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How has the COVID-19 pandemic affected the climate change debate on Twitter?

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ABSTRACT

Climate change and the COVID-19 pandemic share many similarities. However, in the past months, concerns have increased about the fact the health emergency has put on hold during the pandemic many climate adaptation and mitigation policies. We focus our attention on understanding the role of the recent health emergency on the transmission of information related to climate change, jointly with other socio-economic variables, social norms, and cultural dimensions. In doing so, we create a unique dataset containing the number of tweets written with specific climate related keywords per country worldwide, as well as country specific socio-economic characteristics, relevant social norms, and cultural variables. We find that socio-economic variables, such as income, education, and other risk-related variables matter in the transmission of information about climate change and Twitter activity. We also find that the COVID-19 pandemic has significantly decreased the overall number of messages written about climate change, postponing the climate debate worldwide; but particularly in some vulnerable countries. This shows that in spite of the existing climate emergency, the current pandemic has had a detrimental effect over the short-term planning of climate policies in countries where climate action is urgent.

1. Introduction

The climate crisis is expected to be the most dangerous problem ever faced by Humanity. However, some authors argue that in the past few months and due to the urgency during the ongoing COVID-19 pandemic, concerns about climate change have been put on hold in some countries. For example, in Brazil, during 2020 a significant number of pieces of legislation that relax environmental laws, from easing forest protections to declassifying the toxicity of pesticides were approved during the second wave of COVID-19(Vale et al., 2021). In the same period, the United States has rolled back certain environmental regulations and appeared to direct stimulus funds toward reinvigorating the fossil fuel industry (Rosenbloom and Markard, 2020). In the meantime, the German Council of Economic Experts (2020) produced a report on the coronavirus crisis without including any environmental considerations, or mentioning the words climate change or sustainability. The Columbia Climate School (2020) also reports the delays of COP-26 and international negotiations related to the protection of the environment that may allow countries to move their actions away from the fight against climate change. The International Energy Agency has noted delays in climate friendly policies and related investments (International Energy Agency (IEA, 2020). In addition, some private companies have increased the production of waste and pollution, due to the consequence of the heavy use of plastics, and private transportation. These are just a few examples that illustrate the complex effects of COVID-19 in relation to climate change adaptation and mitigation policies.

While the current health pandemic also offers unprecedented insights into how the global climate crisis may be managed, it also manifests a clear need to tackle climate change as an urgent manner (Klenert et al., 2020; Mandanedo and Manning, 2020). Fuentes et al. (2020) examine both global crises, showing that both are global public bads, carrying very large economic costs, while sharing that *ex-ante* mitigation and prevention are cheaper than managing *ex-post* impacts.

There are two characteristics that define the nature of provision of public goods, as those representing climate control policies. In particular, many individuals can obtain gains from them, while exclusion of other beneficiaries from such associated impacts is a difficult or almost impossible task (non-excludability and non-rivalry). These intrinsic characteristics may generate certain incentives for misbehavior, by which individuals may not be willing to contribute to push forward with

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the provision of the public good (in our case, climate-control related actions), given that they will have a gain or loss based on what the rest of the society will do anyway. This free-riding problem may be particularly acute in cases where individuals feel that it is unfair for them to fix a problem caused by third parties. This argument has been put forward by many countries recently, in the context of the Paris Agreement. Individuals may not be willing to contribute with their effort either to this public good provision of climate control, because they may feel that their contribution is meaningless, with respect to the magnitude of the problem at hand; and no matter how much effort they put individually, the problem will not be solved. Others may consider that the problem will not be fixed in their lifespan, preferring to enjoy the present, and leaving the issue to be solved by future generations. These temporal dimensions may undermine the understanding of the current urgency of the problem. In short, multiple reasons can be found to explain the under-provision of public goods due to economic selfishness.

Therefore, in order to understand the dynamics of the provision towards climate change policies, it is of interest to analyze how information about climate change is being transmitted. Twitter conversations related to climate change are being considered as a proxy for societal concerns and awareness of the problem, as in previous studies (Jacques and Know, 2016; Maynard and Bontcheva, 2015). In particular, we investigate what type of relationship exists between climate change-related Tweets, and other socio-economic characteristics, cultural variables, social norms, and external shocks. It is particularly relevant to understand how the current pandemic has impacted the climate change debate. In order to undertake this analysis, we gather information obtained from Twitter from 2018 onwards. In total, more than 48 million tweets (48,234,241 tweets) have been gathered worldwide in more than 210 countries (See Appendix A).

1.1. Objectives and hypotheses

Our main research objective is to show that although the recent pandemic and climate change are both are public bads, the attention required to fight the current pandemic and the subsequent reduction of emissions due to massive lockdowns of the population, and initial mobility restrictions, have diminished current concerns about climate change, reducing the public debate about climate change in many countries. A second objective of our research is to understand the role of cultural variables and social norms related issues when communicating about climate change.

Specific research hypotheses examined in this paper are related to the mechanisms by which social media information about climate change is being transmitted. In particular, we aim to test the following research hypotheses:

1 Risk aversion increases the dissemination about climate change.
2 Altruism increases the dissemination of information about climate change.
3 The current COVID-19 pandemic has reduced the communication activity around the climate change debate.

The rest of the paper is structured as follows: Section 2 presents a short literature review about public goods, climate change and Twitter usage. Section 3 contains the data description employed in our analysis, while Section 4 shows the empirical model and results. Finally, the paper concludes in Section 5.

2. Literature review

Research, mainly based on behavioral economics, shows the great importance of human interactions in terms of reciprocity and conformity (Bardsley and Sausgruber, 2005), altruism (Andreoni, 1989, 1990; Fong and Luttmer, 2009); cultural differences (Casson et al., 2002); social capital (Anderson et al., 2004); information framing (Cookson, 2000), and other behavioral anomalies (Gowdy, 2008) in the provision of public goods. These contributions have shown the cognitive limitations of traditional economic theory, based on self-interested and rational individuals. In summary, studies from behavioral economics have shown that environmental justice and social norms also affect individual decisions, and therefore should be taken into account in traditional economic models. As it turns out, when considering a global problem (bad) such as climate change, individuals can be influenced by values and beliefs shared in groups for which they feel a sense of belonging (Hoffman, 2011).

The idea of cooperation in the provision of public goods has been put forward by many scholars, including Ostrom (2000), who suggested that articulated plans based on sharing common social norms can determine a “good” provision and conservation of the public good. Brekke and Johansson-Stenman (2008), suggest that what it may be rational for a single country or individual, may be suboptimal for the group; and particular, if all follow rational self-interested paths, a global good or a certain level of comprise of provision will not be achieved.

Previous attempts to understanding climate change information and communication dynamics on Twitter have been undertaken. In particular, and in terms of assessing the impact of Twitter conversations on the diffusion of information related to climate change, Kirilenko and Stepchenkova (2014) analyzed messages in five different languages (English, German, Russian, Portuguese and Spanish), finding geographical differences related to tweeting, different time patterns, and the importance given to the impact of events in the discussion. They found large variations across metropolitan areas and by topic. Cody et al. (2015) analyzed the collective sentiment through different episodes related to climate change, concluding that natural disasters and other phenomena related to climate change contributed to a decrease in the level of overall happiness. Kirilenko et al. (2015) also analyzed the use of Twitter in the USA to assess whether people related a change in the perceived temperature with the global driver of climate change. Maynard and Bontcheva (2015) used Twitter to analyze and understand the social engagement regarding climate change, with the aim of helping organizations to carry out better campaigns of information and improving societal understanding. Holmberg and Hellsten (2015) studied whether gender differences are important when explaining the communication of climate change. They found that overall, female and male tweeters used a similar language, denoting differences regarding the use of hashtags and usernames.

In addition, the social impact of specific natural disasters has also been analyzed with social media. For example, Kryvasheyeu et al. (2016) studied the impact of the Hurricane Sandy on Twitter conversations, finding a relationship between the proximity to the hurricane path and social media activity. Jacques and Knox (2016) also analyzed tweets about hurricane Sandy to understand the denial discourse of climate change. They found three major groups of denials: those who reject climate science because climate science is a conspiracy favoring growth of government; those who oppose renewable energy and energy taxation; and finally, a third group expressing fear of governmental abuse of power. Sisco et al. (2017) analyzed Twitter conversations to assess how extreme weather events generate attention to climate change, finding that the financial damage linked to these events is a good predictor of the attention paid to climate change in the USA. Roxburgh et al. (2019) assess the role climate change may or may not have played in influencing three high-magnitude extreme weather events– Hurricane Irene, Hurricane Sandy and Snowstorm Jonas, finding that climate change conversations matter in different ways in the three evaluated events. More recently, Loureiro and Alló (2020) assess how social media data from Twitter facilitate international comparisons in terms of preferences and emotions towards climate and energy policies in two different countries (Spain and the UK). Consequently, the previously existing literature highlights the importance and validity of social media reflecting that “human sensors” may anticipate economic impacts (Kirilenko et al., 2015).

We extend these previous analyses by considering the role of additional socioeconomic variables not previously studied in information transmission, in the context of conversations related to climate change. We consider the impact of risk perceptions, time preferences, and social factors when transmitting information about climate change. In summary, we look at the role of social norms and cultural variables in shaping the climate change debate during the period of analysis. In a second step, we specifically consider the impact of COVID-19 in Tweeting activity related to climate change.

3. Dataset description

3.1. Twitter data

Twitter is a social network which has around 313 million monthly active users in 2020 (OBerlo, 2021). In order to undertake the objectives of this research, a monthly database has been created containing information about tweeting activity related to climate change in 213 countries, registering more than 100 tweets per location (See Appendix A) since 2018 and until September 2020 (recording around 48,234,241 tweets).

The data collection process has been based in the search for tweets through the use of hashtags and keywords. Thus, requests have been made through the library Tweepy for Python which works with Twitter API (2021) specifying a "keyword" or specific "hashtags". At the same time a tweet was received, another request was made about the user that published the message. With respect to the user, in order to gain information about their gender, the GenderAPI was employed (GenderAPI, 2019). This API can detect gender from social media by querying usernames. The assignment type is probabilistic, and when the username has registered under a name not included in its database, the unknown category is assigned as a default. As described by Santamaría and Mihaljević (2018), its database size is by far one of the largest employed for gender identification studies (particularly when compared with similar tools). This sort of identification method is quite popular, and its accuracy is one of the highest achieved. Results show that about 25 % of the total registered tweets have been written by female (38 % if we only consider users whose gender has been identified).

As there are some restrictions in terms of downloads from Twitter, a timetable has been established to collect the data. Worldwide data collection is done targeting two main languages: English and Spanish. Specifically, Mondays, Wednesdays, Fridays and Sundays the API collected tweets in Spanish that were published in the last 30 days; while Tuesdays, Thursdays and Saturday collected tweets in English. It is important to specify that both tweets and retweets have been recorded.

Although data collection is very extensive, the final dataset contains information from 20 countries,[1] recording a total of 36,205,609 usable tweets (75 % of the total). Table 1 presents the distribution of tweets and information about countries with the highest rate of number of tweets (in total, they represent more than 92.82 % of tweets from the sample of 20 countries). As can be seen, three countries represent over half of the number of tweets in this dataset; the USA accounts for around 33.42 % of tweets, followed by Spain with around 15.37 % of tweets, and the UK represents around 10.31 % of the total. In addition, it can also be observed that the most predominant hashtags are #climatechange, #weather and #climate. Moreover, users also tweet about the disasters suffered related to climate change, including wildfires, droughts or hurricanes. Graph 1 shows the number of total tweets by country, and as can be seen the USA, UK and Australia are the most active countries on these social media; whereas in the case of Spanish-speaking countries, the most predominant is Spain, followed by Argentina, Mexico, Chile and Colombia.

Table 1
Percentage of number of tweets and hashtags by country.

Country	Percentage (%)	Most popular hashtags
United States	33.42	#climatechange, #weather, #hurricane
Spain	15.37	#climatechange, #climate, #flood
United Kingdom	10.31	#climatechange, #weather, #climateaction
Argentina	8.64	#climatechange, #hurricane, #wildfire
Mexico	8.39	#climatechange, #climate, #hurricane
Chile	7.04	#climatechange, #drought, #wildfire
Australia	4.88	#climatechange, #climateaction, #drought
Colombia	4.77	#climatechange, #climate, #globalwarming
Total	92.82	

Source: Own elaboration

In terms of temporal variations, the highest number of tweets was registered during the fall 2019 and early 2020, with a clear drop from March 2020 onwards. Graph 2 shows the distribution of tweets over time for the final sample. Graph 3 shows the evolution of tweets over time but considering the Hemisphere where tweets were posted, in order to control for seasonal variations. This reinforces the importance of the impact of COVID-19 on social media communication about climate change.

3.2. Sociodemographic variables dataset

The Twitter dataset has been augmented with socio-economic variables collected from the Organisation for Economic Co-operation and Development (OECD) (2020) and from the World Bank Statistics. In particular, the national GDP comes from the Quarterly National Accounts published by the OECD (a variable that has been transformed and expressed as GDP/number of internet users). Furthermore, and in order to collect a proxy for education, the public expenditures on education, expressed as a % of GDP from The World Development Indicators dataset (World Bank, 2020) has been included (5.2 %). In addition, we account for the language in the country, with Spanish-speaking countries generating about 25 % of the sample of tweets (See Table 2).

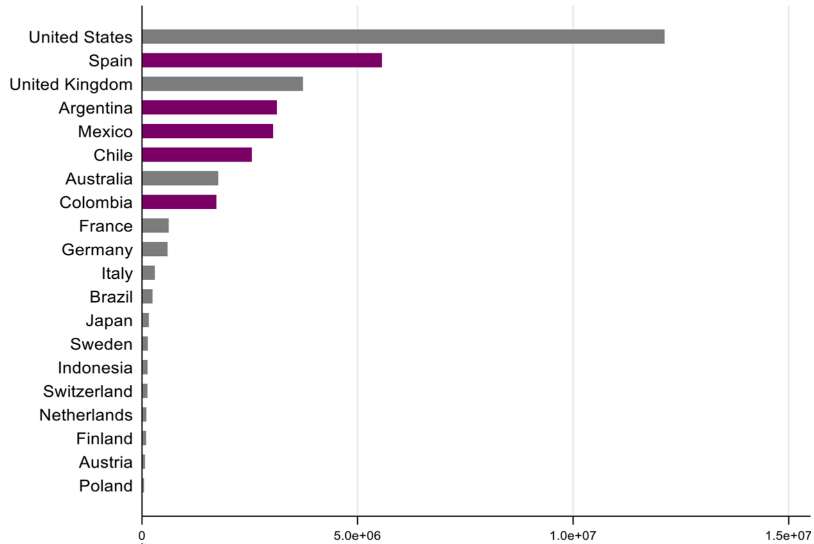
3.3. Experiencing climate change impacts

To analyze the main factors affecting how people communicate about climate change on Twitter, additional variables have been added to this social media dataset. Thus, it is expected that in countries where important climate-related catastrophes or extreme events have occurred, an increase in Twitter activity may be registered around these phenomena. To reflect these types of events and natural disasters, information from the International Disaster Database (EM-DAT) (2020) has been collected. We find that mainly eight type of natural disasters have been experienced during the period of analysis: droughts, earthquakes, extreme temperature episodes, floods, landslide, storms, volcanic activity and wildfires. All of these, except earthquakes, can be related to climate change (either as a cause or a direct consequence). As an example, and according to Stenchikov (2016), volcanic eruptions may produce long-term impacts in oceans and in the atmosphere, activating complex climate feedbacks.

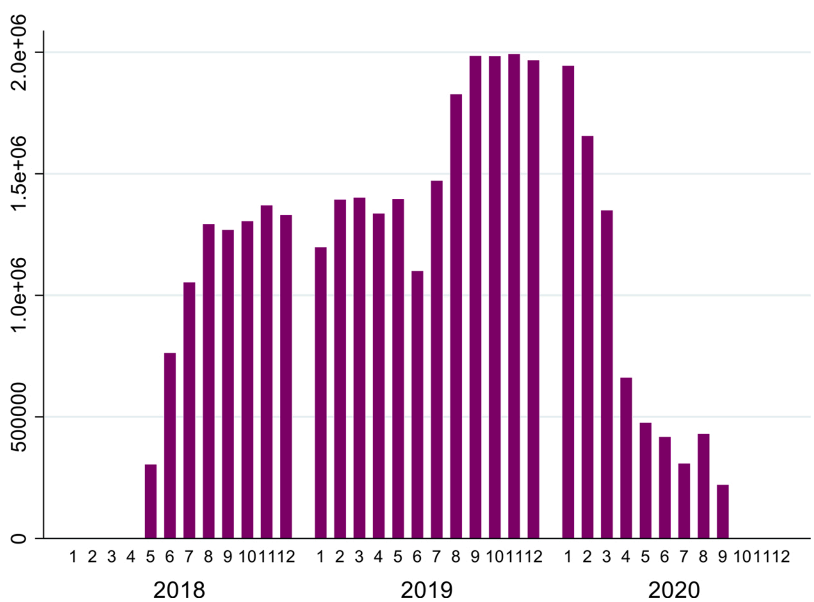
3.4. Organization of UNFCC climate change conferences

Additional variables referring to the organization of the international climate change Conferences of the Parties (COP conferences) by United Nations Climate Change (UNFCC, 2020) have been considered, in order to assess the impact of these events on the attention given in social media to climate change. Five different UNFCC COP conferences took place during 2018-September 2020 around the world, as described in Table 2.

[1] The final dataset contains data from 20 countries due to the existence of missing values when merging information retrieved from Twitter with additional variables. An important limitation is that the World Values Survey has only been conducted in a reduced set of countries.



Graph 1. Number of tweets by country.
Source: own elaboration



Graph 2. Temporal variation of tweets.
Source: own elaboration

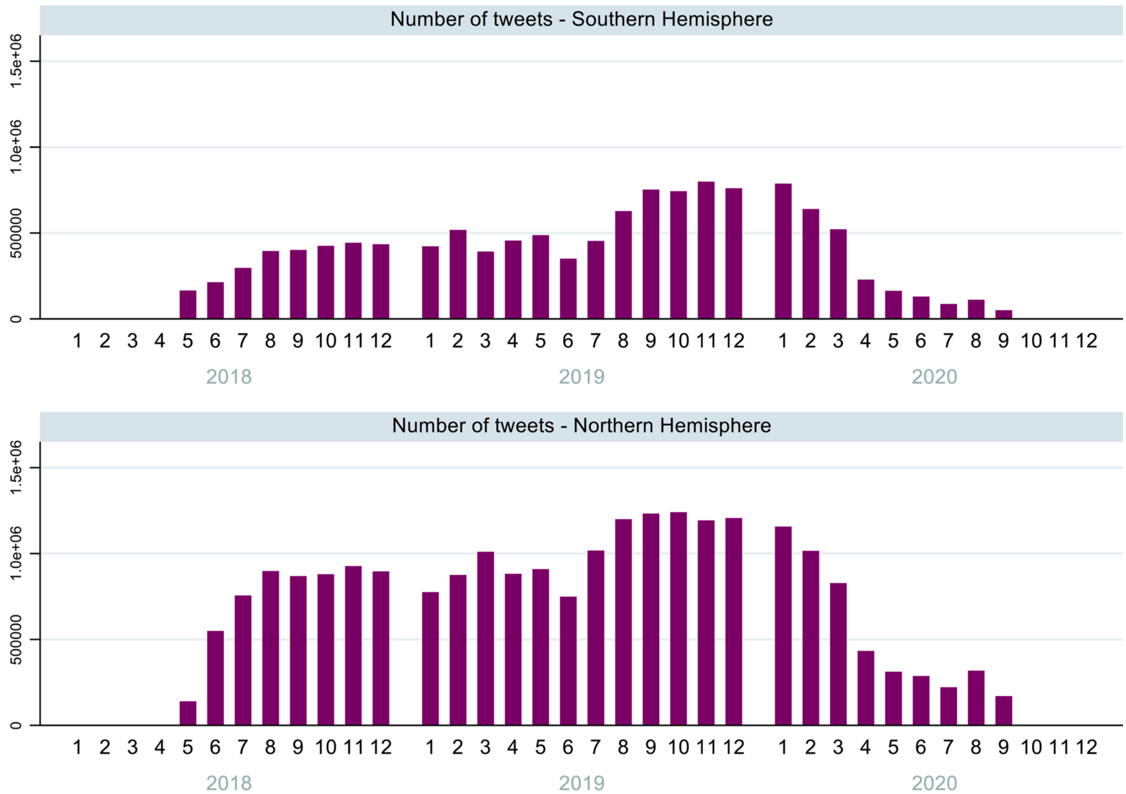
3.5. *Risk, time and social variables*

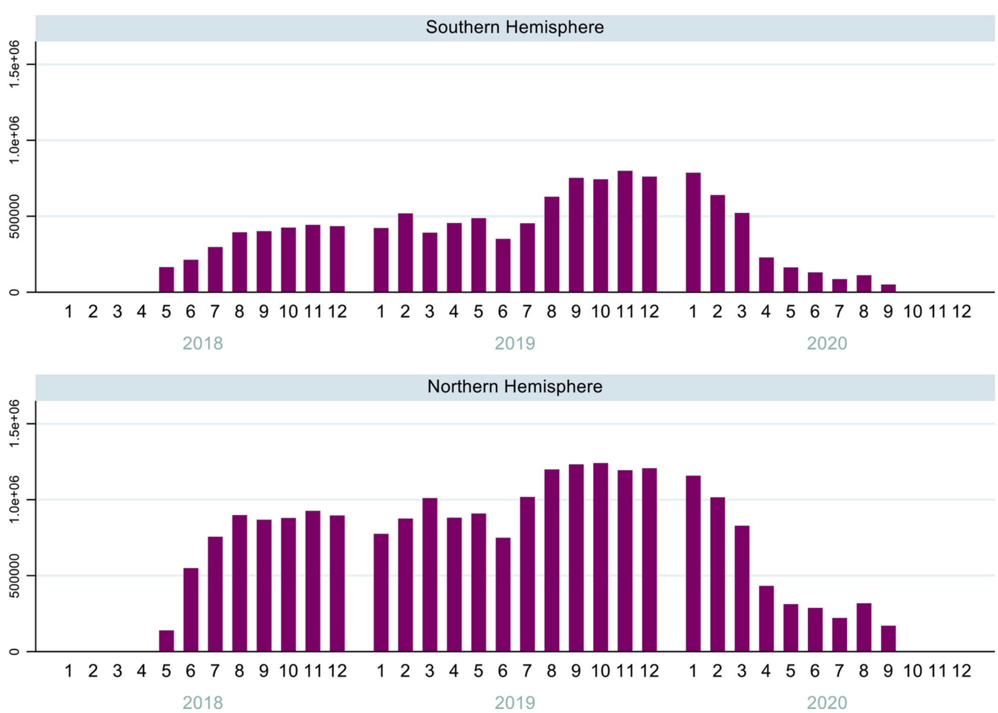
Finally, with the aim of testing the effect of risk perceptions, time preferences, and other social factors when transmitting information about climate change, variables referring to social norms were included. Specifically, variables extracted from the Global Preference Survey (2020) which is a "*globally representative dataset on risk and time preferences, positive and negative reciprocity, altruism and trust*" have been considered (although in the empirical specifications, two of them have been dropped due to high correlation problems[2]). These variables representing preferences are based on 12 survey items (see Falk et al., 2018, for more details). The variables finally considered are: a risk-taking indicator that expresses the "willingness to take risks in general," altruism ("willingness to give to good causes"), trust ("people have only the best intentions"), and negative reciprocity ("willingness to punish unfair behavior toward others") (See Table 2 for detailed description). It is important to note that in order to interpret these measures, Falk et al. (2018) indicate that each preference was standardized at the individual level; therefore, each measure has a mean of zero and a standard deviation of one. Thus, we have information about the difference to the world mean expressed in standard deviations.

3.6. *Political views*

In order to understand how political views shape the debate about climate change, an indicator of political orientation was also included. This information comes from the World Values Survey, Wave 7: 2017-2020 and it is an index that ranges from 1 (left) to right (10). McCright et al. (2015) have analyzed whether the political ideology may imply differences in terms of perception about climate change; finding

[2] Patience shows a correlation coefficient of 0.775 with GDP. Positive reciprocity shows a correlation coefficient of 0.779 with altruism.





Graph 3. Temporal variation of tweets by Hemisphere.
Source: own elaboration

that in Europe, those closer to right- wing parties are less likely to worry about the climate problem than those closer to left- wing parties.

3.7. *Covid-19 pandemic*

To control for the potential impact of the COVID-19 pandemic, while considering the fact that the impact has been heterogeneous across countries, we have included a variable denoting monthly deaths

Table 2
Summary statistics.

Variable	Description	Mean	Std. Dev.
Lntweets	Ln[Number of tweets/internet users)*100,000]	3.559	1.889
	Socioeconomic characteristics		
Women	Percentage of tweets posted by women	24.877	6.588
GDP/Internet Users	GDP/Number of internet users	0.053	0.016
Spanish speaking countries	1, if the country is a Spanish-speaking country; 0 otherwise	0.250	0.433
Education expenditure	General government expenditure on education expressed as a percentage of GDP.	5.168	1.005
	Natural disasters		
Drought	Number of droughts suffered according to the EM-DAT for each specific period of time	0.008	0.087
Earthquake	Number of earthquakes suffered according to the EM-DAT for each specific period of time	0.027	0.172
Extreme temperatures	Number of extreme temperatures episodes suffered according to the EM-DAT for each specific period of time	0.036	0.203
Flood	Number of floods suffered according to the EM-DAT for each specific period of time	0.136	0.433
Landslide	Number of landslides suffered according to the EM-DAT for each specific period of time	0.011	0.103
Storm	Number of storms suffered according to the EM-DAT for each specific period of time	0.098	0.379
Volcanic activity	Number of volcanic activity episodes suffered according to the EM-DAT for each specific period of time	0.015	0.134
Wildfires	Number of wildfires suffered according to the EM-DAT for each specific period of time	0.017	0.150
	Climate change meetings		
CCmeeting_april_Bonn18	1, indicating the meeting about climate change that took place in April 2018 in Bonn; 0 otherwise	0.030	0.172
CCmeeting_sept_Bangkok18	1, indicating the meeting about climate change that took place in September 2018 in Bangkok; 0 otherwise	0.030	0.172
CCmeeting_dec_Katowice18	1, indicating the meeting about climate change that took place in December 2018 in Katowice; 0 otherwise	0.030	0.172
CCmeeting_june_Bonn19	1, indicating the meeting about climate change that took place in June 2019 in Bonn; 0 otherwise	0.030	0.172
CCmeeting_dec_Madrid19	1, indicating the meeting about climate change that took place in December 2019 in Madrid; 0 otherwise	0.030	0.172
	Variables from the Global Preference Survey		
Risk taking	Global Preference Survey: Two items to measure this preference. 1)Self-assessment: willingness to take risks in general 2) Lottery choice sequence using staircase method	−0.058	0.152
Negative reciprocity	Global Preference Survey: Three items to measure this preference. 1)Self-assessment: willingness to take revenge. 2) Self-assessment: willingness to punish unfair behavior toward self. 3)Self-assessment: willingness to punish unfair behavior toward others	0.034	0.226
Altruism	Global Preference Survey: Two items to measure this preference .1) Donation decision. 2)Self-assessment: willingness to give to good causes	−0.040	0.280
Trust	Global Preference Survey: 1) Self-assessment: people have only the best intentions	0.023	0.226
	Variables from the World Values Survey		
Left-right index	Index that measures the political orientation. It ranges from 1 (left) to 10(right)	5.510	0.440
	COVID-19 Variables		
Deaths COVID-19	Number of deaths recorded as a consequence of COVID-19/ 1000	0.996	4.795

recorded per country according to the European Centre for Disease Prevention and Control (2021) as a consequence of COVID-19. In addition, individual cross-products identifying the effect of COVID-19 deaths per country have been included.

4. Empirical model and results

4.1. Empirical models

Our empirical strategy is based on the estimation of a baseline regression that models tweeting about climate change with respect to socioeconomic variables (income, education gender), social norms, political preferences, experiences with climate-related extreme events, and the celebrations of the UNFCC COP conferences.

In particular, the regression to be estimated has been specified as follows:

$$Ln(Y_{it}) = \alpha + \beta X_{it} + \gamma Z_{it} + \delta D_{it} + \eta T_{it} + \varepsilon_{it} \tag{1}$$

Where Y_{it} represents the number of tweets normalized by the number of internet users per country (i) and month (t), which is being modeled as a function of a vector of socio-economic variables X_{it}, social norms, time and risk preferences, and political views represented by Z_{it}, actual impacts caused by climate change D_{it}, and the variable T_{it} that controls for the impact of the COVID-19 pandemic (number of deaths). An extended specification has been also considered, including cross-product variables between the country indicators and the COVID-19 indicator. This may reflect heterogeneous perceptions about the relationship between climate change and the COVID-19 pandemic.

4.2. Results

Baseline results are reported in Table 3. In terms of socio-economic factors that may affect the transmission of information in Twitter, we find that wealth (GDP) and education play significant roles increasing the number of Tweets surrounding the topic of interest. Furthermore, Spanish-speaking countries are more likely to tweet about climate change than the rest. This may be explained by the high degree of climate vulnerability of Latin American countries and Spain. We also find that women tweet less about climate change than males, as in general. Previous work has shown a positive and clear impact of actual experiences with catastrophic events on tweeting activity (Roxburgh et al. (2019). Our results reinforce these previous findings, by showing

Table 3
Baseline results.

Lntweets	Baseline Robust OLS Coef.	Robust Std. Err.	P>|t|	Baseline Tobit Coef.	Std. Err.	P>|t|
		Socioeconomic characteristics				
Women	0.003	0.011	0.802	0.004	0.007	0.535
GDP_Internet users	60.031	3.089	0.000	57.893	3.153	0.000
Education expenditure	0.293	0.060	0.000	0.276	0.049	0.000
Spanish-speaking countries	3.716	0.112	0.000	3.647	0.118	0.000
		Experience with climate change				
Drought	−1.293	0.456	0.005	−1.356	0.462	0.003
Earthquake	−0.209	0.257	0.416	−0.133	0.278	0.632
Extreme temperatures	0.242	0.220	0.271	0.230	0.229	0.315
Flood	0.061	0.086	0.481	0.035	0.110	0.753
Landslide	0.045	0.333	0.892	−0.092	0.484	0.850
Storm	0.105	0.113	0.353	0.105	0.123	0.393
Volcanic activity	−0.674	0.518	0.193	−0.441	0.365	0.227
Wildfires	0.789	0.217	0.000	0.780	0.300	0.010
CCmeeting_april_Bonn18	−1.751	0.257	0.000	−1.707	0.260	0.000
CCmeeting_sept_Bangkok18	0.575	0.185	0.002	0.540	0.252	0.032
CCmeeting_dec_Katowice18	0.671	0.199	0.001	0.630	0.255	0.014
CCmeeting_june_Bonn19	0.133	0.184	0.470	0.121	0.256	0.636
CCmeeting_dec_Madrid19	0.739	0.211	0.000	0.736	0.253	0.004
Constant	−2.178	0.339	0.000	−1.982	0.336	0.000
Sigma				1.390	0.074	
N	759			759		
Root MSE	1.238					
F	84.060					
Prob > F	0.000					
R-squared	0.584					
Loglikelihood				−1191.831		
LRChi2				674.900		
Prob > Chi2				0.000		
Pseudo R2				0.221		

that countries suffering wildfires significantly increase the number of tweets about climate change (also floods for the Robust OLS regression), whereas droughts and volcanic activity have a negative impact on this type of communication. The media attention caused by wildfires, together with the immediate impacts of these events on society, clearly show immediate reactions in Twitter; while in the case of draughts, the associated effects may become relevant after several weeks or months to the population. In addition to prior experiences with catastrophic events, we also find that social norms and cultural variables help explaining the number of tweets about climate change. In particular, we find evidence that altruistic societies and those trusting scientific advice are more willing to contribute and share messages about climate change. We also find that the communication dynamics changes over time, increasing almost always after international UNFCC COP conferences (with the exception of the one celebrated in Bonn 2018), and decreasing in general with the COVID-19 epidemic.

When controlling for the cultural and social-norms dimensions, we find that citizens from countries whose willingness to take risks is higher- note that the risk-taking measure is negative- are less likely to tweet about climate change. This may suggest that averting behavior may be a common precaution taken by countries that are more risk adverse, and information transmission may encourage averting behavior. Citizens from countries with higher scales on altruism and trust are also more willing to tweet and share information about climate change. These findings are intuitive since they may be more willing to share their experiences, but also their neighbors' experiences in terms of climate impacts. On the contrary, and in line with previous literature, countries with right wing political orientations are less willing to tweet about climate change. In summary, we find that social norms matter, and help shaping the climate debate.

When analyzing the effect of COVID-19 on tweeting about climate change (Table 4), results show a negative impact of the number of deaths as a consequence of COVID-19, implying that since the pandemic started, the number of conversations about climate change has decreased. Looking at country-specific effects, we find that for most countries, the trend of climate related tweets is negative over the pandemic period, with interesting exceptions. Countries such as Italy, France, Finland, the USA and the UK have shown a positive trend in conversations of climate change-related topics after COVID-19, whereas other Latin American countries (such as Argentina, Chile, Colombia) and Asian (Indonesia) but also other European countries (Sweden, Switzerland and Austria) have experienced the opposite effect. This may show that although economic growth has been compromised quite severely worldwide, the effects of this impact on inequality and poverty are much more acute in low and mid-income countries. In these areas, the need to restore traditional economic activities is rather urgent, and as a consequence, economic impacts related to climate change become relatively less important in the scope of daily conversations. On the contrary, Twitter conversations from wealthier countries, in general, have shown a more positive outlook about climate change mitigation and adaptation policies, making the climate debate more predominant during the COVID-19 pandemic. This shows that for developed countries, there is a clear complementarity in the discussion of both topics; and not necessarily, a substitution between topics (climate change debate or COVID debate) as in mid-income and low-income countries.

5. Conclusions

In this paper we investigate the relationship between contributing to the climate change debate on Twitter and the occurrence of the COVID-19 pandemic, while considering socio-economic factors, political preferences and aspects related to social norms. Our results confirm our main research hypotheses, showing that the public debate about climate change has been slowed down in many countries after the pandemic. This is a troubling situation, particularly because some countries where the climate policies have been reduced are developing countries and are therefore more vulnerable to climate impacts. We also find evidence about the impact of cultural variables and social norms in the communication of climate change.

Our results also show interesting international differences in terms of

Table 4
Extended results.

Lntweets	Extended Robust OLS Coef.	Robust Std. Err.	P>|t|	Extended Tobit Coef.	Std. Err.	P>|t|
		Socioeconomic characteristics				
Women	−0.023	0.012	0.064	−0.018	0.008	0.020
GDP_Internet users	42.005	5.241	0.000	39.799	4.482	0.000
Education expenditure	0.444	0.097	0.000	0.393	0.069	0.000
Spanish-speaking countries	3.922	0.220	0.000	3.815	0.180	0.000
		Experience with climate change				
Drought	−1.651	0.666	0.013	−1.743	0.501	0.001
Earthquake	0.324	0.213	0.129	0.347	0.261	0.184
Extreme temperatures	0.261	0.221	0.238	0.257	0.211	0.225
Flood	0.162	0.080	0.045	0.146	0.106	0.172
Landslide	0.226	0.319	0.480	0.015	0.443	0.973
Storm	0.174	0.114	0.127	0.182	0.115	0.114
Volcanic activity	−0.917	0.506	0.071	−0.646	0.352	0.067
Wildfires	0.553	0.204	0.007	0.539	0.278	0.053
CCmeeting_april_Bonn18	−1.737	0.238	0.000	−1.776	0.253	0.000
CCmeeting_sept_Bangkok18	0.532	0.183	0.004	0.496	0.242	0.041
CCmeeting_dec_Katowice18	0.718	0.201	0.000	0.673	0.246	0.006
CCmeeting_june_Bonn19	0.107	0.185	0.564	0.094	0.247	0.705
CCmeeting_dec_Madrid19	0.742	0.199	0.000	0.745	0.244	0.002
		Risk, time and social factors (+)				
Risk taking	1.324	0.464	0.004	1.315	0.387	0.001
Altruism	1.118	0.209	0.000	1.020	0.217	0.000
Trust	0.369	0.278	0.185	0.481	0.265	0.070
Negative reciprocity	−0.091	0.253	0.718	−0.157	0.252	0.535
Left-right index	−0.321	0.110	0.004	−0.303	0.117	0.010
Deaths COVID-19	−0.054	0.009	0.000	−0.055	0.018	0.003
Deaths*Spain	0.028	0.018	0.124	0.027	0.057	0.634
Deaths*France	0.085	0.013	0.000	0.086	0.050	0.087
Deaths*UK	0.146	0.025	0.000	0.145	0.041	0.001
Deaths*Argentina	−0.171	0.036	0.000	−0.167	0.119	0.163
Deaths*Italy	0.071	0.014	0.000	0.073	0.053	0.165
Deaths*Mexico	0.003	0.016	0.837	0.003	0.037	0.931
Deaths*Australia	1.419	0.871	0.104	1.251	2.148	0.561
Deaths*Austria	−2.273	1.161	0.051	−2.226	2.016	0.270
Deaths*Chile	−0.325	0.113	0.004	−0.320	0.167	0.057
Deaths*Colombia	−0.170	0.046	0.000	−0.172	0.084	0.040
Deaths*Finland	3.036	1.252	0.016	3.075	4.532	0.498
Deaths*Indonesia	−0.576	0.086	0.000	−0.929	0.331	0.005
Deaths*Japan	−0.341	0.920	0.711	−0.693	1.576	0.660
Deaths*Netherlands	0.062	0.060	0.303	0.060	0.242	0.804
Deaths*Poland	−1.612	0.973	0.098	−1.824	1.088	0.094
Deaths*Sweden	−0.574	0.263	0.030	−0.576	0.319	0.072
Deaths*Germany	−0.016	0.057	0.773	−0.019	0.165	0.910
Deaths*Switzerland	−0.486	0.231	0.036	−0.459	0.845	0.587
Deaths*USA	0.048	0.010	0.000	0.050	0.022	0.024
Constant	0.501	1.036	0.629	0.706	0.888	0.427
Sigma				1.111	0.063	
N	660			660		
Root MSE	1.120					
F	141.280					
Prob > F	0.000					
R-squared	0.671					
Loglikelihood				−961.836		
LRChi2				742.1		
Prob > Chi2				0		
Pseudo R2				0.2784		

(+) Deaths*Brazil is the omitted cross-product.

the relationship between COVID-19 and climate change conversations on Twitter. Conversations about climate change increased after COVID-19 in the case of Australia, the UK, and France, while they decreased in most Latin American countries, and other countries with a less interventionist approaches of COVID-19 policies (Austria and Sweden, for example). Our results resemble the frictions between climate change adaptation policies and post COVID-19 acceleration policies, which have been clearly demonstrated in some countries. Nevertheless, we also show that these contradictions between economic growth and sustainable recovery are not universal. Climate and COVID-19 concerns seem to be more closely aligned in developed countries, while more tensions and contradictions seem to be emerging in developing countries.

In this context, awareness and information campaigns about the linkages between both crises may be quite relevant to build resilience against such global public bads in the near future. Future research may consider the relationship and evolution of Tweets concerning both topics. In summary, we believe that understanding the role played by social norms and cultural dimensions is crucial to form a global and coherent state of opinion about international topics that are becoming important threats for the future of Humanity. It is only then that we would be able to design successful and meaningful control policies worldwide.

CRediT authorship contribution statement

Maria L. Loureiro: Conceptualization, Methodology, Funding, Writing-Reviewing and Editing. **Maria Allo**: Data curation, Estimation and Writing.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A

Country	Number of tweets	Country	Number of tweets	Country	Number of tweets	Country	Number of tweets	Country	Number of tweets
United States	12,100,000	Singapore	62,219	Azerbaijan	11,935	Sierra Leone	4255	Anguilla	691
Spain	5,565,081	Ghana	57,239	Sudan	11,275	Macedonia	4007	Macau	626
United Kingdom	3,731,300	Cameroon	53,988	Bahamas, The	11,271	Andorra	4004	Montserrat	595
Argentina	3,128,437	Uganda	53,308	Somalia	10,795	Madagascar	3981	Eritrea	590
Mexico	3,038,144	South Korea	52,017	Croatia	10,581	Burkina Faso	3913	Dominica	586
Chile	2,548,771	Czech Republic	50,747	Slovakia	10,314	Man, Isle of	3895	St. Vincent and the Grenadines	464
Canada	2,332,737	Greece	49,653	Iceland	9942	Kazakhstan	3687	Svalbard	448
Australia	1,766,554	Haiti	49,087	Papua New Guinea	9895	New Caledonia	3530	Bermuda	445
Colombia	1,725,805	Denmark	48,567	Slovenia	9780	Togo	3516	French Guiana	436
Venezuela	1,370,689	United Arab Emirates	47,993	Oman	9295	Gibraltar	3372	South Georgia and the South Sandwich Is	402
India	1,139,674	South Africa	47,587	Namibia	9053	Seychelles	3038	Comoros	255
Ecuador	702,154	Turkey	46,362	Jordan	9014	French Polynesia	2912	Sao Tome and Principe	219
France	617,979	Poland	45,623	Cambodia	8936	Gabon	2814	San Marino	197
Germany	592,990	Bangladesh	43,641	Rwanda	8897	Netherlands Antilles	2787	Cook Islands	195
Peru	385,123	Tanzania, United Republic of	39,984	Malawi	8827	Guernsey	2729	Pitcairn Islands	147
Puerto Rico	361,334	Nepal	35,053	Afghanistan	8793	Uzbekistan	2653	Federated States of Micronesia	141
Italy	295,924	Saudi Arabia	34,104	Algeria	8793	Brunei	2603	Kiribati	118
Paraguay	294,500	Ukraine	32,566	Belize	8442	Guyana	2603		
Ireland	266,055	Romania	30,398	Tunisia	8430	Greenland	2517		
Uruguay	245,844	Israel	28,665	Byelarus	8297	Niger	2301		
Brazil	243,768	Zimbabwe	28,281	Zaire	7957	St. Lucia	2199		
Kenya	223,761	Iran	28,080	Syria	7950	Aruba	2018		
Panama	217,152	Bosnia and Herzegovina	26,471	Estonia	7833	Burundi	1946		
Belgium	200,155	Vietnam	26,106	Yemen	7743	Suriname	1920		
Nigeria	178,432	Luxembourg	26,067	Latvia	7629	Guadeloupe	1836		
Philippines	175,570	Jamaica	25,712	Malta	7450	Congo	1730		
Dominican Republic	172,428	Sri Lanka	25,695	Mongolia	7401	Bhutan	1685		
Pakistan	171,872	Morocco	23,147	Jersey	7263	Guam	1675		
Bolivia	165,326	Egypt	23,103	Barbados	7251	Central African Republic	1631		
New Zealand	157,839	Taiwan	21,927	Lithuania	6947	Fiji	1495		
Japan	156,723	Hungary	21,490	Mauritius	6677	Reunión	1414		
Thailand	149,290	Grenada	20,904	Botswana	6625	St. Kitts and Nevis	1365		
El Salvador	146,910	Serbia	20,087	Kuwait	6541	Antigua and Barbuda	1357		
Guatemala	142,810	Iraq	18,332	North Korea	5795	Tajikistan	1209		
Cuba	134,951	Kyrgyzstan	17,194	Armenia	5620	Equatorial Guinea	1204		
Sweden	132,192	Qatar	17,003	Libya	5523	Nauru	1204		
Indonesia	128,457	Laos	16,005	Turkmenistan	5354	Falkland Islands (Islas Malvinas)	1144		
Honduras	126,878	Angola	15,502	Senegal	5322	Guinea-Bissau	1117		
Switzerland	124,667	Georgia	15,381	Mali	5147	American Samoa	1061		
Costa Rica	122,267	Zambia	14,908	Mozambique	5077	Mauritania	1054		
Malaysia	105,041	Ethiopia	14,639	Guinea	4916	Swaziland	1052		
Netherlands	100,830	Trinidad and Tobago	14,346	Albania	4812	Northern Mariana Islands	958		
Russia	100,251	Ivory Coast	13,991	Bahrain	4768	Cayman Islands	936		
Portugal	97,832	Liberia	13,022	Montenegro	4643	Gaza Strip	870		

(*continued on next page*)

(*continued*)

Country	Number of tweets	Country	Number of tweets	Country	Number of tweets	Country	Number of tweets	Country	Number of tweets
Finland	93,984	Lebanon	12,833	Lesotho	4584	Liechtenstein	822		
Norway	93,661	Antarctica	12,756	Moldova	4545	Martinique	799		
China	79,428	Bulgaria	12,702	Gambia, The	4456	Faroe Islands	787		
Nicaragua	77,822	Myanmar (Burma)	12,642	Benin	4433	Djibouti	772		
Austria	68,380	Cyprus	12,463	Chad	4400	Cape Verde	720		

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