Environmental Science and Pollution Research (2023) 30:61766–61777
https://doi.org/10.1007/s11356-023-26252-6

RESEARCH ARTICLE

Impact of COVID-19 on China's business and economic conditions: the importance of quantile asymmetries

Assad Ullah[1,2] · Xinshun Zhao[2] · Aamir Aijaz Sayed[3] · Azka Amin[4] · Adeel Riaz[5]

Received: 19 October 2022 / Accepted: 27 February 2023 / Published online: 18 March 2023

Abstract

China has remained a growth engine for the global economy for the last several years. In this study, we assess the impact of COVID-19 on China's business and economic conditions; employing the quantile-on-quantile (QQ) regression and the quantile causality approaches. These econometrics batteries suit our research postulation, as they are capable to delineate underlying asymmetries across the whole distribution, based on which we can infer whether the response of China's business and economic conditions towards COVID-19 is heterogenous or homogenous. Utilizing the novel business and economic conditions measures, we observed that COVID-19 had initially disrupted both business and economic conditions in China. However, they showcased recovery over time. Our in-depth analysis allowed us to infer that the effect of COVID-19 on China's business and economic conditions is heterogeneous across different quantiles, and there is reliable evidence of asymmetry. The outcomes of quantile causality in mean and variance corroborate our primary estimations. These findings educate policymakers, companies, and other stakeholders to understand the nuances of China's business and economic conditions vis-a-vis COVID-19 in the short-run and as time elapsed.

Keywords COVID-19 · Business condition · Economic condition · Quantile-on-Quantile regression · Quantile causality · China

Introduction

To cope with one of the world's largest health crises in history, governments enacted extreme control measures to contain the spread of the novel coronavirus (COVID-19). These containment measures were indispensable for saving precious lives; however, they came up with some residuals; i.e., they had detrimental effects on the business and economic operations as some countries experienced economic recessions during the period. Owing to COVID-19, quite a few businesses were forced to close either voluntarily or involuntarily as they were mandated by the government, whereas the rest had to opt for a substantial overhaul in their operations in order to stay afloat. Being the epicenter of COVID-19, both the business and economic conditions of China received significant blows in the short-run; there remains an unanswered question of whether they exhibit recovery over time. This study intends to answer this question by inquiring the impact of COVID-19 on China's business and economic conditions during the pandemic peak period and beyond.

Owing to the COVID-19 pandemic, the global economic growth showcased significant decline during 2020,

Responsible Editor: Arshian Sharif

✉ Assad Ullah
assad@henu.edu.cn

Xinshun Zhao
zxshun@henu.edu.cn; xinshunzhao.henu@outlook.com

Aamir Aijaz Sayed
aamirank@gmail.com

Azka Amin
azkaamin321@yahoo.com

Adeel Riaz
adeelriaz@henu.edu.cn

[1] School of Economics and Management, Hainan Normal University, Haikou, China

[2] School of Economics, Henan University, Kaifeng, China

[3] Institute of Management, Commerce & Economics, Shri Ram Swaroop Memorial University, Lucknow, India

[4] School of Economics, Hainan University, Haikou, China

[5] School of Business, Henan University, Kaifeng, China

as several industrialized economies, including the UK, Japan, Germany, the USA, and France, experienced a slump of 1.98%, 0.85%, 2.22%, 1.22%, and 5.83%, respectively, in their GDP, and the Chinese economy was no exception. According to the National Bureau of Statistics of China (2020), the gross domestic product (GDP) of China dropped to 6.8% during the first quarter of 2020, as businesses remained close during the initial phase of the pandemic. Wholesale and retail were the most adversely affected sectors, contracting by 17.8%. Among others, the construction sector was the hardest hit as it declined by 17.5%, followed by the transportation sector. The tourism industry also followed suit and reported a fall of 68.8%. These statistics motivate us to explore whether the adverse impact of COVID-19 on China's business and economic conditions persists or they realize recovery as time elapsed.

Quite a few researchers have studied the economic consequences of COVID-19 pandemic. The prime distinction between our work and previous studies is as follows; researchers have explored the impact of COVID-19 on individual aspects of businesses and the economy in the context of China, such as the COVID-19 and firm investment and performance (Jiang et al. 2021a, b; Shen et al. 2020); COVID-19 and manufacturer operations (Chen et al. 2021); COVID-19-stock and bond markets (Chuanjian Li et al. 2021; Liu et al. 2021; Mezghani et al. 2021; Sun et al. 2021a, b; Yi et al. 2021); COVID-19 and SMEs (Dai et al. 2021; Sun et al. 2021a, b); COVID-19 and shipping industry (Gavalas et al. 2022; Marobhe 2021); COVID-19 and financial development (Jiang et al. 2021a, b); COVID-19 and housing market (Yang and Zhou 2021); COVID-19 and trade, tourism, transport, and electricity consumption (Ruiz Estrada et al. 2020); COVID-19 and trade (Cao et al. 2021; Cooray and Palanivel 2021; Chunding Li and Lin 2021; Zhang et al. 2021; Zhao et al. 2021); and COVID-19 and economic performance (Zhang et al. 2021). However, there remains an unexplored area to determine the impact of COVID-19 on overall business and economic conditions in China. Utilizing comprehensive indices of business and economic conditions and the novel quantile-on-quantile regression and quantile causality approaches, which relate the quantile of the independent variable to the quantiles of the dependent variable and delineate the overall dependence structure across distribution and pinpoint causal association among quantiles of variables—we attempt to bridge this gap in the literature.

Studying the economic consequences of COVID-19 in the context of China is of prime interest for several reasons. Firstly, China is the second-largest economy worldwide and is the first country where COVID-19 was reported. Secondly, as an emerging economy, China has remained the engine of worldwide growth for the past few years. However, due to the recent pandemic, the decline in China's economic statistics is not only bad for its economy but also espouses negative consequences for the economies across the globe.

To contain the spillovers from the COVID-19 to the business and economic environment, it is crucial to investigate the new insights that could be helpful for policymakers in order to propose new and effective policies. In this context, we aim to augment the current literature pertaining to the economic consequences of COIVD-19 in the following manner. Firstly, we explore the impact of COVID-19 on China's business and economic conditions, employing comprehensive indices for both business and economic conditions. The economic condition index comprises the weights of several economically significant variables, which have marked effect on the economic cycles such as treasury bond interest rate spread, new investment projects initiated, product sales rate, money supply (M2), logistics such as freight volume, fixed asset investment, retails sales, imports and exports, Government taxation, corporate profits and household disposable income, industrial production, government revenue and expenditures, and product inventory. The business condition index is based on the entrepreneur's judgment and forecast about macro-policies and market circumstances. It reflects the entrepreneur's confidence in the overall macro-economic condition. The business condition index covers eight major sectors with respect to industry coverage, including manufacturing, mining, gas, water, power production and supply, real estate, construction, social services, transportation wholesale and retail trade, accommodation and retail trade and information transmission and computer and software. Secondly, we have employed quantile-on-quantile (QQR) estimation approach proposed by Sim and Zhou (2015). The quantile-on-quantile regression (QQR) approach demonstrates how the quantiles of the independent variable affect the relative quantiles of the dependent variable and is capable of discerning the varying degree (asymmetric) effects. The novelty of the QQR approach is that it incorporates the fundamentals of quantile regression and non-parametric estimations. The asymmetric approaches have received marked attention in recent time owing to confirmation of nonlinearities in various domains of economics and finance. (Chang et al. 2020a; Hossain et al. 2023; Khan et al. 2019; Pata and Caglar 2021; Sharif et al. 2020a, b; Sharif et al. 2017, 2019, 2022; Sim and Zhou 2015; Suki et al. 2020; Syed et al. 2022; Ullah et al. 2020; Ullah et al. 2021; Umair and Yousuf 2022; Wan et al. 2022; Yasmeen et al. 2022). Thirdly, we aim to determine the causal association between COVID-19 and China's business and economic conditions in a quantile framework. The non-parametric causality-in-quantiles approach portrays a complete picture of non-causal directional associations at various quantiles among variables.

Data and estimation methodology

We have used the quantile-on-quantile regression (QQR) pioneered by Sim and Zhou (2015) and the Troster et al. (2018) quantiles causality estimation techniques as our main estimation tools. The sample period of our study spanning from 3rd February AQ62020 to 29th March 2021 is defined by the data availability of business and economic conditions in China. We obtained the COVID-19 cases from the Centre for Systems Science and Engineering at Johns Hopkins University, USA. The data for the business and economic conditions indices are retrieved from the CEIC database. The economic condition index comprises components that tend to lead or coincide with the economic cycles. These components are in line with global standards; i.e., all the selected variables in the index demonstrate cyclical behavior and are economically significant. These components include treasury bond interest rate spread, money supply (M2), imports and exports, new investment projects initiated, product sales rate, logistics such as freight volume, fixed asset investment, retail sales, Government taxation, corporate profits, and household disposable income, industrial production, government revenue and expenditures, and product inventory. The business condition index, also known as the management climate index of enterprises, is an index based on enterprises' judgment and forecast about macro-policies. It exhibits enterprises' confidence in macroeconomic circumstances. The business condition index includes eight major sectors with respect to industry coverage, including manufacturing, power production and supply, mining, gas, water, real estate, construction, social services, transportation, wholesale and retail trade, accommodation and retail trade and information transmission and computer and software. In the subsequent section, we explain the model specification and the key features of the quantile-on-quantile (QQR) and causality in quantiles (QC) estimation techniques.

Quantile-on-quantile regression (QQR) approach

The quantile-on-quantile regression (QQR) approach is an enhanced version of the standard quantile regression (QR) model, which evaluates the impact of one variable on the different conditional quantiles of another variable. The majority of the studies in the extant literature have utilized the classical linear regression technique for empirical estimation purposes. With advanced estimation analyses, scholars have shifted attention from the classical linear regression to the conventional quantile regression (QR) suggested by Koenker and Bassett (1978). Compared to the conventional least square, the QR technique evaluates the effect of explanatory variables at the tail and the center of the distribution, hence, providing a more comprehensive and robust estimate throughout the study (Koenker and Ng 2005). The local linear regression (LLR) of Stone (1977) and Cleveland (1979) is used to investigate the variable local effect and to avoid the curse of dimensionality, which is associated with the non-parametric models. The LLR estimation assists in studying the local impact of an independent variable on the dependent variable by allocating more weight to the immediate neighbor in the dataset.

Subsequently, scholars further pushed the edges of the envelope and introduced the QQR approach, which incorporates the benefits of conventional quantile regression and non-parametric estimation techniques. The QQR method suits well with the data exhibiting non-linear or asymmetric characteristics (Sim and Zhou 2015). Thus, based on the combined benefits of QR and LLR, quantile-on-quantile (QRR) can analyze the relationship between the quantiles of explanatory variable and dependent variable in a comprehensive fashion. The QQR estimation technique is widely employed in various research domains, including oil and capital market nexus (Chang et al. 2020b; Sim and Zhou 2015), energy-growth related studies (Kumah and Mensah 2022), and COVID-19-stock market/cryptocurrency studies (Hashmi et al. 2021; Iqbal et al. 2021). Considering the aforementioned advantages of the QQR, we intend to explore the impact of COVID-19 on China's business and economic conditions in a quantile-on-quantile framework. Starting with the non-parametric quantile regression, our models take the following form;

$$BC_t = \beta^{\theta}\left(COVID_t\right) + \mu_t^{\theta} \tag{1}$$

$$EC_t = \beta^{\theta}\left(COVID_t\right) + \mu_t^{\theta} \tag{2}$$

where BC, EC_t denotes business and economic conditions of China for period t, $\mathrm{COVID_t}$ denotes the total COVID-19 cases in period t, and θ denotes the θth quantile distribution of BC_t and EC_t. The subscript μ_t^{θ} denotes the quantile error terms whose conditional θth is presumed to be zero. As there is no previous information available on COVID and business and economic conditions, we assume $\beta^{\theta}(\bullet)$ as an unknown function.

To reinforce the relationship between the θth quantile of Chinese economic and business conditions and the τth quantile of COVID-19, Eqs. 1 and 2 are evaluated in the neighborhood of $COVID^{\tau}$ by employing the LLR estimation technique. Based on the unknown value of $\beta^{\theta}(\bullet)$, the equation is rewritten employing the first-order Taylor expansion method, around the quantile of $COVID^{\tau}$

$$\beta^{\theta}(COVID_t) \approx \beta^{\theta}(COVID^{\tau}) + \beta^{\theta'}(COVID^{\tau})(COVID_t - COVID^{\tau}) \tag{3}$$

where $\beta^{\theta'}$ portrays partial derivative of $\beta^{\theta'}(COVID^{\tau})$ referred to as marginal response and represents the slope of coefficient in an LLR model.

The vital trait of Eq. 3 is that parameters $\beta^{\theta}(COVID^{\tau})$ and $\beta^{\theta'}(COVID^{\tau})$ are doubled indexed in θ and τ. Consequently $\beta^{\theta}(COVID^{\tau})$ and $\beta^{\theta'}(COVID^{\tau})$ are the function of θ and $COVID^{\tau}$ and that $COVID^{\tau}$ are function of τ. As $\beta^{\theta}(COVID^{\tau})$ and $\beta^{\theta'}(COVID^{\tau})$ are both functions of θ and τ as a result, both can be rewritten as $\beta_0(\theta, \tau)$ and $\beta_1(\theta, \tau)$ respectively. In this respect, Eq. (3) can be reframed as follows;

$$\beta^{\theta}\left(COVID_t\right) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(COVID_t - COVID^{\tau}) \quad (4)$$

Substituting Eq. 4 into Eq. (1) and Eq. (2), we express the QQR approach in its functional form as below;

$$BC_t = \frac{\beta_0(\theta,\tau) + \beta_1(\theta,\tau)\left(COVID_t - COVID^{\tau}\right) + \mu_t^{\theta}}{(*)} \quad (5)$$

$$EC_t = \frac{\beta_0(\theta,\tau) + \beta_1(\theta,\tau)\left(COVID_t - COVID^{\tau}\right) + \mu_t^{\theta}}{(*)} \quad (6)$$

where $(*)$ portrays the conditional quantile of the business and economic conditions. Equations 5 and 6 quantify the real effect (θth) quantile of COVID on (τth) of business and economic conditions. Furthermore, we have not observed a linear relationship between the quantiles of the variables. Consequently, Eqs. 5 and 6 examine the overall effect of COVID-19 on China's business and economic conditions through the dependence between their distribution. The selection of bandwidth is critical in non-parametric estimations such as the QQR. Much like the ordinary least square, a simple minimization is used to derive Eqs. 7 and 8, which captures the impact of COVID on China's business and economic conditions across different quantiles.

$$min_{b0,b1}\sum_i^n \rho\theta\left[BC_t - b_0 - b_1(\widehat{COVID}_t - \widehat{COVID}^{\tau})\mathrm{K}\left(\frac{F_n(\widehat{COVID}_t - \tau)}{h}\right)\right] \quad (7)$$

$$min_{b0,b1}\sum_i^n \rho\theta\left[EC_t - b_0 - b_1(\widehat{COVID}_t - \widehat{COVID}^{\tau})\mathrm{K}\left(\frac{F_n(\widehat{COVID}_t - \tau)}{h}\right)\right] \quad (8)$$

where $\rho\theta$ is the quantile loss function constitute as $\rho\theta(u) = u(\theta - 1(u<0))$, and i denotes the function of an indicator. Further, K $(*)$ and h are the kernel density function and bandwidth parameters, where K $(*)$ measures the observation of $COVID^{\tau}$ while the minimal weights are negatively assigned to the distribution function of $\widehat{COVID}_t$ as $F_n(\widehat{COVID}_t - \tau) = \frac{1}{n}\sum_{k=1}^{n} I(\widehat{COVID}_k < \widehat{COVID}_t)$.

While employing the non-parametric estimation techniques, the criteria of bandwidth selection are more critical, as it controls variance and bias (Sim and Zhou 2015; Shahzad et al. 2017). The selection of bandwidth determines the smoothness of the estimates as it investigates the dimensions of the neighborhood around the target point. A smaller bandwidth results in higher variance outcomes, whereas the larger bandwidth provides higher bias. Hence, maintaining a balance between variance and bias for optimum bandwidth is mandatory. Taking insights from Chowdhury et al. (2021) and Khalifa et al. (2017) studies, we use the bandwidth parameter, h = 0.05 (5%) for the Gaussian kernel in our empirical analysis.

Granger causality in quantiles

Subsequent to applying the quantile-on-quantile (QQR) approach, it is desirable to delineate the causal relationship between quantiles of COVID and quantiles of business and economic conditions. To this end, we utilize the Granger causality in quantiles approach by Troster et al. (2018). The non-parametric causality-in-quantiles technique predicated on the vector autoregression (VAR) framework extracts the complete outcomes of non-causal directional associations at various quantiles among variables, otherwise ignored by the traditional Granger causality approach (Granger 1969). Linear Granger causality estimates could be biased. They are derived based on the median, which cannot unveil the causal relationships at lower, medium, and higher quantiles (Troster et al. 2018).

Empirical results and discussion

Stationarity and data normality check

Moving forward with the empirical estimation, first, we have examined the stochastic properties of our model. Table 1 shows the summary statistics of COVID-19, business and

Table 1 Stochastic properties of variables

	COVID	BC	EC
Mean	13.314	2.269	3.155
Median	13.351	2.343	3.211
Maximum	13.539	2.456	3.274
Minimum	12.920	1.898	2.972
Std. Dev	0.168	0.163	0.115
Skewness	−0.711	−0.763	−0.332
Kurtosis	2.766	2.781	1.347
Jarque–Bera	5.273	6.035	8.072
Probability	0.072	0.049	0.018

The probability values correspond to the Jarque-Berra test

economic conditions. The stochastic properties show that all the variables are negatively skewed, meaning all the variables are skewed to the left. In addition, descriptive statistics also show that the kurtosis of all the variables is less than three, which indicates that the distribution is platykurtic. Sim and Zhou (2015) advocated that before applying quantile-on-quantile regression (QQR), it is pertinent to test the data normality. Being an asymmetric model, the QQR provides robust estimates if data exhibits non-linear characteristics. In the summary statistics reported in Table 1, the probability value of the Jarque–Bera (JB) rejects the null hypothesis of data normality, signifying the non-normal characteristic of our model which warrants to utilize the non-parametric approaches such as the QQR and causality in quantile test instead of standard linear Granger causality approach.

Previous studies highlight that before applying the quantile regression, it is essential to confirm the stationarity of the series. Koenkar and Xiao (2004) suggested that performing unit root rest provides robust estimates and removes the probability of biased results, which helps examine the unit root properties across quantiles and conditional mean. However, this test does not consider the linear trend and covariates into the quantiles. Therefore, to resolve the above issue, we have employed the quantile unit root test suggested by Galvao (2009) and Koenker and Xiao (2004) over the traditional unit root test. These conventional tests cannot provide an unbiased estimate of normality. Furthermore, we have employed the BDS non-linearity test to estimate the presence of non-linearity in the data series. Table 2 shows that for all the variables, among various dimensions, the probability value at 1% rejects the claim of linearity, implying that our data series is exhibiting non-linear behavior. The Kruse (2011) nonlinear unit root tests reported in Table 3 further affirm nonlinearity in our model. The presence of non-linearity further validates the reason to opt for the non-parametric quantile approaches such as the QQR and causality-in-quantiles approaches.

Table 4 depicts the outcomes of the quantile autoregressive (QAR) unit root test. In the present study, we have employed 19 sub-quantiles extending from 0.05 to 0.95. In the QAR unit root test, we compare the t-statistics with the critical value (C.V) to check for the presence of the unit root. If the t-statistic value is less than the C.V, we will reject the null hypothesis of $\alpha(\tau) = 1$ for each quantile. However, if the t-statistic value is more than C.V, the null hypothesis $\alpha(\tau) = 1$ will not be rejected. In Table 3, the summary of the QAR unit root test reveals that the t-statistics of the lower upper and middle quantile of variables included in our model is less than the critical value at 5% significance level. These results infer that our data is stationarity at lower, middle, and higher quantiles.

After examining stationarity characteristics, we discuss the empirical outcomes of COVID-19 vis-à-vis business and economic conditions in quantile-on-quantile settings. Figure 1 showcases the impact of COVID-19 quantiles on the quantiles of China's business condition. The lower quantiles of COVID-19 have negative effect on the lower quantile of business condition. In contrast, medium to high quantiles of COVID-19 are affecting the medium to the high quantile of business conditions positively. These outcomes are supported by the fact that COVID-19 initially had negative effect on China's business condition, but later on, the business operations bounced back to normal condition. One plausible reason for the recuperation of China's business condition is the support of the business sector by the Chinese government. The relationship of the quantiles of COVID-19 with the quantiles of the economic condition is depicted in Fig. 2. We notice that lower to medium quantiles of COVID-19 have negative effect on the lower to medium quantiles of economic condition. These outcomes corroborate the initial hostile impact of COVID-19 on China's economic condition.

On the contrary, the medium to higher quantiles of COVID-19 were observed to influence the medium to high quantiles of economic conditions in a positive manner. The number of cases reported were lower at the onset of the pandemic and it gradually increased, so we can deduce that lower quantiles of the COVID-19 were during the period when the pandemic just started and it affected the economic condition negatively during the time but later on it demonstrated recovery. These results entail that with the passage of time, the economic operations got back on track owing to proper measures taken by the Chinese government. It is also pertinent to mention that owing to COVID-19, the Chinese economy exhibited imminent contraction; nonetheless, the

Table 2 BDS non-linearity test outcomes

BDS statistics		Embedding dimension = m			
Series	m = 2	m = 3	m = 4	m = 5	m = 6
COVID	0.162***	0.263***	0.317***	0.336***	0.332***
BC	0.152***	0.246***	0.295***	0.310***	0.310***
EC	0.119***	0.174***	0.183***	0.158***	0.141***

*** and ** show the rejection of null (H_0) at 1% and 5% level respectively

Table 3 Kruse nonlinear unit root test outcomes

Specifications	CVD	BC	EC
No constant	4.318**	3.276**	4.069***
With constant	1.324	2.737*	3.385**
With constant and trends	3.423**	3.671**	3.444***

***, **, and * denote the rejection of the null of a unit root at 1%, 5%, and 10% significance levels

Table 4 Quantile autoregressive (QAR) unit root test results

Quantiles	COVID			BC			EC		
	t-statistics	CV	Persistence	t-statistics	CV	Persistence	t-statistics	CV	Persistence
0.05	−5.783	−2.514	0.320	−3.435	−2.499	0.267	−3.166	−2.471	0.125
0.10	−1.136	−2.671	0.705	−1.757	−2.759	0.479	−3.199	−2.552	0.144
0.15	0.000	−3.145	1.000	0.000	−2.571	1.000	−0.024	−2.659	0.994
0.20	0.000	−3.312	1.000	0.000	−2.882	1.000	0.000	−3.324	1.000
0.25	0.000	−3.242	1.000	0.000	−3.235	1.000	0.000	−2.348	1.000
0.30	0.000	−3.131	1.000	0.000	−3.155	1.000	0.000	−2.398	1.000
0.35	0.000	−3.107	1.000	0.000	−3.327	1.000	0.000	−2.395	1.000
0.40	−10.495	−2.668	1.000	0.000	−3.293	1.000	0.000	−2.310	1.000
0.45	−4.618	−3.074	1.000	−12.957	−3.410	1.000	−8.906	−2.795	1.000
0.50	−2.025	−2.765	1.000	−0.009	−3.269	1.000	−37.407	−2.632	1.000
0.55	0.000	−2.880	1.000	−0.213	−3.369	1.000	2.955	−2.616	1.000
0.60	0.000	−2.825	1.000	0.000	−3.410	1.000	0.000	−2.310	1.000
0.65	0.000	−2.933	1.000	0.000	−3.221	1.000	0.000	−2.310	1.000
0.70	0.000	−2.912	1.000	0.000	−3.265	1.000	0.000	−2.620	1.000
0.75	0.000	−2.710	1.000	0.000	−3.316	1.000	0.000	−2.647	1.000
0.80	−0.001	−2.918	1.000	0.000	−3.384	1.000	0.000	−2.714	1.000
0.85	−2.506	−2.993	0.505	0.000	−2.959	1.000	−5.554	−3.151	0.103
0.90	−4.102	−2.728	0.082	−4.063	−2.672	0.095	−5.463	−2.771	0.001
0.95	−4.246	−2.310	0.061	−3.982	−2.601	0.053	−4.477	−2.828	−0.004

The above table includes point estimates, t-statistics, and the CV (critical values) of the quantile unit test by Koenker and Xiao (2004) and Galvo (2009). The decision criterion is if t-statistic is smaller than the critical value, the null hypothesis of $\alpha(\tau)=1$ will be rejected at a level of 5% significance

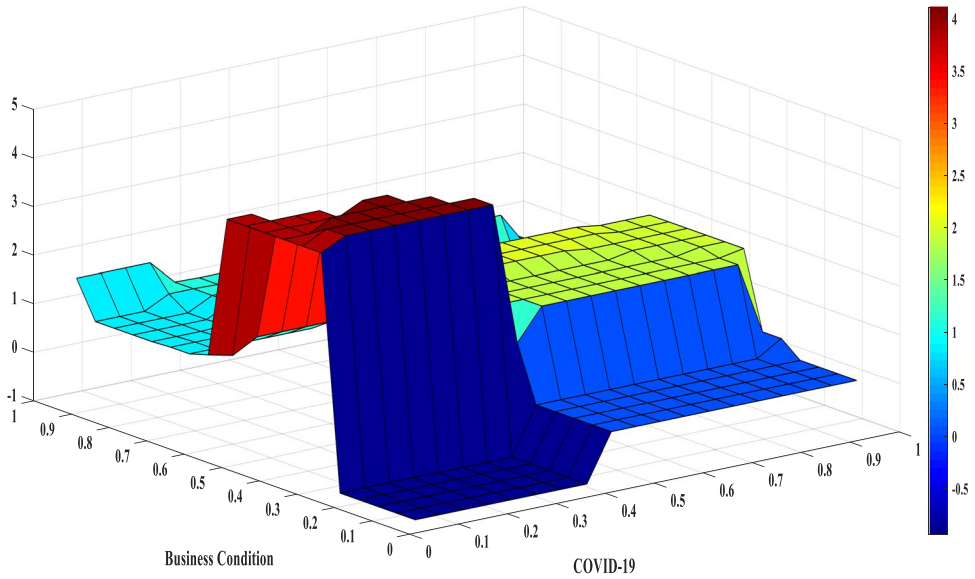

Fig. 1 Effect of COVID-19 on business condition

Chinese economy grew by 2.3% in 2020. This growth witnessed the bounce-back of the Chinese economy despite the fact that COVID-19 was initially discovered in the country. These outcomes make China the sole economy exhibiting economic growth in the year stricken by the world's largest pandemic in history. The growth on behalf of the Chinese economy is mainly attributed to the strict measure about the epidemic in the initial phase coupled with government stimulus. Moreover, the practical measures of the virus containment enabled China to resume economic operations, which led to the surge in exports to many countries hit by the COVID-19 pandemic.

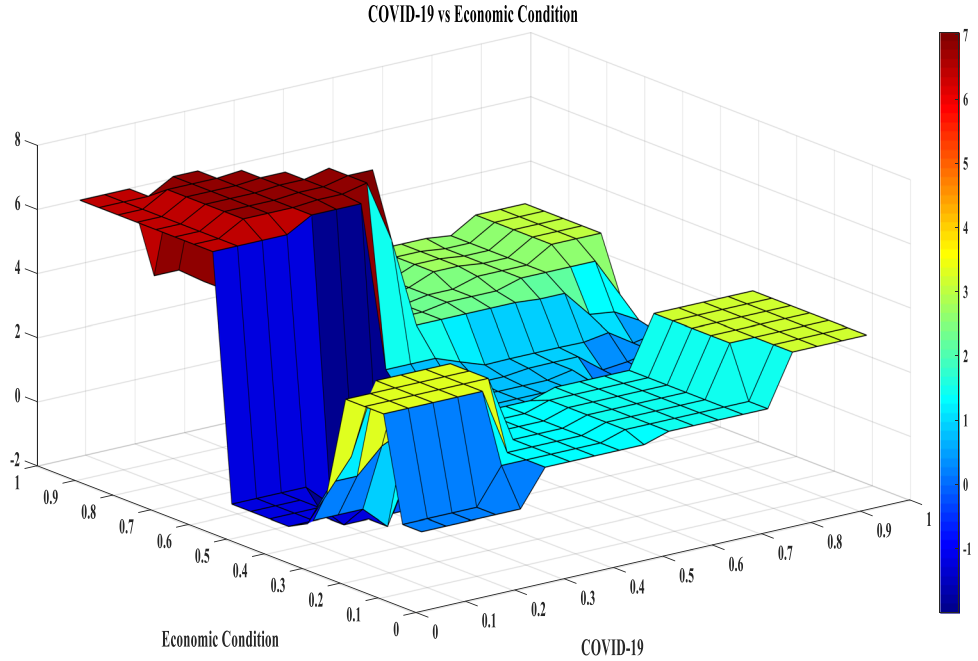

Fig. 2 Effect of COVID-19 on economic condition

Granger causality in quantiles

This section pertains to estimating the Granger causality in quantile among COVID-19, business and economic conditions. Table 5 summarizes the Granger causal association among variables at different quantiles. The results show that there is bidirectional causality between COVID-19 and business condition for lower to high quantiles (0.20–0.80) except for highest quantiles (0.90–0.95) and lowest quantile (0.05–0.10). We also obtained similar results in the case of COVID-19 vis-à-vis economic condition. A unidirectional causal relationship was obtained at 0.85 quantile between COVID and business/economic conditions. We also noticed a bidirectional lead-lag relationship between business and economic conditions. These outcomes infer a significant lead-lag relationship between COVID-19 and China's business and economic conditions. Being the epicenter of COVID-19, both business and economic conditions in China received massive blows during the initial phase of the pandemic. This scenario compelled businesses to opt for voluntary and involuntary shutdowns, due to which the economic wheel in China confronted various frictions. Nevertheless, later on, both the business and economic conditions witnessed recovery owing to effective measures taken by the Chinese government, such as government stimulus and smart lockdowns. These measures enabled China to resume economic operations promptly, which led to the surge in exports to many countries hit by the COVID-19 pandemic.

Robustness check

The main outcomes will be deemed robust when the average value of the slope parameters for QQR is approximately akin to the parameters obtained via the traditional quantile regression (QR). In Fig. 3 and Fig. 4, the mean values of QQR emulate the QR values; i.e., both are exhibiting similar patterns. These outcomes entail that our main estimations are robust.

Additionally, we have employed the non-parametric causality in quantiles (QC) approach by Balcilar et al. (2017) to determine whether our results are robust to alternative econometric specifications. The prime advantage of the quantile causality approach is that it determines causality in quantiles among COVID-19, business and economic conditions not only in mean but also in the variance. The outcomes of the non-parametric causality in quantiles suggest that COVID-19 has a causal linkage with business and economic conditions. Figure 5a demonstrates the null hypothesis of no causality is rejected at quantiles 0.65 and 0.85. Similarly, in Fig. 5b, the null (H_0) of no causality receives rejection at quantiles 0.30, 0.35, and 0.85. These outcomes entail that COVID-19 causes business condition. In the similar vein, Fig. 6a and b infer that COVID-19 has lead-lag association with economic condition. The null hypothesis in Fig. 6a is rejected at quantiles 0.70 and 0.90 and the null of non-causality between COVID-19 and economic condition is rejected at 0.60 quantile as depicted by Fig. 2b. These outcomes further validate our main estimations.

Table 5 Granger causality in quantiles

Quantile	COVID ↛ BC	BC ↛ COVID	COVID ↛ EC	EC ↛ COVID	BC ↛ *E* C	EC ↛ BC
[0.05;0.95]	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.05	0.152	1.000	0.182	1.000	0.182	0.152
0.10	0.848	0.152	0.848	0.152	0.848	0.848
0.15	0.152	**0.030**	0.152	**0.030**	0.152	0.152
0.20	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.25	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.30	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.35	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.40	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.45	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.50	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.55	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.60	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.65	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.70	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.75	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.80	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
0.85	**0.030**	0.152	**0.030**	0.152	**0.030**	**0.030**
0.90	0.152	0.727	0.152	0.727	0.152	0.152
0.95	0.152	0.303	0.273	0.303	0.273	0.152

↛ stands for the null postulation (does not Granger causes)

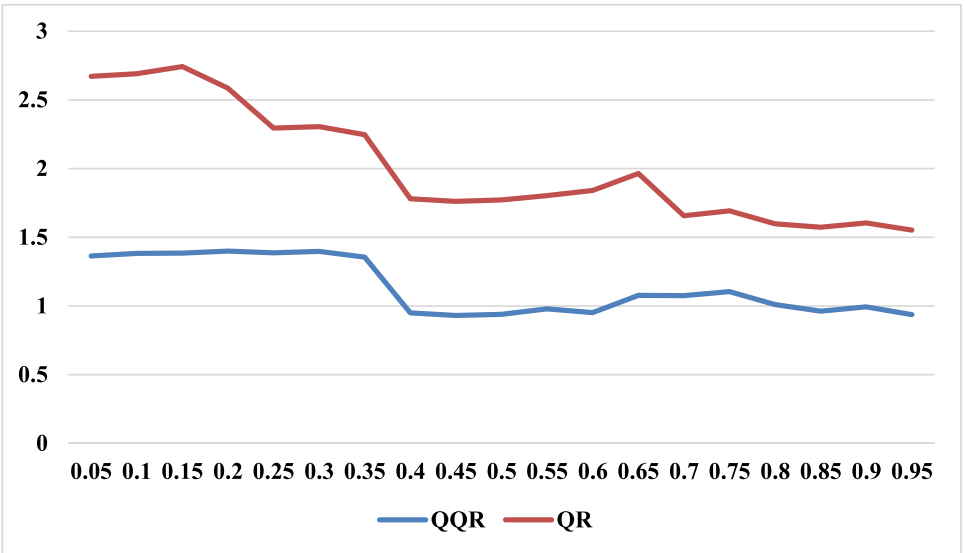

Fig. 3 Effect of COVID-19 on business condition

Conclusion and policy implications

This study aimed to analyze the impact of the COVID-19 on China's business and economic conditions. To this end, we utilized the novel quantile-on-quantile approach of Sim and Zhou (2015) and causality in quantiles approach of Troster et al. (2018). These outcomes imply that at the onset of the pandemic, both business and economic conditions reacted negatively towards COVID-19; however, the latter's effect subsided over time, and both the business and economic conditions exhibited recuperation. We deduce that the relationship between COVID-19 and business and economic conditions in China is heterogeneous. These outcomes entail that the strict containment measures impeded both business and economic conditions when more COVID-19 cases were reported. However, they bounced back when the Chinese

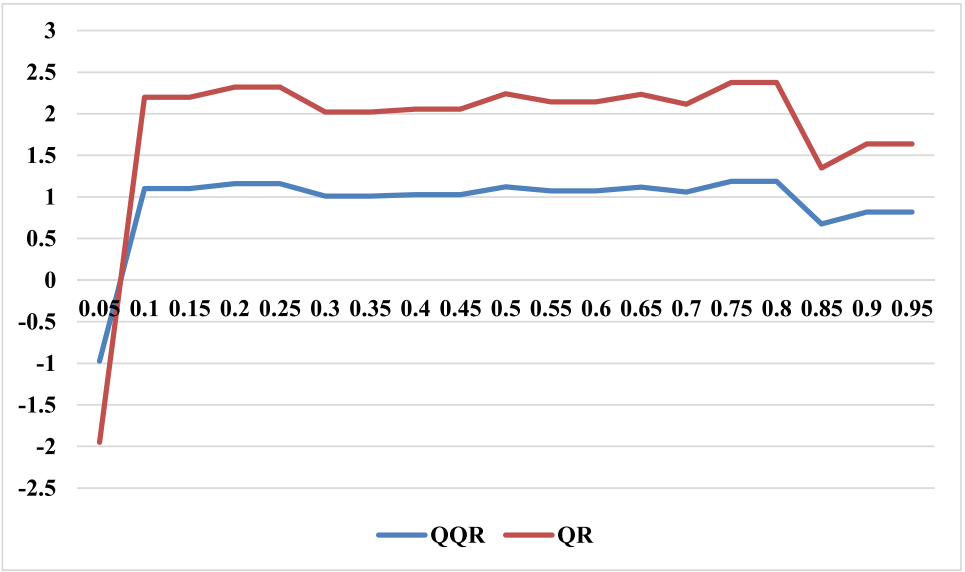

Fig. 4 Effect of COVID-19 on economic condition

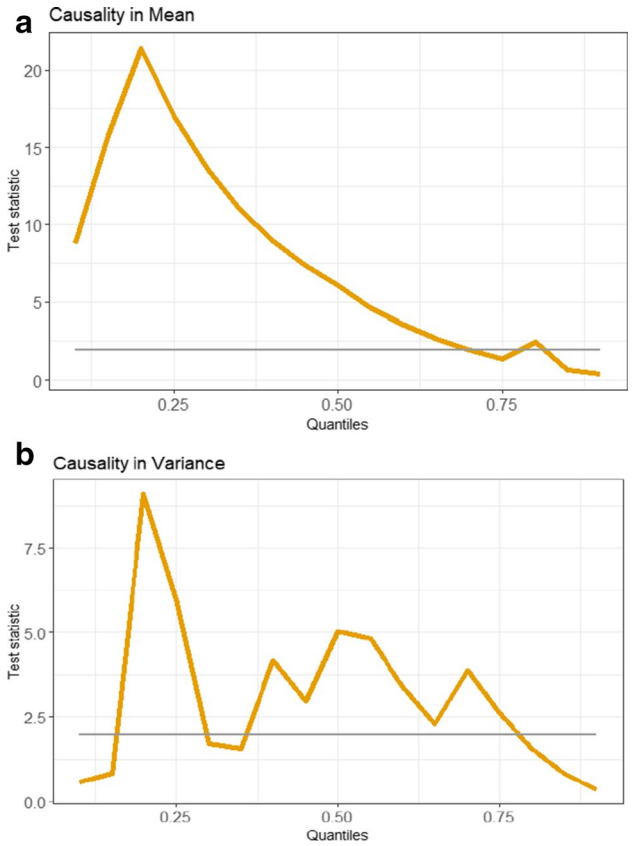

Fig. 5 **a** The null postulation for QC: COVID does not Granger causes business condition. **b** The null postulation for QC: COVID does not Granger causes business condition

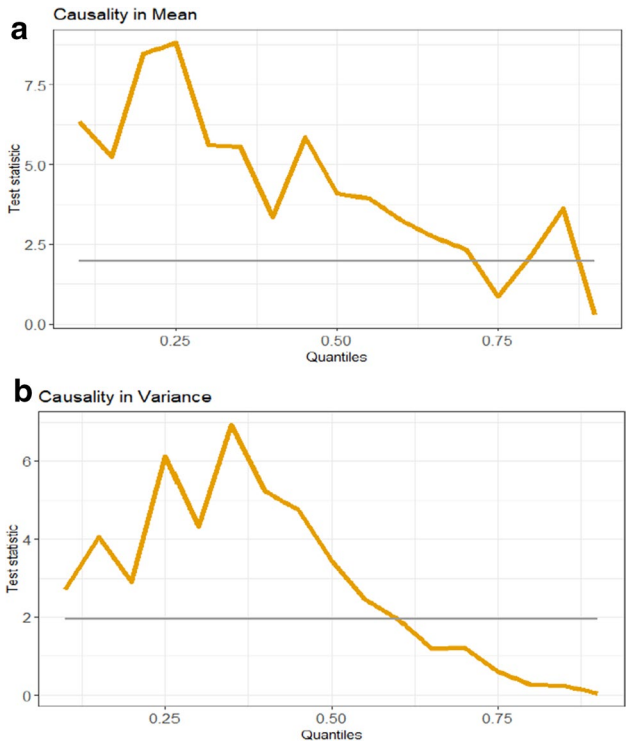

Fig. 6 **a** The null postulation for QC: COVID does not Granger causes economic condition. **b** The null postulation for QC: COVID does not Granger causes economic condition

government lifted the ban on social distancing and assisted businesses to continue their operations. The initial strict measures coupled with government stimulus have enabled the Chinese government to control the outbreak's spread and achieve quick economic recovery compared to other countries. Although the Chinese economy has recorded a decrease in retail sales growth in 2020, the exports witnessed a significant surge attributed to the demand from many countries receiving huge economic blows from the

pandemic. To appease the COVID-19 pandemic shocks and realize maximum recovery, the Chinese authorities need to recalibrate both fiscal and monetary policies aiming to uplift businesses. A short-term containment policy, macroeconomic adjustments, and full support of government stimulus would be advisable for healthy business and economic conditions. It is worthy of mentioning that the Chinese economy is moving in the right direction in the ongoing pandemic. However, there are still frictions in normal business operations and steady economic growth in the wake of novel coronaviruses variants such as the delta and omicron. A pragmatic healthcare policy such as the smart lockdowns has somehow provided stability to the business and economic conditions in the country; nonetheless, timely decisions about healthcare policy will equip all the stakeholders to come up with a solution to confront prospective health crises. Recently the rest of the world have lifted COVID-19 restrictions and have stabilized their business and economic activities. The Chinese government is following the suit and taking practical steps which is commendable but still there are pandemic related restrictions in the country. The higher authorities may need to abolish these restrictions so that business and economic operations exhibit steadiness and continue to flourish much like the pre-pandemic era. Such measures will enhance international exchanges which will further lubricate the wheel of the Chinese economy. This research article focused the impact of COVID-19 on China's business and economic conditions. The research question at hand can be further probed with the lens of environmental quality as authorities in the People's Republic of China are striving to overcome environmental quality challenges (Pata et al. 2023; Pata and Caglar 2021; Pata and Isik 2021) and COVID-19 is no exception, as it has espoused further economic, financial and environmental challenges. Addressing these challenges is currently beyond the scope of this research work. The findings of our research work will not only enable the Chinese economy but also serve as a blueprint for other countries across the globe to shake off the drag engendered by the novel coronavirus.

Author contribution Assad Ullah conceived the idea, wrote original draft, and finished formal analysis. Xinshun Zhao supervised the article and contributed towards conceptual and computational part of the study. Aamir Aijaz Sayed and Azka Amin revised literature review section and verified the methodology. Adeel Riaz analyzed the data and reviewed final draft. All authors discussed the results, reviewed and finalized the draft.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval Not applicable

Consent for publication Not applicable

Consent to participate Not applicable

Competing interests The authors declare no competing interests.

References

Balcilar M, Bekiros S, Gupta R (2017) The role of news-based uncertainty indices in predicting oil markets: a hybrid nonparametric quantile causality method. Empir Econ 53(3):879–889. https://doi.org/10.1007/s00181-016-1150-0

Cao L, Li T, Wang R, Zhu J (2021) Impact of COVID-19 on China's agricultural trade. China Agric Econ Rev. https://doi.org/10.1108/CAER-05-2020-0079

Chang BH, Sharif A, Aman A, Suki NM, Salman A, Khan SAR (2020a) The asymmetric effects of oil price on sectoral Islamic stocks: new evidence from quantile-on-quantile regression approach. Resour Policy. https://doi.org/10.1016/j.resourpol.2019.101571

Chang BH, Sharif A, Aman A, Suki NM, Salman A, Khan SAR (2020b) The asymmetric effects of oil price on sectoral Islamic stocks: new evidence from quantile-on-quantile regression approach. Res Policy 65:101571. https://doi.org/10.1016/j.resourpol.2019.101571

Chen S, Su W, Chen J, Li KW (2021) The effects of covid-19 on manufacturer operations: evidence from China. Transform Bus Econ

Chowdhury MAF, Meo MS, Aloui C (2021) How world uncertainties and global pandemics destabilized food, energy and stock markets? Fresh evidence from quantile on quantile regressions. Int Rev Financ Anal 76:101759. https://doi.org/10.1016/j.irfa.2021.101759

Cleveland WS (1979) Robust locally weighted regression and smoothing scatterplots. J Am Stat Assoc 74(368):829–836. https://doi.org/10.1080/01621459.1979.10481038

Cooray NS, Palanivel T (2021) The impact and implication of the COVID-19 on the trade relationship between China and the United States: the political economy perspectives. Transnatl Corp Rev. https://doi.org/10.1080/19186444.2021.1972700

Dai R, Feng H, Hu J, Jin Q, Li H, Wang R, Wang R, Xu L, Zhang X (2021) The impact of COVID-19 on small and medium-sized enterprises (SMEs): evidence from two-wave phone surveys in China. China Econ Rev. https://doi.org/10.1016/j.chieco.2021.101607

Gavalas D, Syriopoulos T, Tsatsaronis M (2022) COVID–19 impact on the shipping industry: an event study approach. Transp Policy. https://doi.org/10.1016/j.tranpol.2021.11.016

Galvao AF (2009) Unit root quantile autoregression testing using covariates. J Econ 152(2):165–178

Granger CWJ (1969) Investigating causal relations by econometric models and cross-spectral methods. Econometrica. https://doi.org/10.2307/1912791

Hashmi SM, Chang BH, Rong L (2021) Asymmetric effect of COVID-19 pandemic on E7 stock indices: evidence from quantile-on-quantile regression approach. Res Int Bus Financ 58(June):1–11. https://doi.org/10.1016/j.ribaf.2021.101485

Hossain ME, Rej S, Hossain MR, Bandyopadhyay A, Tama RAZ, Ullah A (2023) Energy mix with technological innovation to abate carbon emission: fresh evidence from Mexico applying wavelet tools and spectral causality. Environ Sci Pollut Res 30(3):5825–5846

Iqbal N, Fareed Z, Wan G, Shahzad F (2021) Asymmetric nexus between COVID-19 outbreak in the world and cryptocurrency market. Int Rev Financ Anal. https://doi.org/10.1016/j.irfa.2020.101613

Jiang J, Hou J, Wang C, Liu H (2021b) COVID-19 impact on firm investment—evidence from Chinese publicly listed firms. J Asian Econ 75:101320

Jiang C, Zhang Y, Razi U, Kamran HW (2021a) The asymmetric effect of COVID-19 outbreak, commodities prices and policy uncertainty on financial development in China: evidence from QARDL approach. Economic Research-Ekonomska Istrazivanja, 0(0), 1–36. https://doi.org/10.1080/1331677X.2021.1930092

Khalifa A, Caporin M, Hammoudeh S (2017) The relationship between oil prices and rig counts: the importance of lags. Energy Econ. https://doi.org/10.1016/j.eneco.2017.01.015

Khan SAR, Sharif A, Golpîra H, Kumar A (2019) A green ideology in Asian emerging economies: from environmental policy and sustainable development. Sustain Dev 27(6):1063–1075. https://doi.org/10.1002/sd.1958

Koenker R, Bassett Jr, G (1978) Regression quantiles", Econometrica: J Econ Soc. 46(1):33–50

Koenker R, Xiao Z (2004) Unit root quantile autoregression inference. J Am Stat Assoc 99(467):775–787

Koenker R, Ng P (2005) A Frisch-Newton Algorithm for Sparse Quantile Regression. Acta Math Appl Sin Engl Ser 21(2):225–236

Kruse R (2011) A new unit root test against ESTAR based on a class of modified statistics. Stat Pap 52(1):71–85

Kumah SP, Mensah JO (2022) Are cryptocurrencies connected to gold? A wavelet-based quantile-in-quantile approach. Int J Finan Econ 27(3):3640–3659

Li C, Lin X (2021) COVID-19 and trade: simulated asymmetric loss. J Asian Econ 75:101327

Li C, Su CW, Altuntaş M, Li X (2021) COVID-19 and stock market nexus: evidence from Shanghai Stock Exchange. Economic Research-Ekonomska Istrazivanja. https://doi.org/10.1080/1331677X.2021.1941181

Liu Z, Huynh TLD, Dai PF (2021) The impact of COVID-19 on the stock market crash risk in China. Res Int Bus Financ 57:101419. https://doi.org/10.1016/j.ribaf.2021.101419

Zhang M, Ali S, Kirikkaleli D, Khan Z (2021) Natural resources commodity prices volatility and economic performance: Evidence from China pre and post COVID-19. Resour Policy 74:102–338

Marobhe MI (2021) Investors' reactions to COVID-19 related announcements: evidence from the cargo shipping industry. Rev Behav Financ. https://doi.org/10.1108/RBF-04-2021-0071

Mezghani T, Boujelbène M, Elbayar M (2021) Impact of COVID-19 pandemic on risk transmission between googling investor's sentiment, the Chinese stock and bond markets. China Financ Rev Int. https://doi.org/10.1108/CFRI-08-2020-0120

Pata UK, Caglar AE (2021) Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: evidence from augmented ARDL approach with a structural break. Energy. https://doi.org/10.1016/j.energy.2020.119220

Pata UK, Isik C (2021) Determinants of the load capacity factor in China: a novel dynamic ARDL approach for ecological footprint accounting. Resour Policy. https://doi.org/10.1016/j.resourpol.2021.102313

Pata UK, Erdogan S, Ozkan O (2023) Is reducing fossil fuel intensity important for environmental management and ensuring ecological efficiency in China? J Environ Manage 329:117080

Ruiz Estrada MA, Park D, Lee M (2020) The evaluation of the final impact of Wuhan COVID-19 on trade, tourism, transport, and electricity consumption of China. SSRN Electron J. https://doi.org/10.2139/ssrn.3551093

Sharif A, Saha S, Loganathan N (2017) Does tourism sustain economic growth? Wavelet-based evidence from the United States. Tour Anal 22(4):467–482. https://doi.org/10.3727/108354217X15023805452022

Sharif A, Raza SA, Ozturk I, Afshan S (2019) The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: a global study with the application of heterogeneous panel estimations. Renew Energy 133:685–691. https://doi.org/10.1016/j.renene.2018.10.052

Sharif A, Afshan S, Chrea S, Amel A, Khan SAR (2020a) The role of tourism, transportation and globalization in testing environmental Kuznets curve in Malaysia: new insights from quantile ARDL approach. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-020-08782-5

Sharif A, Baris-Tuzemen O, Uzuner G, Ozturk I, Sinha A (2020b) Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: evidence from Quantile ARDL approach. Sustain Cities Soc 57(August 2019):102138. https://doi.org/10.1016/j.scs.2020.102138

Sharif A, Saqib N, Dong K, Khan SAR (2022) Nexus between green technology innovation, green financing, and CO2 emissions in the G7 countries: the moderating role of social globalisation. Sustain Dev 30(6):1934–1946

Shahzad SJH, Nor SM, Ferrer R, Hammoudeh S (2017) Asymmetric determinants of CDS spreads: U.S. industry-level evidence through the NARDL approach. Econ Model 60(September 2016):211–230

Shen H, Fu M, Pan H, Yu Z, Chen Y (2020) The impact of the COVID-19 pandemic on firm performance. Emerg Mark Financ Trade 56(10):2213–2230. https://doi.org/10.1080/1540496X.2020.1785863

Sim N, Zhou H (2015) Oil prices, US stock return, and the dependence between their quantiles. J Bank Finance. https://doi.org/10.1016/j.jbankfin.2015.01.013

Stone CJ (1977) Consistent nonparametric regression. Ann stat 23(2):595–620

Suki NM, Sharif A, Afshan S, Suki NM (2020) Revisiting the environmental Kuznets curve in Malaysia: the role of globalization in sustainable environment. J Clean Prod 264:121669. https://doi.org/10.1016/j.jclepro.2020.121669

Sun Y, Wu M, Zeng X, Peng Z (2021a) The impact of COVID-19 on the Chinese stock market: sentimental or substantial? Financ Res Lett. https://doi.org/10.1016/j.frl.2020.101838

Sun Y, Zeng X, Zhao H, Simkins B, Cui X (2021b) The impact of COVID-19 on SMEs in China: textual analysis and empirical evidence. Financ Res Lett. https://doi.org/10.1016/j.frl.2021.102211

Syed AA, Kamal MA, Ullah A (2022) An Asymmetric Analysis of the Influence That Economic Policy Uncertainty , Institutional Quality , and Corruption Level Have on India's. Digit Bank Serv Bank Stab 14(6):32–38

Troster V, Shahbaz M, Uddin GS (2018) Renewable energy, oil prices, and economic activity: a Granger-causality in quantiles analysis. Energy Econ 70:440–452. https://doi.org/10.1016/j.eneco.2018.01.029

Ullah A, Zhao X, Kamal MA, Zheng J (2020) Modeling the relationship between military spending and stock market development (a) symmetrically in China: an empirical analysis via the NARDL approach. Physica A: Statistical Mechanics and Its Applications. https://doi.org/10.1016/j.physa.2019.124106

Ullah A, Zhao X, Kamal MA, Riaz A, Zheng B (2021) Exploring asymmetric relationship between Islamic banking development and economic growth in Pakistan: Fresh evidence from a nonlinear ARDL approach. Int J Finan Econ 26(4):6168–6187

Umair M, Yousuf MU (2022) Evaluating the symmetric and asymmetric effects of fossil fuel energy consumption and international capital flows on environmental sustainability: a case of South Asia. Environ Sci Pollut Res 1–17

Wan Q, Miao X, Afshan S (2022) Dynamic effects of natural resource abundance, green financing, and government environmental

concerns toward the sustainable environment in China. Resour Policy 79:102954
Yang M, Zhou J (2021) The impact of COVID-19 on the housing market: evidence from the Yangtze river delta region in China. Appl Econ Lett. https://doi.org/10.1080/13504851.2020.1869159
Yasmeen R, Hao G, Ullah A, Shah WUH, Long Y (2022) The impact of COVID-19 on the US renewable and non-renewable energy consumption: a sectoral analysis based on quantile on quantile regression approach. Environ Sci Pollut Res 29(60):90419–90434
Yi X, Bai C, Lyu S, Dai L (2021) The impacts of the COVID-19 pandemic on China's green bond market. Financ Res Lett. https://doi.org/10.1016/j.frl.2021.101948
Zhang WW, Dawei W, Majeed MT, Sohail S (2022) COVID-19 and international trade: insights and policy challenges in China and USA. Economic Research-Ekonomska Istraživanja 35(1):1991–2002https://doi.org/10.1080/1331677X.2021.1930091
Zhao Y, Zhang H, Ding Y, Tang S (2021) Implications of COVID-19 pandemic on China's exports. Emerg Mark Financ Trade. https://doi.org/10.1080/1540496X.2021.1877653