Air Quality, Atmosphere & Health (2020) 13:1439–1451
https://doi.org/10.1007/s11869-020-00898-4

Consequences of COVID-19 on the social isolation of the Chinese economy: accounting for the role of reduction in carbon emissions

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Received: 4 July 2020 / Accepted: 29 July 2020 / Published online: 13 August 2020

Abstract

The main contribution of the present study to the energy literature is to explore the relationship between economic growth and pollution emission amidst globalization. In contrast to the existing studies, this research examines the effects of economic and social isolation as dimensions of globalization. The present paper allows underpinning the impact on the Chinese economic development of the isolation phenomenon as a consequence of coronavirus (COVID-19). To this end, annual time–frequency data is used to achieve the hypothesized claims. The study resolutions include (1) the existence of a long-run association between the outlined variables; (2) the long-run estimates suggest that the Chinese economy, over the investigated period, is inelastic to pollutant-driven economic growth; and (3) the Chinese isolation is less responsive to its economic growth while the country political willpower is elastic as demonstrated by a government commitment to dampen the effect of the COVID-19 pandemic. This confinement is marked by the aggressive response by the government officials resolute by flattening the exponential impact of the pandemic. Based on these robust results, some far-reaching policy implications are underlined in the concluding remarks section.

Keywords Economic growth · COVID-19 · CO_2 emissions · Isolation · Globalization · China

Introduction

Only a decade ago, the global economy made some efforts to recover from the Great Recession, where globalization played an essential role in the scale of the crisis. In 2019, Asia was the engine of global economic growth, wherein China and India count with the highest growth rates (IMF 2020). However, recently both IMF and OECD revised down projections for 2019 and 2020. In the case of China, an ongoing structural slowdown is underlined despite its growth rate close to 5% (OECD 2020). Like the majority of the economies, China is mostly integrated globally (OECD 2020). In addition, the Chinese economy is a significant commodity importer, and by taking advantage of the globalization phenomenon, it became the largest manufactory exporter.

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However, the evolution of the world economic growth is linked to the development of Asian economies, mainly the Chinese economy. The outbreak of the COVID-19 has spread the virus not just at the national level but also around the globe. Given the speed and scale of COVID-19, the effects go far beyond mortality (Fernandes 2020). Under the declaration of the pandemic crisis, China, followed by many other economies, had to isolate both socially and economically through severe lockdowns. Like in previous outbreaks, the impact of COVID-19 might provoke an economic crisis (Keogh-Brown and Smith 2008), which is expected to be a lot more dramatic than the one caused by SARS (OECD 2020). The economic confidence in the Chinese economy has decreased and seems to intensify financial stress (OECD 2020). Thus, it is expected to affect economic growth as well as trade activity (Leiva-Leon et al. 2020), which are closely linked to globalization, energy consumption, and CO_2 emissions.

The globalization process is declining in China, with pernicious economic consequences of the outbreak. Industrialization, social interactions, and tourism are also put on hold, and restricting these activities is expected to cause a decline in globalization and its impacts. In addition, change in trade patterns is one of the challenges to be faced lately by the industry. This problem is even more intense in the case of China, which is a net exporter with high dependence on imports. China is a major importer of commodities (OECD 2020), especially from Africa. However, with the outbreak, China is experiencing a considerable reduction in consumption and production, as well as in trade.

Consequently, the COVID-19 outbreak and the need for lockdowns have led to a decrease in energy consumption. The economic and industrial activities have been put on hold, and therefore, a drastic reduction in energy consumption is experienced, followed by a decrease in CO_2 emissions. The mitigation of trade, as a proxy of globalization, under the current context, is also expected to be linked with energy consumption (Solarin et al. 2016). Since the increase of globalization in China and its consequent entrance into the World Trade Organization in 2001, the Chinese economy started to develop faster via exports. This move put China as the leader not just in manufacturing trade, but also among one of the earliest economies to have sustained positive current account balance.

With the outbreak and spread of COVID-19, Chinese trade started reducing drastically due to bans imposed by many countries on business and social activities with China. Moreover, steps taken to curb the spread of COVID-19 have led to 15–40% reductions in output across different sectors, which might have reduced at least a quarter of the country's CO_2 emissions in the past 2 weeks, the period within which activities would usually have resumed after the Chinese new year holiday.

Over the same period, COVID-19 could have cut global emissions by 100 $MtCO_2$ ($MtCO_2$) to date (see Figs. 1 and 2), while China released around 400 $MtCO_2$ in 2019 whether the impacts of CO_2 emissions are diminished or reversed along, where the government's response to the crisis is among the main aspects to consider (Table 1). COVID-19 could cut 50% of global oil demand in January–September 2020 (IEA 2020). Under the crisis scenario, the Chinese government's policies and strategies, aimed to curb the disruption caused by COVID-19 outbreak, may balance these short-term impacts on energy and CO_2 emissions, the same way as was the case in the global financial crisis (GFC) and the internal economic slowdown in 2015.

The negative impact of the COVID-19 outbreak on energy consumption pattern will lead to a reduction in the emission of CO_2 emissions, as reported in the recent study of Zambrano-Monserrate et al. (2020). A decline in CO_2 emissions in developed countries can also be said to be a consequence of the rise in services and information-intensive industries, instead of high-energy intensive and carbon-intensive industries (Huang et al. 2018). Before the COVID-19 lockdown, global CO_2 emissions were expected to be like those in 2019, but the effect of confinement on CO_2 emissions are estimated to decrease about 17% globally (Le Quéré et al. 2020).

The present study seeks to analyze further the impact of COVID-19 outbreak over the Chinese economy. Hence, the focus is on determining the effects of the cut-offs of carbon emissions on Chinese economic growth during confinement. In doing so, carbon emissions are assumed to be dirty inputs. The lack of data implies adopting a strategy based on the study of stochastic process and elasticity, following a cointegration framework. These allow predicting the current situation and might be a proper tool for policymakers. Hence, econometric tools are used to determine the degree to which carbon emissions impact the Chinese economy and if the reduction in emissions levels will induce a decrease in income levels. This way, it is expected to identify warning signs, as well as to project the impacts of changes in carbon emission and globalization on the Chinese economy.

While carbon emissions and their implications are considered in previous literature for testing the Environmental Kuznets Curve (Sidneva and Zivot 2014), the present study assumes carbon emissions as a dirty input. It looks for how stationarity trend of carbon emissions helps to predict the adoption of new regulations. Furthermore, the study of Gil-Alana and Solarin (2018) outlined the variances between a trend and difference stationarity data generating process (DGP), which aid in ascertaining the possibility of long-run effects as it concerns environmental blueprints. As such, these approaches rely on the projection of forwarding pollutant emissions and affirming precision of the forecast. In addition, in the econometrics literature, dealing with stable and non-stable series, the long-term properties emanate from its

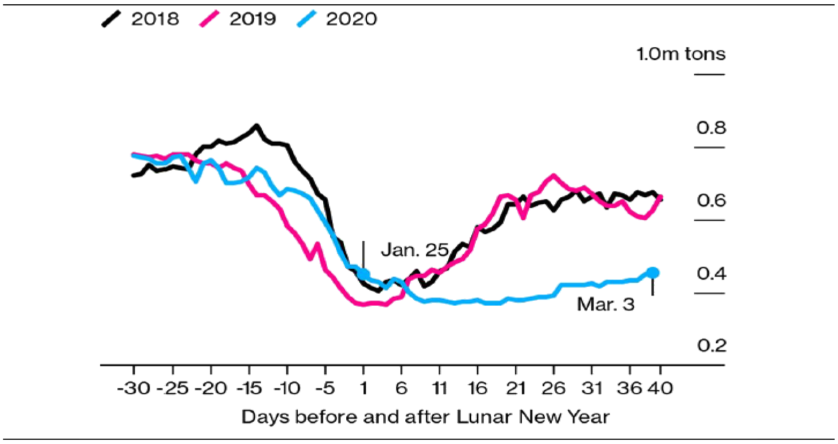

Fig. 1 Daily coal consumption at six major power firms in China (March 2020). Source: China Coal Transport & Distribution Association (2020), showing daily coal consumption for 6 major coastal power groups. Note: Right now, estimates are ranging between just under 60% and more than 70%. Bloomberg (2020): https://www.bloomberg.com/news/articles/2020-03-05/a-new-number-to-watch-for-china-s-economy-the-resumption-rate

deterministic trend components. The series containing unit root generates uncertainty in the long term, while stationary (permanent) variables are free of uncertainty in GDP. On the contrary, modeling with non-stationary variable possess traits of uncertainty.

Three approaches are proposed for the Chinese economy: (1) examining the stationarity properties of the CO_2 emissions by both traditional and novel Fourier ADF-GLS, LM unit root test; (2) the linkage between economic growth and carbon emissions, under a globalization setting. Empirical outcomes might help policymakers on whether they should implement environmental restrictions. It would lead to reduce emissions or allow economic activities to address the pollution control automatically, where (3) cointegration is considered a suitable technique in this context based on the provision for elasticities to induce the impact of carbon emissions over economic growth in China since December 2019, after confirmation of the first case of COVID-19 in Wuhan. This method will ensure more flexibility in the dynamic specification of the model. Furthermore, by considering globalization, additional information about the nature of the shocks is included. Transitory isolation of the Chinese economy, both economic and social, as components of globalization, must be considered for approximating to the real situation.

The structure of the paper is as follows: the second section reviews previous literature, the third section presents dataset and methodology, while the results of the analyses are presented in the fourth section. The fifth section compiles the discussion of the findings, and the final section provides conclusions and policy recommendations.

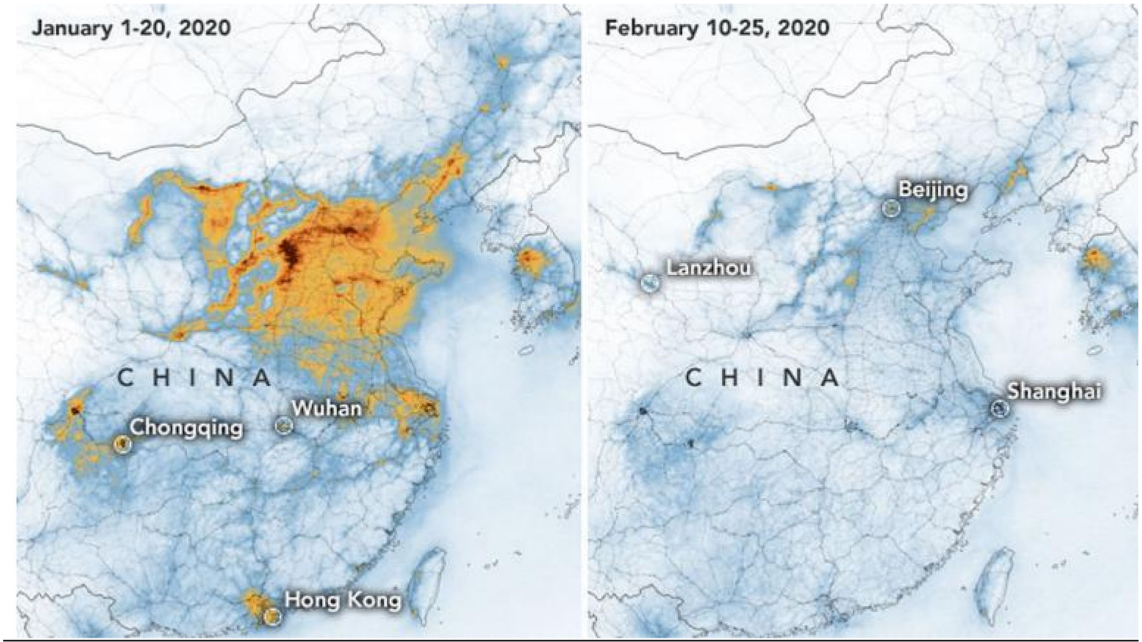

Fig. 2 Greenhouse gas emissions in China. Source: The European Space Agency (2020). Note: The decline in economic activity in China is now visible from space. This trend is confirmed in China's big cities. In the second half of February, there was no activity

Table 1 Chinese demand by-product (thousand barrels per day)

	Demand			Annual change (kb/day)		Annual change (%)	
	2018	2019	2020	2019	2020	2019	2020
LPG and ethane	1620	1722	1822	102	100	6.3	5.8
Naphtha	1268	1300	1395	32	95	2.6	7.3
Motor gasoline	2984	3108	3102	123	− 6	4.1	− 0.2
Jet fuel and kerosene	812	857	849	45	− 8	5.5	− 0.9
Gas/diesel oil	3355	3579	3569	224	− 10	6.7	− 0.3
Residual fuel oil	432	416	375	− 16	− 40	− 3.8	− 9.7
Other products	2503	2676	2694	173	18	6.9	0.7
Total products	12,975	13,657	13,806	682	149	5.3	1.1

Source: IEA (2020)

Literature review

Limited studies exist on the stationarity assessment of carbon emissions. Reviews by Aldy (2006) or Lee and Chang (2009) have explored the carbon emissions movement of the developed, and industrialized countries and non-stability of the developing countries was assessed through the stationarity testing procedure proposed by Carrion-i-Silvestre et al. (2009). Several studies tested the stationarity properties of carbon emissions (e.g., Romero-Avila 2008; Ahmed et al. 2016). Christidou et al. (2013) applied a non-linear panel unit root test confirming the stationary for 33 nations during 1870–2006. On the other hand, there is an impressive entirety of papers that provide the proof for the non-stationary of carbon discharges (Criado and Grether 2011). Different investigations confirm that carbon emanations follow unit root process (Li and Lin 2013; Presno et al. 2018). Under these outcomes, Jaunky (2011) demonstrated that CO_2 emissions for high-earning nations are I(1) integrated. Yamazaki et al. (2014) indicated that in the OECD countries, per capita CO_2 emissions follow unit root. Barros et al. (2016) applied fragmentary combination for the global series of carbon discharges and arrangement of every one of its five segments (gas, fluids, solids, concrete creation, and gas flaring). The observational outcomes indicated that the arrangement is non-stationary with the integration order fundamentally over 1.

Furthermore, on the literature trajectory between globalization, energy consumption, and economic growth, several studies analyzed the relationship between globalization, energy consumption, and economic growth (see Solarin et al. 2016; Alola et al. 2019; Wu et al. 2019). However, studies have ignored mainly a various aspect of globalization, i.e., political globalization, social globalization, and economic globalization. Solarin et al. (2016) discovered that there exists a positive correlation between globalization and energy consumption in the long term. Energy consumption, urbanization, financial development, and economic growth have positive effects on emissions, in the presence of globalization. On the contrary, openness to trade, foreign direct investment, and innovation have exhibited negative impacts on emissions, as reported by Shahbaz et al. (2019).

Furthermore, Alola et al. (2019) show that energy consumption is strongly related to globalization in the long run while adopting the Autoregressive distributed lag approach. Tourism can be considered a form of social globalization, which promotes CO_2 emissions in both the short and long term, while the real income and level of globalization promote CO_2 emissions only in the long term. Thus, ensuring the sustainability of global energy use, it is pertinent to shift from import-oriented economies to export-based economies.

In addition, export-oriented and emerging economies, such as China, need to adjust trade pattern to ensure economic and ecological competence in the global market, aside from improving production efficiencies (Wu et al. 2019). As energy is an essential factor for economic growth, its conservation may harm growth pattern (Ouedraogo 2013).

Furthermore, tourism exposure, as a consequence of the globalization process, and the amount of energy consumed is in long-run equilibrium relationship with CO_2 emissions. Development of tourism has led not only to a considerable increase in energy use but also to climate change (Katircioglu 2014, Katircioglu et al. 2020). Energy consumption, level of real income/output, and globalization play essential roles in achieving environmental sustainability. Trade openness leads to an increase in globalization while having an inverse impact on pollution (Akadiri et al. 2019).

While considering the effects of carbon emissions associated with consumption of electricity from non-renewable sources, Apergis and Payne (2012) found a unidirectional causal relationship between economic growth and renewable electricity consumption in the short run and bidirectional causality between them in the long run. Second, there exists a two-way causal relationship between non-renewable electricity consumption and economic growth both in the short and long run. Economic growth has a positive and statistically significant effect on energy consumption in the short run.

An increase in real GDP is likely to affect energy demand since energy is a considerable input in the production process (Ouedraogo 2013). Finally, there is a positive correlation between globalization and energy consumption in the long term (Solarin et al. 2016). To our knowledge, no study has looked at the influence of the COVID-19 outbreak on energy consumption, economic growth, and globalization. This process is what the present study is aimed at investigating.

Empirical methodology and data

Over the last decade, the Chinese economy has been plagued with air pollution (Zhang et al. 2014) due to massive industrialization and anthropogenic activities. To this end, the present study attempts to validate a direct relationship between economic growth and carbon emissions in China between 1981 and 2014, to establish the elasticity relationship between carbon emissions and economic growth for policy formulation. We also explore the impact of economic, social, and political globalization on economic growth, and the effect of confinement, isolating both economic and social globalization. We assume that carbon emissions, as dirty input (Emir and Bekun 2019), exert a direct impact over economic growth. In other words, we expect to confirm that rising carbon emissions will lead to ascending economic growth (Balsalobre et al. 2020) to determine the elasticity relationship between these variables and induce the impact of the reduction in carbon emissions on economic growth in China during 2020 confinement. To strengthen the model toward a closed economy, the empirical model proposes the omission of the economic and social globalization variables, which are more related to the movement of people, businesses, intermediate goods, and raw materials.

On the premise of the highlighted literature, the present study is also motivated by the campaign of United Nations Sustainable Development Goals (UN-SDG-3, 8, 11, 13, and 17) that borders around sustainability, good health, economic expansion, climate change mitigation issues, and global partnership in the context of our study. The SDGs informed the construction of variables adopted for the econometric analysis, and subsequently, the following hypotheses were presented to tie study aim properly:

> H1: There is a direct connection between per capita CO_2 and per capita GDP in China.

The present study seeks to underpin if economic activities in a highly industrialized nation (such as China) trigger pollution emission. In addition, several studies have validated the relationship (Adedoyin et al. 2020) without considering the interconnectedness of countries. This validation led to the construction of the next hypothesis:

> H2: There is a direct linkage between globalization and economic growth. According to the UN-SDG-17 that outlined the role of partnership for sustainability, the present study seeks to understand the directional nature of connection in a cointegrated framework for China.
> H3: The economic and social isolation, as a consequence of the COVID-19 pandemic, present an adverse effect over the Chinese economic growth.

This hypothesis is in line with UN-SDG-3, where the emphasis is placed on sustainable health for national prosperity. In the context of the global pandemic for the case of China, the present study seeks to understand the effect of social isolation and its implications on economic growth while considering health status.

For testing these hypotheses, we propose two models (Eqs. 1 and 2), as follows:

$$LGDP_t = \alpha_0 + \alpha_1 LCO2_t + \alpha_3 LEG_t + \alpha_4 LSG_t + \alpha_5 LSP_t + \varepsilon_{it} \quad (1)$$

Equation 1 contains logarithm expression of per capita gross domestic product— $LGDP_t$, and per capita carbon emissions—$LCO2_{t–}$ (World Bank 2020), considered as dirty input, to investigate the relationship between these variables. Equation 1 also includes the economic (LEG_t), social (LSG_t), and political (LPG_t) globalization (KOF 2020) in logarithm form.

Our primary model (Eq. 2) represents the effects of both economic and social globalization are isolated, to understand the lockdown assumed for Chinese Administration during COVID-19 crisis:

$$LGDP_t = \alpha_0 + a_1 LCO2_t + a_5 LSP_t + \varepsilon_{it} \quad (2)$$

An essential aspect of the present study is to validate the existence of a decoupling that varies over time and therefore invalidates the long-term predictions. To do this, we first analyze the processes and stochastic properties of the variables used. In consequence, we need to examine the stationarity properties of the selected variables to formulate long-term policy implications. In time series analysis, changes in a model parameter in temporal stationarity signifies that variance and average are constant. In consequence, we assume that when a model parameter alters its individual projected value and the mean, policy-level shocks have no permanent impact on them, and those shocks are not sturdy. However, in case a model parameter demonstrates non-stationarity, policies leaning toward adopting that parameter will be useful (Perron 1989). Consequently, policy-level standpoint requires to be deliberated to the tenure of the effect.

In the incidence of stationarity, every policy shock needs not to endure transitory impact, or they might not prove to be impactful. Fleeting policies—the ones to alter the capacity of applicable model parameters—will be likely to demonstrate individual momentary impacts. Perpetual fluctuations consequently call for a more enduring policy-level standpoint in a condition of this kind. Conversely, in the incidence of non-stationarity, transitory shocks will demonstrate lasting impacts (Belbute and Pereira 2017).

The present study follows this methodology; if unit root analysis is suitable for checking stationarity properties of the series and in consequence, it will disclose appropriate policy recommendations. Even traditional unit root tests—ADF test (Dickey and Fuller 1981), PP test (Phillips and Perron 1988), KPSS test (Kwiatkowski et al. 1992), DF-GLS test (Elliott et al. 1996), or NP test (Ng and Perron 2001)—follow their test procedures; these tests are likely to assent to the null hypothesis that is mostly grounded on the presence of unit root, while the model parameters contain structural breaks (Perron 1989). Another unit root tests by Lee and Strazicich (2003) recommend a bi-break lowest Lagrange multiplier (LM) unit root test, with alternative hypothesis unequivocally inferring trend stationarity.

Furthermore, Zivot and Andrews (1992) (ZA) and Lumsdaine and Papell (1997) (LP) unit root tests ponder upon the same number of structural breaks. Also, ZA and LP undertake no breaks as the null hypothesis, while stemming the critical points. Accordingly, alternative hypothesis signifies the persistence of structural breaks, although model parameters might demonstrate non-stationarity. Consequently, LM test admits breaks and deliberates the occurrence of unit root where the ideal count of breaks is endogenously governed. Hence, LM test outcome is more agreeable in the incidence of two structural breaks. In econometric literature, we also find a variant of Gallant's (1981) Flexible Fourier Form, Enders and Lee (2012a, 2012b), or Rodrigues and Taylor (2012) proposed Fourier unit root test, where, rather than choosing specific break periods, their count, and arrangement, the measurement issue is transmuted into slotting in the applicable frequency modules within the empirical model (Enders and Lee 2012b).

So, Fourier unit root tests count on estimations while deliberating deviances from the average in measurable expressions using trigonometric expressions. In the pursuit, Enders and Lee (2012a) applied LM regression, which was promoted initially by Schmidt and Phillips (1992). On the other hand, Rodrigues and Taylor (2012) opted for GLS regression based on Elliott et al. (1996), while Enders and Lee (2012b) employed Dickey and Fuller (1981) regression. Consequently, these estimation procedures will be recognized as Fourier LM, Fourier GLS, and Fourier ADF, correspondingly. Once we have checked the stochastic properties of the proposed variables to be allowed to establish long-run policy recommendations, the primary aim of the present paper is to estimate the emissions–GDP elasticities (Cohen et al. 2018), so as to establish a robust pattern for considering how the reduction in emissions will infer over economic growth, via long-run elasticities. Cohen et al. (2018) used the standard decomposition cycle or trend used in many other fields of economics. A panel cointegration model was used by Narayan and Narayan (2010) to evaluate the elasticities of emissions in the short and long run as regards the developing economies' output.

Fisher–Johansen's cointegration test (1991) joins separate estimation procedures while associating estimation procedures from distinct cross-sections. $\mathit{\Pi}_i$ is the p value of a specific cointegration module for cross-section i. The null hypothesis for the panel thus turns out to be

$$-2\sum_{i=1}^{N}\log(\mathit{\Pi}_i)\rightarrow\chi^2 2N \tag{3}$$

χ^2 values are built upon MacKinnon–Haug–Michelis (1999), and p values are calculated by Johansen's cointegration trace and maximum eigenvalue tests.

FMOLS (fully modified least squares) and the DOLS (dynamic ordinary least squares) methods are used for validating the hypotheses. These econometric methods can tackle the endogeneity and serial correlation issues. They are also valid for samples with lesser size by disregarding inaccuracy caused by sample bias (Narayan and Narayan 2005).

Empirical results and discussions

This section presents and interprets the study's empirical results, as highlighted in the "Empirical methodology and data" section. These sections proceed with tests of variables stationarity properties and subsequent tests accordingly.

As the starting point of the analysis, we have analyzed the unit root properties of the model parameters, and in this pursuit, we have employed the DF-GLS, ADF, and LM unit root tests, and the test outcomes are recorded in Table 2. The test outcome divulges that the model parameters are stationary after first difference, and thereby indicating their order on integration to be unity. However, these tests cannot produce a robust outcome in the presence of unknown structural breaks, and therefore, we have employed Fourier unit root test (see Table 3). The result of Fourier unit root test divulges that the model parameters are integrated into the presence of structural breaks. From empirical results, we can induce the selected variables for predicting long-term effect.

In consequence, the stationarity properties of carbon emissions determine whether the policies will be useful or not. Our study also presents limitations, as we are not considering the technical effect (Alvarez et al. 2017) and the effects of renewable energy use. However, the present study focuses on the carbon emissions–GDP elasticities and how the absence of the globalization process infers. In consequence, our empirical

Table 2 Traditional unit root test outcome

Parameters	Tests	Test statistics		Critical value		
		Level	First difference	At 1%	At 5%	At 10%
CO_2	DF-GLS	−2.7849	−3.7104*	−3.77	−3.19	−2.89
	ADF	−2.7387	−3.6354*	−4.29	−3.56	−3.22
	NP_{MZa}	−18.9520*	−16.2955*	−23.8	−17.3	−14.2
	NP_{MZt}	−3.0663*	−2.7869*	−3.42	−2.91	−2.62
	NP_{MSB}	0.1618*	0.1710*	0.14	0.17	0.19
	NP_{MPT}	4.8800*	5.9874*	4.03	5.48	6.67
GDP	DF-GLS	−1.1337	−2.9493*	−3.77	−3.19	−2.89
	ADF	0.1789	−4.2470*	−4.27	−3.56	−3.21
	NP_{MZa}	−13.3996	−15.0661*	−23.80	−17.30	−14.20
	NP_{MZt}	−2.4191	−2.7416*	−3.42	−2.91	−2.62
	NP_{MSB}	0.1805*	0.1820*	0.14	0.17	0.19
	NP_{MPT}	7.7193	6.0664*	4.03	5.48	6.67
GE	DF-GLS	−1.1340	−4.9708*	−3.77	−3.19	−2.89
	ADF	−0.8276	−5.0945*	−4.29	−3.56	−3.22
	NP_{MZa}	−3.3362	−14.9674*	−23.8	−17.3	−14.2
	NP_{MZt}	−1.0793	−2.7354*	−3.42	−2.91	−2.62
	NP_{MSB}	0.3235	0.1828*	0.14	0.17	0.19
	NP_{MPT}	23.3162	6.0895*	4.03	5.48	6.67
GS	DF-GLS	−1.3696	−4.4263*	−3.77	−3.19	−2.89
	ADF	−0.8645	−4.3364*	−4.29	−3.56	−3.22
	NP_{MZa}	0.7679	−14.6777*	−23.8	−17.3	−14.2
	NP_{MZt}	0.8410	−2.7010*	−3.42	−2.91	−2.62
	NP_{MSB}	1.0952	0.1840*	0.14	0.17	0.19
	NP_{MPT}	258.5660	6.2549*	4.03	5.48	6.67
GP	DF-GLS	−1.1417	−5.5285*	−3.77	−3.19	−2.89
	ADF	−0.8249	−5.4340*	−4.29	−3.56	−3.22
	NP_{MZa}	−3.1251	−15.3701*	−23.8	−17.3	−14.2
	NP_{MZt}	−1.0358	−2.7692*	−3.42	−2.91	−2.62
	NP_{MSB}	0.3314	0.1802*	0.14	0.17	0.19
	NP_{MPT}	24.4274	5.9465*	4.03	5.48	6.67

*Signifies stationarity

results (Tables 2 and 3) may be misleading to make policy recommendations if we only consider carbon emissions–economic growth consequence. Therefore, we also consider the effects of economic, social, and political globalization, and absence of economic and social globalization caused by socioeconomic isolation imposed by the Chinese authorities as a result of the COVID-19 outbreak.

Subsequently, we have obtained evidence of a long-term relationship that allows us to make recommendations that are more than temporary in nature. The next step is to estimate the connection between carbon emissions and economic growth through cointegration. To proceed, we need to confirm the long-run relationship between proposed variables through cointegration tests (see Table 4).

After ascertaining the long-run association among the model parameters, three different tests are applied: fully modified ordinary least squares (FMOLS) suggested by Phillips and Hansen (1990), dynamic ordinary least squares (DOLS) proposed by Saikkonen (1991) and Stock and Watson (1993), and conical cointegration regression (CCR) based on Park (1992). This battery of tests is capable of endowing us with consistent and robust test outcomes, given the small volume of data. FMOLS outcomes are robust in the presence of serial correlation and endogeneity, which might be arising out of the probable cointegrating association among the model parameters (Phillips 1995), while DOLS allows the elimination of possible feedback persistent in the cointegrating association among the model parameters.

The results of causality analysis (Table 5) highlight the degree of predictability of each variable on another. A one-way causal relationship between economic and social globalization and CO_2 emissions is endorsed. This result suggests

Table 3 Fourier ADF, LM, and GLS unit root test outcome

Parameters	Tests	Level		Critical value		
		Test statistics	Number of Fourier	At 1%	At 5%	At 10%
Level						
CO_2	ADF	−3.0349	1	−4.95	−4.35	−4.05
	LM	−3.5175	1	−4.69	−4.10	−3.82
	GLS	−3.7766	1	−4.77	−4.17	−3.88
GDP	ADF	−5.2195*	3	−4.45	−3.78	−3.44
	LM	−5.2606*	1	−4.69	−4.10	−3.82
	GLS	−4.7071*	1	−4.77	−4.17	−3.88
GE	ADF	−3.2486	1	−4.95	−4.35	−4.05
	LM	−3.1283	1	−4.69	−4.10	−3.82
	GLS	−3.3508	1	−4.77	−4.17	−3.88
GS	ADF	−3.5491*	4	−4.29	−3.65	−3.29
	LM	−3.4531	1	−4.69	−4.10	−3.82
	GLS	−3.3147	1	−4.77	−4.17	−3.88
GP	ADF	−3.1381	3	−4.45	−3.78	−3.44
	LM	−2.2623	1	−4.69	−4.10	−3.82
	GLS	−3.0721	1	−4.77	−4.17	−3.88
First difference						
CO_2	ADF	−2.4426	2	−4.69	−4.05	−3.71
	LM	−4.1202*	1	−4.69	−4.10	−3.82
	GLS	−3.9875*	1	−4.77	−4.17	−3.88
GDP	ADF	−5.8272*	4	−4.29	−3.65	−3.29
	LM	−3.6416	1	−4.69	−4.10	−3.82
	GLS	−4.0663*	1	−4.77	−4.17	−3.88
GE	ADF	−4.7790*	1	−4.95	−4.35	−4.05
	LM	1.3125	3	−3.98	−3.31	−2.96
	GLS	−4.3315*	1	−4.77	−4.17	−3.88
GS	ADF	−2.6401	1	−4.95	−4.35	−4.05
	LM	−6.9083*	1	−4.69	−4.10	−3.82
	GLS	−5.2089*	1	−4.77	−4.17	−3.88
GP	ADF	−5.0045*	4	−4.29	−3.65	−3.29
	LM	−4.5284*	4	−3.85	−3.18	−2.86
	GLS	−5.1866*	2	−4.28	−3.65	−3.32

*Signifies stationarity

that economic and social integration with the rest of the world drives CO_2 emissions over the sampled period. However, there is a deviation since December 2019, after the first case of the COVID-19 was reported in Wuhan. These translate into low emissions level over the recent months. This outcome resonates the novel and recent findings of Zambrano-Monserrate et al. (2020). However, this finding has further impact given the isolation of China from the rest of the world to ameliorate the health issues, which also have its environmental implication. These revelations are suitable for proper policy contrition with synergy with other macroeconomic indicators of China. Further insights on causality results are highlighted in Fig. 3.

Table 4 Cointegration test results

Unrestricted cointegration rank test (trace)

Hypothesized Number of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical value	Probability
$r \leq 0$	0.756518***	116.3903	69.81889	(0.0000)
$r \leq 1$	0.670621***	72.59616	47.85613	(0.0001)
$r \leq 2$	0.493293***	38.16927	29.79707	(0.0043)
$r \leq 3$	0.283929**	17.09479	15.49471	(0.0285)
$r \leq 4$	0.195448***	6.741543	3.841466	(0.0094)

5 cointegrating vectors are considered; ***, **, and * represent statistical level of significance value at 1, 5, and 10%, respectively

Table 5 Causality test results

Null hypothesis:	Observed	*F* statistic	Probability
LGDP ≠> LCO2	32	1.659**	(0.04855)
LCO2 ≠> LGDP		0.329	(0.37095)
LGE ≠> LCO2	32	4.54151**	(0.0417)
LCO2 ≠> LGE		1.22505	(0.2775)
LGP ≠> LCO2	32	0.39555	(0.5343)
LCO2 ≠> LGP		0.05798	(0.8114)
LGS ≠> LCO2	32	3.39011*	(0.0758)
LCO2 ≠> LGS		1.99034	(0.1689)
LGE ≠> LGDP	32	1.04018	(0.3162)
LGDP ≠> LGE		6.11637**	(0.0195)
LGP ≠> LGDP	32	3.37740*	(0.0764)
LGDP ≠> LGP		0.12886	(0.7222)
LGS ≠> LGDP	32	0.83329	(0.3689)
LGDP ≠> LGS		6.87025*	(0.0138)
LGP ≠> LGE	32	5.90930**	(0.0215)
LGE ≠> LGP		0.00978	(0.9219)
LGS ≠> LGE	32	1.53949	(0.2246)
LGE ≠> LGS		2.13349	(0.1549)
LGS ≠> LGP	32	0.20806	(0.6517)
LGP ≠> LGS		11.3896***	(0.0021)

***, **, and * represent statistical level of significance value at 1%, 5%, and 10% respectively. Here ≠> means "Granger cause another" the null hypothesis for the causality test

Table 6 shows all the values obtained from the FMOLS, DOLS, and CCR estimations for the proposed Eqs. 1 and 2. The empirical results confirm the direct connection between selected explanatory variables (CO_2, EG, SG, PG) and economic growth (LGDP). At the same time, Eq. 1 considers globalization process, and in Eq. 2, we omit the impact of economic and social globalization (we found that political globalization is maintained during COVID-19 crisis).

The outcome of Eqs. 1 and 2 across three methodological procedures demonstrate that CO_2 emissions have a direct impact on the GDP. If we compare both models, we can observe that when we isolate the effects of both economic and social globalization, the connection between carbon emissions and economic growth is higher (0.099766), and even the explanatory power of the adjusted R^2 has been reduced (Fig. 4). The primary concern, however, is to find the nature of GDP and CO_2 relationship under a confinement scenario, which explains that an increase in 1% of carbon emissions (considered as dirty input) (Balsalobre et al. 2020) will increase economic growth by 0.09%. This result evidences that the Chinese economy is inelastic to economic growth in the presence of economic and social isolation. Interestingly, the long-run regression of DOLS, FMOLS, and CCR all resonates higher magnitudes of the impact of political willpower of dirty economic relative to model (1) with the interaction with rest of the world by the incorporation of the economic and social dimension of globalization as reported in Table 6.

These results suggest that the Chinese economy does not respond to pollutant emission over the sampled period. This outcome echoes the study of Emir and Bekun (2019) for the case of Romania. Table 5 reports the causality analysis over the outlined variables. We see a unidirectional causality running from economic globalization to CO_2 emissions. Similarly, one-way causality is observed between social globalization and CO_2 emissions, while no causality is seen between political globalization and CO_2 emissions. These results help us understand the predictive power of one variable over another. We observe that both social and economic interaction of economics response to increases in pollution economy. At the same time, political willpower is crucial to mitigating pollution economy, which has been demonstrated in the current study as no causal interaction is seen between economic growth and $CO_{2.}$ The plausible explanation could be the current disposition of the Chinese economy to be insulated from the rest of the nations.

Fig. 3 Pairwise Granger causality tests scheme

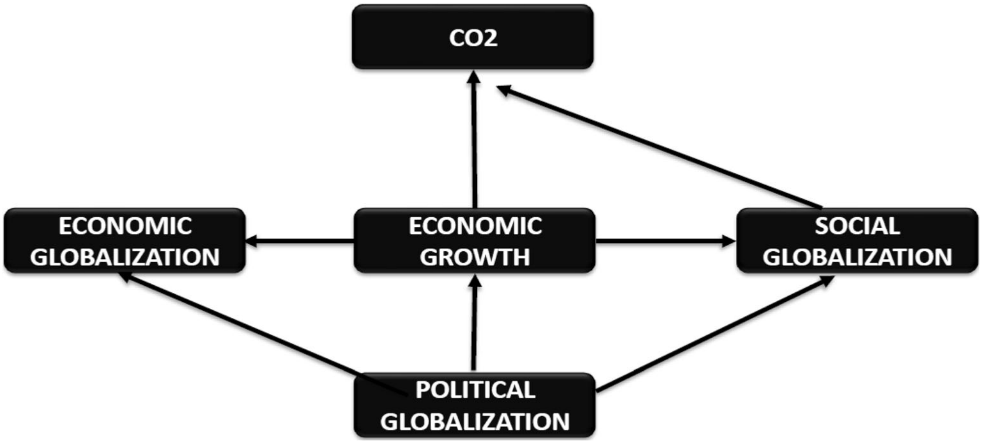

Table 6 FMOLS, DOLS, and CCR estimation of long-run coefficient

Variables	Equation 1			Equation 2		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
LCO2	0.015987*	0.015399*	0.016211*	0.099766**	0.091830***	0.094221**
	[7.480671]	[6.526038]	[7.445579]	[2.385010]	[1.944264]	[2.216742]
LGE	0.261509*	0.269817*	0.262830*			
	[29.18012]	[20.76840]	[26.39132]			
LGS	0.205224*	0.205458*	0.204685*			
	[45.23206]	[47.57804]	[46.67654]			
LGP	0.490505*	0.482779	0.489244*	1.299037*	1.314573*	1.307272
	[46.37683]	[29.16463]	[47.58904]	[10.30842]	[9.890783]	[11.15901]
C	0.089991*	0.094005	0.092400*	− 1.882247*	− 1.947697*	− 1.913966
	[2.919269]	[2.297708]	[3.274027]	[− 3.718014]	[− 3.611626]	[− 4.095952]
R^2	0.999888	0.999982	0.999887	0.973575	0.986936	0.972833
Adjusted R^2	0.999871	0.999959	0.999871	0.971753	0.981959	0.970959
SE of regression	0.003014	0.001624	0.003018	0.044623	0.034140	0.045245
Log likelihood	6.45E−06	1.84E−06	6.45E−06	0.003766	0.002808	0.003766
Mean dependent variable	3.874410	3.880246	3.874410	3.874410	3.880246	3.874410
SD dependent variable	0.265502	0.254175	0.265502	0.265502	0.254175	0.265502
Sum squared residual	0.000245	3.43E−05	0.000246	0.057745	0.024476	0.059367

Dependent variable: *LGDP* (1981–2014)

t statistic is given in [ ]. *P* values of *, **, and *** show significance at 1, 5, and 10%, respectively

Conclusion and policy implications

In more recent times, the world has experienced several uncertainties ranging from the Great Depression in the 1930s, Global Food Crises of 2006 to the Great Recession burn of the global financial crisis (2008–2009) to the very recent pandemic of COVID-19, which stem from the Republic of China at Wuhan. As an extreme event, the outbreak of COVID-19 has damaged the global economic growth generating a specific impact on the environment. The COVID-19 pandemic has radically altered patterns of energy demand in both China and around the rest of the world. Current estimations have assessed the decrease in CO_2 emissions during forced confinements. These mentioned uncertainties have a ripple effect on socioeconomic and macroeconomic indicators of any nation. Thus, given the current happening and isolation of the Republic of China from the rest of the community of nations to mitigate the effect of the COVID-19 pandemic, we focus on the Chinese economy. For testing the highlighted hypotheses proposed in the present study, conventional and current econometrics tools were adopted over annual time frequency from 1981 to 2014. Assuming that COVID-19 significantly has reduced the concentration of emission in the atmosphere (Wang and Su 2020), the empirical estimation traces and validates the cointegration relationship between economic growth and pollutant emission (CO_2), all dimensions of globalization (social, economic, and political) in China oversampled period. The long-run regressions of DOLS, FMOLS, and CCR validate a positive and inelastic relationship between economic growth and pollutant emission in China. This outcome is indicative to government officials of China, as it implies that the Chinese economy is not responsive to dirty (CO_2) economic growth. This is seen in the reduction of pollutant emissions in recent times because of less industrial activities that pollute the environment (see Fig. 1 for more insights into this argument). This position of carbon reduction admits COVID resonates the recent declaration by the report of Carbon Brief about the reduction of CO_2 emissions based on the decline in coal consumption.

Furthermore, the current study constructed twin models, where model 2 is the baseline, focused on the isolation effects of both social and economic globalization on economic growth in recent time. The regression indicates that the political willpower of the government administrators of Chinese economy to curb the wild spread of health challenges that cut across the globe. This is endorsed by the positive and elastic effect of the political wave of globalization to economic growth. Thus, despite the Chinese economy isolation from the rest of the world, economic growth was still experienced, given the positive and significant growth trajectory (see

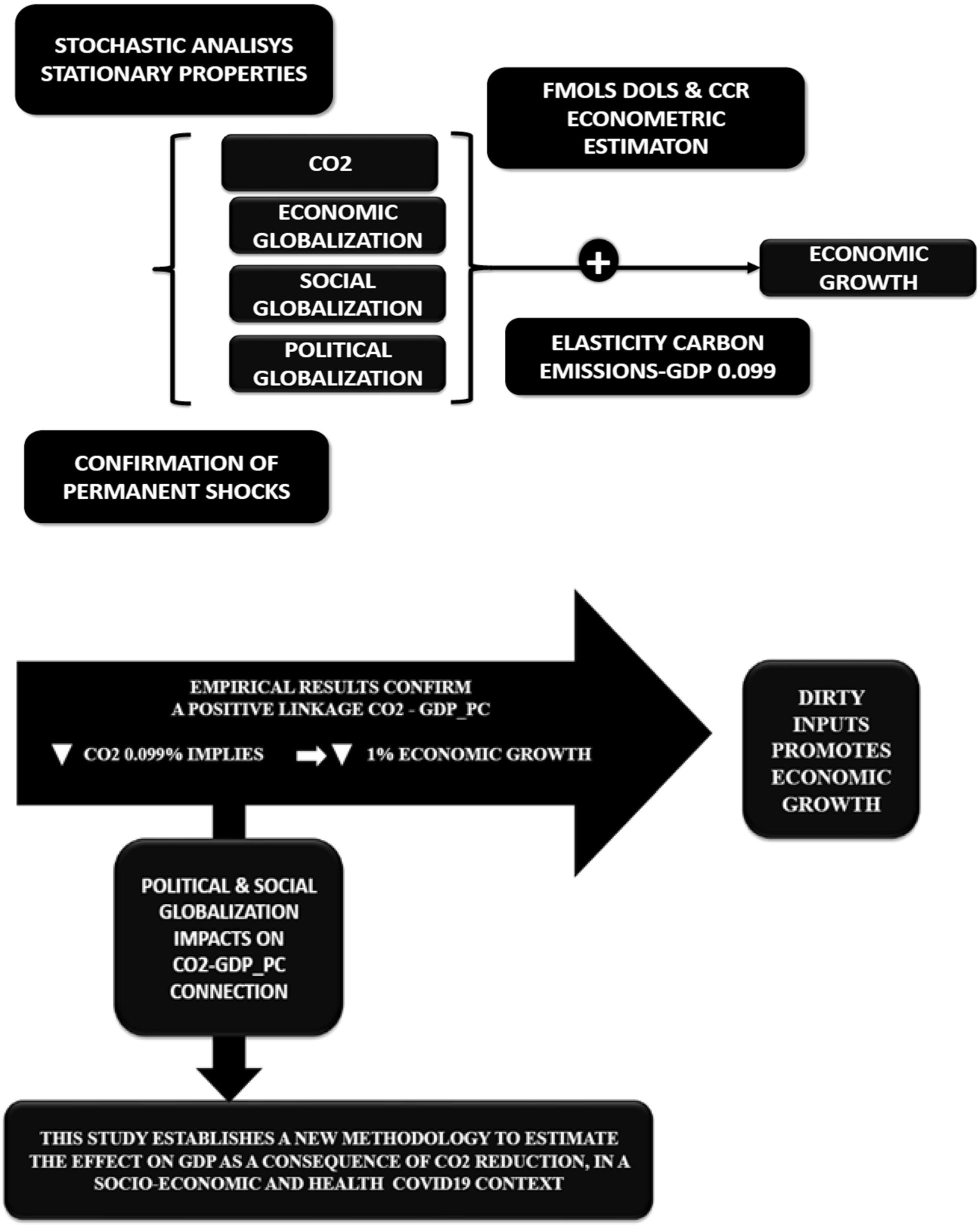

Fig. 4 FMOLS, DOLS, and CCR estimation results scheme

Table 6). However, the more inclusive model displays a significant impact of social and economic globalization on Chinese economic growth as confirmed by the causality analysis; both economic and social globalization predicts pollutant emissions. This result suggests that interaction with the rest of the world contains externalities directly connected with the environment. It is worth mentioning that isolation from the rest of the world does not show any causality with pollutant emission in the present study. These calls for intensive policy mix linked to the environment, as isolation from the rest of the world has its implications, and given the trade-off between economic growth and pollutant emissions, there is a need for caution when liberalizing the economy, as well as strong political willpower aiming to mitigate the adverse effect of globalization at all time.

Recent studies (Le Quéré et al. 2020; Wang and Su 2020) confirm the reduction in emissions in China since the beginning of COVID-19 crisis, as result of the implementation of strict confinement measure amend the spread of the virus at both national and international level (e.g., restrictions on trade and international tourism). This should shorten the spread of the pandemic. However, the laydown restrictions come with some economic (negative) implications.

While OECD countries are expected to register an economic decrease of their real GDP between 7.5 and 9.3% depending on single- or double-hit scenario caused by COVID-19 crisis, China presents a more optimistic situation with a range of decrease between 2.6 and 3.7% (OECD 2020). These projections are in line with our study results for the Chinese economy. Even this research on COVID-19 crisis was in full swing, and limitations were faced for such an analysis. Despite this, our study aims to establish a methodology that serves as a tool for predicting the economic impact of COVID-19 not just in China but globally. Obtaining data on the reduction of emissions monthly allows us to adapt the growth forecasts according to the levels of CO_2, under a model that has considered the isolation caused by this crisis and its effects for the economy. Moreover, this methodology might be considered for other economies strongly affected by COVID-19 (e.g., EU, USA, Brazil, or India), but also for more local predictions regarding the levels of water pollution (PME) or the levels of NO_2 or GHG.

The current study is not void of policy direction for all stakeholders and the government administrator in China. The isolation of the Chinese economy from the rest of the world makes both conventional and health sense. This action is timely and worthwhile to help flatten the rise of the spread of COVID-19 and after that, reduce the working and active (workforce) population as results of infection from the virus. We observe that the willpower of the Chinese government is significant, and there is no causality between political globalization and pollutant emission against contract expectation where both social and economic globalizations engender CO_2 emissions. The current study employed the government of the day to sustain the current momentum.

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