Fossil CO_2 emissions in the post-COVID era

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Five years after the adoption of the Paris climate Agreement, growth in global CO_2 emissions has begun to falter. The pervasive disruptions from the COVID-19 pandemic has radically altered the trajectory of global CO_2 emissions. Contradictory effects of the post-COVID investments in fossil fuel-based infrastructure and the recent strengthening of climate targets must be addressed with new policy choices, to sustain a decline in global emissions in the post-COVID era.

Global fossil CO_2 emissions are set to decrease by around 2.6 billion tonnes of CO_2 ($GtCO_2$) in 2020, to 34 $GtCO_2$ (Fig. 1). This projected decrease, caused largely by the measures implemented to slow the spread of the COVID-19 pandemic, is about 7% below 2019 levels, according to the analysis of the Global Carbon Project[1] based on multiple studies[2-4] and recent monthly energy data. A 2.6 $GtCO_2$ decrease in global annual emissions has never been observed before. Yet cuts of 1-2 $GtCO_2$ per year are needed throughout the 2020s and beyond to avoid exceeding warming levels in the range 1.5°C to well below 2°C, the ambition of the Paris Agreement[5]. The drop in CO_2 emissions from responses to COVID-19 highlights the scale of actions and international adherence needed to tackle climate change.

The 2020 decrease in emissions masks complex dynamics and differences in countries' responses to the COVID-19 pandemic over time. In most countries, emissions decreased at the peak of the country's confinement, by on average 27% based on an updated analysis of indirect data[3] (see Methods). Widespread disruptions in the transport sector had the largest impact on emissions. By end of 2020, COVID-related confinement measures were still acting to decrease daily emissions by around 7% below 2019 levels (Fig. 1b), with the largest share of the decrease also due to transport emissions (Extended data Fig. 1). Here, we put the change in 2020 emissions in the context of the recent changes in fossil CO_2 emissions in the five years since the Paris climate Agreement was adopted in 2015, and discuss the implications of COVID-19 for the evolution of global CO_2 emissions. We focus on fossil CO_2 emissions which is the largest contributor to the rise in anthropogenic greenhouse gases.

The Paris Agreement builds on the Kyoto Protocol which was adopted in 1997, with commitments for emissions reductions for 37 mostly high-income economies (see Methods). This so-called “Annex B” country group accounted for 35% of global emissions in 2019 (12.5 $GtCO_2$ yr^{-1}). During the five years since the Paris Agreement was adopted, emissions in the Annex B country group decreased by 0.10 $GtCO_2$ yr^{-1} (–0.8%) on average each year (mean of 2016-2019 compared to 2011-2015), with a further decrease of about 1.2 $GtCO_2$ (–9%) in 2020 alone due to the COVID-19 restrictions (Fig. 1, Fig. 2, Extended data Fig. 2).

Decreases in emissions were firmly set in motion by around 2005 among most Annex B countries, whether accounting for emissions that occurred in a given country (territorial emissions) or based on all goods and services consumed in a given country even when produced elsewhere[6] (consumption emissions; Fig. S1). In the countries where emissions significantly decreased over more than a decade, previous analysis[7] highlighted that the displacement of fossil energy by renewable energy and a decreasing use of energy were the common contributing factors, accounting for 47% and 36% of the decrease in emissions (median across countries), respectively. The size of the decrease in emissions across countries was correlated to the number of climate and energy policies in place[7], with a separate study corroborating that indeed the policies drove the decrease in emissions[8]. The decreasing use of energy was also partly explained by low growth in GDP following the 2008-2009 global financial crisis.

As a group, the 99 upper-middle income economies accounted for 51% of global emissions in 2019 (17.8 $GtCO_2$ yr^{-1}; see Methods). 28% of the global total was from China alone. This is also the group where emissions have risen the most, with a median growth among countries of 30% between 2005 and 2019. However, the growth in emissions in this country group has slowed considerably in the past five years, with mean annual growth of 0.14 $GtCO_2$ yr^{-1} (+0.8%) on average each year (mean of 2016-2019 compared to 2011-2015), around five times less (half when excluding China) than the growth during the previous two 5-year periods (in absolute value; Extended data Fig. 2). Thirty of the 99 countries in the group have shown decreases in emissions during 2016-2019 compared to 2011-2015 (Fig. 2), suggesting that action to reduce emissions is now in motion in a large number of countries. The growing number of climate change laws and policies in place (over 2,000 worldwide[9]) appears to have played a key role in curbing the growth in emissions in the past five years pre-COVID-19[8]. Emissions decreased by about 0.8 $GtCO_2$ (–5%) in 2020 alone due to the COVID-19 restrictions (Fig. 1).

As a group, emissions originating from the 79 lower-middle income and low-income economies are much lower than in the other two groups, accounting for 14% of global emissions in 2019 (4.9 $GtCO_2$ yr^{-1}; see Methods). Emissions in this lower-income group have grown by 0.18 $GtCO_2$ yr^{-1} (+4.5%) on average each year (mean of 2016-2019 compared to 2011-2015) with no notable slowdown at the group level (Extended data Fig. 2). Emissions decreased in nine countries during that same time interval (Fig. 2). Emissions decreased by about 0.4 $GtCO_2$ (–9%) in 2020 alone due to the COVID-19 restrictions (Fig. 1).

Although the measures to tackle the COVID-19 pandemic will reduce emissions by about 7% in 2020, they will not, on their own, cause lasting decreases in emissions because these temporary measures have little impact on the fossil fuel-based infrastructure that sustains the world economy[2]. However, economic stimuli on national levels could soon change the course of global emissions if investments towards green infrastructure are enhanced while investments encouraging the use of fossil energy are reduced[2,10]. Announcements as of December 2020[11] suggest significant green stimulus packages with limited investments in fossil-based activities by the European Union, France, the UK, Spain, Germany, and Switzerland, but investments continue to be overwhelmingly dominated by fossil fuels in most countries, including in the United States and China. Investments in response to the global financial crisis of 2008-2009 led to an immediate rebound of emissions to their pre-crisis trajectory by 2010[12] (Fig. 1). Although a full rebound appears unlikely in 2021[13-15] given the persistence of the pandemic and the effects of pre-COVID climate policy[7,9], it hinges to a large extent on the alignment of economic stimulus packages and other incentives with climate objectives[2,16]. Early data suggest economic drivers and other factors were driving global emissions up in December 2020, potentially offsetting the decreased caused by confinement measures[4,17].

The disruption of emissions trajectories due to the COVID-19 pandemic means strategic actions now could minimise the rebound and reinforce cuts in global emissions in the long term. The nature of the disruptions in 2020[18], particularly affecting transportation, suggest that incentives to expedite the large-scale deployment of electric vehicles, and to encourage and make space for active transport (safe walking and cycling) in cities are timely. Support to improve and promote remote communications for businesses and organisations, home working, and regional tourism, in addition to encouraging a return to public transportation as soon as it is safe to do so, could reduce total transportation needs. The resilience of renewable energy production throughout the crisis[13], falling costs, and air quality benefits, are additional incentives to support large-scale deployment of renewable energy as a post-crisis measure, which is needed to provide low-carbon electricity. These measures could curb emissions immediately, minimising the rebound, and build momentum for a change in emissions trajectory in the long-term.

Experience from several previous crises show that the underlying drivers of emissions reappear if not immediately, then within a few years (Fig. 1). Therefore to change the trajectory in global CO_2 emissions in the long-term, the underlying drivers also need to change. The growing commitments by countries to reduce their emissions to net zero within decades provides a substantial strengthening of climate ambition. This is now backed by China (by 2060 but with no details on scope), the USA (by 2050 as detailed in President Joe Biden's electoral climate plan)[19], and by the European Commission (by 2050 with strengthened ambition of at least 55% reduction by 2030), the three biggest emitters. The effective implementation of these ambitions, both within and beyond COVID-19 recovery plans, will be essential to change global emissions trajectory. Most current COVID-19 recovery plans are in direct contradiction with countries' climate commitments [11].

Year 2021 could mark the beginning of a new phase in tackling climate change. The science is established and international agreements are in place, with some evidence that growth in global CO_2 emissions is already faltering. The task of sustaining decreases in global emissions of the order of billion tonnes of CO_2 per year [20] while supporting economic recovery, human development, and improved health, equity, and well-being, lies in current and future actions. The pressing timeline is constantly underscored by the rapid unfolding of extreme climate impacts[21].

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Methods

Emissions for 1990-2019. This analysis is based solely on fossil CO_2 emissions, which includes the combustion of fossil fuels, the production of cement and other process emissions, as fully described elsewhere[1]. For territorial emissions of the 41 countries that report their emissions to the UNFCCC for 1990-2018, these reports are used directly. For territorial emissions of other countries, emissions estimates are from CDIAC for the period 1990-2018 derived primarily from energy statistics published by the United Nations[22]. Territorial emissions are extended to 2019 using the growth rate in energy published by BP and converted to emissions using fuel-specific conversions[1]. The uncertainty is set to ±5% and represents ±1 σ. Consumption emissions for 1990-2018 are estimated based on trade data using established methods, and are taken here directly from the Global Carbon Budget 2020 update [1].

Emissions for 2020. The national changes in fossil CO_2 emissions during 2020 is an update from a previous study published in May 2020[3]. Country emissions exclude international transport (aviation and shipping) as in UNFCCC guidelines, contrary to the original study[3] which allocated international to the country where they occur. International transport here is accounted in the global emissions only. Changes in emissions are based on changes in activity for six sectors of the economy as a function of the level of confinement, and uses prior emissions of CO_2 in each sector for 71 countries representing 97% of the emissions, and the degree of confinement for each country and each day of 2020. Compared to the original published study[3] and the interim update[1], the parameters for activity change were updated to incorporate new information that became available at the end of 2020, and further adjusted to fit available monthly data in the US and India (see Supplementary Information). These updates in parameters did not alter the results significantly. The full range of uncertainty is for a decrease in 2020 emissions in the range 3% to 12%, from uncertainty in the activity parameters[3].

Comparison of the 2020 decrease in emissions with other estimates. Compared to the published estimate, the changes in emissions from the COVID-19 confinement measures during January-April 2020 is almost unchanged, with a minor update from 1.05 to 1.08 $GtCO_2$ for the world, and with also minor changes for individual countries other than the scope excluding international transport (see above). The global change in fossil CO_2 emissions in other estimates as updated in the Global Carbon Budget is for a 2020 decrease of 6% based on monthly energy data available for the USA, EU27, and India and GDP for the rest of the world, 7% based on the Carbon Monitor [4], and 13% based on Google mobility data [2], for a median value of 7% based on expert judgement [1], also consistent with the assessment form the International Energy Agency of 8% [13].

Country groups follow the Annex B of the United Framework Convention on Climate Change (UNFCCC), and the World Bank classification for lending groups in 2021 [23]. A full list is provided in the Supplementary Information.

Data availability

The Global Carbon Project CO_2 emissions data are available upon publication at https://www.icos-cp.eu/science-and-impact/global-carbon-budget/2020 with the daily emissions for year 2020 at https://www.icos-cp.eu/gcp-covid19. Territorial emissions to 2019 can also be accessed from the web site globalcarbonatlas.org

Code availability

A template for estimating changes in national emissions based on the confinement index during the COVID-19 pandemic will be made available here: https://www.icos-cp.eu/gcp-covid19.

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Author contributions

C.L.Q., G.P.P., P.F., J.G.C., and R.B.J. conceived and designed the project. R.M.A. provided emissions data. C.L.Q. and M.W.J. produced the analysis. All the authors contributed to the interpretation of the results and wrote the paper.

Competing interests

The authors declare no competing interests.

Additional information

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Figure Captions

Figure1. Global fossil CO_2 emissions. **a.** Annual emissions for 1970-2019 in $GtCO_2\ yr^{-1}$, including a projection for 2020 (in red) based on the analysis of the Global Carbon Project [1], and their uncertainties (shading; see Methods). **b.** Daily change in emissions in 2020 compared to a mean day in 2019, for the globe in percent, updated from initial publication in May 2020 [3]. **c.** as in b. but for three economic income groups: The Annex B country group of

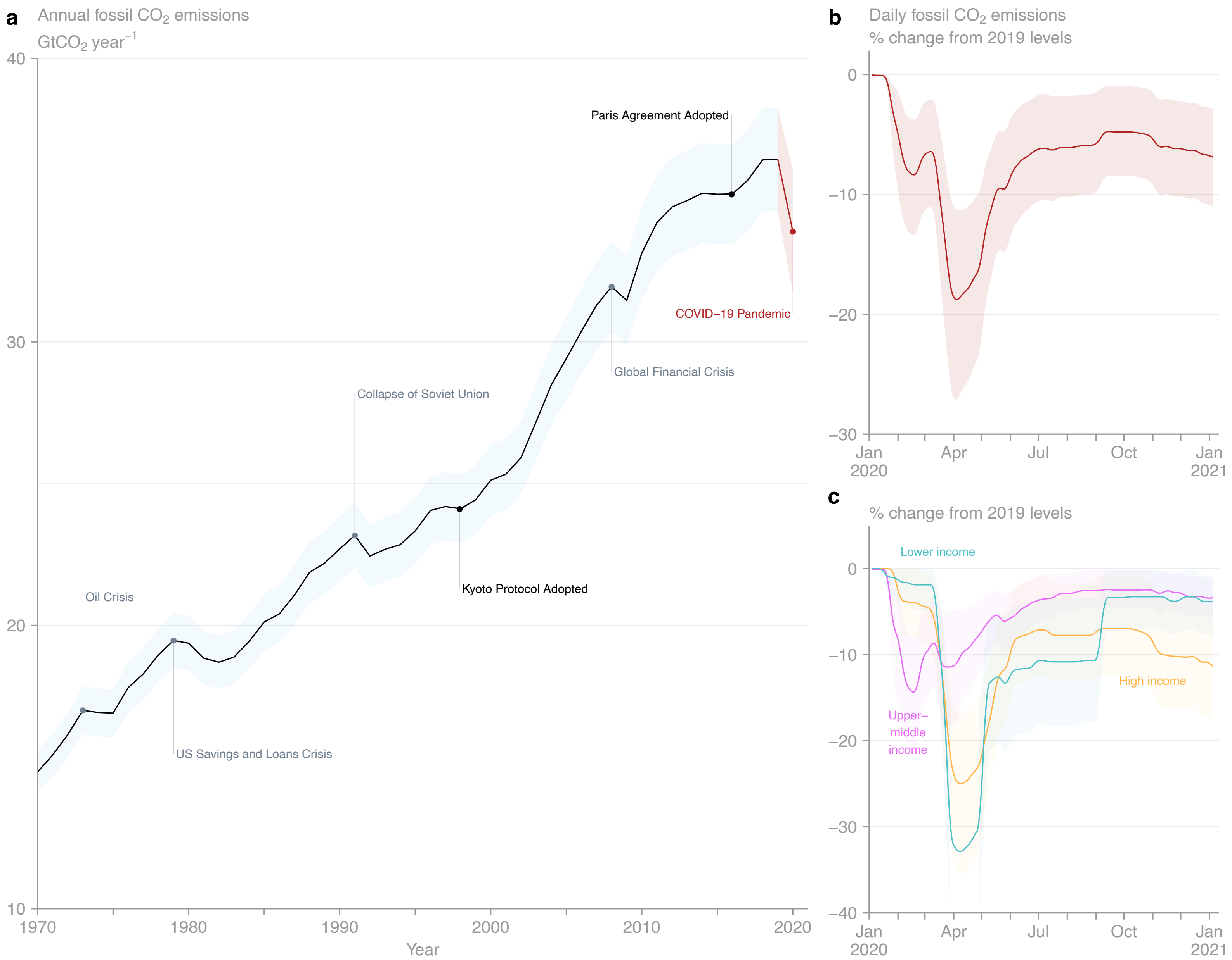
mostly high-income economies with emissions targets under the Kyoto protocol, upper middle-income economies (including China) as defined by the World Bank, and lower middle-income and low-income economies (including India) as a single group. Global economic and energy crises are highlighted in panel **a**, along with key international policy dates.

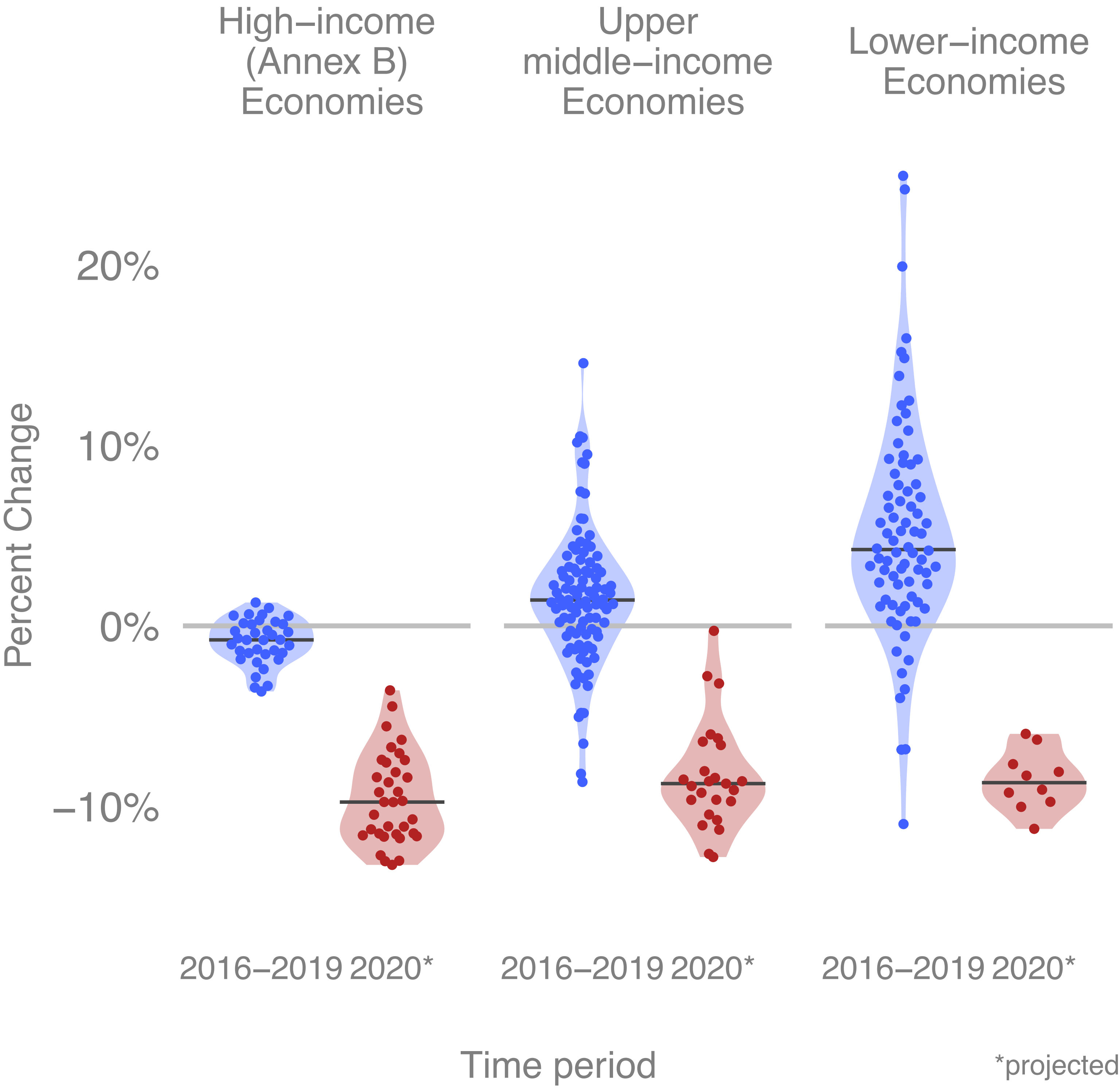
Figure 2. Change in fossil CO_2 emissions (percent per year) in the five years since the adoption of the Paris climate Agreement. Changes are shown for individual countries (dots) separated in three economic groups as in Fig. 1. Changes are annual mean during 2016-2019 (blue) compared to the period 2011-2015, with year 2020 (red) shown separately for fewer countries. The median of the country values is shown for each country group, with the plotted violins showing the distribution of the data using a kernel density estimation. The estimated decrease in 2020 emissions is updated from a previous study and includes the effect of the COVID-19 confinement measures alone [3].

Extended data Figure Captions

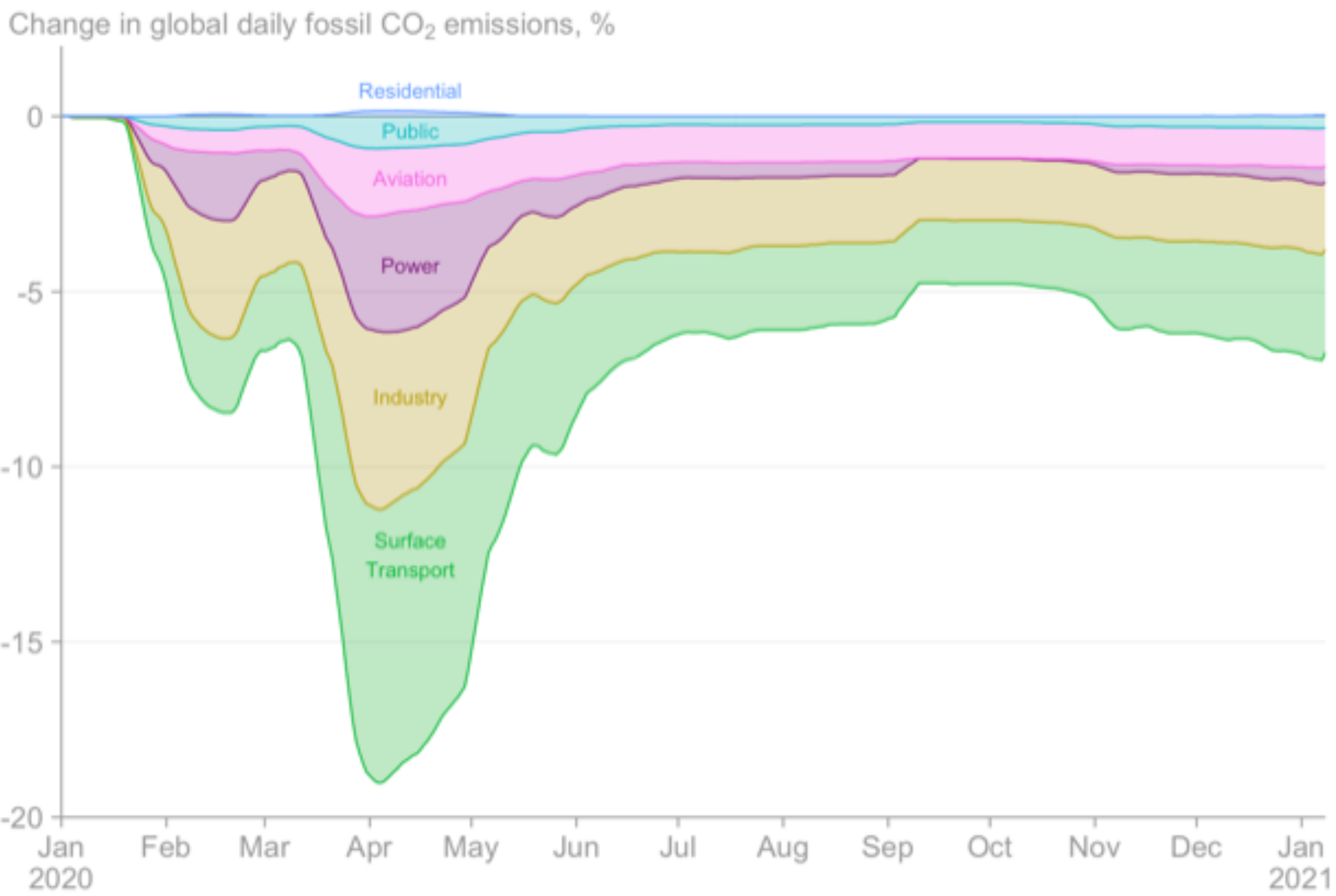
Extended data Figure 1. Sectoral contribution to the daily global change in emissions in 2020 caused by the confinement measures in place to slow the spread of the COVID-19 pandemic (percent). This is an update of a previous estimate[3] (see Supplementary Information for information on the update, and the original reference for a discussion of uncertainties).

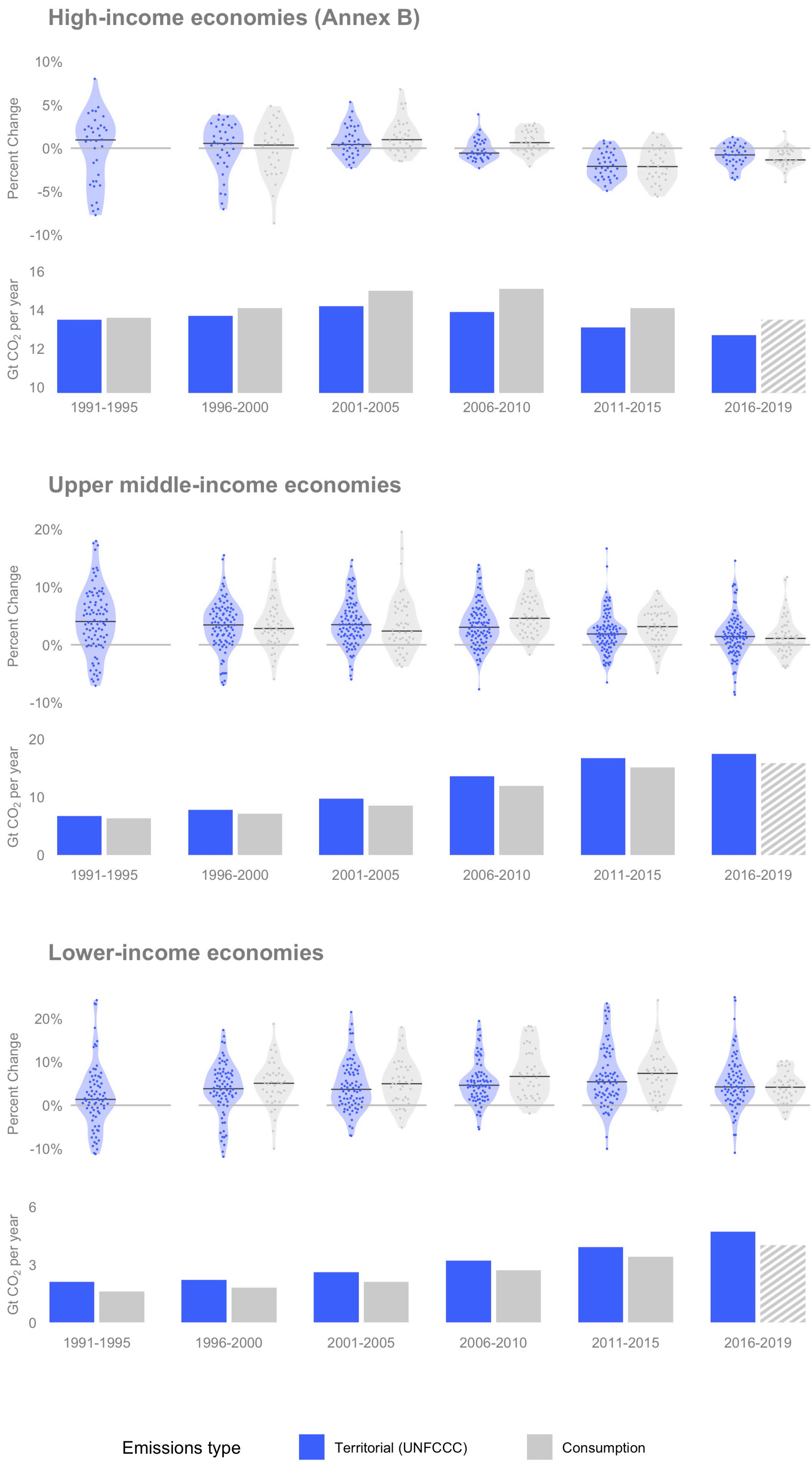
Extended data Figure 2. Evolution of fossil CO_2 emissions in 5-year periods since 1991 (as in Figure 2). Mean annual changes are shown for individual countries (dots, in percent) separated in three economic groups as in Fig. 2, with the median for each country group and the distribution of the data shown using a kernel density estimation. The mean emissions for each group and each period are shown at the bottom, based on territorial emissions following UNFCCC accounting, and based on consumption emissions (note variable y-axis; $GtCO_2\ yr^{-1}$).


a
Annual fossil CO_2 emissions
$GtCO_2$ $year^{-1}$
40
30
20
10
1970
1980
1990
2000
2010
2020
Year
Paris Agreement Adopted
COVID−19 Pandemic
Global Financial Crisis
Collapse of Soviet Union
Kyoto Protocol Adopted
Oil Crisis
US Savings and Loans Crisis
b
Daily fossil CO_2 emissions
% change from 2019 levels
0
−10
−20
−30
Jan 2020
Apr
Jul
Oct
Jan 2021
c
% change from 2019 levels
Lower income
High income
Upper−middle income
0
−10
−20
−30
−40
Jan 2020
Apr
Jul
Oct
Jan 2021



High−income (Annex B) Economies
Upper middle−income Economies
Lower−income Economies
20%
10%
0%
−10%
Percent Change
2016−2019
2020*
2016−2019
2020*
2016−2019
2020*
Time period
*projected


Change in global daily fossil CO_2 emissions, %
Residential
Public
Aviation
Power
Industry
Surface Transport
0
-5
-10
-15
-20
Jan 2020
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan 2021



High-income economies (Annex B)
Percent Change
10%
5%
0%
-5%
-10%
Gt CO_2 per year
16
14
12
10
1991-1995
1996-2000
2001-2005
2006-2010
2011-2015
2016-2019
Upper middle-income economies
Percent Change
20%
10%
0%
-10%
Gt CO_2 per year
20
10
0
1991-1995
1996-2000
2001-2005
2006-2010
2011-2015
2016-2019
Lower-income economies
Percent Change
20%
10%
0%
-10%
Gt CO_2 per year
6
3
0
1991-1995
1996-2000
2001-2005
2006-2010
2011-2015
2016-2019
Emissions type
Territorial (UNFCCC)
Consumption