Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement

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Abstract

Government policies during the COVID-19 pandemic have drastically altered patterns of energy demand around the world. Many international borders were closed and populations were confined to their homes, reducing transport and consumption patterns. Here we compile government policies and activity data to estimate the decrease in CO_2 emissions during forced confinement. Daily global CO_2 emissions decreased by –17% (–11% to –25%) by early April 2020 compared to mean 2019 levels, primarily from changes in surface transport. At their peak, emissions in individual countries decreased by –27% on average. The impact on 2020 annual emissions depends on the duration of the confinement, with a low estimate of –4% (–2% to –7%) if pre-pandemic conditions return by mid-June, and a high estimate of –8% (–3% to –14%) if some restrictions remain worldwide until end of 2020. Government actions and economic incentives post-crisis will likely influence the global CO_2 emissions path for decades.

Introduction

Before the COVID-19 pandemic of 2020, emissions of carbon dioxide had been rising by about one percent per year over the previous decade[1-3], with no growth in 2019[4] (also updated from Peters et al. 2020[3]; see Methods). Renewable energy production was expanding rapidly amid plummeting prices[5], but much of the renewable energy was being deployed alongside fossil energy and did not replace it[6], while emissions from surface transport continued to rise[3,7].

The emergence of COVID-19 was first identified on 30 December 2019[8] and declared a global pandemic by the World Health Organization on 11 March 2020. Cases rapidly spread initially mainly in China during January, but quickly expanding to South Korea, Japan, Europe (mainly Italy, France and Spain) and the US between late January and mid-February, before reaching global proportions by the time the pandemic was declared[9]. Increasingly stringent measures were put in place by world governments in an effort, initially, to isolate cases and stop the transmission of the virus, and later to slow down its rate of spread. Measures imposed ramped up from the isolation of symptomatic individuals, to the ban of mass gatherings, mandatory closure of schools, and even mandatory home confinement (Table 1). Population confinement is leading to drastic changes in energy use, with expected impacts on CO_2 emissions.

Despite the critical importance of CO_2 emissions for understanding global climate change, systems are not in place to monitor global emissions in real time. CO_2 emissions are reported as annual values[1], often released months or even years after the end of the calendar year. Despite this, some proxy data is available in near real time or at monthly intervals. High-frequency electricity data is available for some regions (e.g., Europe[10] and US[11]), but rarely the associated CO_2 emissions data. Fossil fuel use is estimated for some countries at the monthly level, with data usually released a few months later[1,12]. Observations of CO_2 concentration in the atmosphere are available near-real time[13,14], but the influence of the natural variability of the carbon cycle and meteorology is large and masks the variability in anthropogenic signal over short period[15,16]. Satellite measurements of column CO_2 inventory[17] have large uncertainties and also reflect the variability of the natural CO_2 fluxes[18], and thus cannot yet be used in near-real time to determine anthropogenic emissions.

Given the lack of real time CO_2 emissions data, we take an alternative approach to estimate country level emissions based on a confinement index representing the effect of different policies. The change in CO_2 emissions associated with the confinement is informative in multiple ways. First, the changes in emissions are entirely due to a forced reduction in energy demand. Although in this case the demand disruption was neither intentional nor welcome, the effect provides a quantitative indication of the potential and limits that extreme measures could deliver with the current energy mix (for example, a higher rate of home working or reducing consumption). Second, during previous economic crises, the decrease in emissions was short-lived with a post-crisis rebound that restored emissions to their original trajectory, except when these crises were driven by energy factors such as the oil crises of the 1970s and 1980s, which led to significant shifts in energy efficiency and development of alternative energy sources[19] (Fig. 1). For example, the 2008-2009 Global Financial Crisis saw global CO_2 emissions decline –1.4% in 2009, immediately followed by a growth in emissions of +5.1% in 2010[20], well above the long-term average. Emissions soon returned to their previous path almost as if the crisis had not occurred.

The economic crisis associated with COVID-19 is markedly different from previous economic crises in that it is more deeply anchored in constrained individual behaviour. At present it is unclear how long and deep the crisis will be, and how the recovery path will look, and therefore, how CO_2 emissions will be affected. Keeping track of evolving CO_2 emissions can help inform government responses to the COVID-19 pandemic to avoid locking future emissions trajectories in carbon-intensive pathways.

Method and results

In this analysis, we use a combination of energy, activity, and policy data available up to the end of April 2020 to estimate the changes in daily emissions during the confinement from the COVID-19 pandemic, and its implications for the growth in CO_2 emissions in 2020. We compare this change in emissions to mean daily emissions for the latest available year (2019 for the globe) to provide a quantitative measure of relative change compared to pre-COVID conditions.

Changes in CO_2 emissions are estimated for three levels confinement and for six sectors of the economy, as the product of the CO_2 emissions by sector before confinement and the fractional decrease in those emissions due to the severity of the confinement and its impact on each sector (Eq.1, see Method). The analysis is done over 69 countries, 50 US states and 30 Chinese provinces representing 85% of the world population and 97% of global CO_2 emissions.

The confinement index is defined on a scale of 0 to 3 that allocates the degree to which normal daily activities were constrained for part or all of the population (Table 1). A scale of 0 indicates no measures are in place, 1: policies are targeted at small groups of individuals suspected of carrying infection, 2: policies are targeted at entire cities or regions or that affect about 50% of society, and 3: national policies significantly restrict the daily routine of all but key workers, affecting approximately 80% of society (see Extended Methods in Supplementary Information). During the early confinement phase around Chinese New Year in China (starting January 25), around 30% of global emissions were in areas under some confinement (Fig. 1). This increased to 70% by the end of February, and over 85% by mid-March when confinement in Europe, India and the US started, while China later relaxed confinement (Fig. 1). At its peak in early April, 89% of global emissions were in areas under some confinement.

The six economic sectors covered in this analysis are: (1) power (44.3% of global fossil CO_2 emissions), (2) surface transport (20.6%), (3) industry (22.4%), (4) public buildings and commerce (here shortened to “public”; 4.2%), (5) residential (5.6%), and (6) aviation (2.8%; see Methods). We collected time-series data (mainly daily) representative of activities emitting CO_2 in each sector, to inform the changes in each sector as a function of the confinement level (Fig. 2). The data represents changes in activity, such as electricity demand or road and air traffic, rather than direct changes in CO_2 emissions. We make a number of assumptions to cover the six sectors based on the available data and the nature of the confinement (Table 2; see Methods; Supplementary Tables S1-S10). Changes in the surface transport and aviation sectors were best constrained by indicators of traffic from a range of countries, including both urban and nation-wide data. Changes in power-sector emissions were inferred from electricity data from Europe, US, and India. Changes in industry were inferred mainly from industrial activity in China and steel production in the US. Changes in the residential sector were inferred from UK smart meter data, while changes in the public sector was based on assumptions about the nature of the confinement. All activity changes are relative to typical activity level prior to the COVID-19 pandemic (see Extended Methods in the Supplementary Information).

Activity data shows the changes in daily activities were largest in the aviation sector, with a decrease in daily activity of –75% (–60% to –90%) during confinement level 3 (Table 2). Surface transport saw its activity reduce by –50% (–40% to –65%), while industry and public sectors saw their activity reduce by –35% (–25% to –45%) and –33% (–15% to –50%), respectively. Still during confinement level 3, power saw its activity decrease by a modest –15% (–5% to –25%), while the residential sector saw its activity increase by +5% (0% to +10%). Activity data also shows substantial decreases in activity during confinement levels 2, and only small decreases during confinement level 1 (Table 2).

Daily changes in CO_2 emissions

The effect of the confinement was to decrease daily global CO_2 emissions by –17 (–11 to –25) $MtCO_2\ d^{-1}$, or –17% (–11% to –25%) by 7 April 2020 (Table 2), relative to the mean level of emissions in 2019. The change in emissions on 7 April was the largest estimated daily change during 1 January to 30 April 2020. Daily emissions in early April are comparable to their levels of 2006 (Fig. 3). The values in $MtCO_2\ d^{-1}$ are close to the value in percent coincidentally, because we currently emit about 100 $MtCO_2\ d^{-1}$. For individual countries, the maximum daily decrease averaged to –27% (±9% for ±1σ), although the maximum daily decrease did not occur during the same day across countries, hence the decrease is more pronounced than the global maximum daily decrease. Estimated changes quantify the effect of confinement only, and is relative to underlying trends prior to the COVID-19 pandemic. The daily decrease in CO_2 emissions during the pandemic is as large as the seasonal amplitude in emissions estimated from data published elsewhere[21,22] (–17 $MtCO_2\ d^{-1}$), which results primarily from the higher energy use in winter than summer in the Northern Hemisphere. The range in estimate reflects the range of parameter values (Table 2) based on the spread in underlying data (Fig. 2).

Global emissions from surface transport fell by –36% or –7.5 (–5.9 to –9.6) $MtCO_2\ d^{-1}$ by 7 April 2020 and made the largest contribution to the total emissions change (–43%; Fig. 4; Table 2). Emissions fell by –7.4% or –3.3 (–1.0 to –6.8) $MtCO_2\ d^{-1}$ in the power sector, and by –19% or –4.3 (–2.3 to –6.5) in the industry sector. Emissions from surface transport, power and industry were the most affected sectors in absolute values, accounting for 86% of the total reduction in global emissions. CO_2 emissions declined by –60% or –1.7 (–1.3 to –2.2) $MtCO_2\ d^{-1}$ in the aviation sector, yielding the largest relative anomaly of any sector, and by –21% or –0.9 (–0.3 to –1.4) $MtCO_2\ d^{-1}$ in the public sector. The large relative anomalies in the aviation sector correspond with the disproportionate effect of confinement on air travel (Table 2). A small growth in global emissions occurred in the residential sector, with +2.8% or +0.2 (–0.1 to +0.4) $MtCO_2\ d^{-1}$ and only marginally offsets the decrease in emissions in other sectors.

The total change in emissions until the end of April is estimated to amount to –1048 (–543 to –1638) $MtCO_2$ (Table S13). Of this, the changes are largest in China where the confinement started, with a decrease of –242 (–108 to –394) $MtCO_2$, then in the US, with –207 (–112 to –314) $MtCO_2$, then Europe, with –123 (–78 to –177) $MtCO_2$, and India, with –98 (–47 to –154) $MtCO_2$. These changes reflect both the fact that these are regions that emit high levels of CO_2 on average, and their severe confinement in the period through end of April. The integrated changes in emissions over China $MtCO_2$ are comparable in magnitude with the estimate –250 $MtCO_2$ of Myllyvirta (2020)[23] up to the end of March. The global changes in emissions is also consistent with global changes in NO_2 inventory from satellite data, although the concentration data is complex to interpret (see Supplementary Figures S1-S2).

Implications for global fossil CO_2 emissions in 2020

The change for the rest of the year will depend on the duration and extent of the confinement, the time it will take to resume normal activities, and the degree to which life will resume its pre-confinement course. At the time of press, most countries that were under confinement level 3 had announced dates when they anticipated some confinement would be lifted. Dates ranged between mid-April and mid-May. We use those dates where available, and for other countries we assume end of confinement corresponding to neighbouring regions or States (see Supplementary Tables S15-S16). It is possible that end of confinement is delayed in some countries and therefore these dates are likely the earliest possible dates. Nevertheless, the mounting social[24,25] and economic pressure[26], along with improving management of healthcare means systematic postponement is unlikely.

We assessed the effect of the recovery time by conducting three sensitivity tests. Our sensitivity tests are not intended to provide a full range of possibilities, but rather to indicate the approximate effect of the extent of the confinement on CO_2 emissions. Before COVID-19 we expected global emissions to be similar to those in 2019[2], so the effect of confinement on CO_2 emissions provided above might be approximately equivalent to the actual change from 2019 emissions. Our sensitivity tests do not attempt to quantify the effects of multiple confinement waves, or of deeper and sustained changes in the economy that could result from either the collapse of tens of thousands of small and medium businesses or government economic stimulus packages.

In the first sensitivity test, we assume that after the announced dates for initial deconfinement, activities will return to pre-crisis level within 6 weeks (around mid-June), as observed for coal use in industry in China[23]. In this case, the decrease in emissions from the COVID-19 crisis would be –1524 (–795 to –2403) $MtCO_2$, or –4.4% (–2.3% to –7.0%). In the second sensitivity test, we assume it takes 12 weeks to reach pre-confinement levels (around the second half of July), because of low productivity resulting from social trauma, and low confidence. This longer period is more aligned with announcements of gradual deconfinements, for example in France, UK and Norway, where a gradual deconfinement is planned over the coming months, and with time-scales for expected progression of the illness[27]. In this case, the decrease in emissions from the COVID-19 crisis would be –1923 (–965 to –3083) $MtCO_2$, or –5.6% (–2.8% to –9.0%).

In the third sensitivity test, we make the same assumption as the second test, but further assume that confinement level 1 remains in place in all countries examined until the end of the year. This is consistent with the situation in China in general, where although measures were lifted at the end of February in most provinces, there are still some restrictions on specific activities such as restricted international travel. It is also more aligned with latest understanding of the dynamics of transmission of the disease, suggesting prolonged or intermittend social distancing may be necessary into 2022[28]. In this case, the decrease in emissions from the COVID-19 crisis would be –2729 (–986 to –4717) $MtCO_2$, or –8.0% (–2.9% to –14%).

At the regional levels, the low sensitivity test led to mid-point decreases in emissions for year 2020 of –2.3%, –6.7%, –5.6% and –5.3% respectively for China, the US, Europe (EU27+UK) and India, while the high sensitivity test led to mid-point decreases of –5.1%, –11.3%, –9.3%, and –8.8% for those same countries (Table S14). For comparison for the US alone, the EIA (2020) provides a forecast of a decrease in emissions of –7.5% in 2020 [29], taking into account all projected economic factors, which is between our scenario tests 1 & 2.

In spite of the broader effects on the economy that are not included in our analysis, our 2020 estimates are similar to what can be inferred based on the projections of the International Monetary Fund (IMF) for 2020 of –3% reduction in global Gross Domestic Product[30] combined with an average CO_2/GDP improvement of –2.7% over the past decade[31], which gives a –5.7% reduction in CO_2 emissions in 2020. These independent global and US projections are similar to the middle sensitivity test 2 of confinement that we present in this publication (see Table S14), while the projection of the International Energy Agency of –8% decrease in CO_2 emissions in 2020 aligns with our high-end test 3[32]. The IMF and EIA further forecast that emissions will rebound +5.8% and +3.5% in 2021, respectively for the world and US economies.

Discussion

The estimated decrease in daily CO_2 emissions from the severe and forced confinement of world populations of –17% (–11% to –25%) at its peak are extreme and probably unseen before. Still, these correspond to the level of emissions in 2006 only. The associated annual decrease will be much lower (–4.4% to –8.0% according to our sensitivity tests), which is comparable to the rates of decrease needed year-on-year over the next decades to limit climate change to 1.5°C warming[33,34]. These numbers put in perspective both the large growth in global emissions observed over the past 14 years, and the size of the challenge we have to limit climate change in line with the Paris climate Agreement.

Furthermore, most changes observed in 2020 are likely to be temporary as they do not reflect structural changes in the economic, transport, or energy systems. The social trauma of confinement and associated changes could alter the future trajectory in unpredictable ways[35], but social responses alone, as shown here, would not drive the deep and sustained reductions needed to reach net zero emissions. Scenarios of low-energy/material demand explored for climate stabilisation explicitly aim to match reduced demand with higher wellbeing[35,36], an objective that is not met by mandatory confinements. Still opportunities exist to set structural changes in motion by implementing economic stimuli aligned with low carbon pathways.

Our study reveals how responsive the surface transportation sector's emissions can be to policy changes and economic shifts. Surface transport accounts for nearly half the decrease in emissions during confinement, while active travel (walking and cycling, including ebikes) has attributes of social distancing that are likely to be desirable for some time[28] and could help to cut back CO_2 emissions and air pollution as confinement is eased. For example, cities like Bogota, New York, and Berlin are rededicating street space for pedestrians and cyclists to enable safe individual mobility, with some changes likely to become permanent. Follow-up research could explore further the potential of near-term emissions reductions in the transport sector without impacting societal well-being.

Several drivers push towards a rebound with an even higher emission trajectory compared to policy-induced trajectories before the COVID-19 pandemic, including calls by some governments[37] and industry to delay Green New Deal programs and to weaken vehicle emission standards[38], and the disruption to clean energy deployment and research from supply issues. The extent to which world leaders consider the net zero emissions targets and the imperatives of climate change when planning their economic responses to COVID-19 is likely to influence the pathway of CO_2 emissions for decades to come.

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Methods.

Changes in emissions

Changes in emissions $\Delta CO_2^{c,s,d}$ in $MtCO_2$ d^{-1} for each country/state/province (*c*), sector (*s*), and day (*d*) are estimated using the following Equation:

$$\Delta CO_2^{c,s,d} = CO_2^c \times \delta S^c \times \Delta A^{s,d(CI,c)} \qquad (1)$$

Where CO_2^c in $MtCO_2$ d^{-1} is the mean daily emissions for the latest available year (2017 to 2019) updated from the Global Carbon Project for world countries (GCP; 2019)[1] (see Extended Methods in the Supplementary Information), EIA[39] for the US, and national statistics[40] for Chinese provinces. δS^c is the fraction of emissions in each sector using data from the IEA[41] for world countries, EIA[39] for the US, and national statistics[40] for Chinese provinces. $\Delta A^{s,d(CI)}$ is the fractional change in activity level for each sector compared with pre-COVID levels (Table 2), as a function of the confinement index *CI* for each day of the year and each country (see Supplementary Tables S15-S16). The combination of CO_2 emissions data from GCP and sector distribution from IEA enabled the use of country's own reported emissions to the UNFCCC, building on our previous work[42], and means more recent emissions could be used. Our analysis is done for 69 countries accounting for 97% of global emissions. We do not estimate changes in other countries.

Parameter choices

The choices of parameters by sector is based on data that represent changes in activity rather than directly changes in CO_2 emissions, and assumptions about the nature of the confinement. Most data are available daily up to 15 April 2020. All data (Fig. 2) are representative of changes compared to a typical day prior to confinement, taking into account seasonality and day of the week. The changes were calculated differently depending on the data availability and the causes of the seasonality and weekly variability. Sectors and parameter choices are described in detail in the Extended Methods section of the Supplementary Information with the key elements summarised here.

The power sector (44.3% of global CO_2 emissions) includes energy conversion for electricity and heat generation. The change in electricity and heat assumes this sector follows the change observed in electricity demand data for the US[43], selected European countries[10], and India[44].

The industry sector (22.4%) includes production of materials (e.g. steel), manufacturing, and cement. The change in industry is based on China coal consumption for six coal producers[23] and on steel production in the US[45].

The surface transport sector (20.6%) includes cars, light vehicles, buses and trucks, as well as national and international shipping. The change in transport is based on the Apple mobility data[46] for world countries, US [47] and UK [48] traffic data and urban congestion data from TOMTOM [49]. The changes in shipping are based on forecast by the World Trade Organization.

The public sector (4.2%) includes public buildings and commerce. The change in the public sector is based on surface transport for the upper limit, assuming it is proportional to the change in the workforce. It is based on electricity changes for the lower limit, with the central value interpolated between the two.

The residential sector (5.6%) represents mostly residential buildings. The changes in residential sector is based on reports of residential use monitored with UK smart meters[50].

The aviation sector (2.8%) includes both domestic and international aviation. It is based on the total number of departing flights by Aircrafts on Ground (OAG [51]).

Data availability

Global Carbon Project CO_2 emissions data are available at: https://www.icos-cp.eu/global-carbon-budget-2019
International Energy Agency IEA World Energy Balances 2019 @IEA are available at www.iea.org/statistics/
European Network of Transmission System Operators Electricity Transparency Platform (ENTSOE) are available at https://transparency.entsoe.eu/
Power System Operation Corporation Limited (POSOCO) data are available at https://posoco.in/reports/daily-reports/
Energy Information Administration (IEA) data are available at https://www.eia.gov/realtime_grid/
CO_2 emissions data for China are available at http://dx.doi.org/10.1038/s41597-020-0393-y/
Coal changes from China industry are available at https://www.carbonbrief.org/analysis-coronavirus-has-temporarily-reduced-chinas-co2-emissions-by-a-quarter/
American Iron and Steel Institute data are available at https://www.steel.org/industry-data/
TOMTOM Traffic Index are available at https://www.tomtom.com/en_gb/traffic-index/
MS2 Corporation traffic data are available at https://www.ms2soft.com/traffic-dashboard/
Apple Mobility Trends data are available at https://www.apple.com/covid19/mobility/,
UK traffic data from the Cabinet Office Briefing are available at https://www.gov.uk/government/collections/slides-and-datasets-to-accompany-coronavirus-press-conferences
Octopus Energy Tech smartmeter data are available at https://tech.octopus.energy/data-discourse/2020-social-distancing/index.html

Aircraft on Ground OAG data are available at https://www.oag.com/coronavirus-airline-schedules-data/

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Author contributions

C.L.Q., R.B.J., J.G.C., P.F., and G.P.P. conceived and designed the project. C.L.Q. and A.J.P.S. conceived the Confinement index and together with Y.S. they produced it. C.L.Q., R.B.J., M.W.J., S.A., R.M.A., A.J.D.-G., D.R.W., F.C. provided and analysed data. C.L.Q. produced the analysis. All authors contributed to the interpretation of the results and wrote the paper.

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Figure 1. Fraction of global CO_2 emissions produced in areas which are subject to confinement (percent). CO_2 emissions from nations and states in each confinement level (see Table 1) are aggregated as a fraction of global CO_2 emissions. CO_2 emissions are from the Global Carbon Project[1] (see Methods).

Figure 2. Change in activity by sector during Confinement level 3 (percent). The data includes: for the power sector, temperature-adjusted electricity trends in Europe[10], India[44], and the US[43]; for the industry sector, coal use in industry in China[23] and US steel production[45]; for the surface transport sector, cities congestion[49], country mobility[46], UK[48] and US state[47] traffic data; for the residential sector, UK smart meter data[50]; and for aviation, aircraft departures[51]. Each data point (filled circles) represents the analysis of a full time series, and shows the changes in activity compared to typical activity levels prior to COVID-19, correcting for seasonal and weekly biases. These changes along with the nature of the confinement are used to set the parameters in Eq. 1. (See Methods). The data is randomly spaced to highlight the volume of some data streams. Empty points represent mean value amongst the sample of data points, while the whiskers mark the standard deviation from the mean. The plotted violins represent the kernel density estimate of the probability density function for each sample of data points.

Figure 3. Global daily CO_2 emissions ($MtCO_2\ d^{-1}$). **(Left panel)** Annual mean daily emissions in the period 2000-2019 (black line), updated from the Global Carbon Project[1,3] (See Methods), with uncertainty of ±5% (±1σ; grey shading). Also on this panel are the daily emissions in 2020 estimated here (red line). **(Right panel)** Daily CO_2 emissions in 2020 (red line, same as left panel) based on the confinement index (CI) and corresponding change in activity for each CI level (Figure 2), and its uncertainty (red shading; Table 2). Daily emissions in 2020 are smoothed with a 7-day box filter to account for the transition between confinement levels.

Figure 4. Change in global daily fossil CO_2 emissions by sector ($MtCO_2\ d^{-1}$). The uncertainty ranges represent the full range of our estimates. Changes are relative to annual mean daily emissions from those sectors in 2019 (see Methods). Daily emissions are smoothed with a 7-day box filter to account for the transition between confinement levels. Note that the y-axes range differs for the upper and lower panels.

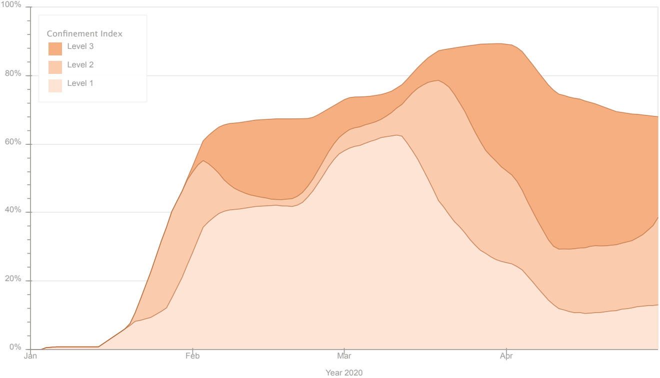
Table 1. Definition of the Confinement Index (CI). The Confinement Index categorises the level of restrictions to normal activities that have the potential to influence CO_2 emissions. It is based on the policies adopted by national and sub-national governments.

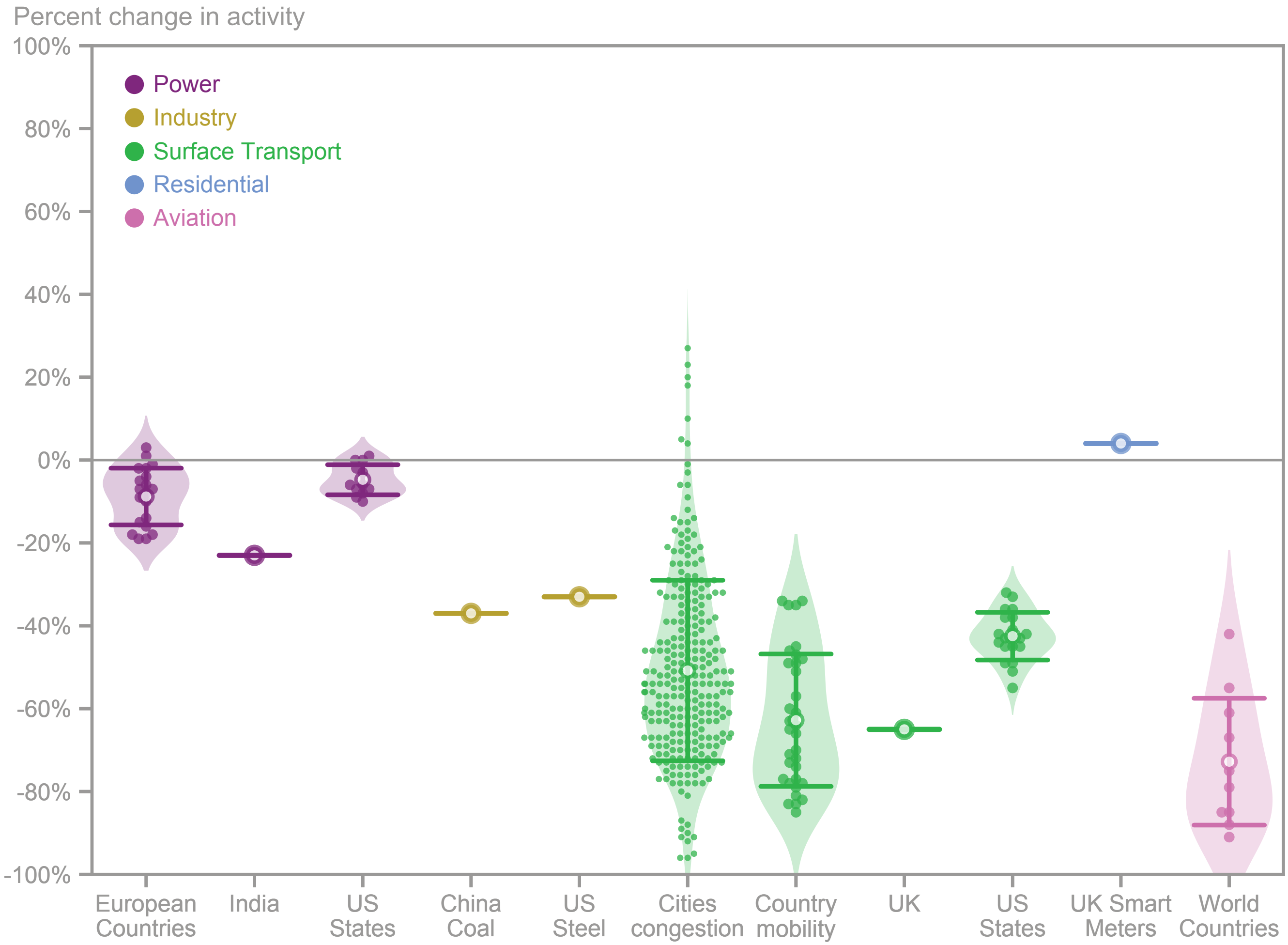
Level	**Description**	**Policy examples**
0	No restrictions	
1	Policies targeted at long distance travel or groups of individuals where outbreak first nucleates	- Isolation of sick or symptomatic individuals - Self-quarantine of travellers arriving from affected countries - Screening passengers at transport hubs - Ban of mass gatherings >5000 - Closure of selected national borders & restricted international travel - Citizen repatriation
2	Regional policies that restrict entire city/region or ~50% of society from normal daily routines	- Closure of all national borders - Mandatory closure of schools, universities, public buildings, religious/cultural buildings, restaurants, bars, and other non-essential businesses, within a city or region - Ban public gathering >100 and social distancing >2m - Perhaps also accompanied by recommended closures at a broader or national level - Mandatory night curfew
3	National policies that significantly restrict the daily routine of all but key workers, ~80% of workforce.	- Mandatory national 'lockdown' requiring household confinement of all but key-workers - Ban public gathering >2 and social distancing >2m

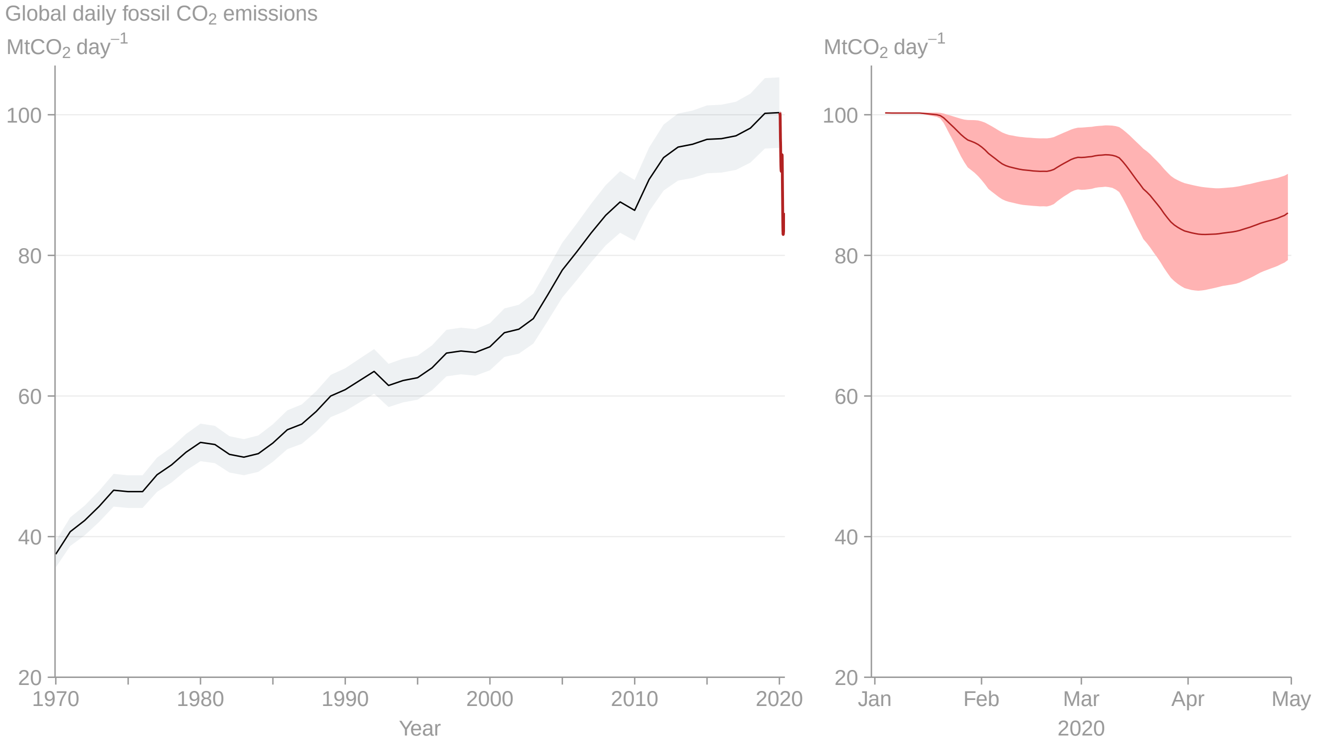
Table 2. Change in activity as a function of the confinement level (percent). (Left) Parameters used in Eq. 1 for each sector (ΔA^s). (Right) Results for the globe, on the day with the maximum change (4th April 2020). The change is estimated relative to the mean level of emissions in 2019 (see Methods).

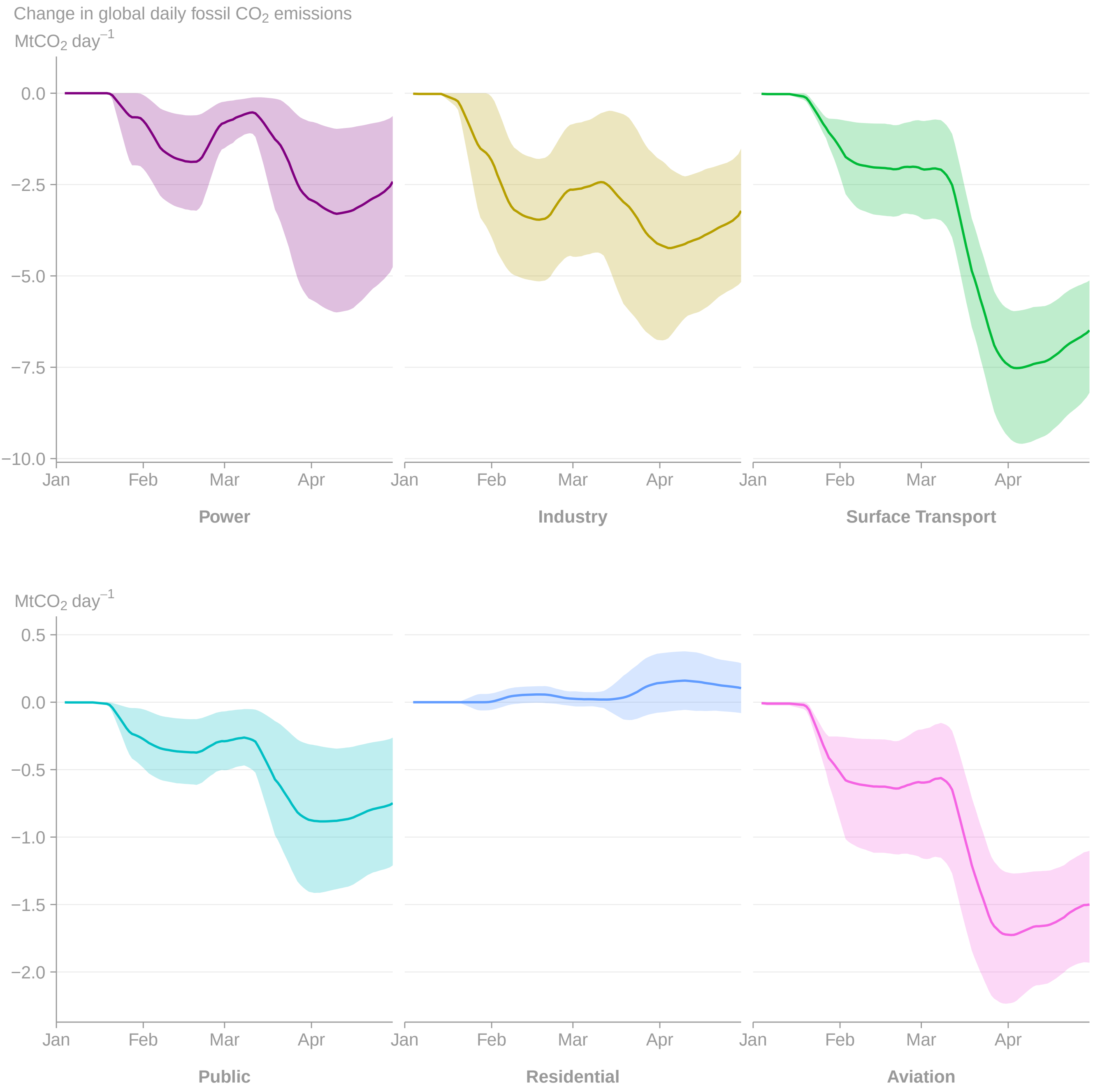
	Change in activity as a function of confinement level (Eq. 1)			Results
	Level 1	**Level 2**	**Level 3**	**daily change 7 April 2020**
Power	0% (0% to 0%)	–5% (0% to –15%)	–15% (–5% to –25%)	−7.4% (−2.2% to −14%)
Industry	–10% (0% to –20%)	–15% (0% to –35%)	–35% (–25% to –45%)	−19% (−10% to −29%)
Surface Transport	–10% (0% to –20%)	–40% (–35% to –45%)	–50% (–40% to –65%)	−36% (−28% to −46%)
Public	–5% (0% to –10%)	–22.5% (–5% to –40%)	–32.5% (–15% to –50%)	−21% (−8.1% to −33%)
Residential	0% (0% to 0%)	0% (–5% to +5%)	+5% (0% to +10%)	+2.8% (−1.0% to +6.7%)
Aviation	–20% (0% to –50%)	–75% (–55% to –95%)	–75% (–60% to –90%)	−60% (−44% to −76%)
Total				−17% (−11% to −25%)

Fraction of global CO_2 emissions produced in area which are subject to confinement




Percent change in activity
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
● Power
● Industry
● Surface Transport
● Residential
● Aviation
European Countries
India
US States
China Coal
US Steel
Cities congestion
Country mobility
UK
US States
UK Smart Meters
World Countries


Global daily fossil CO_2 emissions
$MtCO_2$ day^{-1}
100
80
60
40
20
1970
1980
1990
2000
2010
2020
Year
$MtCO_2$ day^{-1}
100
80
60
40
20
Jan
Feb
Mar
Apr
May
2020


Change in global daily fossil CO$_2$ emissions
MtCO$_2$ day^{-1}
0.0
−2.5
−5.0
−7.5
−10.0
Jan
Feb
Mar
Apr
Power
Industry
Surface Transport
MtCO$_2$ day^{-1}
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Public
Residential
Aviation