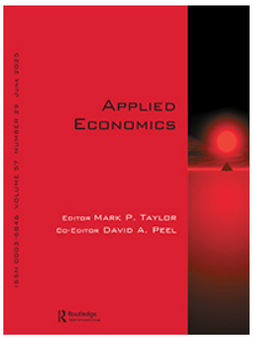

Applied Economics

ISSN: 0003-6846 (Print) 1466-4283 (Online) Journal homepage: www.tandfonline.com/journals/raec20

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To cite this article: Assad Ullah, Xinshun Zhao, Mesut Dogan & Chenghui Ye (2025) The impact of COVID-19 vaccines on China's overall and sectoral stock returns: a quantile-based analysis, Applied Economics, 57:29, 4127-4143, DOI: 10.1080/00036846.2024.2348183

To link to this article: https://doi.org/10.1080/00036846.2024.2348183

APPLIED ECONOMICS
2025, VOL. 57, NO. 29, 4127–4143
https://doi.org/10.1080/00036846.2024.2348183

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The impact of COVID-19 vaccines on China's overall and sectoral stock returns: a quantile-based analysis

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ABSTRACT

This research analyzes the response of China's stock market returns (overall and sector-specific) to COVID-19 vaccines. We examine these relationships using quantile-on-quantile (QQR) regression and causality-in-quantile (CQ) approaches. The empirical results show that the higher quantiles of COVID-19 vaccines propel the higher quantiles of the Shanghai stock returns (SSR). Simultaneously, the higher quantiles of COVID-19 vaccines negatively influence the lower quantiles of the Shanghai stock returns. On the sectoral level, consumer discretionary, basic materials, industrial, utilities, and telecommunication sectors exhibit similar trends to those observed in the Shanghai stock market. The study emphasizes that COVID-19 vaccines tend to increase Shanghai stock returns during bullish market condition, and this impact becomes adverse when the market showcases a bearish trend. These findings serve as insights for policymakers, investors, and other stakeholders.

KEYWORDS

COVID-19 vaccines; stock returns; quantile-on-quantile regression; quantile causality; China

JEL CLASSIFICATION

G10; G11; G18

I. Introduction

The response of financial markets towards the COVID-19 (henceforth, CoV) pandemic was unsurprising as financial markets always remain vulnerable to the black swan events. The recent pandemic severely impacted economic and financial systems compared to the great influenza pandemic (Barro, Ursúa, and Weng 2020). In this connection, the extant literature has well-established the hostile impact of CoV on financial markets (Ashraf 2020; Baker et al. 2020; Doko Tchatoka, Puellbeck, and Masson 2022; Hui and Chan 2022; Narayan, Phan, and Liu 2021; Ramelli and Wagner 2020; Ullah et al. 2023; Zhang, Hu, and Ji 2020; Zhou et al. 2023). Likewise (Al-Awadhi et al. 2020), Yan (2020), and (Zhou et al. 2023) reported the adverse effect of CoV on the stock market (henceforth, SM) in the context of China.

In a nutshell, quite a few studies have evaluated the impact of CoV on stock markets (henceforth, SMs) (Caferra et al. 2022; Guo, Li, and Li 2021; Harjoto, Rossi, and Paglia 2021; He et al. 2020; Mao, Wang, and Bibi 2024; Yu, Xiao, and Liu 2021). Nonetheless, the literature pertaining to the impact of the COVID-19 vaccines (henceforth, CVAC) is still in a nascent phase (Khalfaoui et al. 2021; Li et al. 2021; Belhoula et al. 2024). The introduction of COVID-19 vaccines CVAC in December 2020 has assisted in subsiding the world's largest health crisis and provided leverage to the global economic and financial systems. Concurrently, the SMs exhibited recuperation as the investors' confidence was somehow restored owing to the CVAC introduction, which relaxed the CoV protocols. In this respect, we aim to determine whether China's SM returns towards response towards CVAC heterogeneously or homogeneously.

Our work advances the literature in the following manner. The existing have determined the effect of CoV on SMs. However, the relationship between the CVAC and SM returns merits further attention. Belhoula et al., (2024) connected CoV and CVAC to SMs but their study was undertaken in Middle East and North Africa region (MENA) region. In another study, Khalfaoui et al. (2021) ascertained the overall impact of the CVAC on SM returns in the United States. The point of difference between our study and the work of (Khalfaoui et al. 2021) is that we aim to explore

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the impact of the CVAC on 'the overall and sectoral level stock returns' in the context of China. We contend that determining the impact of CoV on disaggregate levels in China will enable us to delineate whether the CVAC has homogenous/heterogeneous impact on various industries' stock returns. To this end, we utilize the novel QQR approach, which discovers the correlation between variables at each point of their corresponding distributions. The asymmetric or nonlinear approaches such as QQR, Wavelet Coherence, NARDL, QARDL, etc., have received attention recently as researchers have established that data exhibit non-linear characteristics in various areas of economics and finance (Afshan et al. 2021; Bouri et al. 2017; Chang et al. 2020; Kartal and Depren 2023; Nusair and Al-Khasawneh 2022; Pham and Nguyen 2021; Qamruzzaman and Jianguo 2018; Rehman and Kang 2021; Shahzad et al. 2021; Tiwari et al. 2023; Wen et al. 2022). Moreover, we aim to discern the causal linkages between CVAC's quantiles and China's overall and sectoral stock returns. The CQ, pioneered by (Troster, Shahbaz, and Uddin 2018), demarcates the complete quantile-on-quantile causal relationship among variables. Studying the behaviour of China's SM vis-à-vis CVAC is essential owing to the fact that it has a marked spillover effect on the world's major SMs (Qian et al., 202ed3). The findings of our study will assist policymakers to chalk out appropriate policy inferences, enlighting investors to augment their portfolio diversification strategies.

The research results show that higher quantiles of CVAC correlate with higher quantiles of the Shanghai SM returns (henceforth, SSR), suggesting that CVAC augments SM returns. Conversely, the higher quantiles of CVAC negatively influence the lower quantiles of the SSR. The materials, consumer discretionary, telecommunication, utilities, and industrial sectors observed a similar trend. The study suggests that the CVAC's relationship with overall and sectoral stock returns in China is influenced by market conditions i.e. the association is positive when the market is doing well, whereas, the positive effect of CVAC subsides and turns negative during bearish period. These findings provide useful insights for policymakers and investors regarding the heterogenous association between CVAC and China's overall and sectoral stock returns.

The rest of the paper is structured as follows. Section II pertains to data and estimation methodology. Section III outlines and reports empirical outcomes. Finally, Section IV presents concluding remarks.

II. Data and estimation framework

The Shanghai Stock Exchange (overall and sectoral stock indices) were collected from the CEIC database. We calculated the daily returns for the Shanghai SM and sectoral stocks via$R_t = \log(P_t/P_{t-1})$, where P_t represent daily closing prices. Owing to holidays in the stock exchange, we tallied the CoV daily vaccine to the available dates of stock exchange data. We took the daily CVAC data from the website (www.ourworldindata.org). The data of this article spans from 31 December 2020, to 25 January 2022. To avoid biases in the results, we did not extend the data sample afterwards because more than 80% of the population was vaccinated and zero-COVID policy was relaxed in early 2022.[1] The beginning date of our work is defined by the first CVAC date in China. All the variables used in the analysis are in logarithmic form.

To measure the influence of CVAC on overall and sectoral stock returns in China, we have used the QQR approach. The QQR regression approach introduced by (Sim and Zhou 2015) has given preference over conventional quantile regression as the former can delineate the dependence across the whole distribution of the independent and the dependent variables. The QQR estimation technique is superior because it embeds the characteristics of quantile regression and non-parametric estimations (Chang et al. 2020). To achieve the objective of our study, we begin with the following non-parametric quantile model;

$$\mathrm{SMR_t} = \gamma^{\theta}(\mathrm{CVAC_t}) + \mathrm{u_t^{\theta}} \qquad (1)$$

Where SMR denotes stock returns at period t, CVAC represents the COV-administered vaccines,

[1] www.ourworldindata.org.

theta the is the theta to the t h quantile of the conditional distribution of SMR,and u_t^{θ} stands for quantile disturbance term. Since no prior information is available on the link between the CVAC and SM returns, γ^{θ} (.) assumed to be unknown. Subsequently, we linearize the function γ^{θ} (.) around the quantile of VAC^{τ} via first-order Taylor expansion as follows;

$$\gamma^{\theta}(\mathrm{CVAC_t}) \approx \gamma^{\theta}\mathrm{CVAC}^{\tau} + \gamma\theta'(\mathrm{CVAC}^{\mathrm{t}})(\mathrm{CVAC_t} - \mathrm{CVAC}^{\tau}) \quad (2)$$

Where $\gamma\theta'$ is the partial derivative of gamma to the theta, in terms of $\mathrm{CVAC_t}$ which is also known as the marginal effect. Taking insights from Sim and Zhou (2015) work, we redefine γ (VAC^{τ}) and $\gamma^{\theta\prime}$ (CVAC^{τ}) as γ_0=(θ,) and γ_1=(θ,τ). Then, Equation 2 can be re-framed as;

$$\gamma^{\theta}(\mathrm{CVAC_t}) \approx \gamma_0(\theta,\tau) + \gamma_1{}'(\theta,\tau)(\mathrm{CVAC_t} - \mathrm{CVAC}^{\tau}) \quad (3)$$

Finally, we substitute Equation 3 into equation 2 to obtain the following equation:

$$\mathrm{SMR_t} = \frac{\gamma_0(\theta,\tau) + \gamma_1(\theta,\tau)(\mathrm{CVAC} - \mathrm{CVAC}) + \mathrm{u_t^{\theta}}}{(*)} \quad (4)$$

Note $*$ refers to the conditional quantile of SM returns. Additionally, it portrays the relationship between the quantile SM returns (θ^{th}) and the quantile of vaccine (τ^{th}) of parameters γ_0 and γ_1. Similar to the ordinary least square (OLS), a simple minimization is utilized to obtain Equation 5, which captures the impact of CVAC on SM returns.

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$$\min_{\gamma_0\gamma_1} \sum_{\mathrm{i}}^{\mathrm{n}} \rho\theta\Big[\mathrm{SR_t} - \gamma_0 - \gamma_1\Big(\widehat{\mathrm{CVAC_t}} - \widehat{\mathrm{CVAC}^{\tau}}\Big) - \alpha(\theta)(\mathrm{rt}-1]\ \mathrm{K}\left(\frac{\mathrm{F_n}(\widehat{\mathrm{CVAC_t}} - \tau)}{\mathrm{h}}\right) \quad (5)$$

Note, $\rho\theta$ represents quantile loss function and K(.). The symbols $K(*)$ and $h$denote kernel density function and bandwidth parameters, respectively. Where K(.) measures the observation of VAC while minimal weights are inversely allotted to the distribution function of $\widehat{CVAC_t}$ and $\widehat{CVAC^{\tau}}$as;

$$\mathrm{F_n}(\widehat{\mathrm{CVAC_t}}) = \frac{1}{\mathrm{n}}\sum_{\mathrm{k}=1}^{\mathrm{n}} \mathrm{I}(\widehat{\mathrm{CVAC_k}} < \widehat{\mathrm{CVAC_t}}) \quad (6)$$

Sim and Zhou (2015) advocated that bandwidth selection is one of the prime requirements of non-parametric analysis. Bandwidth selection helps determine the neighbourhood close to the target point, and hence, it controls the smoothness of the measurement. Therefore, our study employed a bandwidth parameter h = 0.05.

Quantile Granger causality

To determine whether the lead-lag linkage between CVAC and stock returns exists in quantiles, the causality-in-quantiles (CQ) approach (Troster et al. 2018) is utilized. The non-parametric CQ approach predicates on the VAR (vector autoregression) framework and derives the complete Q-on-Q causal dependency among variables (Troster et al. 2018). contends that the conventional linear Granger causality methodology (Granger 1969) may often lead to biased outcomes as it computes causal association based on median and does not have the power to capture causality between variables at lower, medium, and higher quantiles.

III. Empirical results and discussion

Table 1 reports the stochastic properties of the variables. As the value of kurtosis is greater than 3, it entails that our variables are exhibiting non-linear behaviour. The notion of nonlinearity is highlighted by the statistic of the Jarque-Bera test, as it rejects the null (H_0) of normality in the model. These outcomes necessitate the applicability of nonlinear models; hence, the QQR approach applied in our case is appropriate.

Tables 2–4 report the quantile unit root test outcomes. The reported columns include 19 sub-quantiles ranging from 0.05 to 0.95 and their corresponding t-stats, critical values, and persistence values. To determine the characteristics of the unit root, t-statistics are compared to the critical values. If the value of the t-statistic is less than the critical

Table 1. Descriptive statistics

	SH	CVAC	CDISC	CSTAP	EGY	FIN
Panel A						
Mean	0.0001	20.7896	0.0002	−0.0004	0.0013	−0.0005
Median	0.0001	21.3584	−0.0002	0.0002	0.0021	−0.0017
Maximum	0.0355	21.8147	0.0841	0.0703	0.0840	0.0384
Minimum	−0.0454	15.3196	−0.0947	−0.2423	−0.0642	−0.0376
Std. Dev.	0.0093	1.2083	0.0163	0.0247	0.0225	0.0118
Skewness	−0.3094	−1.7490	0.1589	−4.2253	0.0576	0.4237
Kurtosis	6.6014	6.0428	12.2085	44.8938	4.0595	4.2420
J-Bera	119.6233	192.5490	760.5353	16362.4600	10.1757	20.2494
Probability	0.0000	0.0000	0.0000	0.0000	0.0062	0.0000
Panel B	**HLTC**	**IND**	**IT**	**MAT**	**TELE**	**UTIL**
Mean	−0.0008	0.0006	−0.0004	0.0007	0.0000	0.0010
Median	0.0007	0.0010	0.0004	0.0023	0.0006	0.0007
Maximum	0.0752	0.1082	0.0507	0.0931	0.0426	0.1605
Minimum	−0.2062	−0.0977	−0.1166	−0.0635	−0.0685	−0.0515
Std. Dev.	0.0234	0.0175	0.0183	0.0189	0.0144	0.0202
Skewness	−3.3050	0.4478	−1.1252	0.1923	−0.5036	2.4537
Kurtosis	30.1034	14.4464	10.2555	6.0255	5.4397	20.9014
Jarque-Bera	6972.1240	1180.9090	516.9542	83.3278	62.4088	3086.5230
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Probability values pertains to the Jarque-Bera statistic. SHR is Shanghai stock returns, VAC denotes COVID-19 vaccines, COD is the consumer discretionary stock returns. COS is the consumer staples stock returns. ENE is the energy stock returns. FIN is the financial stock returns. HLTC is the healthcare stock returns, IND is industrials stock returns, IT is information technology stock returns, MAT is materials stock returns, TELE is telecommunication stock returns and UTIL is utilities stock returns.

Table 2. Quantile unit root test results

	SH			VAC			CDISC			CSTAP		
Quantile(s)	t-statistics	CV	$\alpha(\tau)$ persistence	t-statistics	CV	$\alpha(\tau)$ persistence	t-statistics	CV	$\alpha(\tau)$ persistence	t-statistics	CV	persistence
0.05	−2.672	−3.064	−0.031	−21.091	−2.310	0.992	−3.128	−2.712	−0.055	−1.801	−2.904	−0.129
0.10	−5.063	−2.856	0.093	−11.808	−2.310	0.991	−5.963	−2.528	−0.037	−5.434	−2.858	−0.084
0.15	−7.800	−2.960	0.122	−11.477	−2.310	0.987	−8.999	−2.942	0.038	−11.466	−2.800	−0.064
0.20	−9.077	−3.166	0.067	−10.097	−2.310	0.987	−8.797	−2.893	0.087	−13.038	−2.723	−0.039
0.25	−9.860	−2.967	0.025	−12.580	−2.310	0.984	−10.283	−2.945	0.034	−14.157	−2.738	−0.018
0.30	−11.226	−2.876	−0.013	−13.036	−2.375	0.983	−12.773	−2.904	0.076	−14.568	−2.751	−0.010
0.35	−11.767	−2.761	−0.058	−14.843	−2.491	0.981	−14.834	−2.955	0.057	−17.175	−2.663	−0.085
0.40	−11.854	−2.750	−0.013	−15.828	−2.534	0.979	−13.656	−2.947	0.058	−17.705	−2.706	−0.032
0.45	−12.774	−2.707	−0.059	−13.325	−2.566	0.979	−13.342	−2.877	0.097	−18.980	−2.684	−0.017
0.50	−13.855	−2.864	−0.067	−6.376	−2.634	0.977	−14.249	−2.809	0.071	−18.006	−2.793	−0.023
0.55	−15.373	−2.889	−0.089	−6.553	−2.640	0.974	−14.183	−2.786	0.048	−18.863	−2.854	−0.008
0.60	−13.983	−2.674	−0.039	−6.267	−2.738	0.971	−13.601	−2.704	0.055	−18.795	−2.733	0.019
0.65	−13.879	−2.652	−0.040	−6.832	−2.796	0.963	−12.158	−2.785	0.038	−17.048	−2.738	−0.003
0.70	−14.218	−2.844	−0.067	−8.767	−2.841	0.948	−11.818	−2.670	0.010	−13.582	−2.672	0.033
0.75	−12.566	−2.611	−0.064	−11.527	−2.836	0.923	−10.748	−2.684	0.044	−11.815	−2.792	0.061
0.80	−11.899	−2.678	−0.103	−7.374	−2.916	0.913	−9.728	−2.798	0.017	−9.462	−2.703	0.076
0.85	−9.353	−2.731	−0.083	−9.698	−2.588	0.905	−9.529	−2.692	−0.025	−8.345	−2.488	0.106
0.90	−6.327	−2.498	−0.037	−6.593	−2.623	0.896	−6.346	−2.626	0.082	−7.095	−2.310	0.140
0.95	−6.346	−2.310	0.000	−9.134	−2.310	0.839	−4.369	−2.388	0.194	−6.160	−2.310	0.200

The above table include t-statistics, critical values and persistence of quantile unit test by Koenker and Xiao (2004) and Galvo (2009). The rule of thumb is, if t-statistic is smaller than critical value, the null hypothesis of $\alpha(\tau) = 1$ will be rejected at 5% level.

values, the null (H_0) of $\alpha(\tau) = 1$ will be rejected for the respective quantile. If the t-statistic value is greater than the critical value, then the null (H_0) of $\alpha(\tau) = 1$ is accepted. In the table reporting the values of the quantile unit root, we observed that the t-statistics of quantiles (lower, upper, and middle) of the respective variables are less than the corresponding critical values. These results affirm stationarity in quantiles.

Subsequent to confirming stationarity in quantiles, we begin to discuss the impact of vaccines administered on Shanghai and sectoral stock returns. The outcomes of the quantiles of vaccines on the quantiles of Shanghai stock returns reported in Figure 1 exhibit that the higher quantiles of vaccines (0.90–0.95) have significant positive impact on the higher quantiles (0.90–0.95) of the SSR. These outcomes entail that as the ratio of vaccines increased, the returns of the Shanghai SM responded positively. As the impact between the quantile of vaccines and the quantile of the Shanghai and sectoral stock returns occurs in

Table 3. Quantile unit root test results

	EGY			FIN			HLC			IND		
Quantile(s)	t-statistics	CV	$a(\tau)$ persistence	t-statistics	CV	$a(\tau)$ persistence	t-statistics	CV	$a(\tau)$ persistence	t-statistics	CV	$a(\tau)$ persistence
0.05	−4.728	−2.640	0.008	−3.737	−2.747	−0.127	−1.651	−3.024	−0.022	−3.690	−3.066	−0.107
0.10	−5.486	−2.727	−0.059	−6.144	−2.738	−0.129	−5.447	−3.074	0.064	−6.414	−2.842	−0.118
0.15	−6.530	−2.622	−0.110	−8.779	−2.631	−0.149	−7.329	−3.080	−0.054	−9.057	−2.994	−0.003
0.20	−10.090	−2.631	−0.140	−14.904	−2.701	−0.129	−10.842	−2.911	−0.036	−10.186	−2.927	−0.025
0.25	−10.991	−2.800	−0.139	−12.753	−2.785	−0.034	−13.208	−2.745	−0.017	−12.103	−2.977	−0.063
0.30	−12.449	−2.822	−0.121	−14.025	−2.740	−0.007	−14.015	−2.752	0.001	−13.633	−2.847	−0.029
0.35	−14.510	−2.946	−0.195	−14.572	−2.753	−0.010	−14.799	−2.760	0.009	−15.097	−2.797	−0.104
0.40	−16.326	−2.937	−0.202	−14.537	−2.860	−0.081	−15.406	−2.555	0.016	−15.296	−2.781	−0.072
0.45	−16.211	−3.044	−0.184	−14.472	−2.929	−0.069	−16.018	−2.721	0.023	−16.853	−2.806	−0.042
0.50	−15.728	−2.966	−0.214	−14.717	−3.132	−0.095	−15.703	−2.651	0.018	−18.061	−2.708	−0.052
0.55	−16.975	−3.036	−0.186	−14.345	−3.031	−0.092	−16.817	−2.692	−0.039	−18.768	−2.710	−0.071
0.60	−16.257	−3.135	−0.235	−12.439	−3.077	0.004	−16.379	−2.568	−0.014	−19.045	−2.680	−0.113
0.65	−16.124	−3.136	−0.223	−12.987	−2.868	−0.069	−16.452	−2.494	−0.003	−16.541	−2.704	−0.138
0.70	−14.656	−3.124	−0.167	−11.638	−2.836	−0.061	−15.717	−2.511	0.079	−16.384	−2.774	−0.142
0.75	−11.958	−3.077	−0.134	−8.510	−2.734	−0.010	−15.630	−2.366	0.110	−15.557	−2.769	−0.135
0.80	−9.139	−3.141	−0.150	−7.448	−2.824	−0.014	−15.462	−2.310	0.097	−13.883	−2.829	−0.116
0.85	−7.122	−3.302	−0.124	−5.455	−2.744	0.055	−14.769	−2.310	0.086	−9.546	−2.795	−0.227
0.90	−5.040	−3.125	−0.067	−4.970	−2.763	−0.050	−8.743	−2.310	0.064	−8.224	−2.769	−0.276
0.95	−3.484	−2.609	0.109	−4.094	−2.844	−0.170	−5.231	−2.310	0.003	−4.178	−2.525	−0.125

Table 4. Quantile unit root test results

	IT			MAT			TELE			UTIL		
Quantile(s)	t-statistics	CV	$a(\tau)$ persistence	t-statistics	CV	persistence	t-statistics	CV	persistence	t-statistics	CV	persistence
0.05	−2.000	−3.157	0.047	−1.651	−3.024	−0.022	−3.690	−3.066	−0.107	−2.000	−3.157	0.047
0.10	−6.014	−2.983	−0.011	−5.447	−3.074	0.064	−6.414	−2.842	−0.118	−6.014	−2.983	−0.011
0.15	−8.593	−3.110	−0.090	−7.329	−3.080	−0.054	−9.057	−2.994	−0.003	−8.593	−3.110	−0.090
0.20	−10.233	−2.927	−0.046	−10.842	−2.911	−0.036	−10.186	−2.927	−0.025	−10.233	−2.927	−0.046
0.25	−12.103	−2.861	−0.042	−13.208	−2.745	−0.017	−12.103	−2.977	−0.063	−12.103	−2.861	−0.042
0.30	−12.582	−2.905	−0.023	−14.015	−2.752	0.001	−13.633	−2.847	−0.029	−12.582	−2.905	−0.023
0.35	−13.740	−2.766	−0.004	−14.799	−2.760	0.009	−15.097	−2.797	−0.104	−13.740	−2.766	−0.004
0.40	−15.025	−2.798	−0.061	−15.406	−2.555	0.016	−15.296	−2.781	−0.072	−15.025	−2.798	−0.061
0.45	−14.339	−2.793	−0.040	−16.018	−2.721	0.023	−16.853	−2.806	−0.042	−14.339	−2.793	−0.040
0.50	−13.715	−2.744	−0.074	−15.703	−2.651	0.018	−18.061	−2.708	−0.052	−13.715	−2.744	−0.074
0.55	−12.717	−2.652	−0.064	−16.817	−2.692	−0.039	−18.768	−2.710	−0.071	−12.717	−2.652	−0.064
0.60	−12.652	−2.674	−0.037	−16.379	−2.568	−0.014	−19.045	−2.680	−0.113	−12.652	−2.674	−0.037
0.65	−13.381	−2.809	−0.071	−16.452	−2.494	−0.003	−16.541	−2.704	−0.138	−13.381	−2.809	−0.071
0.70	−11.994	−2.752	−0.081	−15.717	−2.511	0.079	−16.384	−2.774	−0.142	−11.994	−2.752	−0.081
0.75	−9.929	−2.743	0.045	−15.630	−2.366	0.110	−15.557	−2.769	−0.135	−9.929	−2.743	0.045
0.80	−9.437	−2.646	−0.013	−15.462	−2.310	0.097	−13.883	−2.829	−0.116	−9.437	−2.646	−0.013
0.85	−11.202	−2.636	−0.044	−14.769	−2.310	0.086	−9.546	−2.795	−0.227	−11.202	−2.636	−0.044
0.90	−7.402	−2.432	−0.131	−8.743	−2.310	0.064	−8.224	−2.769	−0.276	−7.402	−2.432	−0.131
0.95	−5.553	−2.310	−0.022	−5.231	−2.310	0.003	−4.178	−2.525	−0.125	−5.553	−2.310	−0.022

upper quantiles, it implies that the high number of vaccine administrations bears positive influence on China's leading SM. Interestingly, we also observed that the higher quantiles of vaccines (0.90–0.95) bear a negative influence on the lower quantile of the Shanghai stock returns, which implies that the vaccine may not influence the Shanghai SM when it is not performing well or exhibiting bearish condition.

Regarding the sectoral returns, basic materials, consumer discretionary, telecommunication, utilities, and industrial sectors have similar responses to CVAC administered, much like the Shanghai SM. In terms of the consumer staples and healthcare sectors we observed that the lower to higher quantiles of CVAC negatively impact the lower quantiles of consumer staples and healthcare sector returns. In contrast, the high quantiles of vaccines (0.85–0.95) have positive association with the higher quantiles of consumer staples and the healthcare sector. The positive response of higher quantiles of both energy and financial sectors vis-à-vis high quantile vaccines entails that the demand for energy and financial activities was boosted with the increase in vaccines. We observed that the higher quantiles of vaccines (0.7–0.95) have hostile impact on the lower quantile of the information technology (IT) returns (0.1–0.3),

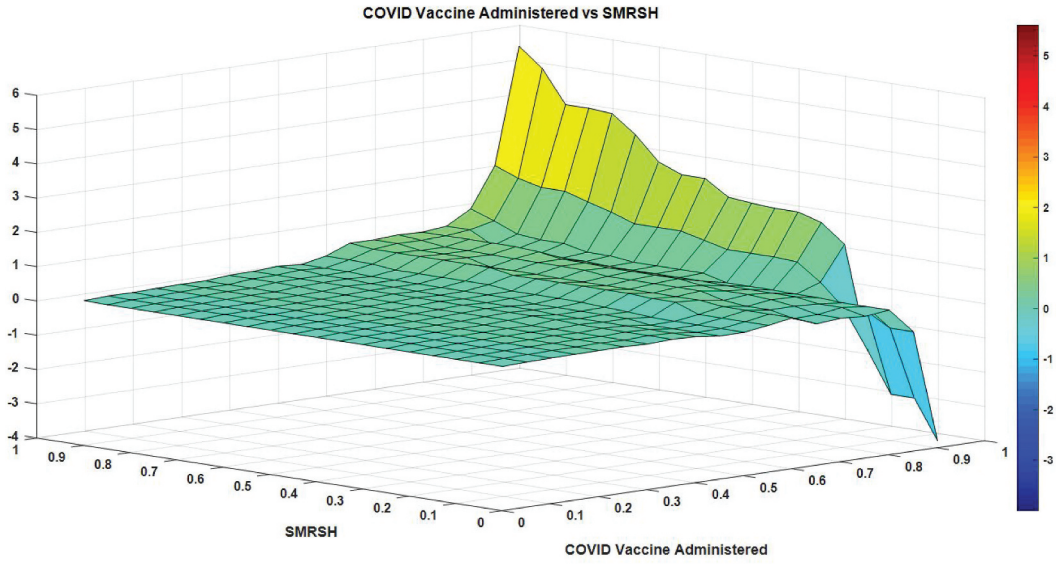


Figure 1. QQ estimates of COVID-19 vaccines and the Shanghai stock market returns.

while the higher quantile bears positive influence on the higher quantile of the information technology returns. The initial negative response of the information technology sector towards vaccines was owing to the fact that the IT sector received huge boost in returns amid the CoV pandemic. These outcomes have been reported in Figures 2 to 11. Tables 5–7 report the outcome of Granger causality-in-quantiles. We noticed a uni-directional causality from the CVAC towards Shanghai SM returns in lower and high quantiles. On a sectoral level, CVAC causes financial, energy, industrial, and utilities sectors in lower quantiles, whereas consumer discretionary was observed to have a causal association with vaccines in higher quantiles.

Robustness check

To ascertain the robustness of the QQR approach, we compare the average estimates of the QQ approach with the coefficients of the conventional quantile regression (QR) depicted in Figure 12. The pictorial representation shows

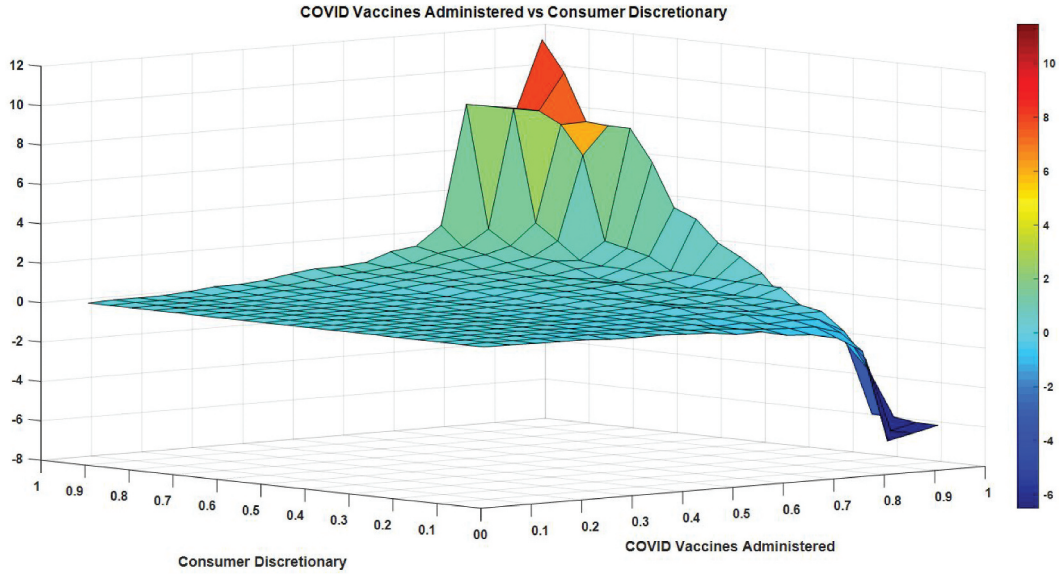


Figure 2. QQ estimates of COVID-19 vaccines and Consumer Discretionary returns.

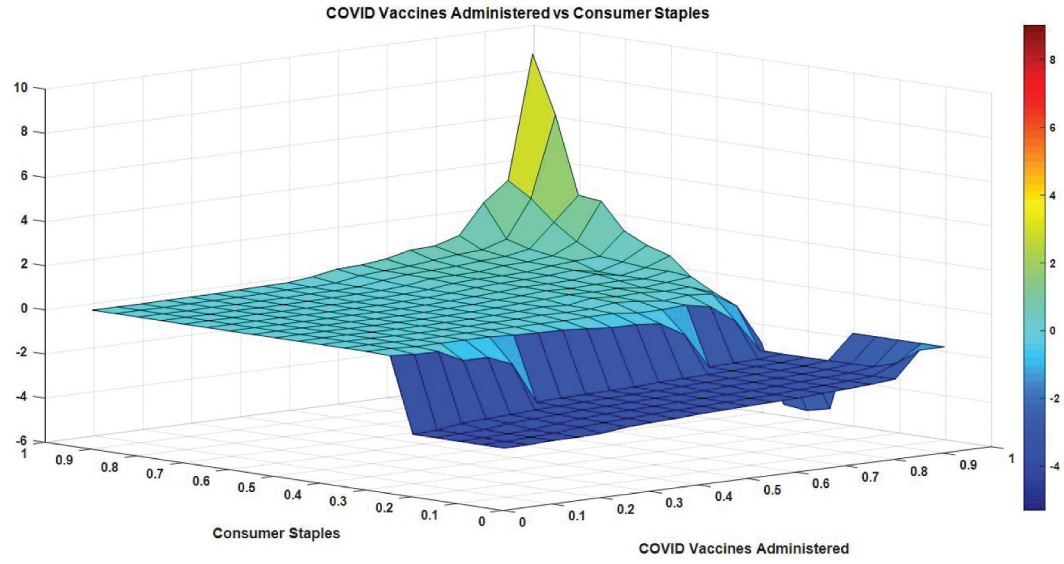


Figure 3. QQ estimates of changes in COVID-19 vaccines and Consumer Staples returns.

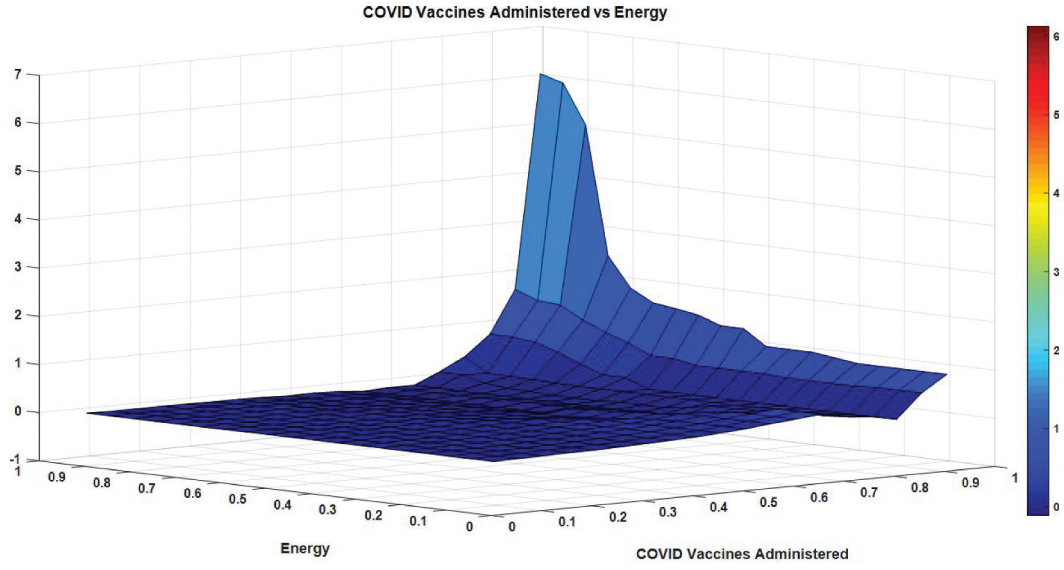


Figure 4. QQ estimates of COVID-19 vaccines and Energy returns.

that the average values of QQ mirror the QR values across all quantiles. These findings validate our primary outcomes determined via the QQ approach.

IV. Conclusion and policy implications

This study evaluated the impact of COVID-19 vaccines on China's overall and sectoral stock returns. To this end, we adopted the novel QQR approach, which delineates the effects across the whole distribution of the dependent and independent variables. Additionally, the quantile causality (CQ) approach was employed to determine the causal associations in quantiles among variables. The empirical outcomes infer the positive impact of CVAC on the Shanghai stock return in high quantiles, which implies that China's leading SM responded amicably to CVAC. Moreover, the high quantiles of CVAC negatively influence the lower quantile of the Shanghai SM. These outcomes underscore that a high number of vaccines may not influence the stock returns when going through a bearish trend.

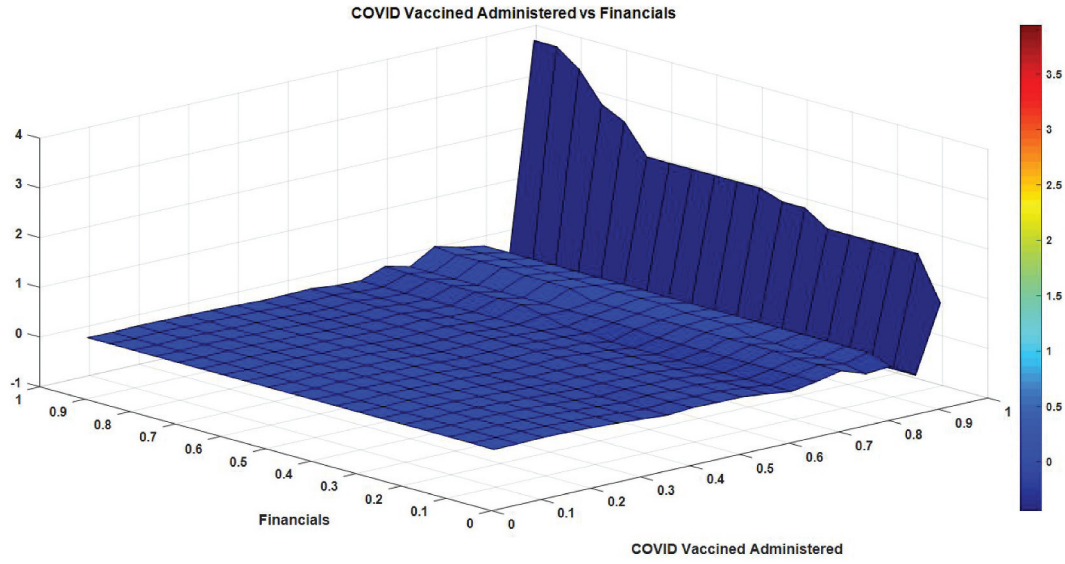


Figure 5. QQ estimates of COVID-19 vaccines and Financial returns.

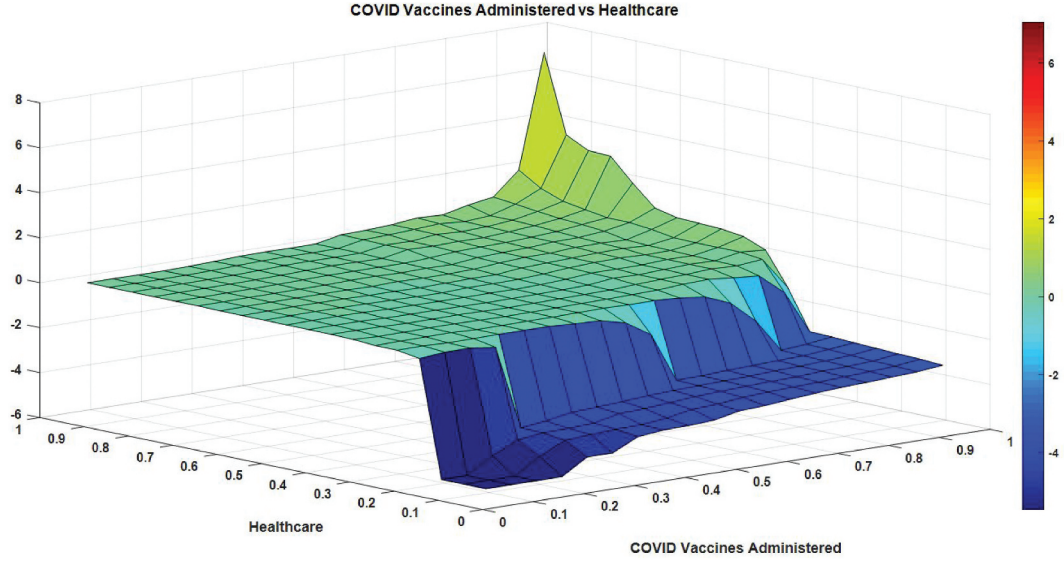


Figure 6. QQ estimates of COVID-19 vaccines and Healthcare returns.

On the sectoral level, we observed that the higher quantiles of vaccines positively affect the high quantiles of basic materials, consumer discretionary, telecommunication, utilities, and industrial sectors. The lower to higher quantiles of CVAC have negative relationship with the lower quantiles of consumer staples and healthcare sectoral returns, whereas the high quantiles of vaccines (0.85–0.95) have positive effect on the higher quantiles of consumer staples and healthcare sector. The positive response of higher quantiles of both energy and financial sectors vis-à-vis high quantile vaccines entails that the demand for energy and financial activities received a boost with the increase in vaccines. We noticed that the higher quantiles of vaccines have hostile impact on the lower quantile of the information technology (IT) returns), while the higher quantile of vaccines bears positive influence on the higher quantile of the information technology returns. We deduce that China's overall and sectoral stock returns have heterogenous or asymmetric association with CVAC. The quantile causality approach affirms the causal relationship between the CVAC and the Shanghai stock returns in lower and high quantiles. The outcomes underscore that the impact of

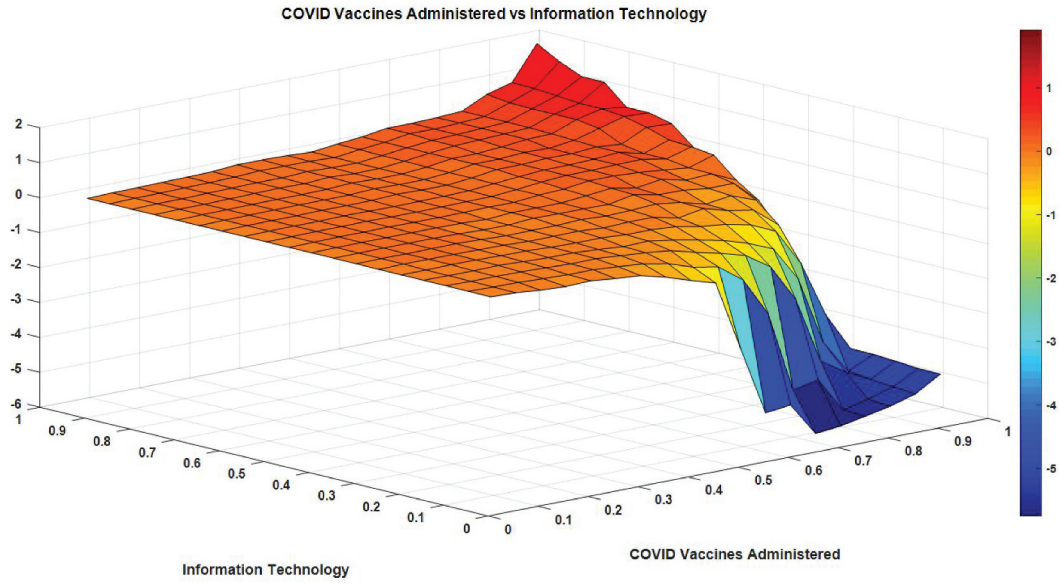


Figure 7. QQ estimates of COVID-19 vaccines and Information Technology.

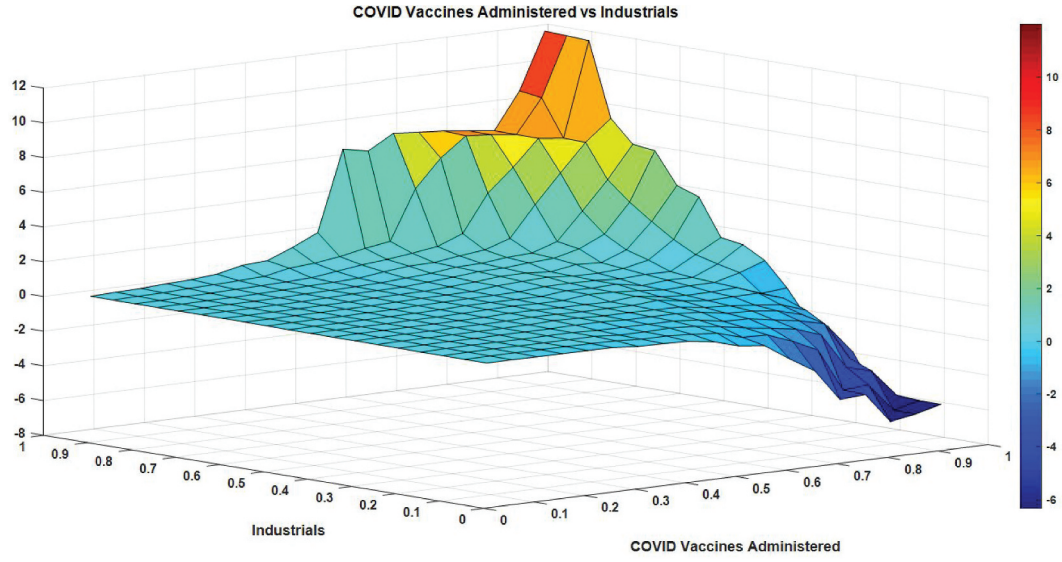


Figure 8. QQ estimates of COVID-19 vaccines and Industrials returns.

CVAC on China's overall and sectoral stock return is disproportionate or heterogeneous, and there is considerable evidence of asymmetry.

The positive impact of CVAC on Shanghai stock returns infer that CVAC substantially buoys investor sentiment. These findings underscore that the vaccination programmes have significantly enhanced investors' confidence during the pandemic. In this respect, policymakers should augment public health measures, including vaccination, as this approach not only assists in overcoming the health crisis but also boosts underlying investor confidence, which is critical for financial market recovery. The positive association between CVAC and China's SM demands innovation in the healthcare industry. Hence, policies aimed to propel research and development in the health sector could not only ease the recent pandemic pressure but also enable the Chinese government to tackle prospective health crises.

The negative impact of higher quantiles of CVAC on the lower quantiles of the stock returns implies that the market may exhibit bearish trends irrespective of other factors, regardless of the

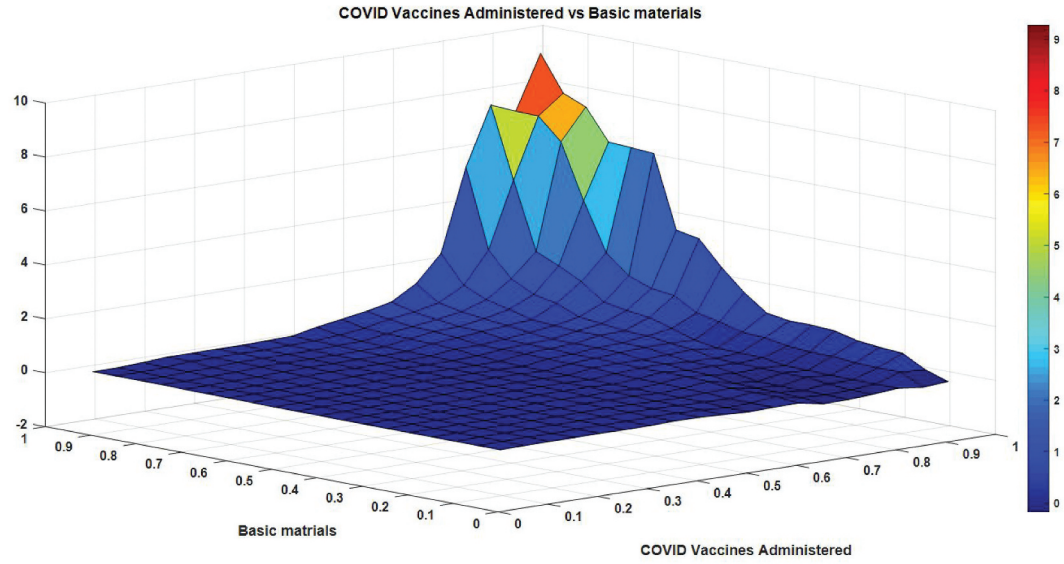


Figure 9. QQ estimates of COVID-19 vaccines and Basic materials returns.

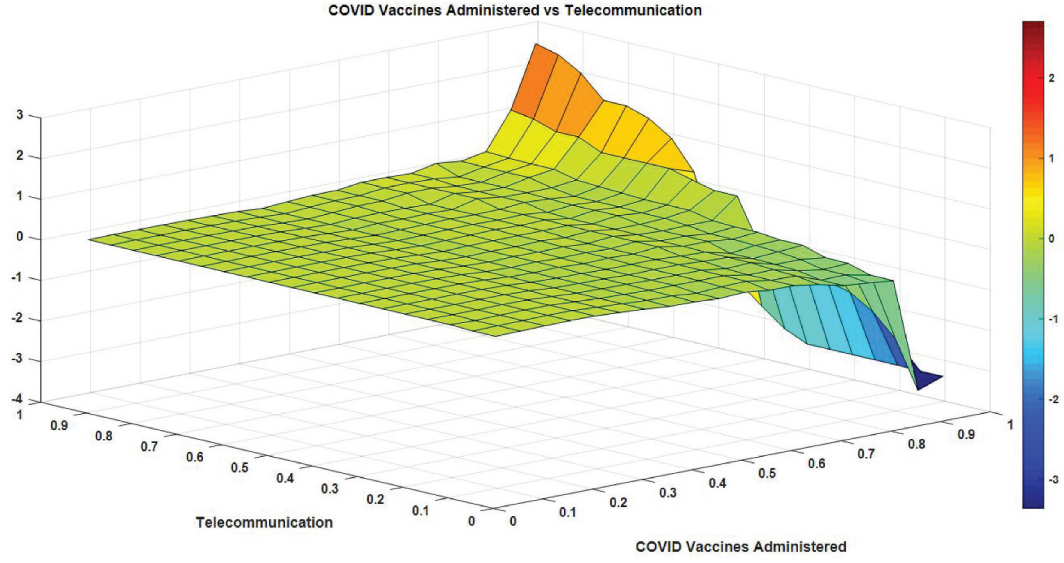


Figure 10. QQ estimates of COVID-19 vaccines and Telecommunication returns.

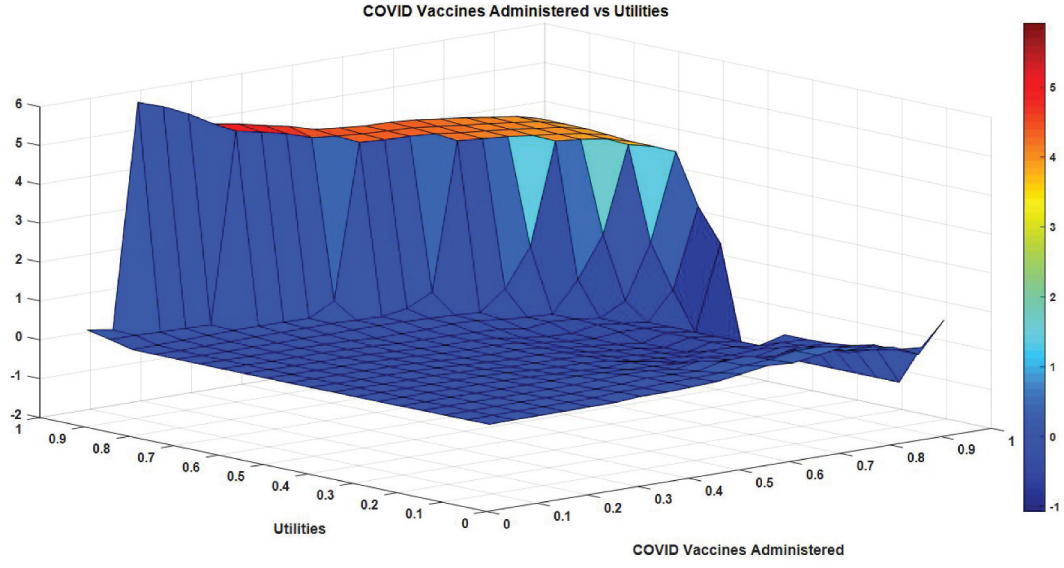
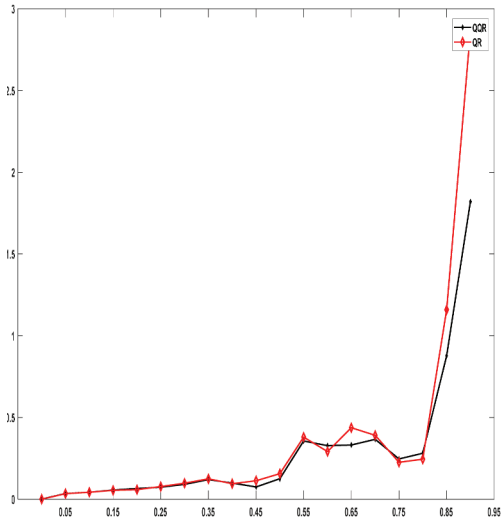
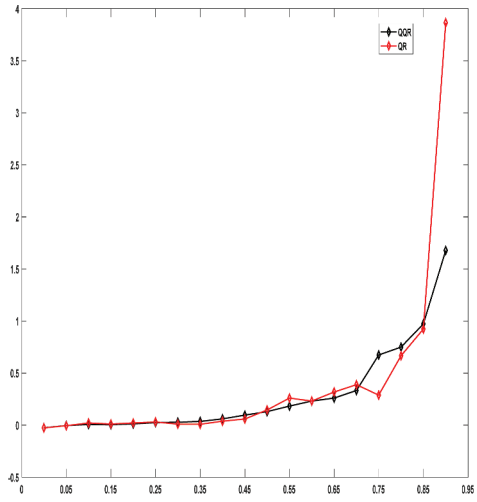


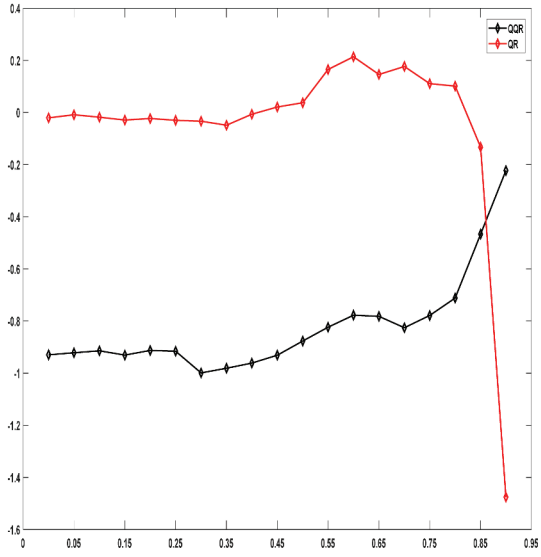
Figure 11. QQ estimates of COVID-19 vaccines and Utilities returns.



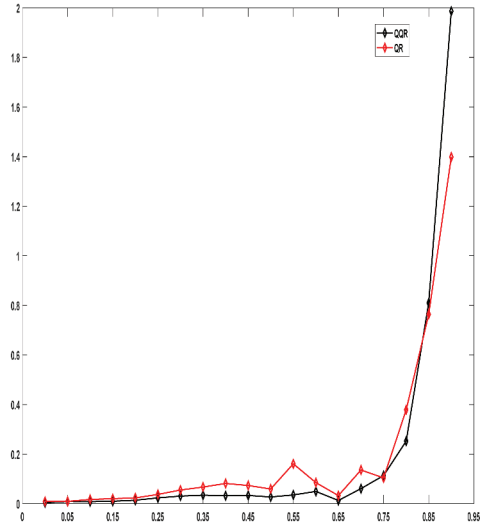
Effect of Vaccines administered on SMR



Effect of Vaccines administered on Consumer Discretionary



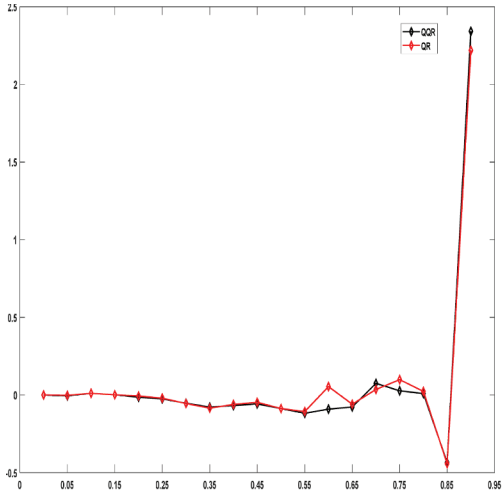
Effect of Vaccines administered on Consumer Staples



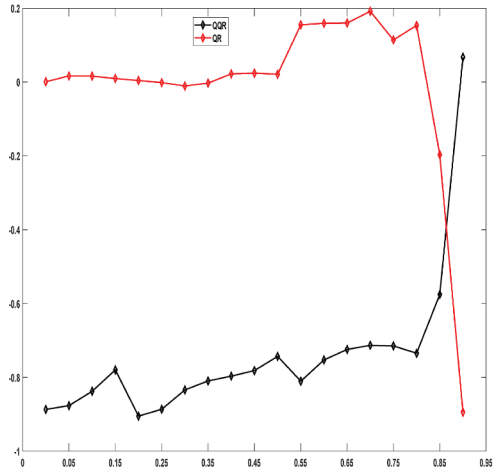
Effect of Vaccines administered on Energy

Figure 12a. Robustness Check of QQR approach

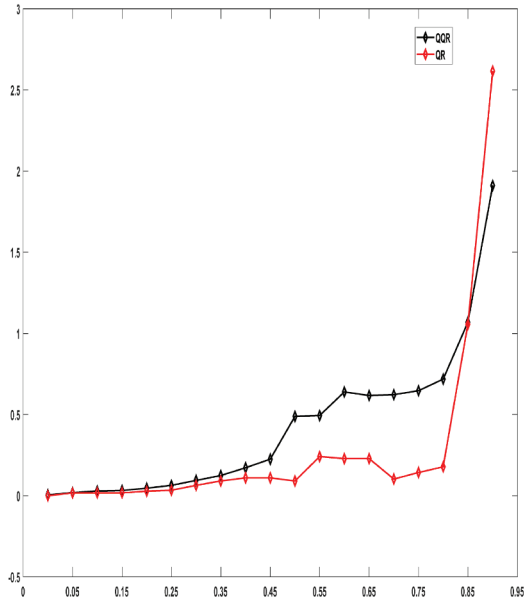
increasing rate of CVAC. The results indicate that relying solely on vaccination programmes may not be effective in uplifting market confidence during turbulent times. Therefore, implementing targeted monetary and fiscal policy measures and targeted economic stimulus could come in handy to support various sectors to restore economic and financial stability. It is also a fact that grappling with all sorts of short-term volatilities is impossible. In this respect, policymakers also need to adopt a diverse nature of recovery strategies, enabling them to build economic and financial systems that can



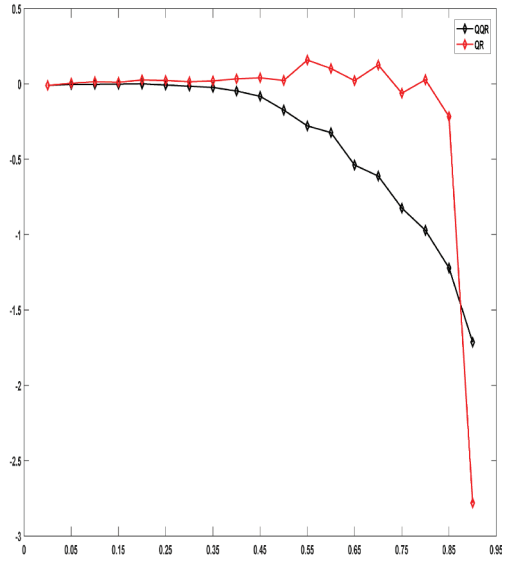
Effect of Vaccines administered on Financials



Effect of Vaccines administered on Healthcare



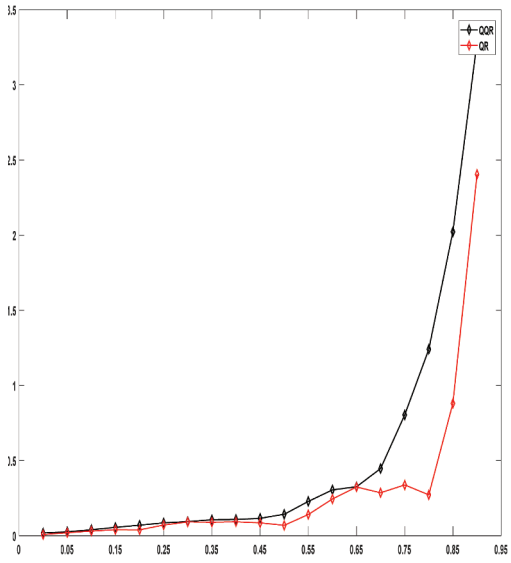
Effect of Vaccines administered on Industrials



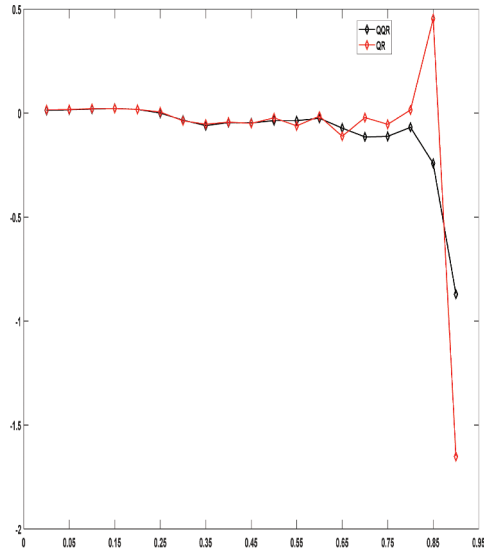
Effect of Vaccines administered on Information Technology

Figure 12b. Continue

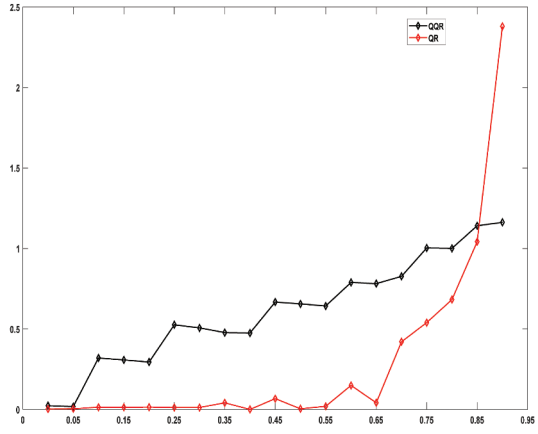
absorb future unforeseen shocks. Our findings also educate investors on predicting stock return vis-à-vis CVAC and augmenting their portfolio diversification strategies. Ensuring the accuracy of vaccination data may enhance investors' confidence, augment public health measures, and restore finan-



Effect of Vaccines administered on Materials



Effect of Vaccines administered on Telecommunication



Effect of Vaccines administered on Utilities

Figure 12c. Continue

Table 5. Quantile granger causality results

Quantiles	CVAC↛SHR	SHR↛CVAC	CVAC↛COD	COD↛CVAC	VAC↛COS	COS↛VAC	VAC↛ENE	ENE↛VAC	VAC↛FIN	FIN↛VAC
[0.05;0.95]	**0.029**	0.988	0.424	0.594	**0.004**	0.988	0.647	1.000	0.906	0.835
0.05	0.265	**0.024**	0.665	**0.024**	0.921	**0.024**	0.524	**0.024**	0.876	**0.024**
0.10	0.276	**0.035**	0.635	**0.029**	0.401	0.365	0.547	**0.035**	0.894	**0.029**
0.15	0.124	0.288	0.735	0.212	**0.075**	0.806	0.618	0.271	0.982	0.106
0.20	0.188	0.594	0.812	0.424	**0.061**	0.935	0.618	0.688	0.976	0.441
0.25	0.206	0.865	0.871	0.759	**0.007**	0.994	0.635	0.929	0.976	0.894
0.30	0.271	0.988	0.900	0.953	**0.004**	1.000	0.653	0.988	0.976	0.959
0.35	0.153	0.971	0.865	0.882	**0.004**	1.000	0.659	0.965	0.971	0.924
0.40	**0.065**	0.694	0.794	0.665	**0.004**	0.988	0.694	0.741	0.865	0.994
0.45	**0.006**	0.424	0.753	0.971	0.115	0.859	0.741	0.841	0.894	0.200
0.50	**0.012**	0.559	0.653	0.653	0.247	0.353	0.729	0.600	0.865	0.494
0.55	**0.006**	0.418	0.553	0.276	0.452	0.394	0.741	0.853	0.829	0.618
0.60	**0.012**	0.735	0.465	0.224	0.298	0.641	0.724	1.000	0.794	0.129
0.65	**0.006**	0.724	0.353	0.224	0.194	0.718	0.712	1.000	0.841	0.494
0.70	**0.006**	0.976	0.294	0.212	**0.050**	0.947	0.700	1.000	0.724	0.588
0.75	**0.094**	0.941	0.253	0.200	**0.004**	0.976	0.712	0.994	0.588	0.429
0.80	**0.041**	0.994	0.135	0.265	**0.004**	0.929	0.694	0.953	0.400	0.753
0.85	**0.047**	1.000	**0.076**	0.329	**0.004**	0.953	0.535	0.947	0.271	0.888
0.90	0.447	0.965	**0.041**	0.506	**0.004**	0.953	0.447	0.888	0.435	0.912
0.95	0.582	1.000	**0.029**	0.982	0.455	0.953	0.388	0.829	0.376	0.835

'0 = →**0**'denotes does not Granger cause. Values in bold are statistically significant at 1%, 5%, or 10% significance level. VAC denotes vaccines, SHR is Shanghai stock returns, COD is the consumer discretionary sector stock returns. COS is the consumer staples sector stock returns. ENE is the energy sector stock returns. FIN is the financial sector stock returns.

Table 6. Quantile granger causality results

Quantiles	VAC ↛ HLC	HLC ↛ VAC	VAC ↛ INDUS	INDUS ↛ VAC	VAC ↛ IT	IT ↛ VAC	VAC ↛ MAT	MAT ↛ VAC
[0.05;0.95]	0.900	1.000	0.294	0.841	**0.094**	0.982	0.406	0.629
0.05	0.759	**0.024**	**0.006**	**0.024**	**0.047**	**0.024**	0.271	**0.024**
0.10	0.882	**0.029**	**0.012**	0.500	**0.059**	0.182	0.382	**0.041**
0.15	0.888	0.582	**0.053**	0.653	**0.065**	0.359	0.229	0.106
0.20	0.924	0.965	0.135	0.700	**0.059**	0.600	0.382	0.159
0.25	0.900	0.994	0.371	0.888	**0.076**	0.900	0.271	0.235
0.30	0.888	0.959	0.494	0.929	**0.065**	0.888	0.382	0.647
0.35	0.882	1.000	0.712	0.971	**0.082**	0.794	0.494	0.576
0.40	0.865	1.000	0.812	0.724	0.100	0.871	0.588	0.482
0.45	0.853	0.871	0.818	0.929	0.147	0.788	0.706	0.753
0.50	0.859	0.947	0.829	0.718	0.176	0.841	0.829	0.788
0.55	0.847	0.976	0.759	0.382	0.194	0.882	0.847	0.447
0.60	0.841	0.776	0.718	0.247	0.247	1.000	0.600	0.194
0.65	0.847	0.812	0.541	0.447	0.265	1.000	0.553	0.359
0.70	0.853	0.794	0.447	0.529	0.271	1.000	0.482	0.429
0.75	0.841	0.918	0.335	0.812	0.265	0.924	0.371	0.535
0.80	0.824	0.976	0.229	0.882	0.271	0.906	0.335	0.694
0.85	0.712	0.965	0.165	0.912	0.271	0.882	0.306	0.782
0.90	0.629	0.965	0.135	0.882	0.241	0.941	0.329	0.824
0.95	0.529	0.959	0.206	0.859	0.212	1.000	0.406	0.900

'0 = →0'/denotes does not Granger cause. Values in bold are statistically significant at 1%, 5%, or 10% significance level. HLC is healthcare stock returns, INDUS is the industrials stock returns. IT denotes Information technology stock returns, MAT is the materials sector stock returns. TEL is the telecommunication sector stock returns. UTIL is the sector stock returns.

Table 7. Quantile Granger causality results

Quantiles	CVAC ↛ TEL	TELE ↛ CVAC	CVAC ↛ UTIL	UTIL ↛ CVAC
[0.05;0.95]	0.571	1.000	0.294	0.841
0.05	0.941	**0.024**	**0.006**	**0.024**
0.10	0.882	0.135	**0.012**	0.500
0.15	0.894	0.606	**0.053**	0.653
0.20	0.894	0.800	0.135	0.700
0.25	0.735	0.953	0.371	0.888
0.30	0.647	0.947	0.494	0.929
0.35	0.606	0.965	0.712	0.971
0.40	0.529	0.982	0.812	0.724
0.45	0.476	0.765	0.818	0.929
0.50	0.400	1.000	0.829	0.718
0.55	0.318	1.000	0.759	0.382
0.60	0.594	1.000	0.718	0.247
0.65	0.512	0.994	0.541	0.447
0.70	0.441	0.976	0.447	0.529
0.75	0.400	0.959	0.335	0.812
0.80	0.318	0.959	0.229	0.882
0.85	0.359	0.918	0.165	0.912
0.90	0.312	0.918	0.135	0.882
0.95	0.165	0.918	0.206	0.859

'0 = →0'/denotes does not Granger cause.

cial stability. Conspicuous communication on the impact of CVAC on China's stock market advocates informed decision-making and paves the way for a friendly investment environment.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The datasets used during the current study are available from the corresponding author upon reasonable request.

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