Carbon Implications of COVID-19

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Abstract

The COVID-19 pandemic has imposed tremendous impacts on every aspect of our lives, and CO_2 emissions are an important one of them. Our results show that global annual carbon emissions declined by over 5% from 2019 to 2020 but rebounded quickly from 2020 to 2021. Although a "green recovery" has been proposed by many countries, changes in lifestyles and varied technical capacities of countries have placed uncertainties on climate change mitigation in the post-pandemic era. Policymakers need to pay attention to the equal and just issue in the global "green recovery".

Introduction

The COVID-19 pandemic brought significant changes to our economies. As an acute disease transmitted through the respiratory system, COVID-19 is highly infectious and can be fatal for vulnerable populations. At the time of writing of this paper, the world had recorded over six million deaths due to COVID-19 (Dong et al., 2020). Since it is a newly emerging disease, knowledges and means of treatment for COVID-19 was limited when the pandemic first started in 2020. To contain the rapid spread of the virus and ease the pressure on public healthcare systems, national governments responded with strict measures to reduce people's interactions. Such measures included, for example, lockdowns, border restrictions, and quarantine. The counter measures were proven to be successful in containing the transmission of COVID-19 and winning time for the development and mass inoculation of vaccines. However, the side-damage to the economies of the world were inevitable. In 2020, global GDP contracted by 3.1%, with the GDP of advanced economies shrinking by 4.5% and emerging market and developing economies shrinking by 2.1%. Among all countries, China is the only major economy that registered a positive economic growth of 2.3% (International Monetary Fund, 2021).

In direct relation to economic activities, the emissions of pollutants, including CO_2, drastically decreased due to reduced consumption and supply in the transport and power sectors (Sikarwar et al., 2021). In the studies of impacts of lockdowns on several cities, considerable direct decreases in all kinds of pollutants were observed from satellite remote sensing (Wang and Su, 2020, Tobías et al., 2020, Jia et al., 2021). However, some scholars predicted (Sikarwar et al., 2021, Tollefson, 2021) that global CO_2 emissions would soon rebound back to pre-pandemic levels. In this study, we used the live updated Carbon Monitor database developed by Liu et al. (2020) to analyse the CO_2 emissions changes in major sectors of economies in 2019, 2020, and 2021, hence proposing the reasons for the difference in CO_2 emissions reductions and rebounds. Policy implications were provided accordingly for the challenges faced in the recovery of our economies.

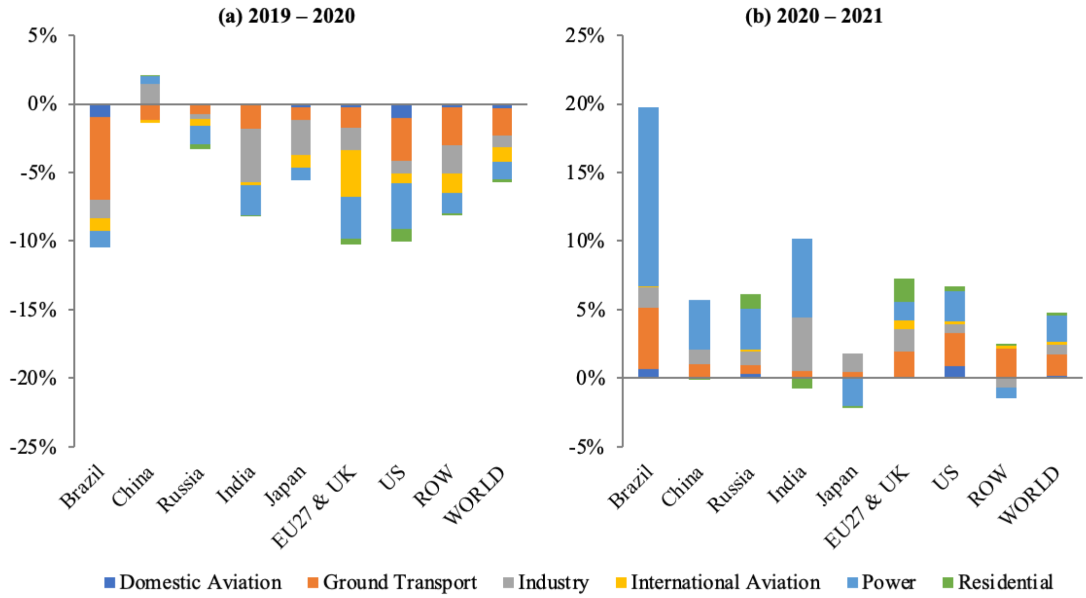
The impacts of COVID-19 on global carbon emissions

From 2019 to 2020, various extents of reduction in CO_2 emissions have been observed across most sectors in most economies. Figure 1 is produced from Carbon Monitor (Liu et al., 2020) data to show the changes of carbon emissions in the world's major economies by sector. Global carbon emissions declined by 5.7% from 2019 to 2020, which was the largest decline since the Kyoto Protocol adopted in 1997. It is evident that all sectors in all economies underwent a reduction in CO_2 emissions, except for the industry (+3.8%), power (+1.2%), and residential (+0.5%) sectors of China. Only China registered a net growth in its CO_2 emissions in 2020, correlating with the positive economic growth of China in 2020. Overall, ground transport is the sector that induced the most decrease in CO_2 emissions across all economies, although it only decreased by 10.9% in world total, much less compared to domestic (-30.9%) and international (-56.1%) aviation (Table 1).

The rebound of carbon emissions after COVID-19 pandemic

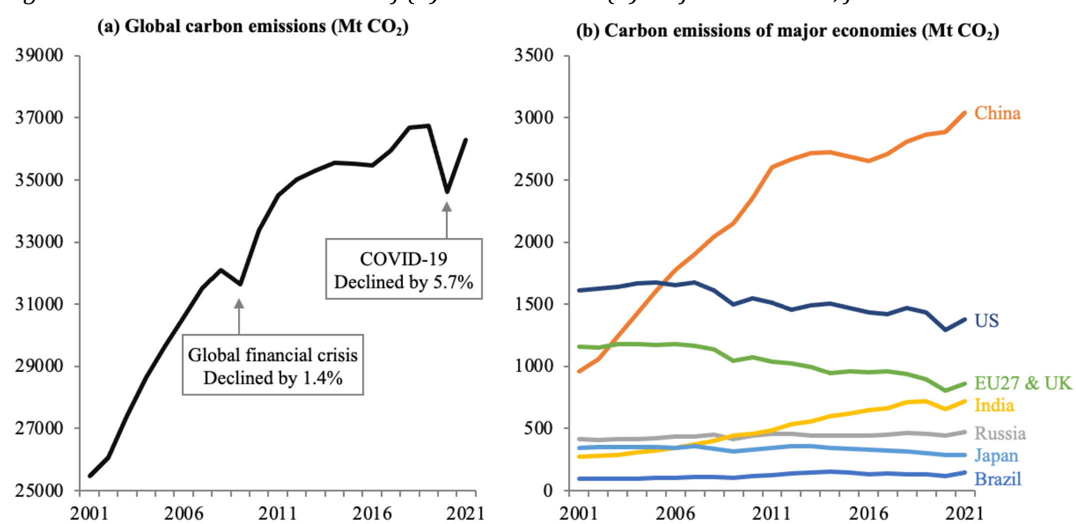
From 2020 to 2021, the trend of decreasing global CO_2 emissions has quickly reversed, with some countries even surpassing CO_2 emission levels in 2019. In Figure 1 (b), it is seen that most economies underwent significant increase in CO_2 emission levels, except for Japan where the trend of reduction continues. It is worth noting that the CO_2 emissions of the international aviation industry keeps dropping for both Japan (-3.8%) and China (-13.5%), very likely a result of their stringent border control rules on COVID-19. Although the major economies investigated in this study have all shown a positive growth in CO_2 emissions of the industry sector, other countries were yet to show evidence of CO_2 emission rebound in 2021 (-2.1%), partially suggesting

Figure 1. Contributions to the total percentage changes in CO_2 emissions in major economies broken down by sectors (a) from 2019 to 2020 and (b), from 2020 to 2021



Source: Carbon Monitor.

Figure 2. Trends in CO2 emissions of (a) the world and (b) major economies, from 2001 to 2021



Source: Carbon Monitor and Global Carbon Budget.

Table 1. Changes in CO2 emissions in major economies by sectors, from 2019 to 2021. Red means that emissions increased, while green means emissions decreased

Brazil (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	10.1	-4.0(-39.8%)	6.1	2.6(42.7%)	8.6
Ground Transport	171.0	-26.2(-15.3%)	144.8	17.5(12.1%)	162.3
Industry	129.8	-6.0(-4.6%)	123.7	5.7(4.6%)	129.4
International Aviation	6.6	-3.8(-57.8%)	2.8	0.2(7.0%)	3.0
Power	80.1	-5.4(-6.7%)	74.7	50.8(68.0%)	125.5
Residential	36.5	0.0(0.0%)	36.5	0.0(0.0%)	36.5
Total	434.0	-45.4(-10.5%)	388.6	76.7(19.7%)	465.3

China (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	62.3	-10.9(-17.5%)	51.4	6.3(12.2%)	57.7
Ground Transport	921.5	-114.9(-12.5%)	806.6	98.4(12.2%)	905.0
Industry	4091.8	155.9(3.8%)	4247.7	111.5(2.6%)	4359.2
International Aviation	31.2	-18.6(-59.6%)	12.6	-1.7(-13.5%)	10.9
Power	4554.8	54.4(1.2%)	4609.2	385.3(8.4%)	4994.5
Residential	800.0	4.4(0.5%)	804.4	-10.2(-1.3%)	794.2
Total	10461.6	70.4(0.7%)	10532.0	589.6(5.6%)	11121.5

Russia (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	15.4	-2.0(-13.0%)	13.4	5.2(38.5%)	18.5
Ground Transport	231.8	-9.4(-4.1%)	222.4	9.5(4.3%)	231.8
Industry	283.7	-5.9(-2.1%)	277.8	14.6(5.2%)	292.4
International Aviation	13.2	-8.0(-60.4%)	5.2	1.8(35.4%)	7.1
Power	838.0	-19.9(-2.4%)	818.1	45.3(5.5%)	863.3
Residential	171.1	-6.4(-3.7%)	164.7	16.0(9.7%)	180.8
Total	1553.2	-51.6(-3.3%)	1501.6	92.3(6.1%)	1593.9

India (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	7.2	-3.3(-45.8%)	3.9	1.3(32.9%)	5.2
Ground Transport	298.8	-41.5(-13.9%)	257.3	10.8(4.2%)	268.1
Industry	749.1	-95.2(-12.7%)	653.9	87.6(13.4%)	741.4
International Aviation	12.0	-6.4(-53.9%)	5.5	0.5(8.9%)	6.0
Power	1194.3	-53.0(-4.4%)	1141.3	129.5(11.3%)	1270.9
Residential	202.4	-2.7(-1.3%)	199.7	-16.9(-8.5%)	182.8
Total	2463.7	-202.1(-8.2%)	2261.6	212.7(9.4%)	2474.3

Japan (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	9.0	-2.5(-27.9%)	6.5	0.0(0.7%)	6.5
Ground Transport	177.7	-10.5(-5.9%)	167.2	4.7(2.8%)	171.9
Industry	268.3	-27.8(-10.4%)	240.5	14.1(5.9%)	254.6
International Aviation	19.4	-10.8(-55.6%)	8.6	-0.3(-3.8%)	8.3
Power	523.2	-10.1(-1.9%)	513.1	-21.1(-4.1%)	492.0
Residential	107.7	0.1(0.1%)	107.8	-1.1(-1.0%)	106.7
Total	1105.4	-61.7(-5.6%)	1043.8	-3.7(-0.4%)	1040.1

EU27 & UK (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	16.5	-7.9(-48.1%)	8.6	2.7(31.5%)	11.3
Ground Transport	878.2	-49.7(-5.7%)	828.5	55.2(6.7%)	883.7
Industry	631.5	-52.2(-8.3%)	579.3	46.0(7.9%)	625.3
International Aviation	189.6	-111.8(-58.9%)	77.9	20.2(26.0%)	98.1
Power	931.9	-99.6(-10.7%)	832.2	39.5(4.7%)	871.7
Residential	618.9	-12.8(-2.1%)	606.1	49.3(8.1%)	655.4
Total	3266.6	-334.1(-10.2%)	2932.5	213.0(7.3%)	3145.5

US (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	173.3	-52.8(-30.4%)	120.6	38.7(32.1%)	159.3
Ground Transport	1642.0	-158.9(-9.7%)	1483.0	111.3(7.5%)	1594.3
Industry	996.8	-46.7(-4.7%)	950.2	31.1(3.3%)	981.2
International Aviation	81.5	-37.4(-46.0%)	44.0	10.1(22.8%)	54.1
Power	1601.9	-168.7(-10.5%)	1433.2	99.9(7.0%)	1533.1
Residential	602.5	-48.1(-8.0%)	554.4	14.8(2.7%)	569.2
Total	5098.1	-512.7(-10.1%)	4585.4	305.8(6.7%)	4891.2

ROW (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	69.1	-28.6(-41.4%)	40.5	8.5(21.0%)	49.0
Ground Transport	2172.9	-298.2(-13.7%)	1874.7	208.1(11.1%)	2082.8
Industry	3571.0	-224.2(-6.3%)	3346.8	-69.4(-2.1%)	3277.4
International Aviation	278.1	-157.7(-56.7%)	120.3	20.6(17.1%)	141.0
Power	3764.8	-157.0(-4.2%)	3607.7	-76.9(-2.1%)	3530.9
Residential	1011.2	-15.8(-1.6%)	995.3	14.5(1.5%)	1009.8
Total	10867.0	-881.7(-8.1%)	9985.3	105.4(1.1%)	10090.7

World (Unit: Mt CO_2)

Sector\Year	2019	Emission Change (Change Rate)	2020	Emission Change (Change Rate)	2021
Domestic Aviation	362.9	-112.1(-30.9%)	250.8	65.2(26.0%)	316.1
Ground Transport	6493.9	-709.4(-10.9%)	5784.5	515.3(8.9%)	6299.9
Industry	10721.9	-302.0(-2.8%)	10419.9	241.1(2.3%)	10661.0
International Aviation	631.5	-354.5(-56.1%)	277.0	51.4(18.6%)	328.4
Power	13489.0	-459.3(-3.4%)	13029.7	652.3(5.0%)	13681.9
Residential	3550.4	-81.5(-2.3%)	3468.9	66.4(1.9%)	3535.3
Total	35249.6	-2018.8(-5.7%)	33230.8	1591.8(4.8%)	34822.6

the differentiated impacts that countries received from the pandemic.

Another observation from the CO_2 emissions of 2021 is that developing countries are more prone to CO_2 emissions rebound than the developed countries. As shown in Figure 1(b) and Table 1, the 2021 CO_2 emission levels of major emerging economies, i.e., Brazil, Russia, India, and China, have all surpassed their pre-pandemic levels in 2019. In contrast, the CO_2 emissions rebound in the developed countries of Japan, the US, and the EU were not sufficient to bring emissions back to their 2019 levels. Specifically, the power sector contributed the most to the rebound in CO_2 emissions in the four emerging economies, accounting for 66.2%, 65.4%, 49.0%, and 60.9% of the CO_2 emissions increase in Brazil, China, Russia, and India in 2021 respectively. These are significantly larger than the reductions that the power sectors of these four economies achieved in 2020. Meanwhile, a comparable rebound in the power sectors is not observed in the developed economies investigated. The power sector of Japan even contributed the most towards Japan's CO_2 emissions reduction in 2021.

The reason for such a phenomenon, as some other research predicted (Wang et al., 2022), is the unbalanced recovery stimulus in green technologies among the developed and developing countries (IEA, 2021). During the first wave of the pandemic, governments' focus of recovery was to respond to the cries from the small businesses and lower income groups on job and income losses. As lockdowns and curfews were being lifted later, interest groups called for jobs to be created in green sectors, such as renewable energy generations and carbon mitigation technologies. Due to technical capacity constraints and the nature of the development phase, emerging economies face barriers in the shift towards a higher mix of green technologies. Without substantial capital investment in green sectors, economic recovery stimulus will only lead to retaliatory consumption - similar to the rebound after the 2008 financial crisis (Wang et al., 2021) - and rapidly push CO_2 emissions beyond the pre-pandemic level. According to the Carbon Monitor (Liu et al., 2020) and Global Carbon Budget (Friedlingstein et al., 2021) shown in Figure 2, neither the 2008 financial crisis nor the 2020 COVID-19 pandemic have reversed the general trend of CO_2 emissions among countries.

Policy implications on green recovery and low-carbon development

In response to the CO_2 emissions rebound, "green recovery for all" should be the key principle to tackle the challenge. Green recovery proposes that countries should ensure that pandemic recovery stimulus must be channelled to green development purposes. Although world leaders have responded to the appeals, green stimulus packages announced by developed countries have dwarfed those proposed by developing countries (Carbon Brief, 2020). In order not to leave out anyone in our endeavour to reach climate neutrality, the next focus of the green recovery stimulus should be building transnational financing mechanisms that bring equal opportunities in green technology development, such as renewable energy, to the less developed world. Multinational development banks will be the key channel to ensure sufficient, and environmentally just, financing for green recovery investment to the global south.

In addition, remote working has been proven to be an alternative way of working that bears CO_2 emissions mitigation potentials, but the welfare gain must be shared by all income groups. Preliminary studies have already proven that carbon mitigation potentials for mass implementation of remote working are considerable in commuting and office heating etc (Carbon Trust, 2021), which is a direct factor for the global reduction in ground transportation CO_2 emissions in 2020 as we have revealed. However, the access to that potential is unequally allocated. Jobs that allow remote working generally involve office workers from the higher income groups. If policymakers and business owners are considering switching to long-term remote working, it is necessary to ensure the social welfare gain is not only concentrated on the higher income groups but also labour-intensive workers from the lower income groups.

Lastly, our findings suggest that strict COVID-19 border control reduces international travels and thus carbon emissions in the aviation and shipping industry, which also creates disruptions and uncertainties for global supply chains (Eroğlu, 2021). Compounded with the global trend in trade protectionism and geopolitical instability, relocation of suppliers may also shift the burdens of carbon emissions (Wang and Wang, 2020). Thus, the resulting carbon leakage, i.e., "outsourcing" of carbon emissions, may jeopardize our global green recovery effort. Hence, intergovernmental management on green supply chains should be paid more attention to - vis-à-vis changing global supply chains in the post-pandemic era.

References

CARBON BRIEF. 2020. *Coronavirus: Tracking how the world's 'green recovery' plans aim to cut emissions* [Online]. Available: https://www.carbonbrief.org/coronavirus-tracking-how-the-worlds-green-recovery-plans-aim-to-cut-emissions [Accessed].

CARBON TRUST 2021. Homeworking report: An assessment of the impact of teleworking on carbon savings and the longer-term effects on infrastructure services.

DONG, E., DU, H. & GARDNER, L. 2020. An interactive web-based dashboard to track COVID-19 in real time. *The Lancet Infectious Diseases,* 20**,** 533-534.

EROĞLU, H. 2021. Effects of Covid-19 outbreak on environment and renewable energy sector. *Environment, Development and Sustainability,* 23**,** 4782-4790.

FRIEDLINGSTEIN, P., JONES, M. W., O'SULLIVAN, M., ANDREW, R. M., BAKKER, D. C. E., HAUCK, J., LE QUéRé, C., PETERS, G. P., PETERS, W., PONGRATZ, J., SITCH, S., CANADELL, J. G., CIAIS, P., JACKSON, R. B., ALIN, S. R., ANTHONI, P., BATES, N. R., BECKER, M., BELLOUIN, N., BOPP, L., CHAU, T. T. T., CHEVALLIER, F., CHINI, L. P., CRONIN, M., CURRIE, K. I., DECHARME, B., DJEUTCHOUANG, L., DOU, X., EVANS, W., FEELY, R. A., FENG, L., GASSER, T., GILFILLAN, D., GKRITZALIS, T., GRASSI, G., GREGOR, L., GRUBER, N., GüRSES, Ö., HARRIS, I., HOUGHTON, R. A., HURTT, G. C., IIDA, Y., ILYINA, T., LUIJKX, I. T., JAIN, A. K., JONES, S. D., KATO, E., KENNEDY, D., KLEIN GOLDEWIJK, K., KNAUER, J., KORSBAKKEN, J. I., KöRTZINGER, A., LANDSCHüTZER, P., LAUVSET, S. K., LEFèVRE, N., LIENERT, S., LIU, J., MARLAND, G., MCGUIRE, P. C., MELTON, J. R., MUNRO, D. R., NABEL, J. E. M. S., NAKAOKA, S. I., NIWA, Y., ONO, T., PIERROT, D., POULTER, B., REHDER, G., RESPLANDY, L., ROBERTSON, E., RöDENBECK, C., ROSAN, T. M., SCHWINGER, J., SCHWINGSHACKL, C., SéFéRIAN, R., SUTTON, A. J., SWEENEY, C., TANHUA, T., TANS, P. P., TIAN, H., TILBROOK, B., TUBIELLO, F., VAN DER WERF, G., VUICHARD, N., WADA, C., WANNINKHOF, R., WATSON, A., WILLIS, D., WILTSHIRE, A. J., YUAN, W., YUE, C., YUE, X., ZAEHLE, S. & ZENG, J. 2021. Global Carbon Budget 2021. *Earth Syst. Sci. Data Discuss.,* 2021**,** 1-191.

IEA 2021. Global Energy Review 2021. *In:* IEA (ed.). Paris

INTERNATIONAL MONETARY FUND 2021. World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. *In:* FUND, I. M. (ed.). Washington, DC.

JIA, M., EVANGELIOU, N., ECKHARDT, S., HUANG, X., GAO, J., DING, A. & STOHL, A. 2021. Black Carbon Emission Reduction Due to COVID-19 Lockdown in China. *Geophysical Research Letters,* 48**,** e2021GL093243.

LIU, Z., CIAIS, P., DENG, Z., LEI, R., DAVIS, S. J., FENG, S., ZHENG, B., CUI, D., DOU, X., ZHU, B., GUO, R., KE, P., SUN, T., LU, C., HE, P., WANG, Y., YUE, X., WANG, Y., LEI, Y., ZHOU, H., CAI, Z., WU, Y., GUO, R., HAN, T., XUE, J., BOUCHER, O., BOUCHER, E., CHEVALLIER, F., TANAKA, K., WEI, Y., ZHONG, H., KANG, C., ZHANG, N., CHEN, B., XI, F., LIU, M., BRéON, F.-M., LU, Y., ZHANG, Q., GUAN, D., GONG, P., KAMMEN, D. M., HE, K. & SCHELLNHUBER, H. J. 2020. Near-real-time monitoring of global CO2 emissions reveals the effects of the COVID-19 pandemic. *Nature Communications,* 11**,** 5172.

SIKARWAR, V. S., REICHERT, A., JEREMIAS, M. & MANOVIC, V. 2021. COVID-19 pandemic and global carbon dioxide emissions: A first assessment. *Science of The Total Environment,* 794**,** 148770.

TOBíAS, A., CARNERERO, C., RECHE, C., MASSAGUé, J., VIA, M., MINGUILLóN, M. C., ALASTUEY, A. & QUEROL, X. 2020. Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic. *Science of The Total Environment,* 726**,** 138540.

TOLLEFSON, J. 2021. Carbon emissions rapidly rebounded following COVID pandemic dip. *Nature (Lond.)*.

WANG, Q., LI, S., LI, R. & JIANG, F. 2022. Underestimated impact of the COVID-19 on carbon emission reduction in developing countries – A novel assessment based on scenario analysis. *Environmental Research,* 204**,** 111990.

WANG, Q. & SU, M. 2020. A preliminary assessment of the impact of COVID-19 on environment – A case study of China. *Science of The Total Environment,* 728**,** 138915.

WANG, Q. & WANG, S. 2020. Preventing carbon emission retaliatory rebound post-COVID-19 requires expanding free trade and improving energy efficiency. *Science of The Total Environment,* 746**,** 141158.

WANG, Q., WANG, S. & JIANG, X.-T. 2021. Preventing a rebound in carbon intensity post-COVID-19 – lessons learned from the change in carbon intensity before and after the 2008 financial crisis. *Sustainable Production and Consumption,* 27**,** 1841-1856.