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Estimating the European CO_2 emissions change due to COVID-19 restrictions

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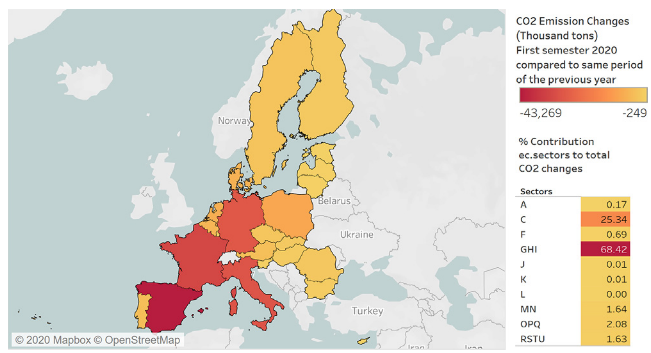
HIGHLIGHTS

- CO_2 emission change is estimated for 23 EU countries and 10 economic sectors.
- 195,600 thousand tons of CO_2 has been avoided during the first 6 months of 2020.
- The imposed restrictions influenced the distribution of the CO_2 emissions change.

GRAPHICAL ABSTRACT



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ABSTRACT

The carbon dioxide variations generated by the socio-economic restrictions imposed by the management of the COVID-19 crisis are analysed in this paper for 23 European countries and 10 economic sectors. By considering the most up to date information on GDP and carbon intensity of production, this paper represents one of the first attempts to estimate the CO_2 emissions change that have taken place in Europe during the first six months of 2020. Results show that more than 195,600 thousand tons of CO_2 have been avoided between January and June 2020, compared to the same period of the previous year, representing a −12.1% emissions change. The largest reductions have taken place in the Manufacturing, Wholesale, Retail Trade, Transport, Accommodation and Food Service sectors, accounting for more than 93.7% of total CO_2 change. Spain, Italy and France have been the most affected areas with −106,600 thousand tons emissions drop. In line with the results provided by previous studies, this paper highlights that the geographical and the sectoral distribution of the CO_2 emissions change has been largely influenced by the magnitude of the COVID-19 impacts. In addition, the carbon intensity of production, characterizing the most affected economic activities, has been the main element of differentiation compared to the previous 2008 crisis. By providing preliminary estimation of the CO_2 emissions change that have taken place across geographical and sectoral activities, this paper contributes to the existing climate policy debate and can support future estimation of CO_2 variations both in a context of confinement release as well as in a context of reintroduced COVID-19 restrictions.

1. Introduction

The outbreak of COVID-19 disease, firstly emerged in China at the end of December 2019, has caused unprecedented socio-economic disruptions and huge human life losses. According to data provided by the World Health Organization, over 44 million cases and more than 1.1

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million deaths have been recorded during the first 10 months of the pandemic (WHO Covid-19 Dashboard). The rapid spread across developed and developing countries, together with the extensive pressure on the health systems have forced most of the governments to introduce various degree of social distance measures. By September 2020, at least 186 countries had imposed restrictions on movements with 82 of them affected by national or regional lockdown (Han et al., 2020).

The forced shut-down of production and consumption activities together with reduced mobility and trade have however generated the deepest global recession since World War II (World Bank, 2020). The severity of the economic consequences and the related social instabilities have then induced most of the world countries to ease some of the restrictions, with the risk of additional pandemic waves.

The large uncertainties related to the characteristics and treatment of the virus, together with the impossibility to forecast the duration of the crisis, makes it difficult to balance the trade-offs between health and socio-economic needs. Extensive debates have then been oriented to question the effectiveness of policies and to investigate multidimensional range of COVID-19 impacts (Arthi and Parman, 2020; Ibn-Mohammed et al., 2020).

Despite the large attention devoted to economy and health (World Bank, 2020a) an increasing number of analysis has also been focusing on the environmental and climate effects (Sovacool et al., 2020). The possibility to use existing evidence and data to model and forecast the socio-economic and environmental impacts of reduced anthropogenic activities is representing a unique opportunity to discuss the existing sustainability constraints and to investigate opportunities for changes (Stoll and Mehling, 2020; Manzanedo and Manning, 2020; Shakil et al., 2020).

Rume and Islam (2020), together with Zambrano-Monserrate et al. (2020) have for example provided preliminary overview of the COVID-19 effects highlighting the trade-offs existing between the environmental benefits of the reduced economic interactions and the environmental costs associated with consumption changes. The increased use of personal protective equipment and waste, together with the temporary reduction of recycling have for example been identified as some of the main environmental threats of the COVID-19 pandemic (Klemes et al., 2020). On the other side, the strict lockdown measures have contributed to drop the energy consumption rates with related impacts on emissions and air quality change. The forced reduction of transport activities and production has then represented an unprecedented opportunity to investigate the incidence of the anthropogenic emissions rate and an increasing number of studies have concentrated on that.

Local variations of pollutants, such as $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, O_3, and NH_3 have for example been analysed for Indian cities (Sharma and Jain, 2020; Sharma et al., 2020; Mahato et al., 2020), Brazil (Nakada and Urban, 2020; Dantas et al., 2020), China (Li et al., 2020; Bao and Zhang, 2020; Isaifan, 2020; Wang et al., 2019), Europe (Menut et al., 2020; Tobia et al., 2020; Sicard et al., 2020; Ordonez et al., 2020; Baldasano, 2020; Collivignarelli et al., 2020) and United States (Berman and Ebisu, 2020; Chauhan and Singh, 2020). Most of these studies have used data from monitoring stations and satellite images, and have observed positive correlations between the severity of the lockdown restrictions and the air quality improvements.

Analyses have also been concentrating on investigating the incidence of the lockdown measures into the greenhouse gases and the carbon dioxide generation. The lack of real time data and the global nature of these pollutants make however difficult to have direct information on the magnitude of change. For this reason, most of the existing studies have been using derivative approaches to estimate the countries and the sectoral emissions change. Recent attempts include Le Quere et al. (2020) that combining government policies and activity data forecasted an annual CO_2 emissions drop ranging between −4% and −7%, depending on the duration of the restrictions. Liu et al. (2020) that used activity data from power generation, industry, transport and residential energy consumption to estimate a CO_2 emissions change of −6.9% for China, −12% for Europe, and −9.5% for United States. The International Energy Agency (2020) that used fossil fuel energy demand to approximate a −5% CO_2 emissions decline between January and April 2020. Han et al. (2021) that combined GDP changes and inventory data to calculate the sectoral and geographical CO_2 emissions change for China, and Myllyvirta (2020) that used coal consumption and economic activity rates to estimate 18% CO_2 emissions drop over a seven-week period in China.

By considering the limited available information, these pioneering studies provide important contributions to understand the role that imposed socio-economic constraints can have in the carbon emissions trends and can support the definition of effective climate strategies.

Most of the analysis conducted so far, have however been focused on the global or on the macro-regional sale (Le Quere et al., 2020) and no previous attempts have been specifically devoted to investigating the CO_2 emissions change that have taken place in the different European countries. The European Environmental Agency is for example expecting to publish the first detailed report on greenhouse gases emissions in the autumn 2021 (EEA website). Given the primary role played by Europe in the international climate negotiations (EC website) and given the rapid changes induced by the ongoing COVID-19 crisis, the availability of timely estimation is of primary importance. Within this context, the main objective of this paper is to investigate the carbon dioxide emissions change that have taken place in Europe in the first six months of 2020, during which the most extensive lockdown restrictions have taken place. Using the most up to date information on GDP and carbon intensity of production, this study represents one of the first attempts to estimate the CO_2 emissions change that have taken place in 23 European countries at industry level breakdown. By discussing the role that different economic activities are playing in the generation of carbon dioxide, the present paper can contribute to the existing climate policy debate. In addition, the provision of timely estimations can be functional to monitor and forecast the future CO_2 emissions change both in a context of confinement release as well as in a context of reintroduced restrictions.

2. Data and methods

Eurostat data have been used in this paper to estimate the carbon impacts of the COVID-19 outbreak for the 23 European countries for which consistent data are available. GDP data at industry level breakdown have been used to calculate the production variations that have taken place in the first semester of 2020 compared to the same period of the previous year. The carbon intensities provided by Eurostat for the year 2018, and reported in Table A1 of Appendix A, have been used to estimate the CO_2 emissions change (Eurostat Air Emission database). In Table 1, the industry breakdown considered in this paper

Table 1
NACE Rev. 2 activity classification.

Code	Description
A	Agriculture, forestry and fishing
C	Manufacturing
F	Construction
G, H, I	Wholesale and retail trade, transport, accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M, N	Professional, scientific and technical activities; administrative and support service activities
O, P, Q	Public administration, defence, education, human health and social work activities
R, S, T, U	Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies

is reported together with the related NACE Rev. 2 activity classification.[1]

Following the approach proposed by Han et al. (2021), where carbon factors and GDP variations are used to estimate the CO_2 emission change, the carbon dioxide emissions drops are here estimated according to Eqs. (1) and (2), where the carbon intensities of the NACE Rev.2 activities are assumed to remain unchanged from the year 2018.

$$CO_2 \text{ emissions} = \sum(GDP_{it} \times EI_i) \quad (1)$$

where GDP is the gross domestic product of time *t*, EI the carbon dioxide emissions intensity of production and *i* refers to the economic activities of Table 1. From Eq. (1), the carbon dioxide emissions changes are then estimated as:

$$\Delta CO_2 \text{ emissions} = \sum(\text{Change rate of } GDP_{it} \times CO_2 \text{ emissions}) \quad (2)$$

In the following section, results are discussed for the 23 European countries for which the most up to date and consistent data are available.

3. Results and discussion

According to data reported in Table A2 of Appendix A, in the first semester of 2020, the CO_2 emissions of the 23 European countries considered in this paper have been more than 195,600 thousand tons lower than in the same period of 2019, representing a percentage drop of 12.1%. Out of these, almost 106,600 thousand tons have taken place in Spain, Italy and France, that experienced the largest GDP (−12.7%, −12.1% and −11.9%, respectively) and CO_2 emissions change (−22.5%, −18.2% and −16.5%, respectively). Heavily affected by the COVID-19 infections these countries have been among the first European areas to introduce lockdown restrictions (ECDC website). The closure of non-essential shops and production, the limitation imposed to the hospitality sector and the sharp decrease of movements, generated extensive implications across the entire economic compartments.

The Wholesale, Retail Trade, Transport, Accommodation and Food Service Activities (G,H,I) together with the Manufacturing (C) sector, resulted to be the most affected activities, accounting for −61.7%% of the overall GDP changes. Traditionally characterized by some of the highest carbon intensities of production, these activities related to more than 93.7% of the total CO_2 emissions drop. In Table A3 of Appendix A, the percentage contribution provided by every economic sector to the overall GDP and CO_2 emissions change is reported for the 23 European countries considered in this paper. According to data provided by Eurostat, the motor vehicle, the textile and the furniture sectors resulted to be the most affected productions, while the pharmaceutical and tobacco have been the only compartments with positive growth rate (Eurostat industrial production database). Tourism related activities, such as food services and accommodation also performed some of the largest turnover decline, with an average 45.8% drop during the second quarter of 2020. Summer tourism destinations, such as Spain, Portugal and Italy recorded the largest percentage reduction (−78.2%, −65.9% and −62.6%, respectively), while Netherlands, Austria and Slovakia have been the only countries with a percentage drop lower than 15% (Eurostat services database).

The Recreation (R, S, T, U), Professional Activities (M, N) and Public Administration (O, P, Q) have also been highly impacted by the COVID-19 restrictions, with an average GDP reduction of 30.6%. The low carbon intensities of these activities (Table A1 of Appendix A) have however generated minor CO_2 emissions change (−5.4%).

In most the European countries, the construction sector (F) has also been negatively affected, with exception of Germany, Sweden, Portugal, Netherland and some Eastern European areas, such as Poland, Romania and the Baltic states, that performed a GDP and carbon dioxide emission increase (Table A2 of Appendix A). Contrary to the decision taken by most of the other EU countries, these areas did not include the construction into the list of activities forced to shut down. Therefore, the impact on GDP has been lower than in countries, such as Italy, Luxemburg and France, that imposed more severe restriction to the construction compartment (IMF website; ECDC website). According to data provide by Eurostat, in these three countries the construction activities fell by 70.0%, 55.7% and 65.0% respectively, between February and April 2020, with reductions that have taken place both in the building and the civil engineering compartments (Eurostat construction database). When considering the carbon dioxide variation, the relatively low carbon intensity of construction (0.149 kg per euro, EU23 average) has induced a CO_2 emission drop that accounted for less than 0.7% (−1343 thousand tons) of the total change.

The Agricultural, Forestry and Fishing sector (A), has been the least affected economic compartment with a GDP variation accounting for 0.13% (−584 million euro) of the total change. According to data provide by OECD (2020a), the COVI-19 related spike in the consumption of vegetable and citrus fruits has contributed to boost a significant increase in the demand of agricultural products, with Spain experiencing the major sectoral gains (+587 million euro). In line with the analysis provided by Eurostat for the food-related retail sector, the demand of agricultural products increased during the two first months of the pandemic and stabilized in the following period (Eurostat retail trade database). The non-closure of supermarkets and essential shops, together with the panic buying behaviours has contributed to sustain the demand of the agricultural compartment (Jaspal et al., 2020). Consequently, minor variations have taken place for the related carbon dioxide emissions change, that reduced by 338 thousand tons (−0.17% of the total change).

The Information and Communication (J) has been the second less affected sector, with a GDP reduction of 3713 million euro (−0.8% of the total GDP change). The working from home recommendations, the forced transition to telehealth and on-line educations, together with the rapid shifts to online retail have largely increased the demand for information systems technologies (He et al., 2020). As a consequence, 13 of the 23 European countries considered in this paper have accounted a GDP increase (Table A2 of Appendix A). Some of the largest variations have taken place in the Eastern European countries, such as Estonia, Lithuania and Romania, where the existing digitalization gaps have been partially reduced as a response to the induced digital transformation (World Bank, 2020b). When considering the carbon dioxide variation, the low carbon intensity of these productions has however generated minor emissions change, accounting for 0.01% of the total CO_2 reduction.

The Financial and Insurance (K) and the Real Estate Activities (L) have also been marginally affected by the COVID-19 related crisis, with an overall GDP drop of around 9800 million euro (2.1% of the total GDP change). As previously reported by OECD (2020b), the large set of measures introduced to support the investments of builders, lenders and tenants together with mortgage repayment suspension have contributed to reduce the overall losses and to promote an economic rebound in the period that followed the lockdown (EC, 2020).

A detailed breakdown of the CO_2 emissions change is reported in Fig. 1 according to sectoral and country level disaggregation.

Despite the differences reported above, general trends can be identified across the industry and the geographical breakdown. As previously highlighted by other studied (Han et al., 2021; Sarkodie and Owusu, 2020; Rugani and Caro, 2020) the spatial distribution of the CO_2 emissions change has been largely influenced by the magnitude of the COVID-19 impact. In addition, the emissions factors characterizing the economic activities of the different European countries have also influenced the variations. When the emission rate was higher 1 (kg per euro) the emission drop has been larger than the GDP change. The G,

[1] NACE (**N**omenclature statistique des **a**ctivités économiques dans la **C**ommunauté **e**uropéenne) is the statistical classification of economic activities in the European Community.

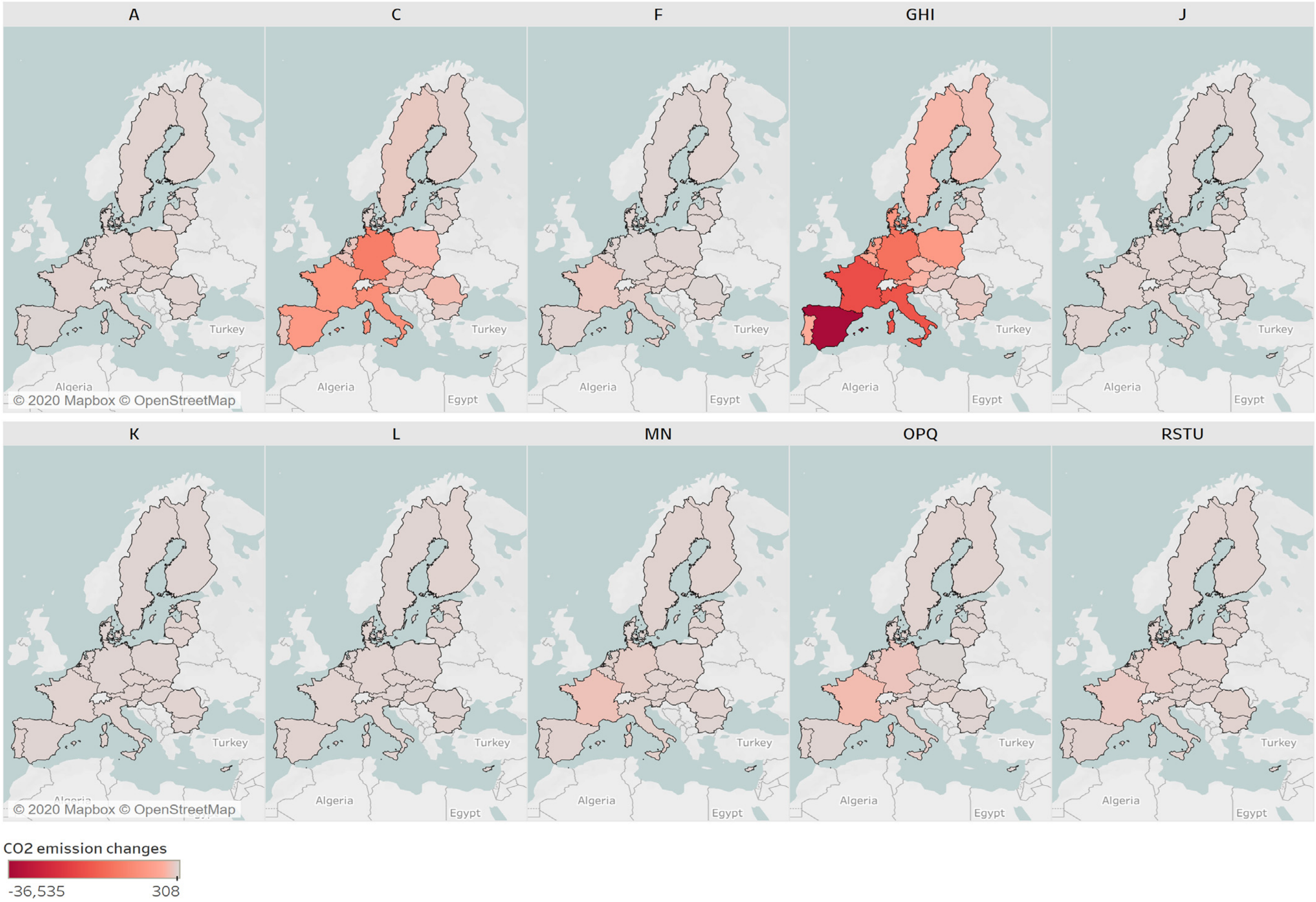

Fig. 1. CO_2 emissions change (thousand tons) - industries and countries breakdown.

H,I sector of Denmark and Bulgaria, characterized by some of the highest emission factors (3.1 kg per euro and 2,3 kg per euro, respectively) have for example accounted for 98.4% and 71.2% of the respective CO_2 drop, with a related 50.3% and 59.8% of GDP change (Table A3 of Appendix A). According to Eurostat data, in both countries, the carbon intensity of the transport sector (3.04 kg per euro in Denmark and 2.17 kg per euro in Bulgaria) is largely above the EU27 average (0.85 kg per euro) (Eurostat Air Emission database). In a similar way, the emissions rate of the manufacturing sector (C) of Bulgaria (1.12 kg per euro) and Cyprus (1.52 kg per euro) have generated an emission drop that has been higher than the GDP change. The opposite trend has been performed by Germany, Italy and Sweden, that have seen a GDP reduction largely higher than the carbon emission drop. According to data reported in Table A1 of Appendix A, these countries have the lowest carbon intensity of manufacturing (0.28 kg per euro, 0.33 kg per euro and 0.24 kg per euro, respectively). As previously highlighted by other studies (Han et al., 2021; Friedlingstein et al., 2019), the impacts on the most pollutant economic activities has been the main factor differentiating the present crisis from the previous 2008 crash, where the financial sector was the most affected economic compartment.

The predominant role that the carbon intensities of production are playing in the estimations of the CO_2 emissions change highlights the importance of up to date information. In relation to this paper, the existing data constraint related to the emissions factors of 2018, have probably generated a slightly overestimation of the CO_2 emissions change. In addition, the unavailability of timely and consistent information related to the energy consumption changes that have taken places in offices and household spaces, have constrained the account of the carbon effects of the working from home recommendations. The limited breakdown of production activities and the related impossibility to provide disaggregated analysis for households and for some of the most affected economic sectors is also representing a limitation of the provided estimations. When consistent data will be available, detailed analysis should then be devoted to investigating the most affected economic activities, such as tourism and transport, together with the most impacted geographical areas. Up to now, the most consistent information related to transport has for example been published by Eurostat in relation to the number of passengers and tons of transported material (Eurostat website). The lack of specific data related to GDP changes, carbon intensities of passengers and freight transport activities, together with the limited information on distances and mobility indexes make however difficult to provide consistent estimations across the 23 European countries considered in this paper.

From a methodological perspective, improvements could be achieved by using energy consumption as drivers of carbon emissions change, as recently attempted by Rugani and Caro (2020), Cheshmehzangi (2020) and Bulut (2020). The lack of timely and consistent energy data is however representing an operational constraint for the geographical and sectoral disaggregation considered in this paper.

Despite the existing limitation, the analyses provided are a preliminary attempt to estimate the carbon dioxide emissions change in a context of limited information and dynamic changes. The results provided, together with the sectoral and the geographical breakdown, can then represent the base for additional analysis and research. Within this context, future investigations could for example be devoted to analysing the impacts of the expected rebound effect and to discuss the implication of potential behavioural changes. As previously highlighted by Sovacool et al. (2020) the transformed working habits, the increased investments in green mobility and the international cooperation emerged during the COVID-19 pandemic could represent a valuable opportunity for the management of the climate crisis.

4. Conclusion

By considering a sectoral and geographical disaggregation of 10 economic compartments and 23 European countries, this paper estimates the CO_2 emissions change that have taken place in the first six months of 2020 due to the imposed COVID-19 restrictions. Results show than more than 195,600 thousand tons of emissions have been avoided compared to the same period of the previous year. Spain, Italy and France, largely affected by the COVID-19 infection, have been the areas with the largest carbon reductions, accounting for more than 55% of the total emission changes. The Manufacturing, Wholesale Retail Trade, Transport Accommodation and Food Service sectors have been the most affected economic compartments and the relatively high carbon intensity of production has been the main element differentiating the carbon impacts of the present economic collapse from the previous 2008 crisis. The results provided are in line, even if slightly overestimated, with those of Liu et al. (2020) that calculated the sector-specific, country-level CO_2 emissions change by using data from the international Carbon Monitor research initiative. When comparing the emission reductions for the industrial activities of Italy, France and Spain, the estimated results are higher in this paper than those provided by the carbon monitor database. The reason could be related to the types of activities included in the industrial sector, to the carbon intensities of fuel and to the fact that in the present study the emission factors of 2018 have assumed to be unchanged. Even with the existing limitations this paper represents one of the first attempts to estimate the national and the sectoral carbon dioxide emissions change that have taken place in Europe and can represent an initial platform for future analysis and researches.

Despite the global impacts of the carbon dioxide emission changes, a better understanding of the regional and economic drivers of pollution is a fundamental element for the design of achievable climate solutions, as recently highlighted during the Paris climate negotiation. In this respect, the 8.5% of GDP drop and the related 12% carbon dioxide emissions change, that have taken place during the first 6 months of 2020, provide an indication of the carbon intensity of the existing economic structure. Within this context, the climate strategies defined in the recent COP agreements and the European objective of 40% greenhouse gas emission reduction should be questioned in relation to the possibility of replicating the emissions drop without causing the extreme socio-economic effects experienced in lockdown. As previously highlighted by other studies (Stoll and Mehling, 2020; Rume and Islam, 2020; Ferrarini et al., 2021) the carbon reduction auspicated by the international climate negotiation should be promoted in line with substantial transformation of the existing socio-economic structure. The extensive discussion emerging between the COVID-19 pandemic and the existing climate crisis should then investigate the carbon risks of the "return to normal" strategies and question the long-term sustainability solutions. The green recovery plans proposed by developed and developing countries, the behavioural changes induced on individual and societies, and the international cooperation emerged during the existing COVID-19 crisis is representing an important opportunity for change. After the failure of the sustainable recovery of the global financial crisis of 2008, the current pandemic can give us a chance that this time cannot be wasted.

CRediT authorship contribution statement

Valeria Andreoni: Conceptualization, Methodology, Investigation, Data analysis, Writing - original draft, Writing - review & editing, Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A1
Carbon intensities – industry and country breakdown (kg per euro).

	A	C	F	G, H, I	J	K	L	M, N	O, P, Q	R, S, T, U
Belgium	1.2100	0.6592	0.0951	0.6799	0.0209	0.0074	0.0026	0.0881	0.1157	0.3361
Bulgaria	0.5679	1.1245	0.2146	2.2957	0.0090	0.0013	0.0026	0.0750	0.0748	0.0283
Czechia	0.5210	0.3900	0.1406	1.0755	0.0089	0.0060	0.0048	0.1809	0.0555	0.0444
Denmark	0.8529	0.1665	0.1216	3.1110	0.0058	0.0049	0.0052	0.0479	0.0568	0.0447
Germany	0.5299	0.2801	0.1092	0.9167	0.0178	0.0147	0.0017	0.0386	0.0978	0.1053
Estonia	0.2754	0.5375	0.0781	1.3413	0.0059	0.0075	0.0399	0.0801	0.3025	0.1930
Spain	0.4179	0.5888	0.0067	1.1053	0.0101	0.0083	0.0005	0.0144	0.0713	0.0282
France	0.3726	0.3715	0.0846	0.5887	0.0085	0.0088	0.0018	0.0746	0.0909	0.1315
Italy	0.3025	0.3286	0.0784	0.6256	0.0045	0.0076	0.0023	0.0333	0.0723	0.0621
Cyprus	0.2129	1.5213	0.0905	0.4150	0.0076	0.0066	0.0017	0.0810	0.0430	0.0649
Latvia	0.7320	0.5151	0.1637	1.3474	0.0099	0.0123	0.0603	0.1092	0.1360	0.0859
Lithuania	0.4115	0.7310	0.0321	2.6628	0.0101	0.0120	0.0063	0.0457	0.1087	0.1029
Luxembourg	0.7634	0.5379	0.0560	2.0082	0.0086	0.0153	0.0082	0.0358	0.0854	0.1266
Hungary	0.5514	0.5375	0.2252	0.9284	0.0575	0.0503	0.0490	0.2035	0.2064	0.1518
Netherlands	0.7726	0.5677	0.0849	1.0101	0.0048	0.0088	0.0068	0.0666	0.0675	0.1505
Austria	0.3338	0.4026	0.1224	0.4205	0.0071	0.0035	0.0011	0.0266	0.0462	0.0640
Poland	2.2792	0.7971	0.0174	1.5737	0.0269	0.2403	0.0494	0.2020	0.3045	0.2525
Portugal	0.5716	0.6095	0.1991	0.9749	0.0089	0.0103	0.0009	0.0560	0.1024	0.1067
Romania	0.1741	0.5963	0.3701	0.8159	0.0264	0.0649	0.0315	0.1386	0.2120	0.2532
Slovenia	0.3436	0.3822	0.6003	0.6668	0.0524	0.0316	0.0196	0.2514	0.1291	0.2609
Slovakia	0.1201	0.8392	0.3543	0.9720	0.0116	0.0133	0.0346	0.1408	0.1726	0.3620
Finland	0.3467	0.3660	0.1058	1.1655	0.0008	0.0398	0.0063	0.0446	0.0680	0.0919
Sweden	0.3074	0.2446	0.0872	0.6924	0.0032	0.0045	0.0056	0.0438	0.0342	0.0499

Table A2
GDP and CO_2 variations – industry and country breakdown (GDP: Million euro; CO_2: Thousand tons).

		A	C	F	G, H, I	J	K	L	M, N	O, P, Q	R, S, T, U	Total change	% change
Belgium	GDP	52	−1813	−914	−6259	−271	−263	195	−2272	−2226	−738	−14,509	−7.53
	CO_2	63	−1195	−87	−4255	−6	−2	0	−200	−257	−248	−6187	−11.31
Bulgaria	GDP	−14	−399	−28	−483	85	47	−159	33	162	−51	−808	−4.19
	CO2	−8	−449	−6	−1109	1	0	0	2	12	−1	−1558	−10.79
Czech Rep.	GDP	69	−2530	−63	−1959	92	−100	−164	−196	17	−175	−5009	−6.17
	CO_2	36	−987	−9	−2107	1	−1	−1	−35	1	−8	−3110	−10.39
Denmark	GDP	106	−509	−244	−2281	−7	259	−46	60	−895	−976	−4532	−3.59
	CO2	91	−85	−30	−7096	0	1	0	3	−51	−44	−7210	−7.92
Germany	GDP	−55	−43,842	2417	−15,880	−1002	252	−15	−14,652	−12,198	−6040	−91,015	−6.52
	CO_2	−29	−12,279	264	−14,557	−18	4	0	−565	−1193	−636	−29,008	−8.18
Estonia	GDP	8	−173	110	−263	113	28	−73	−27	21	−33	−289	−2.91
	CO_2	2	−93	9	−353	1	0	−3	−2	6	−6	−439	−8.81
Spain	GDP	587	−11,333	−5536	−33,054	−1624	91	−1350	−7634	338	−5952	−65,467	−12.74
	CO_2	245	−6673	−37	−36,535	−16	1	−1	−110	24	−168	−43,269	−22.47
France	GDP	−469	−19,935	−11,226	−35,119	−2233	−3268	−1677	−19,100	−21,867	−6399	−121,293	−11.85
	CO_2	−175	−7406	−950	−20,675	−19	−29	−3	−1425	−1987	−841	−33,508	−16.46
Italy	GDP	−374	−27,077	−5882	−30,881	−349	−2085	−3379	−9570	−6776	−3449	−89,821	−12.10
	CO_2	−113	−8897	−461	−19,319	−2	−16	−8	−319	−490	−214	−29,838	−18.18
Cyprus	GDP	−1	−52	−65	−387	24	−6	16	−22	23	−46	−516	−5.62
	CO_2	0	−79	−6	−161	0	0	0	−2	1	−3	−249	−11.62
Latvia	GDP	−5	−63	32	−351	−44	−3	−18	−13	4	−90	−549	−5.00
	CO_2	−4	−32	5	−473	0	0	−1	−1	1	−8	−513	−9.01
Lithuania	GDP	6	−35	5	−224	55	−1	36	−24	−16	−43	−241	−1.35
	CO_2	3	−26	0	−598	1	0	0	−1	−2	−4	−627	−3.22
Luxembourg	GDP	−1	−226	−198	−543	244	−37	43	−23	118	−7	−629	−2.45
	CO_2	−1	−121	−11	−1090	2	−1	0	−1	10	−1	−1213	−12.78
Hungary	GDP	−24	−1351	−153	−723	120	83	−73	−330	−648	−201	−3299	−6.45
	CO_2	−13	−726	−34	−671	7	4	−4	−67	−134	−31	−1669	−7.97
Netherlands	GDP	105	−1795	114	−6282	−214	203	442	−2965	−3751	−1706	−15,850	−4.86
	CO_2	81	−1019	10	−6345	−1	2	3	−197	−253	−257	−7977	−7.28
Austria	GDP	−69	−3803	−351	−6278	168	−7	391	−2648	21	−1020	−13,595	−8.55
	CO_2	−23	−1531	−43	−2640	1	0	0	−70	1	−65	−4370	−13.34
Poland	GDP	−169	−3146	163	−4293	171	47	138	−29	1012	−1107	−7212	−3.58
	CO_2	−386	−2507	3	−6755	5	11	7	−6	308	−279	−9600	−6.36
Portugal	GDP	−87	−1763	97	−3542	51	−130	82	−991	−417	−484	−7183	−8.73
	CO_2	−50	−1074	19	−3453	0	−1	0	−55	−43	−52	−4708	−14.38
Romania	GDP	−131	−3241	503	−760	678	−41	7	−38	151	−787	−3659	−5.33
	CO_2	−23	−1932	186	−620	18	−3	0	−5	32	−199	−2546	−9.03
Slovenia	GDP	−33	−412	−46	−518	−24	10	13	−186	−61	−89	−1347	−7.22
	CO_2	−11	−157	−28	−345	−1	0	0	−47	−8	−23	−621	−9.66
Slovakia	GDP	−28	−1363	−424	−707	−81	−125	107	−230	25	−141	−2968	−8.05
	CO_2	−3	−1144	−150	−687	−1	−2	4	−32	4	−51	−2062	−11.71
Finland	GDP	−53	−773	−20	−1471	96	133	−35	−347	−363	−484	−3315	−3.48
	CO_2	−18	−283	−2	−1714	0	5	0	−15	−25	−44	−2097	−7.39
Sweden	GDP	−5	−3549	169	−3294	241	324	294	−1417	−787	−193	−8214	−3.81
	CO_2	−2	−868	15	−2281	1	1	2	−62	−27	−10	−3230	−7.96
Total	GDP	−584	−129,182	−21,540	−155,549	−3713	−4588	−5224	−62,621	−48,111	−30,209	−461,320	−8.51
	CO_2	−338	−49,562	−1343	−133,838	−27	−23	−3	−3214	−4068	−3194	−195,610	−12.11

Table A3
Percentage contribution of economic activities to GDP and CO_2 variation.

		A	C	F	G, H, I	J	K	L	M, N	O, P, Q	R, S, T, U
Belgium	GDP	0.36	−12.50	−6.30	−43.14	−1.87	−1.81	1.34	−15.66	−15.34	−5.09
	CO_2	1.02	−19.31	−1.41	−68.78	−0.09	−0.03	0.01	−3.24	−4.16	−4.01
Bulgaria	GDP	−1.67	−49.41	−3.50	−59.80	10.47	5.77	−19.71	4.05	20.07	−6.26
	CO2	−0.49	−28.81	−0.39	−71.18	0.05	0.00	−0.03	0.16	0.78	−0.09
Czech Rep.	GDP	1.37	−50.52	−1.26	−39.11	1.83	−2.00	−3.26	−3.90	0.34	−3.49
	CO_2	1.15	−31.73	−0.28	−67.76	0.03	−0.02	−0.03	−1.14	0.03	−0.25
Denmark	GDP	2.35	−11.23	−5.37	−50.32	−0.16	5.71	−1.01	1.33	−19.74	−21.54
	CO2	1.26	−1.18	−0.41	−98.42	0.00	0.02	0.00	0.04	−0.70	−0.60
Germany	GDP	−0.06	−48.17	2.66	−17.45	−1.10	0.28	−0.02	−16.10	−13.40	−6.64
	CO_2	−0.10	−42.33	0.91	−50.18	−0.06	0.01	0.00	−1.95	−4.11	−2.19
Estonia	GDP	2.87	−59.85	38.14	−91.14	38.98	9.66	−25.13	−9.38	7.34	−11.49
	CO_2	0.52	−21.15	1.96	−80.38	0.15	0.05	−0.66	−0.49	1.46	−1.46
Spain	GDP	0.90	−17.31	−8.46	−50.49	−2.48	0.14	−2.06	−11.66	0.52	−9.09
	CO_2	0.57	−15.42	−0.09	−84.44	−0.04	0.00	0.00	−0.25	0.06	−0.39
France	GDP	−0.39	−16.44	−9.26	−28.95	−1.84	−2.69	−1.38	−15.75	−18.03	−5.28
	CO_2	−0.52	−22.10	−2.83	−61.70	−0.06	−0.09	−0.01	−4.25	−5.93	−2.51
Italy	GDP	−0.42	−30.15	−6.55	−34.38	−0.39	−2.32	−3.76	−10.65	−7.54	−3.84

Table A3 (*continued*)

		A	C	F	G, H, I	J	K	L	M, N	O, P, Q	R, S, T, U
	CO_2	−0.38	−29.82	−1.55	−64.75	−0.01	−0.05	−0.03	−1.07	−1.64	−0.72
Cyprus	GDP	−0.19	−10.05	−12.51	−75.01	4.59	−1.12	3.06	−4.26	4.40	−8.89
	CO_2	−0.09	−31.67	−2.35	−64.45	0.07	−0.02	0.01	−0.71	0.39	−1.20
Latvia	GDP	−0.89	−11.44	5.86	−63.87	−7.92	−0.53	−3.26	−2.35	0.71	−16.32
	CO_2	−0.70	−6.30	1.03	−92.05	−0.08	−0.01	−0.21	−0.27	0.10	−1.50
Lithuania	GDP	2.57	−14.68	1.87	−93.07	22.65	−0.37	15.10	−9.79	−6.64	−17.63
	CO_2	0.41	−4.13	0.02	−95.28	0.09	0.00	0.04	−0.17	−0.28	−0.70
Luxembourg	GDP	−0.16	−35.83	−31.46	−86.29	38.74	−5.82	6.77	−3.64	18.78	−1.10
	CO_2	−0.06	−10.00	−0.91	−89.87	0.17	−0.05	0.03	−0.07	0.83	−0.07
Hungary	GDP	−0.74	−40.96	−4.62	−21.91	3.63	2.53	−2.20	−10.00	−19.63	−6.09
	CO_2	−0.81	−43.52	−2.06	−40.20	0.41	0.25	−0.21	−4.02	−8.01	−1.83
Netherlands	GDP	0.66	−11.33	0.72	−39.63	−1.35	1.28	2.79	−18.71	−23.67	−10.76
	CO_2	1.02	−12.78	0.12	−79.55	−0.01	0.02	0.04	−2.47	−3.17	−3.22
Austria	GDP	−0.50	−27.97	−2.58	−46.18	1.24	−0.05	2.87	−19.48	0.16	−7.50
	CO_2	−0.52	−35.04	−0.98	−60.41	0.03	0.00	0.01	−1.61	0.02	−1.49
Poland	GDP	−2.35	−43.62	2.26	−59.52	2.38	0.65	1.91	−0.41	14.03	−15.35
	CO_2	−4.02	−26.12	0.03	−70.37	0.05	0.12	0.07	−0.06	3.21	−2.91
Portugal	GDP	−1.21	−24.54	1.35	−49.31	0.70	−1.81	1.14	−13.79	−5.80	−6.74
	CO_2	−1.06	−22.82	0.41	−73.33	0.01	−0.03	0.00	−1.18	−0.91	−1.10
Romania	GDP	−3.59	−88.58	13.74	−20.76	18.53	−1.13	0.20	−1.04	4.13	−21.50
	CO_2	−0.90	−75.90	7.31	−24.35	0.70	−0.11	0.01	−0.21	1.26	−7.82
Slovenia	GDP	−2.44	−30.59	−3.45	−38.45	−1.79	0.71	0.99	−13.84	−4.51	−6.62
	CO_2	−1.82	−25.37	−4.49	−55.64	−0.20	0.05	0.04	−7.55	−1.27	−3.75
Slovakia	GDP	−0.95	−45.92	−14.28	−23.81	−2.74	−4.22	3.60	−7.76	0.84	−4.76
	CO_2	−0.16	−55.46	−7.28	−33.31	−0.05	−0.08	0.18	−1.57	0.21	−2.48
Finland	GDP	−1.60	−23.31	−0.60	−44.37	2.90	4.02	−1.06	−10.47	−10.94	−14.59
	CO_2	−0.87	−13.49	−0.10	−81.75	0.00	0.25	−0.01	−0.74	−1.18	−2.12
Sweden	GDP	−0.06	−43.20	2.06	−40.10	2.94	3.95	3.58	−17.24	−9.58	−2.34
	CO_2	−0.05	−26.87	0.46	−70.61	0.02	0.04	0.05	−1.92	−0.83	−0.30
Total	GDP	−0.13	−28.00	−4.67	−33.72	−0.80	−0.99	−1.13	−13.57	−10.43	−6.55
	CO_2	−0.17	−25.34	−0.69	−68.42	−0.01	−0.01	−0.00	−1.64	−2.08	−1.63

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