 3 of our 7 Bitcoin companies demonstrate mean reversion in lower quantiles. The coronavirus vaccine and therapeutic group shows evidence of mean reversion largely in lower quantiles only.

4. Conclusion

We document the presence of price bubbles in almost all markets analyzed. In terms of persistence, 24 of our 43 companies demonstrate complete absence of mean reversion, implying higher risk in the long run. Some firms in the work-from-home, cryptocurrency and coronavirus-vaccine groups show reversion in higher quantiles.

The implications of our results are multidimensional. The presence of mean reversion contradicts the Efficient Market Hypothesis and may imply pricing irregularities that are inconsistent with equilibrium asset pricing models (Forbes, 1996).

Another implication of our results is their applicability to trading strategies. Bubbles can be exploited by arbitrageurs to outperform other traders (Westphal & Sornette, 2020). In terms of persistence, several studies (e.g., Balvers et al. 2000; Gropp, 2004) document that excess returns can be generated by exploiting mean reversion of prices. During periods of bubbles, valuation is temporarily mean averting, implying that expected returns from valuation change are positive. Given that bubbles are impacted by both valuation and expected change in profitability (Tarlle et al. 2018), our results can be useful for policy makers in terms of their impact on both valuation and profitability.

Literature on the subject identifies mean-reverting behaviour as a function of numerous factors that can lead to further pricing abnormalities and potential disruption such as market efficiency and company performance (e.g., Jagadeesh and Titman, 1993; Fama and French, 2000), momentums (e.g., Serban, 2010), bullish/bearish market conditions (e.g., Cuñado, Gil-Alana, and de Gracia, 2010 etc.) and herding and market overreaction (e.g., De Bondt and Thaler, 1985, 1987; Zarowin, 1989, 1990). In addition, mean-reversion can be time-varying (e.g., Mukherji, 2011 etc.).

Therefore, given the wide scope and complexity of the phenomenon coupled with the high heterogeneity of markets and companies in our sample, it is beyond the scope of this study to explain the reasons for mean-reversion in some markets/ companies and not in others. However, we acknowledge that more research is needed to investigate the phenomenon in detail to assess

relationship among the listed factors. This inquiry can also be extended with implied volatility and risk premiums in the selected markets as explanatory factors for detecting the presence/absence of mean reversion during a crisis, something that we leave for future research.

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APPENDIX

Table A1. General statistics for selected companies: Close prices

	mean	median	min	max	variance	SD	skewness	kurtosis
Work-from-home product/service companies								
Logitech	63.63	62.27	33.89	104.85	357.44	18.91	0.37	-1.12
Box	17.17	17.27	9.12	22.06	3.79	1.95	-0.89	2.61
Zoom	247.53	242.56	62.49	568.34	21746.85	147.47	0.38	-1.20
Twilio	204.87	212.17	71.70	392.97	8311.25	91.17	0.20	-1.27
Elastic	90.85	88.74	44.12	169.65	827.81	28.77	0.72	-0.18
Vmware	141.43	142.23	93.01	168.73	150.89	12.28	-1.20	2.41
Upland	37.35	36.77	22.38	49.60	36.99	6.08	-0.28	-0.62
Microsoft	190.30	196.84	135.42	231.65	622.83	24.96	-0.35	-1.25
Alphabet	1478.50	1466.02	1054.13	1880.07	32018.08	178.94	0.05	-0.42
Average	274.63	273.87	169.58	398.66	7119.55	56.73	-0.11	-0.12
Stay-at-home product/service companies								
Roku	171.87	145.57	63.84	434.14	6313.15	79.46	1.46	1.44
Netflix	436.75	453.72	293.12	586.34	5529.46	74.36	-0.34	-1.23
Docusign	155.51	163.91	68.68	268.80	4288.91	65.49	-0.05	-1.67
Peloton	67.14	53.03	19.51	167.42	1729.09	41.58	0.78	-0.66
Pinterest	33.40	23.54	10.92	75.07	357.30	18.90	0.97	-0.53
Chewy	50.25	47.52	22.68	114.63	453.58	21.30	0.97	0.48
Average	152.49	147.88	79.79	274.4	3111.92	50.18	0.63	-0.36
Cryptocurrency companies								
Nvidia	384.56	369.44	196.40	582.48	15348.53	123.89	0.04	-1.61
Amd	64.48	55.31	38.71	97.25	337.67	18.38	0.30	-1.50
Square	120.52	100.88	38.09	241.58	3383.84	58.17	0.52	-1.09
Interactive Brokers	49.10	48.58	35.28	69.88	42.77	6.54	0.87	1.39
Cme	182.20	178.48	139.54	223.63	319.18	17.87	0.36	-0.84
Visa	193.91	196.48	135.74	218.73	226.21	15.04	-0.98	0.90
Paypal	159.76	168.05	85.26	247.25	2075.97	45.56	0.10	-1.35
Average	164.93	159.6	95.57	240.11	3104.88	40.78	0.17	-0.59
Bitcoin companies								
Microstrategy	173.03	144.59	92.20	631.00	9024.89	95.00	2.72	7.39
Overstock	38.37	25.91	2.65	122.32	1009.84	31.78	0.54	-0.88
Hive Blockchain	0.44	0.27	0.06	2.65	0.31	0.55	2.50	5.16
Riot Blockchain	3.92	2.29	0.65	28.90	25.89	5.09	2.90	8.36
Marathon	2.85	1.09	0.40	26.39	20.74	4.55	3.38	11.77
Canaan	3.85	3.52	1.79	8.99	3.24	1.80	0.64	-0.49
Grayscale Bitcoin	13.58	11.03	5.54	44.97	57.76	7.60	2.26	4.91
Average	33.72	26.96	14.76	123.6	1448.95	20.91	2.13	5.17
Coronavirus Vaccine companies								
Pfizer	35.21	35.68	27.01	42.56	5.84	2.42	-0.54	1.17
Moderna	60.89	62.61	17.78	169.86	1296.05	36.00	0.81	0.23

Biontech	62.76	58.57	19.68	129.54	722.21	26.87	0.44	-0.80
Johnson & Johnson	146.04	147.19	111.14	162.78	49.46	7.03	-1.19	3.61
Astrazeneca	7968.55	8000.00	6221.00	9320.00	353683.10	594.71	-0.28	-0.67
Novavax	65.11	65.95	3.75	178.51	2681.68	51.78	0.15	-1.49
Inovio	10.76	10.49	2.33	31.69	37.02	6.08	0.86	0.79
Average	1192.76	1197.21	914.67	1433.56	51210.77	103.56	0.04	0.41
Coronavirus therapeutics companies								
Regeneron	514.51	528.61	336.18	658.21	8185.53	90.47	-0.45	-1.06
Gilead	68.25	66.80	56.65	84.00	43.39	6.59	0.26	-1.05
Sorrento	5.82	5.70	1.57	18.82	9.32	3.05	0.70	0.33
Amgen	232.26	233.84	182.24	260.95	204.10	14.29	-0.69	0.77
Abbvie	91.56	90.49	64.50	112.62	76.14	8.73	-0.04	0.23
Glaxosmithkline	1568.93	1575.00	1291.80	1846.00	21363.04	146.16	0.04	-1.16
Eli Lilly	147.79	148.02	114.75	201.26	211.08	14.53	0.27	0.88
Average	375.59	378.35	292.53	454.55	4298.94	40.55	0.01	-0.15

Table A2. General statistics for selected companies: Log returns

	mean	median	min	max	variance	SD	skewness	kurtosis
Work-from-home product/service companies								
Logitech	0.0032	0.0019	-0.1918	0.1576	0.0007	0.0270	-0.4810	13.0598
Box	0.0009	0.0000	-0.1656	0.2085	0.0010	0.0321	0.3823	9.4177
Zoom	0.0068	0.0044	-0.1737	0.4078	0.0026	0.0506	1.6139	13.7710
Twilio	0.0052	0.0038	-0.1036	0.3962	0.0017	0.0408	2.9179	26.8147
Elastic	0.0032	0.0015	-0.1788	0.1287	0.0013	0.0356	-0.2522	4.1621
Vmware	-0.0004	0.0000	-0.1114	0.1025	0.0007	0.0266	-0.2589	3.1367
Upland	0.0015	0.0033	-0.1300	0.1133	0.0012	0.0341	-0.4988	1.6878
Microsoft	0.0017	0.0011	-0.1474	0.1422	0.0007	0.0256	-0.0600	7.5341
Alphabet	0.0015	0.0012	-0.1163	0.0924	0.0005	0.0226	-0.2336	4.6053
Average	0.0026	0.0019	-0.1465	0.1944	0.0012	0.0328	0.3477	9.3544
Stay-at-home product/service companies								
Roku	0.0043	0.0001	-0.2114	0.1767	0.0020	0.0449	0.1533	3.2305
Netflix	0.0025	0.0000	-0.1114	0.1685	0.0008	0.0289	0.5890	4.9744
Docusign	0.0049	0.0023	-0.1471	0.2054	0.0013	0.0360	0.5062	4.9683
Peloton	0.0065	0.0054	-0.2029	0.1601	0.0021	0.0459	-0.1305	1.5150
Pinterest	0.0055	0.0012	-0.1866	0.3613	0.0024	0.0487	1.5747	12.5991
Chewy	0.0059	0.0032	-0.1170	0.1538	0.0017	0.0416	0.2996	1.3331
Average	0.0049	0.002	-0.1627	0.2043	0.0017	0.041	0.4987	4.7701
Cryptocurrency companies								
Nvidia	0.0037	0.0032	-0.1845	0.1716	0.0012	0.0341	-0.2414	5.1491
Amd	0.0033	0.0000	-0.1464	0.1650	0.0013	0.0361	0.3069	3.1974
Square	0.0049	0.0030	-0.2856	0.1575	0.0018	0.0426	-0.7528	7.9797
Interactive Brokers	0.0016	0.0007	-0.1036	0.1548	0.0008	0.0276	0.2192	4.4174
Cme	0.0001	0.0000	-0.1839	0.1184	0.0008	0.0278	-1.0634	11.5345

Visa	0.0008	0.0012	-0.1355	0.1384	0.0006	0.0248	0.2562	7.9881
Paypal	0.0033	0.0014	-0.1582	0.1411	0.0009	0.0306	0.2627	5.7857
Average	0.0025	0.0014	-0.1711	0.1495	0.0011	0.0319	-0.1447	6.5788
Bitcoin companies								
Microstrategy	0.0050	0.0005	-0.1569	0.2636	0.0016	0.0395	1.5612	10.5197
Overstock	0.0097	0.0000	-0.2489	0.2808	0.0058	0.0762	0.5948	1.9721
Hive Blockchain	0.0150	0.0000	-0.2647	0.4486	0.0093	0.0963	0.8495	2.4257
Riot Blockchain	0.0126	0.0000	-0.2968	0.4841	0.0075	0.0866	1.0529	4.4210
Marathon	0.0158	-0.0001	-0.2560	0.8867	0.0137	0.1170	2.1452	10.8809
Canaan	0.0015	-0.0050	-0.2647	0.8273	0.0078	0.0882	3.0302	25.2252
Grayscale Bitcoin	0.0059	0.0000	-0.2544	0.2314	0.0030	0.0551	0.1088	2.8337
Average	0.0094	-0.0007	-0.2489	0.4889	0.007	0.0798	1.3347	8.3255
Coronavirus Vaccine companies								
Pfizer	0.0003	-0.0005	-0.0773	0.0896	0.0004	0.0208	0.0623	3.7418
Moderna	0.0077	0.0000	-0.1797	0.2781	0.0035	0.0594	0.8821	3.1222
Biontech	0.0084	0.0010	-0.3554	0.6650	0.0064	0.0801	2.0533	17.0275
Johnson & Johnson	0.0007	0.0000	-0.0730	0.0800	0.0003	0.0176	0.3474	6.2051
Astrazeneca	0.0003	0.0000	-0.0922	0.0804	0.0004	0.0190	0.1054	3.1189
Novavax	0.0158	0.0013	-0.2780	0.7108	0.0097	0.0984	2.3969	13.3529
Inovio	0.0096	0.0000	-0.4201	0.6970	0.0110	0.1051	1.5284	9.4338
Average	0.0061	0.0003	-0.2108	0.3716	0.0045	0.0572	1.0537	8.0003
Coronavirus therapeutics companies								
Regeneron	0.0018	0.0000	-0.1049	0.1154	0.0006	0.0253	0.3524	2.3667
Gilead	0.0004	-0.0008	-0.0835	0.0973	0.0005	0.0224	0.5748	3.3006
Sorrento	0.0117	0.0000	-0.2513	1.5802	0.0166	0.1289	7.3146	78.9128
Amgen	0.0006	-0.0001	-0.0826	0.1090	0.0005	0.0223	0.7752	4.7752
Abbvie	0.0011	0.0000	-0.1300	0.0872	0.0004	0.0203	-0.3369	7.9344
Glaxosmithkline	-0.0005	0.0000	-0.0775	0.0716	0.0003	0.0170	0.0273	2.7430
Eli Lilly	0.0022	0.0000	-0.1000	0.1568	0.0007	0.0259	1.6405	9.8057
Average	0.0025	-0.0001	-0.1185	0.3168	0.0028	0.0374	1.4783	15.6912

Note: Mean return is the highest for the group of the Bitcoin companies (0.0094), followed by the coronavirus vaccine companies (0.0061). Average median for returns is generally lower than average mean, indicating that the data are skewed to the right. The highest maximum return for the whole sample is observed for Sorrento (1.58), a coronavirus therapeutic company. The highest standard deviation and variance is noted for Marathon (0.1170), a Bitcoin company, while the lowest for Johnson and Johnson (0.076), a coronavirus vaccine company.

Table A3. Bubbles: Work-from-home companies

The table provides the start and end date of price bubbles identified using close price data for the selected companies in the group. Column 3 calculates the ‘number of bubble-days’ which is simply a measure of the length of the bubble from start to end. This is done to facilitate inter-industry comparison for the presence and intensity of bubbles.

start	end	N bubble-days
LOGITECH		
24/02/2020	28/02/2020	5
09/03/2020	09/03/2020	1
12/03/2020	18/03/2020	7
08/05/2020	27/08/2020	112
31/08/2020	02/09/2020	3
05/10/2020	05/10/2020	1
12/10/2020	13/10/2020	2
20/10/2020	06/11/2020	18
11/11/2020	11/11/2020	1
17/12/2020	20/01/2021	35
BOX		
12/03/2020	18/03/2020	7
26/05/2020	26/05/2020	1
ZOOM		
19/02/2020	20/02/2020	2
26/02/2020	27/02/2020	2
03/03/2020	05/03/2020	3
23/03/2020	23/03/2020	1
22/06/2020	26/06/2020	5
01/09/2020	03/09/2020	3
09/09/2020	09/09/2020	1
18/09/2020	27/10/2020	40
TWILIO		
13/01/2020	13/01/2020	1
16/03/2020	16/03/2020	1
07/05/2020	07/05/2020	1
08/07/2020	08/07/2020	1
ELASTIC	no bubbles	
VMWARE	no bubbles	
UPLAND		
09/01/2020	09/01/2020	1
13/01/2020	13/01/2020	1
16/03/2020	16/03/2020	1
01/06/2020	03/06/2020	3
05/06/2020	09/06/2020	5
MICROSOFT		
17/01/2020	17/01/2020	1
04/02/2020	12/02/2020	9
18/02/2020	18/02/2020	1

16/06/2020	16/06/2020	1
18/06/2020	25/06/2020	8
30/06/2020	13/07/2020	14
ALPHABET		
17/01/2020	17/01/2020	1
09/03/2020	09/03/2020	1
12/03/2020	12/03/2020	1
16/03/2020	18/03/2020	3
20/03/2020	23/03/2020	4
11/11/2020	13/11/2020	3
Total bubble-days for the group		312
Number of firms in the sample		9
Average bubble-days for the group		34.67

Table A4. Bubbles: Stay-at-home companies

The table provides the start and end date of price bubbles identified using close price data for the selected companies in the group. Column 3 calculates the ‘number of bubble-days’ which is simply a measure of the length of the bubble from start to end. This is done to facilitate inter-industry comparison for the presence and intensity of bubbles.

start	end	N bubble-days
ROKU		
09/03/2020	09/03/2020	1
11/03/2020	20/03/2020	10
13/10/2020	14/10/2020	2
30/11/2020	01/12/2020	2
04/12/2020	30/12/2020	27
06/01/2021	20/01/2021	15
NETFLIX		
05/02/2020	05/02/2020	1
07/02/2020	20/02/2020	14
10/07/2020	15/07/2020	6
DOCUSIGN		
12/02/2020	19/02/2020	8
21/05/2020	21/05/2020	1
29/05/2020	08/06/2020	11
10/06/2020	23/07/2020	44
29/07/2020	07/08/2020	10
01/09/2020	02/09/2020	2
PELOTON		
10/07/2020	10/07/2020	1
02/09/2020	02/09/2020	1
08/09/2020	10/09/2020	3
21/09/2020	23/09/2020	3
25/09/2020	21/10/2020	27
22/12/2020	23/12/2020	2
PINTEREST		
16/01/2020	20/01/2020	5
07/02/2020	07/02/2020	1
09/03/2020	09/03/2020	1
11/03/2020	23/03/2020	13
24/04/2020	27/04/2020	4
30/04/2020	30/04/2020	1
31/07/2020	10/08/2020	11
12/08/2020	12/08/2020	1
01/10/2020	05/10/2020	5
19/10/2020	19/10/2020	1
21/10/2020	29/12/2020	70
04/01/2021	05/01/2021	2
07/01/2021	20/01/2021	14
CHEWY		

09/04/2020	10/04/2020	2
15/04/2020	20/04/2020	6
22/04/2020	22/04/2020	1
27/04/2020	27/04/2020	1
01/09/2020	02/09/2020	2
08/12/2020	08/12/2020	1
10/12/2020	25/12/2020	16
13/01/2021	18/01/2021	6
Total bubble-days for the group		355
Number of firms in the sample		6
Average bubble-days for the group		59.17

Table A5. Bubbles: Cryptocurrency companies

The table provides the start and end date of price bubbles identified using close price data for the selected companies in the group. Column 3 calculates the ‘number of bubble-days’ which is simply a measure of the length of the bubble from start to end. This is done to facilitate inter-industry comparison for the presence and intensity of bubbles.

start	end	N bubble-days
NVIDIA		
14/02/2020	20/02/2020	7
18/05/2020	26/05/2020	9
08/07/2020	14/07/2020	7
17/08/2020	07/09/2020	22
AMD		
19/02/2020	19/02/2020	1
24/07/2020	07/08/2020	15
01/09/2020	01/09/2020	1
04/12/2020	07/12/2020	4
SQUARE	No bubbles	
INTERACTIVE BROKERS		
13/01/2020	14/01/2020	2
16/01/2020	22/01/2020	7
23/03/2020	23/03/2020	1
15/07/2020	15/07/2020	1
23/12/2020	29/12/2020	7
06/01/2021	19/01/2021	14
CME		
28/10/2020	02/11/2020	6
04/11/2020	05/11/2020	2
VISA		
13/01/2020	23/01/2020	11
29/01/2020	30/01/2020	2
16/03/2020	24/03/2020	9
28/08/2020	28/08/2020	1
02/09/2020	02/09/2020	1
28/10/2020	28/10/2020	1
PAYPAL		
09/03/2020	09/03/2020	1
18/03/2020	18/03/2020	1
20/03/2020	23/03/2020	4
07/05/2020	15/05/2020	9
Total bubble-days for the group		146
Number of firms in the sample		7
Average bubble-days for the group		20.86

Table A6. Bubbles: Bitcoin companies

The table provides the start and end date of price bubbles identified using close price data for the selected companies in the group. Column 3 calculates the ‘number of bubble-days’ which is simply a measure of the length of the bubble from start to end. This is done to facilitate inter-industry comparison for the presence and intensity of bubbles.

start	end	N bubble-days
MICROSTRATEGY		
12/03/2020	23/03/2020	12
11/08/2020	24/08/2020	14
18/11/2020	08/12/2020	21
28/12/2020	20/01/2021	24
OVERSTOCK		
12/03/2020	17/03/2020	6
06/05/2020	14/05/2020	9
02/06/2020	02/06/2020	1
04/06/2020	04/06/2020	1
10/06/2020	10/06/2020	1
22/06/2020	22/06/2020	1
26/06/2020	26/06/2020	1
01/07/2020	26/08/2020	57
HIVE BLOCKCHAIN		
30/01/2020	30/01/2020	1
06/02/2020	12/02/2020	7
18/02/2020	18/02/2020	1
29/04/2020	30/04/2020	2
07/05/2020	08/05/2020	2
03/08/2020	03/08/2020	1
20/11/2020	26/11/2020	7
30/11/2020	20/01/2021	52
RIOT BLOCKCHAIN		
12/03/2020	12/03/2020	1
16/03/2020	16/03/2020	1
08/05/2020	08/05/2020	1
14/05/2020	14/05/2020	1
18/05/2020	20/05/2020	3
10/06/2020	10/06/2020	1
05/08/2020	06/08/2020	2
17/11/2020	17/11/2020	1
23/11/2020	26/11/2020	4
30/11/2020	20/01/2021	52
MARATHON		
08/05/2020	08/05/2020	1
28/07/2020	29/07/2020	2
31/07/2020	03/08/2020	4
05/08/2020	10/08/2020	6
23/11/2020	23/11/2020	1

25/11/2020	25/11/2020	1
16/12/2020	29/12/2020	14
05/01/2021	19/01/2021	15
CANAAN		
16/11/2020	30/11/2020	15
04/01/2021	04/01/2021	1
GRAYSCALE BITCOIN		
11/02/2020	12/02/2020	2
16/03/2020	16/03/2020	1
06/05/2020	08/05/2020	3
06/08/2020	06/08/2020	1
22/10/2020	22/10/2020	1
27/10/2020	27/10/2020	1
04/11/2020	09/11/2020	6
12/11/2020	12/11/2020	1
16/11/2020	26/11/2020	11
30/11/2020	08/12/2020	9
16/12/2020	20/01/2021	36
Total bubble-days for the group		420
Number of firms in the sample		7
Average bubble-days for the group		60

Table A7. Bubbles: Coronavirus Vaccine companies

The table provides the start and end date of price bubbles identified using close price data for the selected companies in the group. Column 3 calculates the ‘number of bubble-days’ which is simply a measure of the length of the bubble from start to end. This is done to facilitate inter-industry comparison for the presence and intensity of bubbles.

start	end	N bubble- days
PFIZER		
24/02/2020	25/02/2020	2
28/02/2020	28/02/2020	1
11/03/2020	12/03/2020	2
16/03/2020	17/03/2020	2
19/03/2020	25/03/2020	7
15/06/2020	16/06/2020	2
18/06/2020	18/06/2020	1
22/07/2020	23/07/2020	2
28/07/2020	29/07/2020	2
10/09/2020	10/09/2020	1
08/12/2020	08/12/2020	1
MODERNA		
17/04/2020	22/04/2020	6
24/04/2020	27/04/2020	4
08/05/2020	20/05/2020	13
25/11/2020	25/11/2020	1
27/11/2020	08/12/2020	12
BIONTECH		
13/07/2020	15/07/2020	3
17/07/2020	28/07/2020	12
JOHNSON & JOHNSON		
12/03/2020	16/03/2020	5
19/03/2020	27/03/2020	9
ASTRAZENECA		
16/03/2020	16/03/2020	1
22/04/2020	22/04/2020	1
20/07/2020	20/07/2020	1
NOVAVAX		
21/01/2020	22/01/2020	2
27/02/2020	28/02/2020	2
20/04/2020	22/04/2020	3
18/05/2020	18/05/2020	1
24/06/2020	25/06/2020	2
07/07/2020	07/07/2020	1
09/07/2020	09/07/2020	1
14/07/2020	11/08/2020	29
17/08/2020	17/08/2020	1
INOVIO		

27/01/2020	27/01/2020	1
04/03/2020	06/03/2020	3
12/03/2020	12/03/2020	1
22/04/2020	22/04/2020	1
24/04/2020	29/04/2020	6
24/06/2020	30/06/2020	7
02/07/2020	07/07/2020	6
17/07/2020	17/07/2020	1
21/07/2020	21/07/2020	1
12/08/2020	13/08/2020	2
18/08/2020	18/08/2020	1
24/08/2020	25/08/2020	2
02/09/2020	08/09/2020	7
Total bubble-days for the group		172
Number of firms in the sample		7
Average bubble-days for the group		24.57

Table A8. Bubbles: Coronavirus therapeutics companies

The table provides the start and end date of price bubbles identified using close price data for the selected companies in the group. Column 3 calculates the ‘number of bubble-days’ which is simply a measure of the length of the bubble from start to end. This is done to facilitate inter-industry comparison for the presence and intensity of bubbles.

start	end	N bubble-days
REGENERON	no bubble	
GILEAD		
24/02/2020	24/02/2020	1
26/02/2020	27/02/2020	2
03/03/2020	10/03/2020	8
18/03/2020	19/03/2020	2
17/04/2020	22/04/2020	6
24/04/2020	04/05/2020	11
26/05/2020	26/05/2020	1
31/07/2020	31/07/2020	1
04/08/2020	14/08/2020	11
19/08/2020	01/09/2020	14
03/09/2020	03/09/2020	1
08/09/2020	11/09/2020	4
21/09/2020	02/10/2020	12
06/10/2020	07/10/2020	2
19/10/2020	13/11/2020	26
22/12/2020	31/12/2020	10
19/01/2021	20/01/2021	2
SORRENTO		
15/05/2020	15/05/2020	1
01/07/2020	14/07/2020	14
20/07/2020	22/07/2020	3
31/07/2020	13/08/2020	14
17/08/2020	17/08/2020	1
AMGEN		
20/04/2020	27/04/2020	8
02/07/2020	09/07/2020	8
20/01/2021	20/01/2021	1
ABBVIE		
23/01/2020	31/01/2020	9
18/03/2020	25/03/2020	8
21/05/2020	21/05/2020	1
23/09/2020	29/09/2020	7
01/10/2020	02/10/2020	2
06/10/2020	06/10/2020	1
21/10/2020	29/10/2020	9
GLAXOSMITHKLINE		
12/03/2020	16/03/2020	5
23/03/2020	24/03/2020	2

22/04/2020	27/04/2020	6
04/09/2020	04/09/2020	1
29/10/2020	30/10/2020	2
ELI LILLY		
11/12/2020	21/12/2020	11
19/01/2021	20/01/2021	2
Total bubble-days for the group		230
Number of firms in the sample		7
Average bubble-days for the group		32.85

Table A9. Tests for quantile unit root, Work-from-home companies

Table contains the results of the quantile nonlinear unit root tests with covariates, YZI_{kss} , estimated as in Yang and Zhao (2020). The asymptotic critical values are calculated with significance at the 1%, 5% and 10% levels. The null hypothesis of the presence of a unit root is rejected if the calculated test statistic is lower in value than calculated asymptotic critical values at the 1% (**), 5% (**) and 10% (*) levels of significance. Statistically significant values of YZI_{k_s} are highlighted in bold, while the respective asymptotic critical values that indicate a significance level are underlined.

Quantiles	QKSS	asymptotic critical values			QKSS	asymptotic critical values			
		1%	5%	10%		1%	5%	10%	
LOGITECH					BOX				
0.1	-0.1476	-3.0838	-2.4297	-2.0884	0.20745	-3.0695	-2.409	-2.0672	
0.2	-0.3889	-3.1096	-2.4668	-2.1266	-2.3475	-3.141	-2.5119	-2.1733	
0.3	0.44184	-3.1172	-2.4777	-2.1378	-3.7235	-3.1866	-2.5772	-2.2444	
0.4	0.32537	-3.1196	-2.4811	-2.1414	-2.8345	-3.2017	-2.5951	-2.2646	
0.5	0.6541	-3.1358	-2.5044	-2.1653	-2.6645	-3.2039	-2.5974	-2.2673	
0.6	1.4494	-3.1318	-2.4987	-2.1595	-4.1696	-3.1779	-2.5648	-2.2309	
0.7	0.73076	-3.1396	-2.5098	-2.1711	-3.3849	-3.1825	-2.5714	-2.2381	
0.8	0.34516	-3.1117	-2.4698	-2.1297	-3.2257	-3.1129	-2.4715	-2.1314	
0.9	-0.8528	-3.0005	-2.3491	-1.9987	-1.5003	-3.0647	-2.4021	-2.0601	
ZOOM					TWILIO				
0.1	-2.0476	-3.0185	-2.3636	-2.0156	0.88744	-3.1586	-2.5371	-2.2008	
0.2	-1.3175	-3.1594	-2.5383	-2.2021	-0.9473	-3.1679	-2.5504	-2.2152	
0.3	-1.2418	-3.1509	-2.5261	-2.1888	-1.5472	-3.1872	-2.578	-2.2454	
0.4	-0.4929	-3.1502	-2.5251	-2.1877	-0.5154	-3.1575	-2.5356	-2.1991	
0.5	-1.3687	-3.1443	-2.5167	-2.1785	-0.5617	-3.1674	-2.5496	-2.2144	
0.6	-0.6645	-3.155	-2.532	-2.1952	0.41241	-3.1678	-2.5503	-2.2151	
0.7	-0.3378	-3.1629	-2.5433	-2.2075	0.20895	-3.1902	-2.5823	-2.25	
0.8	-0.6031	-3.1698	-2.5531	-2.2182	-0.2152	-3.1482	-2.5222	-2.1845	
0.9	0.15642	-3.0943	-2.4448	-2.1039	-0.8443	-3.1457	-2.5186	-2.1806	
ELASTIC					VMWARE				
0.1	1.05531	-3.2695	-2.6791	-2.3626	1.50123	-3.1647	-2.5459	-2.2104	
0.2	0.79724	-3.1866	-2.5772	-2.2445	-0.6425	-3.2113	-2.6053	-2.2764	
0.3	-1.1954	-3.1759	-2.5619	-2.2278	-1.691	-3.1771	-2.5636	-2.2296	
0.4	-1.1623	-3.2001	-2.5933	-2.2626	-3.3027	-3.1561	-2.5335	-2.1968	
0.5	-1.0926	-3.2148	-2.6091	-2.2807	-3.6416	-3.1437	-2.5158	-2.1776	
0.6	-0.4717	-3.2259	-2.6209	-2.2944	-4.8729	-3.1567	-2.5343	-2.1977	
0.7	-0.1229	-3.1619	-2.5419	-2.206	-5.7071	-3.0732	-2.4144	-2.0727	
0.8	-0.4968	-3.1423	-2.5138	-2.1754	-6.8897	-3.0553	-2.3934	-2.0502	
0.9	-1.0552	-3.0924	-2.442	-2.1011	-4.9274	-2.8886	-2.2471	-1.885	
UPLAND					MICROSOFT				

0.1	2.24566	-3.2101	-2.6041	-2.275	-0.0827	-3.2145	-2.6088	-2.2804
0.2	1.36278	-3.2329	-2.6285	-2.3031	-1.1094	-3.2293	-2.6246	-2.2986
0.3	0.2829	-3.2182	-2.6127	-2.2849	-1.3626	-3.2377	-2.6335	-2.3089
0.4	-1.043	-3.2131	-2.6072	-2.2786	-0.7363	-3.1896	-2.5815	-2.2492
0.5	-2.1913	-3.1962	-2.5892	-2.2579	-0.873	-3.1739	-2.559	-2.2246
0.6	-4.7462	-3.1596	-2.5386	-2.2024	-1.2615	-3.1778	-2.5646	-2.2307
0.7	-4.3541	-3.1415	-2.5126	-2.1741	-0.9211	-3.1645	-2.5456	-2.21
0.8	-3.1645	-3.0995	-2.4523	-2.1117	-0.8312	-3.1306	-2.497	-2.1577
0.9	-3.1856	-2.9864	-2.3377	-1.9854	-2.3268	-3.0548	-2.393	-2.0498
	ALPHABET							
0.1	1.83204	-3.2947	-2.7174	-2.4078				
0.2	0.47461	-3.1946	-2.5875	-2.2558				
0.3	-1.1469	-3.1951	-2.5881	-2.2565				
0.4	-0.5661	-3.2071	-2.6009	-2.2713				
0.5	-1.1538	-3.172	-2.5563	-2.2217				
0.6	-2.5105	-3.1583	-2.5367	-2.2003				
0.7	-3.5145	-3.1406	-2.5113	-2.1727				
0.8	-1.8475	-3.1371	-2.5063	-2.1673				
0.9	-1.0196	-2.94	-2.3001	-1.9417				

Table A10. Tests for quantile unit root - Stay-at-home companies

Table shows the results of the quantile nonlinear unit root tests with covariates, YZt_{ks} , estimated as in Yang and Zhao (2020). The asymptotic critical values are calculated with significance at the 1%, 5% and 10% levels. The null hypothesis of the presence of a unit root is rejected if the calculated test statistic is lower in value than calculated asymptotic critical values at the 1% (***) , 5% (**) and 10% (*) levels of significance. Statistically significant values of YZt_{ks} are highlighted in bold, while the respective asymptotic critical values that indicate a significance level are underlined.

Quantiles	t_{ks}	asymptotic critical values			t_{ks}	asymptotic critical values			
		1%	5%	10%		1%	5%	10%	
ROKU					NETFLIX				
0.1	2.81097	-3.0137	-2.3598	-2.0111	-1.3598	-3.0844	-2.4305	-2.0892	
0.2	1.37498	-3.1445	-2.5169	-2.1788	-1.2448	-3.1497	-2.5244	-2.1869	
0.3	1.08076	-3.1418	-2.513	-2.1745	-1.1789	-3.1807	-2.5688	-2.2353	
0.4	1.08872	-3.1569	-2.5347	-2.1982	-0.9046	-3.2045	-2.5981	-2.268	
0.5	0.0425	-3.1624	-2.5426	-2.2067	-0.2768	-3.2023	-2.5957	-2.2654	
0.6	0.54016	-3.1229	-2.4859	-2.1463	-0.9886	-3.2004	-2.5937	-2.263	
0.7	0.64373	-3.1883	-2.5796	-2.2471	-1.884	-3.1755	-2.5613	-2.2271	
0.8	-0.284	-3.1961	-2.5892	-2.2578	-1.4653	-3.1383	-2.508	-2.1691	
0.9	-1.1397	-3.1072	-2.4633	-2.123	-1.3687	-3.0736	-2.4149	-2.0732	
DOCUSIGN					PELTON				
0.1	-1.9969	-3.1783	-2.5653	-2.2315	0.66822	-3.1212	-2.4834	-2.1437	
0.2	-1.843	-3.1579	-2.5361	-2.1997	-0.0782	-3.1561	-2.5335	-2.1968	
0.3	-1.056	-3.161	-2.5406	-2.2046	0.18955	-3.2171	-2.6115	-2.2836	
0.4	-0.3364	-3.1753	-2.5609	-2.2267	0.22997	-3.2107	-2.6047	-2.2757	
0.5	0.48524	-3.1793	-2.5667	-2.233	1.2322	-3.1811	-2.5693	-2.2358	
0.6	0.25754	-3.1918	-2.5845	-2.2524	0.76163	-3.1934	-2.5862	-2.2544	
0.7	1.07831	-3.1753	-2.561	-2.2268	0.43695	-3.1825	-2.5713	-2.238	
0.8	0.46185	-3.142	-2.5133	-2.1748	-0.7149	-3.1599	-2.5389	-2.2028	
0.9	-0.1537	-3.1142	-2.4734	-2.1334	-0.2642	-3.0827	-2.4281	-2.0867	
PINTEREST					CHEWY				
0.1	1.0557	-3.1105	-2.468	-2.1278	-0.4332	-3.0305	-2.3734	-2.0269	
0.2	0.6834	-3.1091	-2.466	-2.1258	-0.6327	-3.1565	-2.534	-2.1974	
0.3	0.06373	-3.1484	-2.5225	-2.1849	-0.0354	-3.1925	-2.5853	-2.2533	
0.4	-0.1612	-3.1492	-2.5236	-2.1861	-0.6037	-3.2165	-2.6109	-2.2829	
0.5	-0.7284	-3.1539	-2.5304	-2.1934	-0.8289	-3.1934	-2.5862	-2.2543	
0.6	0.05368	-3.1514	-2.5267	-2.1895	-0.352	-3.212	-2.606	-2.2772	
0.7	0.12098	-3.1386	-2.5085	-2.1696	0.52286	-3.2132	-2.6074	-2.2787	
0.8	-0.5279	-3.1208	-2.4829	-2.1432	1.1065	-3.2136	-2.6078	-2.2793	
0.9	-0.747	-3.0894	-2.4377	-2.0966	0.90542	-3.1628	-2.5431	-2.2074	

Table A11. Tests for quantile unit root - Cryptocurrency companies

Table shows the results of the quantile nonlinear unit root tests with covariates, $YZt_{k,ss}$, estimated as in Yang and Zhao (2020). The asymptotic critical values are calculated with significance at the 1%, 5% and 10% levels. The null hypothesis of the presence of a unit root is rejected if the calculated test statistic is lower in value than calculated asymptotic critical values at the 1% (***) , 5% (**) and 10% (*) levels of significance. Statistically significant values of $YZt_{k,ss}$ are highlighted in bold, while the respective asymptotic critical values that indicate a significance level are underlined.

Quantiles	QKSS	asymptotic critical values			QKSS	asymptotic critical values			
		1%	5%	10%		1%	5%	10%	
NVIDIA					AMD				
0.1	0.42559	-3.1684	-2.5512	-2.2161	0.29036	-3.0931	-2.443	-2.1022	
0.2	-0.4916	-3.1872	-2.578	-2.2453	-1.0167	-3.1468	-2.5202	-2.1824	
0.3	-1.2755	-3.195	-2.5879	-2.2564	-0.8758	-3.2165	-2.6109	-2.2828	
0.4	-1.3146	-3.1912	-2.5838	-2.2516	-1.3388	-3.1691	-2.5521	-2.2172	
0.5	-1.1688	-3.177	-2.5634	-2.2294	-0.7722	-3.1664	-2.5482	-2.2129	
0.6	-1.2479	-3.2235	-2.6184	-2.2915	-0.7035	-3.1728	-2.5574	-2.2228	
0.7	-0.8803	-3.1491	-2.5235	-2.186	-0.8254	-3.1692	-2.5522	-2.2173	
0.8	-1.6466	-3.0812	-2.4259	-2.0845	-1.7048	-3.195	-2.588	-2.2564	
0.9	-1.2601	-2.9059	-2.2689	-1.907	-1.7213	-3.1484	-2.5225	-2.1848	
SQUARE					INTERACTIVE BROKERS				
0.1	-0.1315	-3.1348	-2.503	-2.1639	1.43745	-3.1493	-2.5238	-2.1863	
0.2	0.33902	-3.1617	-2.5416	-2.2057	0.37932	-3.2241	-2.619	-2.2922	
0.3	-0.0404	-3.1617	-2.5415	-2.2056	0.68931	-3.2174	-2.6119	-2.284	
0.4	-0.6062	-3.1668	-2.5489	-2.2136	0.73761	-3.1775	-2.5641	-2.2302	
0.5	-0.2133	-3.1752	-2.5608	-2.2266	0.3799	-3.1745	-2.5599	-2.2255	
0.6	0.114	-3.1768	-2.5632	-2.2292	-0.7397	-3.1695	-2.5527	-2.2177	
0.7	-0.2805	-3.1706	-2.5543	-2.2195	-1.4111	-3.1627	-2.5429	-2.2071	
0.8	-1.3122	-3.1138	-2.4728	-2.1328	-1.342	-3.1512	-2.5264	-2.1892	
0.9	-1.1689	-3.0563	-2.3942	-2.0512	-1.6785	-3.0183	-2.3634	-2.0154	
CME					Visa				
0.1	-0.4283	-3.1533	-2.5296	-2.1926	2.18128	-3.0884	-2.4363	-2.0952	
0.2	-0.6985	-3.1288	-2.4944	-2.155	1.99537	-3.2138	-2.6081	-2.2796	
0.3	-0.02	-3.1658	-2.5475	-2.2121	-1.178	-3.2361	-2.6318	-2.3069	
0.4	-0.8091	-3.1436	-2.5156	-2.1773	-1.2231	-3.2482	-2.6468	-2.3245	
0.5	-0.6873	-3.1315	-2.4982	-2.159	-2.2349	-3.1959	-2.5889	-2.2575	
0.6	-1.4874	-3.0854	-2.432	-2.0908	-3.5688	-3.1433	-2.5151	-2.1768	
0.7	-1.722	-3.0937	-2.4438	-2.103	-4.0475	-3.1192	-2.4806	-2.1409	
0.8	-2.8455	-2.9832	-2.3351	-1.9824	-4.3157	-3.0143	-2.3603	-2.0117	
0.9	-2.4651	-3.0008	-2.3493	-1.9989	-6.9454	-2.921	-2.2848	-1.9239	
PAYPAL									

0.1	0.5573	-3.0648	-2.4023	-2.0602				
0.2	-0.2762	-3.1629	-2.5433	-2.2075				
0.3	-0.1396	-3.1561	-2.5335	-2.1969				
0.4	-0.6504	-3.15	-2.5247	-2.1873				
0.5	-0.0878	-3.1768	-2.5632	-2.2291				
0.6	0.04146	-3.1651	-2.5464	-2.2109				
0.7	-0.4953	-3.1815	-2.5699	-2.2365				
0.8	0.7426	-3.1819	-2.5705	-2.2371				
0.9	-0.9574	-3.0717	-2.4122	-2.0705				

Table A12. Tests for quantile unit root - Bitcoin companies

Table shows the results of the quantile nonlinear unit root tests with covariates, $YZt_{k,ss}$, estimated as in Yang and Zhao (2020). The asymptotic critical values are calculated with significance at the 1%, 5% and 10% levels. The null hypothesis of the presence of a unit root is rejected if the calculated test statistic is lower in value than calculated asymptotic critical values at the 1% (***) , 5% (**) and 10% (*) levels of significance. Statistically significant values of $YZt_{k,ss}$ are highlighted in bold, while the respective asymptotic critical values that indicate a significance level are underlined.

Quantiles	QKSS	asymptotic critical values			QKSS	asymptotic critical values		
		1%	5%	10%		1%	5%	10%
	MicroStrategy				Overstock			
0.1	-1.5477	-3.124	-2.4875	-2.1479	-0.2382	-3.2083	-2.6021	-2.2727
0.2	-0.328	-3.0701	-2.4099	-2.068	-0.4616	-3.1876	-2.5786	-2.2459
0.3	0.1998	-3.1085	-2.4651	-2.1249	-0.8743	-3.1879	-2.5791	-2.2465
0.4	0.80724	-3.0893	-2.4376	-2.0965	-1.4405	-3.1751	-2.5607	-2.2265
0.5	2.97383	-3.0991	-2.4517	-2.111	-0.5157	-3.149	-2.5233	-2.1858
0.6	3.5097	-3.1321	-2.4991	-2.1598	-0.2353	-3.1695	-2.5527	-2.2177
0.7	2.43191	-3.1198	-2.4814	-2.1416	0.4296	-3.2056	-2.5992	-2.2694
0.8	2.37124	-3.1772	-2.5637	-2.2297	-0.4515	-3.1775	-2.5641	-2.2302
0.9	2.64183	-3.1147	-2.4741	-2.1341	-0.9928	-3.1704	-2.554	-2.2192
	HIVE BLOCKCHAIN				RIOT BLOCKCHAIN			
0.1	-0.9605	-3.0282	-2.3714	-2.0247	-1.8935	-2.7844	-2.1158	-1.7525
0.2	0.341	-2.9979	-2.3469	-1.9962	-0.7918	-2.995	-2.3447	-1.9935
0.3	-0.0637	-2.9785	-2.3313	-1.978	-0.6668	-2.8783	-2.2342	-1.872
0.4	-0.1391	-3.0548	-2.393	-2.0497	-0.7235	-3.0899	-2.4384	-2.0974
0.5	0	-3.0842	-2.4302	-2.089	0	-3.1561	-2.5336	-2.1969
0.6	0.39815	-3.1068	-2.4627	-2.1224	2.22371	-3.1836	-2.5729	-2.2398
0.7	0.37062	-3.1418	-2.513	-2.1746	1.93716	-3.1722	-2.5566	-2.222
0.8	0.39982	-3.2397	-2.6357	-2.3114	1.5618	-3.1734	-2.5582	-2.2238
0.9	-0.2014	-3.1881	-2.5794	-2.2468	1.30925	-3.1915	-2.5841	-2.252
	MARATHON				CANAAN			
0.1	-1.3254	-3.0384	-2.3797	-2.0343	-3.5403	-2.9666	-2.3217	-1.9668
0.2	-2.6852	-2.9046	-2.2673	-1.9053	-3.0144	-3.063	-2.3998	-2.0576
0.3	-1.8883	-2.993	-2.343	-1.9916	-2.9138	-3.1309	-2.4975	-2.1582
0.4	0.11441	-3.0706	-2.4107	-2.0688	-0.9665	-3.1479	-2.5218	-2.1841
0.5	0.0308	-3.12	-2.4817	-2.1419	-0.6308	-3.1544	-2.5311	-2.1942
0.6	1.04849	-3.186	-2.5763	-2.2434	-1.0169	-3.1601	-2.5393	-2.2031
0.7	2.79122	-3.2514	-2.6517	-2.3302	-1.4218	-3.1991	-2.5924	-2.2615
0.8	2.02822	-3.3802	-2.7885	-2.4876	-0.7701	-3.1912	-2.5837	-2.2515
0.9	1.7138	-3.31	-2.7259	-2.4194	-0.7859	-3.1543	-2.5309	-2.194
	GRAYSCALE BITCOIN							

0.1	-1.64	-3.0735	-2.4148	-2.0731				
0.2	-1.5408	-3.0916	-2.4408	-2.0998				
0.3	-0.3962	-3.1425	-2.5141	-2.1757				
0.4	-0.4304	-3.1031	-2.4574	-2.117				
0.5	0	-3.1715	-2.5556	-2.2209				
0.6	1.81581	-3.1702	-2.5537	-2.2189				
0.7	1.40428	-3.184	-2.5735	-2.2404				
0.8	1.6859	-3.1098	-2.4671	-2.1269				
0.9	1.64735	-3.1092	-2.4661	-2.1259				

Table A13. Tests for quantile unit root - Coronavirus Vaccine companies

Table shows the results of the quantile nonlinear unit root tests with covariates, YZt_{kss} , estimated as in Yang and Zhao (2020). The asymptotic critical values are calculated with significance at the 1%, 5% and 10% levels. The null hypothesis of the presence of a unit root is rejected if the calculated test statistic is lower in value than calculated asymptotic critical values at the 1% (***) , 5% (**) and 10% (*) levels of significance. Statistically significant values of YZt_{kss} are highlighted in bold, while the respective asymptotic critical values that indicate a significance level are underlined.

Quantiles	QKSS	asymptotic critical values			QKSS	asymptotic critical values		
		1%	5%	10%		1%	5%	10%
		Pfizer			MODERNA			
0.1	0.64028	-3.1938	-2.5867	-2.2549	-1.0209	-3.0186	-2.3637	-2.0157
0.2	1.21753	-3.1633	-2.5438	-2.208	-1.8831	-3.0527	-2.3913	-2.0478
0.3	1.01207	-3.1833	-2.5725	-2.2393	-1.4745	-3.1292	-2.495	-2.1556
0.4	-1.548	-3.1477	-2.5215	-2.1838	-0.7161	-3.1255	-2.4896	-2.15
0.5	-2.1375	-3.1424	-2.5139	-2.1755	0	-3.1777	-2.5645	-2.2306
0.6	-4.1366	-3.1418	-2.5131	-2.1746	0.28229	-3.2155	-2.6099	-2.2816
0.7	-4.8679	-3.1156	-2.4754	-2.1354	0.8936	-3.2239	-2.6188	-2.292
0.8	-4.7245	-3.12	-2.4816	-2.1419	0.49082	-3.2192	-2.6137	-2.2861
0.9	-4.7469	-3.0172	-2.3626	-2.0144	-0.2632	-3.3065	-2.724	-2.4169
		BIONTECH			JOHNSON & JOHNSON			
0.1	-0.5183	-2.8854	-2.2431	-1.881	2.63071	-3.0635	-2.4004	-2.0583
0.2	0.17494	-3.0764	-2.419	-2.0774	0.96009	-3.1036	-2.4581	-2.1176
0.3	-0.9144	-3.0664	-2.4046	-2.0625	-0.6862	-3.161	-2.5405	-2.2045
0.4	-1.5629	-3.095	-2.4457	-2.1049	-1.8648	-3.1514	-2.5268	-2.1896
0.5	-0.3693	-3.1337	-2.5014	-2.1622	-2.7319	-3.1453	-2.5181	-2.1801
0.6	-1.1131	-3.1503	-2.5253	-2.1879	-2.4844	-3.1219	-2.4844	-2.1448
0.7	-1.0745	-3.166	-2.5477	-2.2123	-4.7338	-3.0931	-2.443	-2.1021
0.8	-2.1066	-3.1392	-2.5093	-2.1706	-5.8608	-2.859	-2.2098	-1.8474
0.9	-1.5404	-3.095	-2.4458	-2.105	-3.825	-3.0109	-2.3575	-2.0085
		ASTRAZENECA			INOVIO			
0.1	-1.3091	-3.1022	-2.4561	-2.1157	-1.3351	-2.9514	-2.3093	-1.9525
0.2	-1.7914	-3.1453	-2.5181	-2.1801	-1.851	-3.0384	-2.3797	-2.0343
0.3	-2.1536	-3.0344	-2.3765	-2.0306	-2.3437	-3.125	-2.489	-2.1494
0.4	-2.3618	-3.146	-2.5191	-2.1812	-1.6818	-3.1377	-2.5072	-2.1682
0.5	-1.3994	-3.1706	-2.5542	-2.2194	-0.5893	-3.1317	-2.4985	-2.1593
0.6	-1.0252	-3.1656	-2.5471	-2.2117	-0.8422	-3.1672	-2.5494	-2.2142
0.7	-1.4298	-3.1851	-2.575	-2.242	-0.1327	-3.1656	-2.5471	-2.2117
0.8	-1.7418	-3.1631	-2.5436	-2.2078	-0.0717	-3.2038	-2.5974	-2.2672
0.9	-1.4825	-3.0467	-2.3865	-2.0422	-0.5397	-3.1085	-2.4652	-2.125

Table A14. Tests for quantile unit root - Coronavirus therapeutics companies

Table shows the results of the quantile nonlinear unit root tests with covariates, $YZt_{k,ss}$, estimated as in Yang and Zhao (2020). The asymptotic critical values are calculated with significance at the 1%, 5% and 10% levels. The null hypothesis of the presence of a unit root is rejected if the calculated test statistic is lower in value than calculated asymptotic critical values at the 1% (***) , 5%(**) and 10% (*) levels of significance. Statistically significant values of $YZt_{k,ss}$ are highlighted in bold, while the respective asymptotic critical values that indicate a significance level are underlined.

Quantiles	QKSS	asymptotic critical values			QKSS	asymptotic critical values		
		1%	5%	10%		1%	5%	10%
	Regeneron				Gelead Sciences			
0.1	-1.647	-3.0107	-2.3573	-2.0083	-2.7809	-2.9792	-2.3319	-1.9787
0.2	-2.0515	-3.1396	-2.5099	-2.1712	-3.6849	-3.0729	-2.4139	-2.0722
0.3	-2.1574	-3.1708	-2.5546	-2.2199	-2.4251	-3.1082	-2.4647	-2.1244
0.4	-1.6452	-3.1998	-2.593	-2.2622	-2.2159	-3.1404	-2.5111	-2.1724
0.5	-1.0365	-3.1776	-2.5644	-2.2305	-0.9947	-3.1398	-2.5102	-2.1714
0.6	-0.4222	-3.1947	-2.5876	-2.256	-0.8183	-3.1627	-2.543	-2.2072
0.7	-0.05	-3.1892	-2.581	-2.2485	0.58429	-3.1736	-2.5585	-2.2241
0.8	-0.2817	-3.2135	-2.6077	-2.2791	0.37322	-3.1889	-2.5805	-2.2481
0.9	-1.877	-3.1497	-2.5243	-2.1869	1.7365	-3.1482	-2.5222	-2.1846
	Sorrento Therapeutics				Amgen			
0.1	-0.9067	-2.8592	-2.2101	-1.8477	1.73352	-3.1242	-2.4878	-2.1482
0.2	0.07977	-2.8763	-2.2316	-1.8694	1.77331	-3.1186	-2.4796	-2.1398
0.3	-0.4554	-3.0327	-2.3752	-2.029	0.51175	-3.1432	-2.5151	-2.1768
0.4	-1.4768	-3.0649	-2.4025	-2.0604	-0.8812	-3.1865	-2.5771	-2.2443
0.5	0	-3.0369	-2.3785	-2.033	-1.0084	-3.1686	-2.5515	-2.2164
0.6	0.33339	-3.0424	-2.383	-2.0381	-1.921	-3.1956	-2.5886	-2.2571
0.7	0.73942	-3.1201	-2.4819	-2.1422	-2.2323	-3.1959	-2.5889	-2.2574
0.8	0.17449	-3.1196	-2.4811	-2.1414	-3.1425	-3.1997	-2.593	-2.2622
0.9	0.02273	-3.1782	-2.5651	-2.2313	-4.5267	-3.0456	-2.3856	-2.0411
	AbbVie				GlaxoSmithKline			
0.1	1.99479	-3.0539	-2.3923	-2.0489	0.8618	-3.08	-2.4242	-2.0827
0.2	1.90324	-3.154	-2.5305	-2.1936	0.0341	-3.1483	-2.5223	-2.1846
0.3	0.84129	-3.1627	-2.5429	-2.2071	0.46143	-3.1466	-2.52	-2.1821
0.4	-0.3426	-3.1514	-2.5267	-2.1895	0.03178	-3.1752	-2.5609	-2.2267
0.5	-0.2459	-3.1532	-2.5293	-2.1923	0	-3.0993	-2.452	-2.1114
0.6	-1.8535	-3.1522	-2.5279	-2.1907	-0.9498	-3.1072	-2.4632	-2.123
0.7	-1.7408	-3.1433	-2.5151	-2.1768	-1.0699	-3.147	-2.5204	-2.1826
0.8	-1.8095	-3.1377	-2.5072	-2.1682	-1.6948	-3.1466	-2.5199	-2.182
0.9	-2.3264	-3.0937	-2.4439	-2.1031	-1.7291	-3.0437	-2.384	-2.0393
	Eli Lilly							

0.1	-0.6397	-2.9603	-2.3166	-1.9609				
0.2	-1.9352	-3.0489	-2.3882	-2.0442				
0.3	-2.48	-3.0565	-2.3944	-2.0514				
0.4	-2.0145	-3.0996	-2.4524	-2.1118				
0.5	-1.1532	-3.1352	-2.5035	-2.1644				
0.6	-1.0435	-3.1497	-2.5244	-2.1869				
0.7	-0.7241	-3.1463	-2.5195	-2.1816				
0.8	-0.1948	-3.1399	-2.5103	-2.1716				
0.9	-0.3192	-3.1679	-2.5505	-2.2153				