Positive attitudes towards COVID-19 vaccines: A cross-country analysis.

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Abstract

COVID-19 severely impacted world health and, as a consequence of the measures implemented to stop the spread of the virus, also irreversibly damaged the world economy. Research shows that receiving the COVID-19 vaccine is the most successful measure to combat the virus and could also address its indirect consequences. However, vaccine hesitancy is growing worldwide and the WHO names this hesitancy as one of the top ten threats to global health. This study investigates the trend in positive attitudes towards vaccines across ten countries, as steps must be taken to improve the trend over time. Furthermore, we investigate those variables related to having a positive attitude, as these factors could potentially increase the uptake of vaccines. We derive our corpus data from vaccine-related tweets, harvested in real-time from Twitter. Using Natural Language Processing, we derive the sentiment and emotions contained in the tweets to construct daily time-series data. We analyse a panel dataset spanning both the Northern and Southern hemispheres from 1 February 2021 to 1 August 2021. To determine the relationship between several variables and the positive sentiment (attitude) towards vaccines, we run various models, including POLS, Panel Fixed Effects and Instrumental Variables estimations. Our results show that more information related to the safety and side-effects of the vaccines are needed to improve positive attitudes towards vaccines. Additionally, government procurement and the vaccine rollout should improve. Accessibility to the vaccine should be a priority, and a collective effort should be made to increase positive messaging about the vaccine, especially on social media. The results of this study are of the utmost importance to policymakers, health workers, and stakeholders who communicate to the public during infectious disease outbreaks. Additionally, the global fight against COVID-19 might be lost if the attitude towards vaccines is not improved.

Keywords: COVID-19; Vaccines; Big Data; Attitudes

JEL classification codes: C55, I18, I31, J18

1. Introduction

In an attempt to curb the spread of COVID-19, minimise the loss of life and take the pressure off the national health systems, governments worldwide started their vaccine rollout campaigns late in December 2020. However, this rapid rollout of the COVID-19 vaccine has created different emotional

responses across the globe. This is problematic since receiving the COVID-19 vaccine is the best possible solution to open up economies and prevent further loss of life. Compounding the problem is the spread of fake news by anti-vaxxers, which has perpetuated the situation by increasing vaccine-hesitancy around the globe (for example, see Sharma [1] and Bonnevie et al. [2]). Spreading fear and anxiety is a significant problem because we know from the existing literature that vaccine efficacy depends not only on the vaccine, but also on the characteristics of the vaccinated (Madison et al. [3], Glaser et al. [4]). Unfortunately, the COVID-19 pandemic has already led to increased depression, loneliness, and stress levels, thereby increasing the efficacy problem (Madison et al. [3]). Adding to this, vaccine hesitancy is growing worldwide and is seen as one of the top ten threats to global health. This makes it easy to see that governments today face a significant challenge.

To this end, our primary aim is to conduct a cross-country panel analysis to investigate the trend in positive attitudes towards COVID-19 vaccines over time. This will enable us to determine whether people are becoming more positive towards accepting the vaccine. A secondary aim lies with determining those variables which are significantly related to a positive vaccine attitude and can inform policymakers.

Previous studies (Lyu et al. [5], Xue et al. [6], Chopra et al. [7]) analysed the emotions in vaccine-related tweets. However, their primary aim was to better understand the public perceptions, concerns, and emotions related to *COVID-19 vaccine topics and discussions* on social media. They determined the sentiments related to topics and discussions and investigated the strength of discussions and sentiments over time. The main limitations of these studies include that they: i) only analysed English tweets, with no attention being paid to specific geographical areas or comparing the sentiment across different countries, ii) did not use sentiment analysis in further analyses, and iii) did not investigate the variables related to positive vaccine attitudes. We overcome these limitations by constructing a daily time series called the Vaccine Positive Attitude Index (VPAI), a real-time measure of people's positive attitudes toward the COVID-19 vaccine across ten countries for the period 1 February 2021 – 1 August 2021. The countries include Australia, Belgium, Germany, Great Britain, France, Italy, the Netherlands, New Zealand, South Africa and Spain.

We derive the VPAI using Big Data by extracting a live stream of tweets for specific geographical areas which contains a list of vaccine-related keywords. After the data is cleaned, we use natural language processing to derive the sentiment and emotions of the tweets. After calculating the mean levels of positive sentiment per day, we investigate the trend over time in the VPAI and compare it across our panel of ten countries under investigation. Additionally, we determine which variables are related to the VPAI and, therefore, when addressed, could create a more positive attitude and increase the uptake of COVID-19 vaccines. To limit the effect of confounding factors, we introduce various estimation techniques to address likely endogeneity. We use POLS as a base model and extend the analyses to include Panel Fixed Effects and Instrumental Variables regressions.

Our results indicate that the VPAI trends downward over time for the whole sample. If we consider the Northern and Southern hemisphere subsamples, we find the same results. Considering the trends per country, we find in all countries a downward trend except Belgium and the Netherlands, which shows a slightly positive trend. Therefore, it is clear that interventions are needed to change the attitude toward vaccines and increase the uptake. From our modelling, we find those variables that can improve the positive attitude towards the COVID-19 vaccines are information-related to the safety and side-effects of the vaccines, improving trust in vaccines, reviewing regulations implemented to limit the spread of the vaccines as it seems that people weigh-up the benefits of being vaccinated against lockdown regulations. Additionally, increased trust in governments to procure and effectively roll out vaccinations should be a priority. Furthermore, social media platforms, such as Twitter, should launch targeted campaigns focusing on educating people about the safety of vaccines, providing progress on the rollout and encouraging all ages to get vaccinated. We are confident that if the factors found significant in the econometric models (confidence levels of 95 per cent or more) are addressed, the positive attitudes towards vaccines will improve. Policy interventions in line with these recommendations will contribute to the universal plan to restore global health and the world economy.

The rest of the paper is structured as follows. The next section contains a brief background of the countries used in our analyses and studies on COVID-19 vaccine hesitancy. Section 3 describes the data

and the selected variables, and outlines the methodology used. The results follow in section 4, while the paper concludes in section 5.

2. Background and literature review

2.1 Country background

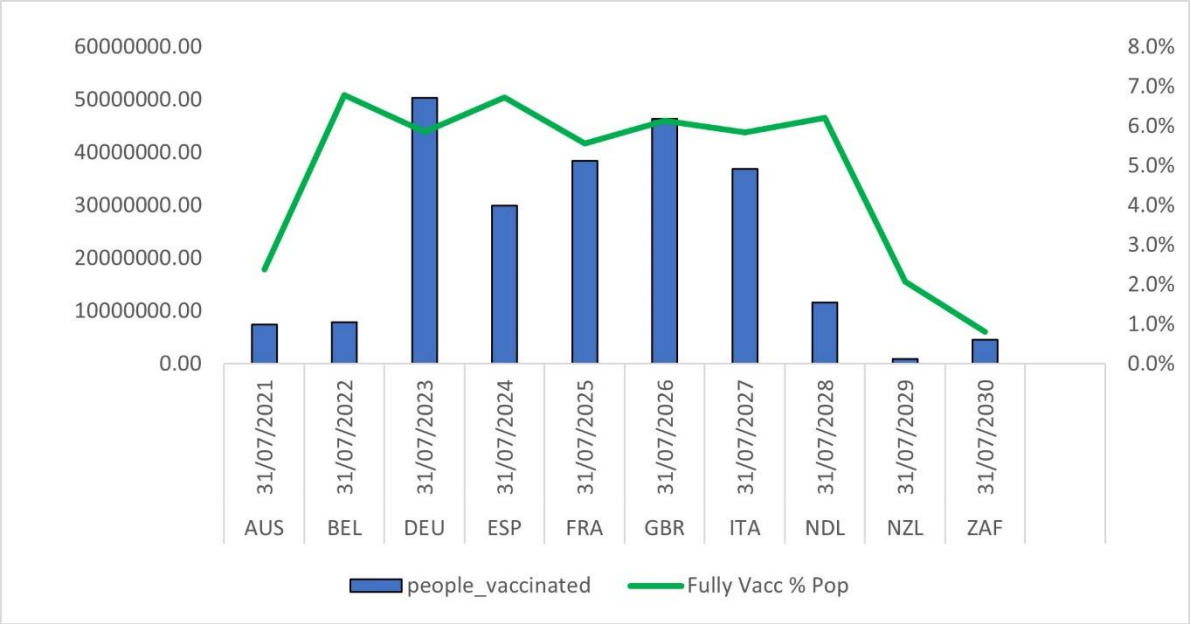
This study focuses on three Southern hemisphere countries; South Africa, New Zealand and Australia and seven Northern hemisphere countries; Belgium, Germany, Great Britain, France, Italy, the Netherlands, and Spain. Primarily the choice of countries is determined by data availability. However, in future studies, the dataset can be extended to include more countries. The current selection of countries from both hemispheres provides unique insights into people's attitudes to the COVID-19 vaccine. Table 1 provides a summary of key facts for each of the countries used in the current study.

Table 1: Key summary facts of countries in this study

Country	Total population	Average happiness levels^ (2020)	Oxford Stringency Index (Average for the period)	First confirmed COVID-19 case (2020)	Date of first lockdown (2020)	Total confirmed COVID-19 cases (28 August 2021)	Total confirmed COVID-19 deaths (28 August 2021)	Date of vaccine rollout	Percentage of the population fully vaccinated (22 August 2021)
Australia	25.5 million	7.09	58.64	25 January	17 March*	51,256	999	22 February 2021	23.82%
Belgium	11.6 million	6.98	58.30	4 February	13 March	1.18 million	25,360	28 December 2020	67.75%
France	66.99 million	6.66	63.15	24 January	17 March	6.81 million	114,506	27 December 2020	55.57%
Germany	83.02 million	7.08	72.71	27 January	22 March	3.93 million	92,136	27 December 2020	58.56%
Great Britain	66.65 million	7.17	66.70	31 January	23 March	6.73 million	132,699	8 December 2020	61.30%
Italy	60.36 million	6.39	74.90	30 January	9 March	4.52 million	129,002	27 December 2020	58.42%
Netherlands	17.28 million	7.73	64.88	27 February	15 March¶	1.97 million	18,339	6 January 2021	62.06%
New Zealand	5.5 million	7.14	26.80	28 February	26 March	3,465	26	19 February 2021	20.74%
South Africa	57.7 million	6.32	51.90	6 March	27 March	2.76 million	81,461	17 February 2021	8.05%
Spain	46.94 million	6.40	64.33	31 January	14 March	4.83 million	84,000	27 December 2020	67.27%

* Australia never officially went into a full lockdown such as that seen in the other countries. We used the day when the closure of international borders was announced as a proxy for "lockdown."
¶ The Netherlands started a so-called 'intelligent lockdown' on this date. ^ The happiness scores cited here reflect the average for the period in 2020 before the first COVID-19 case was announced.
Sources: Hale et al. [8], Greyling et al. [9], Google [10] [11], Roser et al. [12].

From figure 1, it can be seen that the country performing the worst in terms of the total number of people fully vaccinated is New Zealand (1 million people). However, if we consider the vaccinated as a percentage of the total population, South Africa performs the worst with 8.05 per cent as of 31 July 2021. Of interest is the Northern-Southern hemisphere split. All three the Southern hemisphere countries (Australia, New Zealand and South Africa) are outperformed by the countries in the Northern hemisphere. Of the Northern hemisphere countries, France is the worst performer with 55.57 per cent fully vaccinated, whereas Belgium is the best performer (67.75 per cent).



Source: Hale et al. [8]

Figure 1: COVID-19 number of people vaccinated and the percentage of fully vaccinated people per country (31 July 2021)

2.2 Literature on COVID-19 vaccine hesitancy

There is an exponential growth of studies in the literature on COVID-19 vaccine hesitancy as researchers from all disciplines addresses one of the biggest global health threats.

Research regarding COVID-19 vaccine hesitancy spans across both *online surveys* (see, for example, Akarsu et al. [13], Fisher et al. [14], Freeman et al. [15], Ward et al. [16], Seale et al. [17]) and *in-person surveys* (see, for example, Paul et al. [18], Sallam [19]). Primarily these studies found people's hesitancy and refusal of the COVID-19 vaccine were mostly attributed to i) fear driven by possible side-effects

of the vaccine, and ii) the unreliability of what is seen as a new vaccine. Poor compliance with COVID-19 government guidelines was also identified as one of the largest predictors of both COVID-19 vaccine hesitancy and refusal. Additionally, they found willingness to take the COVID-19 vaccine was closely related to one's sense of collective responsibility and campaigning for the 'greater good'. Furthermore, these studies highlighted a need for better and transparent information, the role of anti-vaccination campaigns, and a lack of trust in the government. Interestingly, it was found that low rates of COVID-19 vaccine acceptance were reported in the Middle East, Russia, Africa and several European countries.

Our current study uses *Big Data* to construct a Vaccine Positive Attitude Index (VPAI); therefore, the rest of the literature review will focus on those that also use Big Data, with special attention to three studies closest to ours in spirit. We note there is a burgeoning of literature using Big Data in the form of Twitter to analyse vaccine-related topics. Therefore, we cannot possibly discuss all of them.

For example, Yousefinaghani et al. [20] used vaccine-related tweets to track frequent hashtags, frequent mentions, main keywords, and main themes with positive and negative sentiments in the tweets. Hussain et al. [21] used Facebook and Twitter to study people's hesitancy, perceptions and sentiment towards the COVID-19 vaccine. Küçükali et al. [22], Nuzhath et al. [23], Bonnevie et al. [2] and Thelwall et al. [24] all identified prominent themes about vaccine hesitancy and refusal on social media during the COVID-19 pandemic. These studies found that the most frequent themes that illicit a negative sentiment are anti-vaccination, poor scientific processes, conspiracy theories, mistrust of scientists and governments, lack of intent to get a COVID-19 vaccine, freedom of choice, and religious beliefs.

Sharma et al. [1] and Bonnevie et al. [25] focused on using Twitter to identify suspicious coordinated accounts in the dataset to find misinformation campaigns that drive the conversation against getting the COVID-19 vaccine. Based on an analysis of the collective behaviours and activities of accounts, they found that they correspond to a 'Great Reset' conspiracy theory and ten additional themes such as research and clinical trials and vaccine ingredients.

Three studies that come the closest to ours in spirit are Lyu et al. [5], Xue et al. [6] and Chopra et al. [7]. Lyu et al. [5] used 1.5 million English vaccine-related tweets collected between March 2020 and January 2021 and categorised the tweets into 16 topics grouped into five overarching themes. Their results showed that under their first theme called "Opinions and Emotions Around Vaccines and Vaccination", the topic out of all 16 topics that were mostly tweeted was opinions about vaccination. In terms of their sentiment analysis (using the Syuzhet lexicon) they found that, apart from fluctuations throughout the period, the sentiment increased regarding the COVID-19 vaccine. Their emotions analysis (using the NRC lexicon) found trust was the most prevalent emotion, followed by anticipation and fear. They found that before Moderna, one of the first to test their COVID-19 vaccine on humans in April 2020, fear was the most prevalent emotion.

Xue et al. [6] analysed 4 million English vaccine-related tweets using a list of 20 hashtags from 7 March to 21 April 2020. Their main aim was to identify popular unigrams (one word) and bigrams (two words), salient topics and themes, and sentiments in the collected tweets. In terms of unigrams, they found "virus", "lockdown", and "quarantine" to be the most popular. Bigrams "COVID-19", "stay home", "corona virus", "social distancing" and "new cases" was the most popular. Furthermore, they identified 13 discussion topics from the tweets and categorised them into five different themes. For example, theme 1, "Public health measures to slow the spread of COVID-19", included topics such as face masks, quarantine, test kits, lockdown, safety, vaccine and US shelter-in-place. Their emotions analysis (using the NRC lexicon) showed that anticipation followed by fear, trust, and anger were prevalent across 12 of the 13 topics.

Chopra et al. [7] collected 1.8 million English vaccine-related tweets from across India, the United States, Great Britain, Brazil, and Australia from June 2020 to April 2021. They aimed to create ten lexical categories, split between two classes, namely emotions (6 categories) and influencing factors (4 categories) and study the temporal evolution of these categories across time. The lexical emotions category includes hesitation, sorrow, faith, contentment, anticipation and rage, while their influencing factors are misinformation, vaccine rollout, inequities, and health effects. To measure each category's strength in a given tweet, the authors used the word-count approach. They calculated the strength of the

categories monthly and split their period under investigation in two; Before and After the date when each country's government approved the first COVID-19 vaccine. Their results differed across countries with, for example, India experiencing a decrease in the strength of hesitation experienced after vaccine approval, with mentions of health effects contributing the most in tweets with a positive hesitation score. The United States experienced a significant increase in contentment after their vaccine approval. Rage and discussions on misinformation became significantly higher after vaccine approval in India, whereas the opposite was true for the United States.

Given the above literature review, no other study has done what we propose to do. We will be the first study to use Big Data to determine the sentiment and emotions related to COVID-19 vaccines through a vaccine positive attitude index. Additionally, no other study has followed the trends in attitudes over time and derived emotion and sentiment time-series data across countries to determine the variables that significantly influence a positive attitude towards the COVID-19 vaccine.

3. Data and methodology

3.1 Data

In the analyses, we use a cross-country panel dataset with high-frequency daily data (see section 3.2). We analyse the time period from 1 February 2021 to 1 August 2021 (181 days) across ten countries.

3.1.1 Constructing time-series data using sentiment and emotions analysis

To derive our time-series data which capture sentiment and emotions, we construct variables using Big Data by extracting tweets from Twitter. In our analysis we extracted two sets of tweets based on keywords, the one related to COVID-19 vaccines and the other related to government. The tweets containing these words amounted to 1 047 000 tweets. All tweets were extracted according to specific geographical areas (country).

The first step in our analysis is to determine the tweets' language (we detected 64 different languages), and all non-English tweets were translated to English. After the translation process, we use natural language processing to extract the sentiment and the underlying emotions of the tweets. To test the

robustness of the coding of the sentiment of the translated tweets, we use lexicons in the original language, if available, and repeat the process. We compare the coded sentiment of the translated and original text and find the results strongly correlated.

We make use of a suite of lexicons. Each of them differs slightly but with the main aim to determine the sentiment of unstructured text data. The two lexicons mostly used in our analysis are Sentiment 140 and NRC (National Research Council of Canada Emotion Lexicon developed by Turney and Mohammad [26]). The other lexicons are used for robustness purposes and are part of the Syuzhet package. The lexicons include Syuzhet, AFINN and Bing. The sentiment is determined by identifying the tweeter's attitude towards an event using variables such as context, tone, etc. and it helps one to form an entire opinion of the text. Depending on the lexicon used, the text (tweet) is coded. For example, if a tweet is positive, it is coded as 0, if neutral 2 and if negative 4.

We use the NRC lexicon for the sentiment and emotion analysis to identify the underlying emotions of the tweets. It distinguishes between eight basic emotions: anger, fear, anticipation, trust, surprise, sadness, joy and disgust (the so-called Plutchik [27] wheel of emotions). NRC codes words with different values, ranging from 0 (low) to 8 (high), to express the intensity of an emotion or sentiment.

To construct the time-series data, we use the coding of the tweets and derive daily averages. In this manner, we derive a positive sentiment, a negative sentiment and eight emotion time-series (as a robustness test, we derive the sentiment time-series using different lexicons and compare these results using correlation analyses). We perform various additional robustness tests, for example, to determine whether the sampling frequency significantly influences the results. Tweets are sampled, the sentiment is derived, and we construct the time-series data using daily averages. To test the robustness of the frequency we construct the index, we repeat the exercise but construct the time series per hour. We find similar trends in our hourly and daily time series—indicating that the timescale at which sampling takes place does not significantly influence the information obtained. A random sample of tweets per day is extracted to test if the volume directly influences the results. The time series based on these smaller samples (50 per cent and 80 per cent of the originally extracted tweets) is compared to the original time series, and we find that these are highly correlated.

3.2 Selection of variables

3.2.1 The Outcome Variable: Vaccine Positive Attitude Index (VPAI)

To construct the VPAI index, we follow the method as explained above and extract COVID-19 related tweets using the keywords: *vaccinate, vacc, vaccine, Sputnik V, Sputnik, Sinopharm, Astrazeneca, Pfizer (if NEAR) vaccine, Pfizer-BioNTech, Johnson & Johnson,* and *Moderna*.

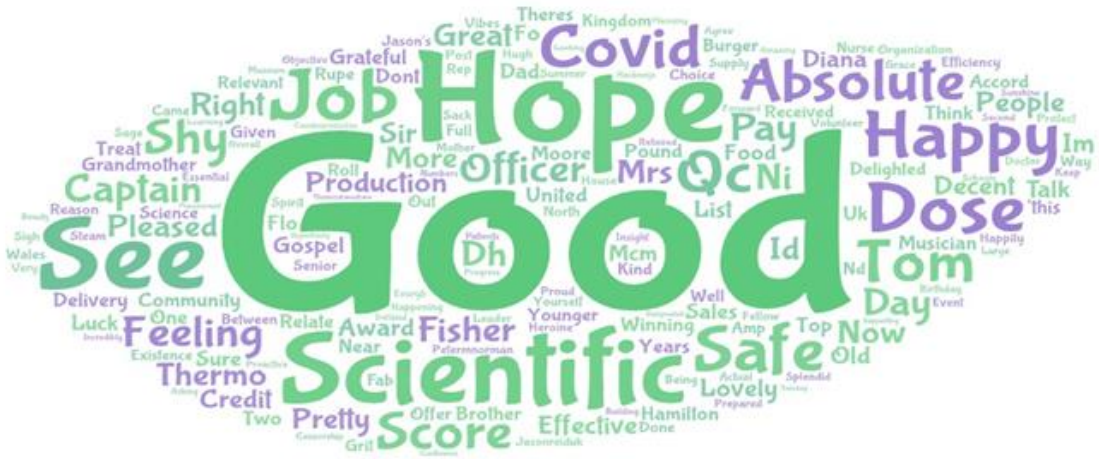
To ensure that the extracted vaccine-related tweets discuss attitudes related to receiving the COVID-19 vaccine, we first constructed word clouds per country. As an example, figure 2 illustrates the word cloud generated for Great Britain. After generating word clouds for all countries, we returned to the original tweets and confirmed the context of the words with high frequencies. We determined that these vaccine-related tweets are indeed related to receiving the vaccine and expressed that "it's good to receive a vaccine" and that people are happy after receiving their second vaccination. For example, tweets that generated the word cloud for Great Britain included:

"*Here it is, worth its weight in gold. My consent form for the covid vaccine next week, normality on the horizon hope"*

"So excited to hear my mum, an NHS nurse, will be receiving the Pfizer Covid-19 vaccine today - a glimmer of hope af"

"Grandmother the vaccine, as you can see, absolutely delighted ?? (all credit to my younger brother for this absolute"

Please note the above tweets were taken directly from Twitter and do not represent the views of the authors or their institutions.



Source: Authors own compilation using word cloud software

Figure 2 Word cloud based on positive sentiment for vaccine-related tweets, Great Britain.

From the positive sentiment vaccine-related tweets, we determined that more than 90 per cent were directly related to receiving the COVID-19 vaccine. We realise that the data carries limited noise, but we believe that this noise does not affect our results, especially considering the large number of tweets analysed.

As discussed in section 3.1.1, we use the NRC lexicon to calculate our VPAI by deriving the mean value of the positive sentiment coded tweets per day and standardising these values using the minimum-maximum method. The index is measured on a scale from 0 to 1, with 0 the lowest positive sentiment and 1 the highest. As a robustness test for the VPAI, we derive a similar index using Sentiment 140. However, in this instance, we calculate the VPAI by expressing the number of positive tweets per day as a percentage of the sum of the number of positive and negative sentiment tweets (see Appendix A for the graphs on the trends in positive attitudes using the VPAI based on Sentiment 140).

3.2.2 Selection of covariates

To select the covariates in the analyses, we used several methods, including relevant literature (see section 2.2), theoretical models, and the analysis of negative sentiment and negative emotion tweets. By analysing, the latter we can determine the major issues that limit the uptake of vaccines and which are likely related to decreased positive attitudes. The reader should note that the negative sentiment

related to vaccine tweets is not the inverse of the positive sentiment. In our analyses, we find that negatively coded tweets mostly relates to anger, fear or sadness due to the procurement or rollout of the vaccines.

In terms of theoretical framework, we use a measure that captures relevant predictors of vaccination behaviour, called the 5C scale. The 5C scale measures the "psychological antecedents of vaccination" as designed by Betsch et al. [28] and is grounded in established theoretical models of vaccine hesitancy and acceptance (Thomson et al. [30], MacDonald et al. [31], Larson et al. [32]) and relates these predictors to psychological models to explain health behaviour (Betsch et al. [29]). Specifically, we note from the 5C that confidence, constraints, and calculation are important when investigating vaccination behaviour.

For the analysis of the negative sentiment and negative emotion vaccine-related tweets, we follow the same process as described in section 3.2.1. For an example of the issues that cause negative sentiment and emotions in people, see the word cloud in figure 3 generated from tweets extracted for South Africa.

Source: Authors own compilation using word cloud software

Figure 3 Word cloud based on negative sentiment for vaccine-related tweets, South Africa.

Sample tweets that generated the word cloud for South Africa's negative sentiment include, for example:

"With an incompetent government, a Minister of Health without a medical degree, NDZs dictatorial tendencies & a rural population still totally unaware of what a pandemic is added to a vaccine shortage, we are doomed"

We are bored about 1) corruption 2) poor vaccine strategy 3) terrible national government 4) incompetent cabinet 5) stealing during a pandemic!"

This vaccine rollout has been disastrous from the government, has cost lives, now another lockdown killing our already hurt economy. Massive change is needed in the running of this country

The rate with which people are dying every day should get SAHPRA concerned and energised to approve more vaccine even on trial basis, this apparent incompetence is really killing and destroying families.

Please note that the above tweets were taken directly from Twitter and do not represent the views of the authors or their institutions.

After conducting an in-depth analysis of the negative sentiment vaccine-related tweets for all ten countries, we discovered that the negative sentiment was mainly related to anger towards governments' incompetence in procurement, the lack of procuring a sufficient number of vaccines and the execution of the vaccine rollout, fear regarding side-effects, fear of people dying because they cannot get access vaccines and people refusing to be vaccinated. Interestingly, the words prominent in the word cloud, such as 'death', 'die', and 'killing', are related to not receiving the vaccine rather than fearing the side effects.

In analysing the negative sentiment tweets, we found that tweets expressing dissatisfaction with governments are false negatives. This means that, in reality, people have positive attitudes towards vaccines. Still, they are negative about government incompetence related to issues such as the rollout process, the procurement and accessibility of vaccines etc., hence the negative sentiment of the tweets. To test this hypothesis, we also create a VPAI in which we add the tweets coded as false negatives to the tweets coded as positive. We name the index VPAI2. See the results of the trends in Appendix B.

Figures 10 to 12 indicate a predominant upward trend. This suggests that if policymakers address the grievances of people related to the abovementioned government incompetence, they can turn around the downward trend in the VPAI.

Therefore, the selected covariates included in the regression analyses are:

1. Trust in the COVID-19 vaccine: as a proxy for how people perceive the safety of the vaccine. To construct this variable, we follow the method as explained in section 3.3.1. We use the *NRC lexicon* to return the emotion score for each COVID-19 vaccine-related tweet for 'trust'. We construct a daily time-series by averaging the measured value of 'trust' per tweet per day (Greyling [9], Betsch et al. [28]). We lag the variable to address likely endogeneity that might spread from confounding factors.
2. Anger towards the government: is included in our interaction variable (see point 8). However, to construct the 'anger towards the government' variable, we first extract all tweets that include the following keywords: government, parliament, ministry, minister, senator, MPs, legislator, political, politics, prime minister. We use the same method to construct the time-series as for the 'trust in the COVID-19 vaccine' variable (Greyling et al. [9], Betsch et al. [28]). We use the anger emotion as a proxy for dissatisfaction with the government. We lag the variable.
3. Compliance: as a proxy for collective responsibility. We follow Sarracino et al. [33] and define compliance as the degree of association between people's behaviours and COVID-19 containment policies to construct the compliance variable. We use information gathered from Google Mobility Reports (the change in duration from the residential category) (Google [10] [11]) and the Stringency Index, which consists of the following nine indicators: school closing, workplace closing, events cancelled, restriction of gatherings, closed public transport, staying at home requirements, restrictions of internal movements, international travel controls, and public information campaigns. The Stringency Index ranges from 0 to 100, with 100 being the most stringent and was sourced from Oxford's COVID-19 Government Response Tracker (Hale [8]). Therefore, we estimate the following equation:

$$res_{ct} = \alpha + \beta_{ct} \cdot Country_c \cdot Day_t \cdot Policy_{ct} + \delta_c \cdot Country_c + \lambda_{ms} + \varepsilon_{ct} \quad (1)$$

where res_{ct} is residential mobility in country c on day t; $Country$ is a vector of dummies for each country included in the dataset; Day is a vector of dummies for the days from 1 February 2021 to August 2021. We focus on this period because prior to February 2021, the vaccine rollout did not occur in all countries under investigation. A vector of dummies is depicted by λ for each combination of month m and hemisphere s, to account for the different seasons and evolution of the pandemic among the Northern and Southern hemispheres. The coefficient β_{ct} is our measure of compliance. It provides the correlation between policy stringency and mobility by country and day. We are aware that creating a daily compliance measure has the risk of introducing noise in the correlation. However, to fulfil our aim of determining the daily evolution of positive attitudes towards vaccines, we do all our analyses daily.

4. All tweets related to vaccines (Greyling [9]) are a proxy for calculations that refer to individuals' engagement with COVID-19 content. We assume that individuals highly engaged with COVID-19 content evaluate the risks of infections and vaccination to make a good decision (Betsch et al. [28]).
5. Daily COVID-19 vaccine doses administered per thousand people (Hale et al. [8], Betsch et al. [28]): a proxy for how well a country's vaccine rollout is being handled. We lag this variable to address likely endogeneity that might spread from confounding factors. The rollout or lack thereof also proxies various constraints such as problems with the physical availability of the COVID-19 vaccine, lack of geographical accessibility, or signalling a less than adequate appeal for vaccination services uptake. We find that the VPAI and the daily vaccines have an inversely proportional relationship; therefore, we transformed this variable using a hyperbolic function.
6. Daily total new cases: a proxy for the evolution of the COVID-19 pandemic across all ten countries (Hale et al. [8]). In our models, we lag new cases to capture people's expectations of the trend of the pandemic.

7. Vaccine policy: we control for the vaccination policy across our ten countries. According to Hale et al. [8], a vaccination policy is classified as follows: 0 - no vaccine available; 1 – vaccine available for one of the following groups: key workers / clinically vulnerable groups / elderly groups; 2 - available for two of the abovementioned groups; 3 - available for all the abovementioned groups; 4 - available for all three groups plus partial additional availability (select broad groups/ages) and 5 – the vaccine is universally available.
8. To capture anger directed towards the government, we use an interaction variable 'government anger' interacted with 'new daily vaccinations'. This variable captures the anger expressed towards the government given the number of new vaccinations per day. We use the above as a proxy for people's dissatisfaction with the vaccination rollout, which also encapsulates procurement, capacity and corruption issues, and accessibility of the vaccines.

Table 2 provides summarised statistics for the variables included in our study.

Table 2: Descriptive statistics of the variables included in the estimations of attitudes against the COVID-19 vaccine

Variable	Observations	Mean/ Frequency (%)	Std Dev.	Min	Max
VPAI	1,780	0.35	0.12	0.10	0.91
Lagged trust in the COVID-19 vaccine	1,780	0.37	0.09	0.16	0.91
Stringency index	1,780	60.88	17.48	22.22	87.96
Residential mobility	1,780	8.32	24.62	-29.67	50.85
Lagged compliance	1,780	1.78	0.446	1.11	4.10
Lagged anger towards the government # Daily vaccinations	1,780	0.84	0.54	0.00	2.52
Vaccine tweets*	1,780	106.32	108.20	6	690
Lagged new daily vaccinations*	1,780	231776.60	219928.20	0	873515
Lagged new daily cases*	1,780	148	154	0	701
Vaccine policy					
0	605	25.80	-	-	-
1	119	5.88	-	-	-
2	444	21.13	-	-	-
3	574	22.08	-	-	-
4	353	13.98	-	-	-
5	305	11.13	-	-	-

Source: Authors' calculations. *Note: Statistics on tweets, new daily vaccinations and cases are given in their original format, though in the models, vaccine tweets were logged, and the hyperbolic function of new daily vaccination were derived and lagged; the new daily cases were logged and lagged, and all variables were smoothed.

3.3 Methodology

We use descriptive statistics to analyse the trend in the VPAI over time and compare the results for the Northern and Southern hemispheres and across the ten countries in our sample. Secondly, we use various econometric techniques to derive and test the robustness of the relationships between our selected covariates and the attitudes towards vaccines.

The correlation between the VPAI and the covariates over time is likely to be affected by confounding factors, such as the severity of the pandemic, exposure to different types of social media, emotional well-being (depression) of the people, accessibility of the vaccine, the prejudice built into the social-cultural environment and the seasons of the year. Therefore, we resort to various econometric techniques to address biases arising from the confounding effects of these variables.

Ideally, we would like to estimate the following equation:

$$VPAI_{ct} = \beta_0 + \beta_1 Vac\_Trust_{ct-1} + \beta_2 Gov\_Anger_{ct-1} + \beta_3 Compliance_{ct-1} + \beta_z X_{ct} + \lambda_m + \mu_c + \epsilon_{ct} \quad (2)$$

where $VPAI_{ct}$ is the vaccine positive attitude index as defined in section 3.2.1 for country c on day t; Vac_Trust_{ct-1} (see section 3.3.1) is the average level of trust related to the COVID-19 vaccine for country c on day $t-1$. $Gov_Anger_{ct-1}$is the average level of anger in government for country c on day $t-1$; $Compliance_{ct-1}$ is the average level of compliance as defined in section 3.2.2 for country c on day $t-1$. X_{ct} is a vector of variables, λ_m are monthly effects capturing common effects across countries, such as seasonal effects, trends in the pandemic and holiday seasons, while μ_c are country effects.

3.3.1 Pooled Ordinary Least Squares (POLS)

As a baseline model, we use a POLS estimation. To address the bias that might spread from reverse causality, we lag 'trust of COVID-19 vaccines', 'government anger', 'compliance', 'the daily number of

COVID-19 vaccinations' and 'cases'. To address heteroscedasticity, we use robust standard errors in the estimated models.

3.3.2 Fixed Effect (FE) estimation

Having the benefit of a panel dataset allows us to control for additional biases, particularly unobserved confounding factors. Specifically, the FE approach reduces the impact of confounding by time-invariant factors, such as the unobserved and, in this instance, observed characteristics of the countries.

To test if the FE model rather than the Random Effects (RE) model is the most efficient estimator in the current study, we use the Haussmann test. We reject the null hypothesis that there is "*no correlation between the unique errors and the regressors in the model"*, confirming that the FE will give the most robust estimations.

The country (individual) FE included in the model addresses the unobserved time-invariant heterogeneity between countries, which considerably reduces the risk of the confounding factors discussed above. Additionally, the FE model also partly addresses bias originating from omitted observed variables (related to country characteristics). However, the FE model cannot address bias for unmeasured time-varying confounding factors or reverse causality. To further address reverse causality, we turn to Instrumental Variable regressions.

3.3.3 Instrumental Variable (IV) regression

In addition to the lagged variables introduced in the POLS and the FE estimations, we also use an IV model to address possible endogeneity and reverse causality. We use the Generalised Method of Moments (GMM) estimation rather than the Two-Stage Least Square (2SLS) estimator, due to the efficiency gains derived from using the optimal weighting matrix. The efficient GMM estimator is robust to the presence of heteroscedasticity of unknown form.

We instrument 'lagged trust in the COVID-19 vaccine' and 'lagged compliance', with 'lagged fear of vaccines', 'lagged disgust with the vaccines' and a two-day lag in 'compliance'. We use the Hansen's J statistic to test for over-identifying restrictions. The joint null hypothesis is that the excluded

instruments are valid instruments, i.e. uncorrelated with the error term and correctly excluded from the estimated equation. A rejection casts doubt on the validity of the instruments. However, in our specified model, serial correlation is present as the error term in one period is correlated with the errors in previous periods. This causes the estimated variances of the regression coefficients to be biased, leading to unreliable hypothesis testing. Therefore, we consider the IV estimations with the results of the POLS and FE estimations.

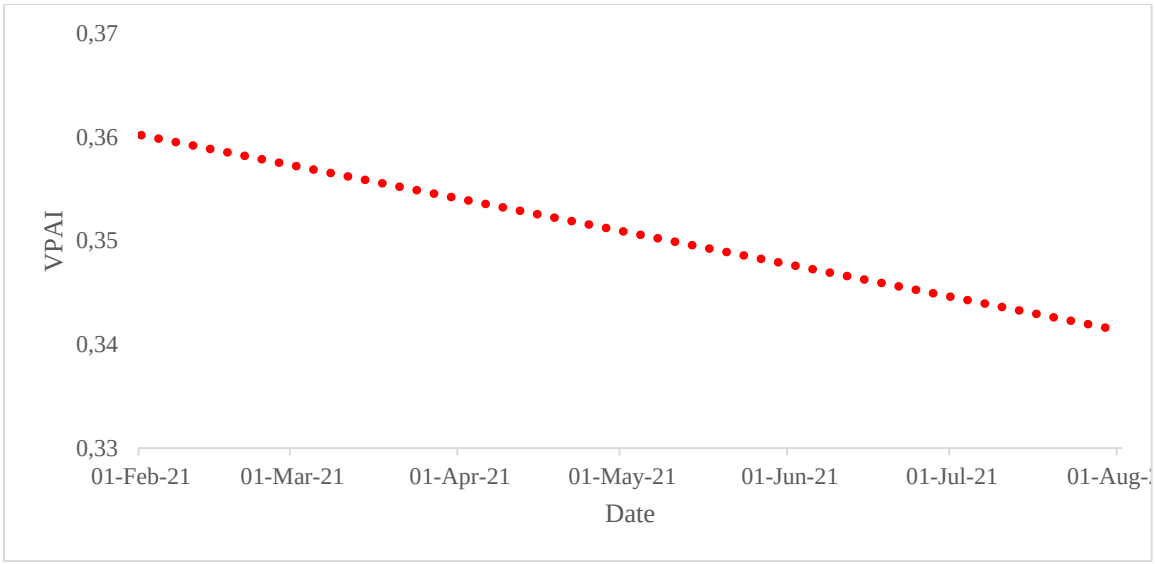
4. Results

4.1 Results of the trend in the VPAI and emotions

We first focus on our descriptive analysis to explain the trends in the VPAI towards the COVID-19 vaccines for the period 1 February 2021 to 1 August 2021. We start by describing the trends in our overall sample, the different hemispheres and then in each country.

4.1.1 Trends in the VPAI

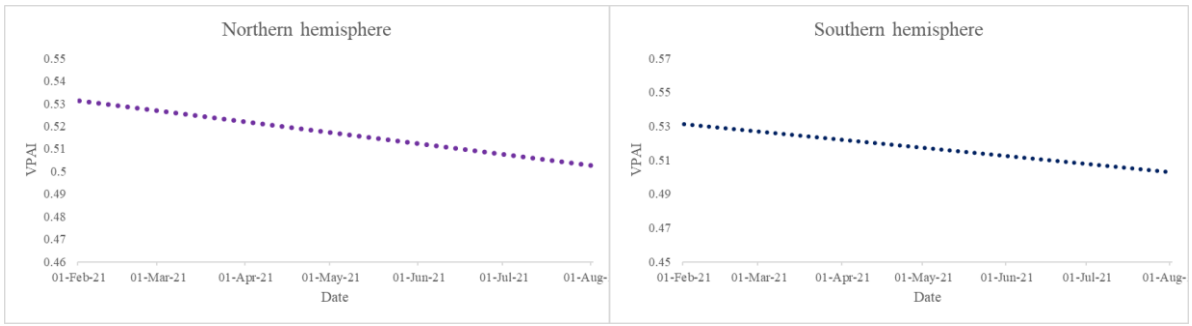
When we consider figure 4, we see that the trend in the VPAI towards the COVID-19 vaccines across all countries was downwards; we note an almost 8 per cent decrease over time (see Appendix A for the results using Sentiment 140 rather than NRC). Section 4.1.2 discusses possible explanations for this downward trend.



Source: Authors' calculations

Figure 4: Trend in positive attitude from February 2021 to August 2021 for the whole sample

Additionally, we note from figure 5 that the downward trend in positive attitude holds across both the Northern and Southern hemispheres. However, the downward trend seems to be stronger in the Southern hemisphere than in the Northern Hemisphere.



Source: Authors' calculations

Figure 5: Trend in positive attitude across the Northern and Southern hemispheres from February 2021 to August 2021.

4.1.2 Trends in positive attitude per country

If we consider the individual countries, figure 6 shows the trend in the VPAI towards the COVID-19 vaccines for each of the ten countries and indicates that the attitude improved in only two countries, namely Belgium and the Netherlands. For the remaining eight countries, the trend was negative over time.

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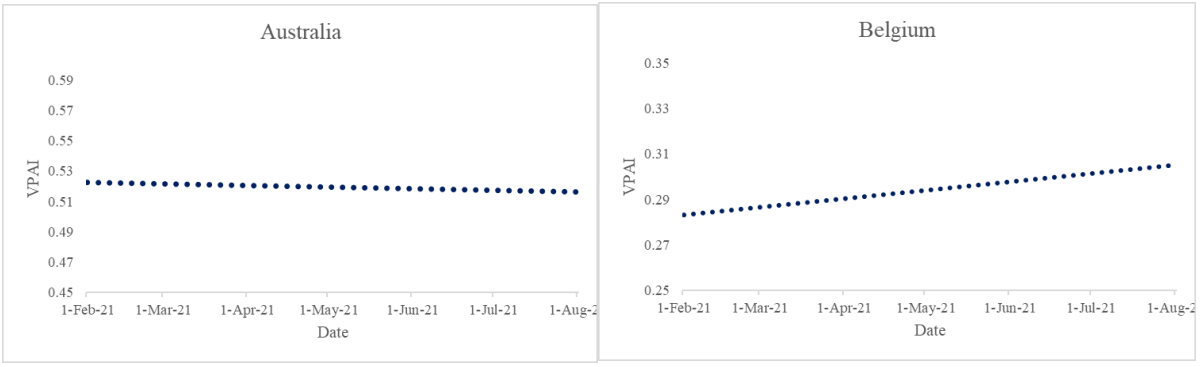

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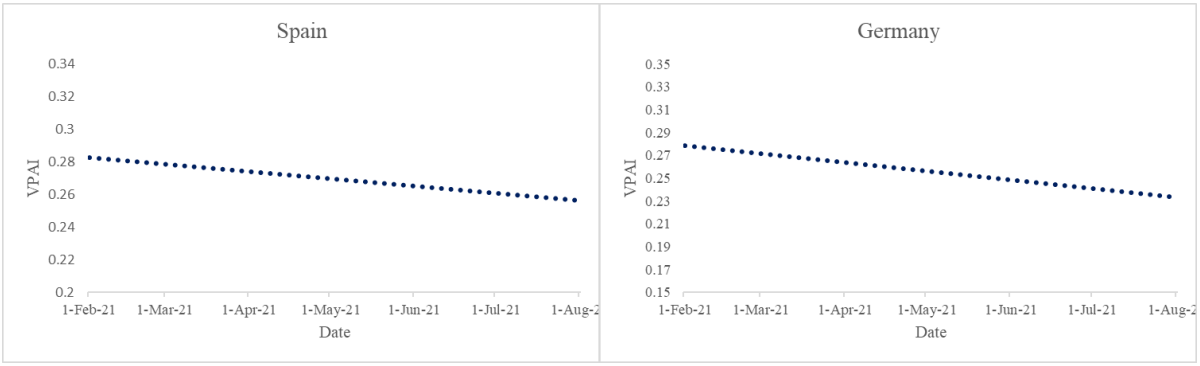

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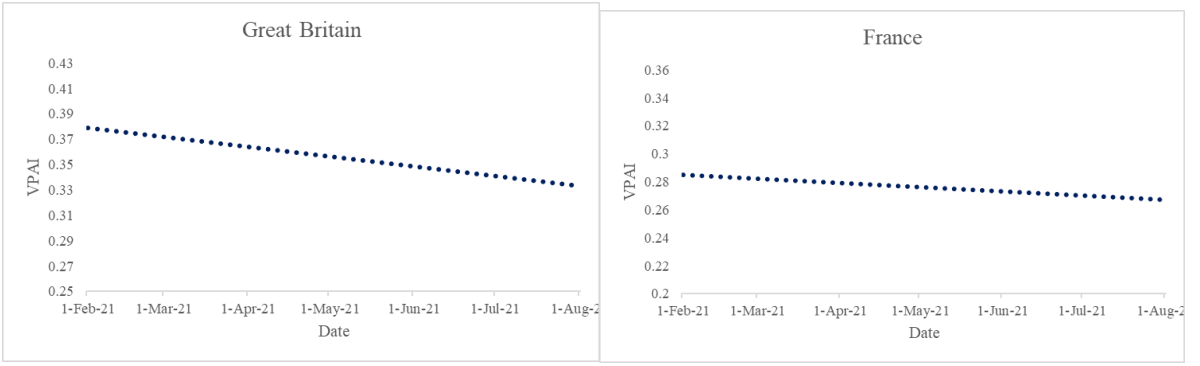

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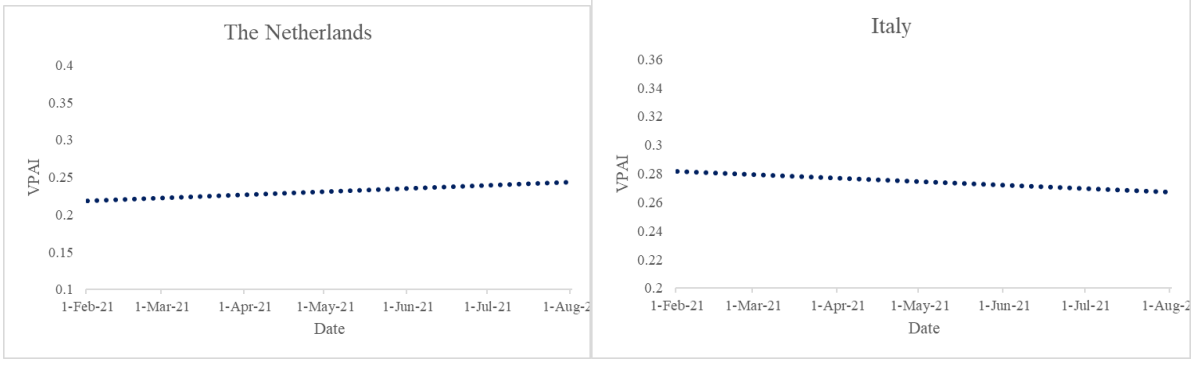

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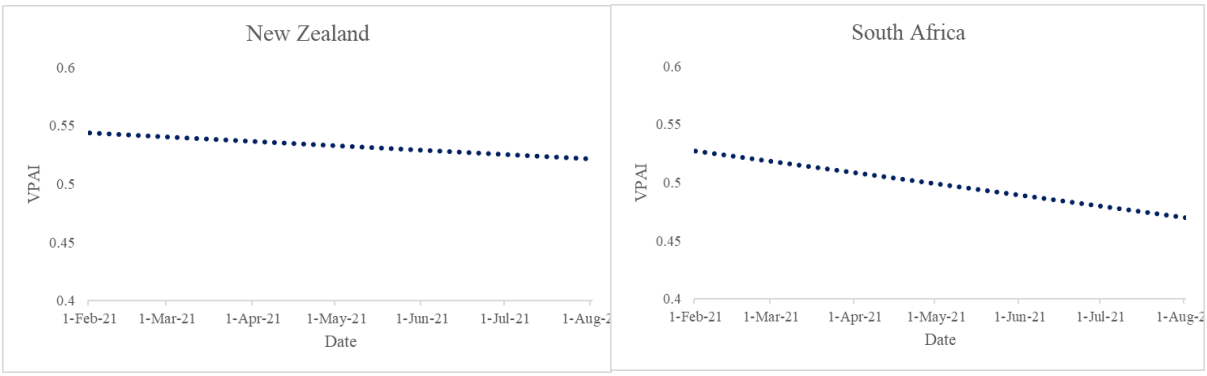

Source: Authors' calculations

Figure 6: Trend in the positive attitude for each of the ten countries

Upon further investigation, we found that the positive trend in the VPAI in Belgium was likely due to the steps taken to correct government failure that plagued the country in 2020. In 2020, Belgium was the European country with the highest loss of life and hospitalisation rate relative to the size of the population in Europe. Belgium was also hit with capacity issues, struggling to get vaccination centres up and running because of vaccine delivery delays. The Belgian people did not trust information coming from their government after reports of political favouritism in deciding who would get what little vaccine stock was available were leaked (Vanham [34]). The above events led to widespread anger towards the politicians for making COVID-19 a political game. However, many steps were taken to correct the situation, likely turning the attitude towards the COVID-19 vaccine positive. The Belgium government set up a COVID-19 task force responsible for logistics and capacity issues as a first step. However, the high uptake of vaccinations is also the result of lockdown regulation policies. The government decided to relax the lockdown restrictions during spring, depending on the vaccination rates rather than case numbers or hospitalisation rates (Vanham [34]). People wanting to return to 'normal' reacted positively to the policy.

The Netherlands was the last European country to start their vaccine rollout on 6 January 2021. Their rollout was hampered by a poor vaccination policy and a conservative strategy that kept more than 40 per cent of its vaccines from being used (Bahceli [35]). However, the Dutch government ended up spending around €6 million on information campaigns in an attempt to increase the vaccine uptake by informing the public about the safety of the various COVID-19 vaccines (Bahceli [35]). On 31 January 2021, a mere 2,430 people had been vaccinated; this number increased significantly, and by 1 August

2021, 9,288,187 people were fully vaccinated. It is safe to say that the information campaigns have paid off, in the long run, causing a slightly positive trend in the VPAI.

Now, let's consider those countries that experienced a decrease in positive attitude over time. Australians have a deep-seated mistrust in their government officials, who seem to implement contradictory regulations across different states. New South Wales (NSW) (Greater Sydney region), home to 32.33 per cent of the total Australian population, has been in lockdown since the middle of June 2021. People living within NSW do not have a great sense of collective responsibility and a significant proportion refuse to comply with government-imposed regulations. In July 2021, approximately 15,000 people protested the lockdowns and demanded that their liberties be restored (Swain [36]). In August 2021 the protests continued, with more than 1,500 police officers disbursing the crowds. Additionally, protestors refuse to wear masks, and the NSW government has collected millions of dollars through fines handed out to people for breaking COVID-19 restrictions. More than $2.5 million in fines have been collected by the state for non-compliance since the COVID-19 pandemic hit in 2020; however, a staggering 30 per cent - or $700,000 - has been collected since 19 July (McPherson [37]). Figure 6 shows the downward trend in positive attitudes towards the COVID-19 vaccine.

Spain shows a downward trend in the VPAI which means that despite vaccination campaigns and a longstanding level of trust that Spaniards have in the public health system, there still is a negative trend. This could possibly be because delivery delays and logistical problem hampered their rollout. In mid-April, when 13 per cent of Great Britain's citizens were fully vaccinated, only about 7 per cent of Spaniards were similarly protected. Future campaigns can rely on the strong family ties of the Spanish and emphasise community benefits of vaccination (AFP [38]).

The Germans responded with anger at their government's proposed policy. The policy stated that only vaccinated people would be allowed to enter venues like sports stadiums, movie theatres or restaurants because the residual risk was deemed to be high in such places. In July 2021, Chief of Staff Helge Braun announced that he did not expect another COVID-19 related lockdown in Germany (Schultheis [39]). However, this would mean that if there was a future outbreak, the liberties of the unvaccinated would

be taken away with immediate effect. Germany has also seen an increase in people not showing up for their vaccination appointments, with 5 to 10 per cent skipping appointments daily since July 2021. This can be seen as a likely reason for the decreasing trend in the VPAI. Adding fuel to the fire, Germany's anti-lockdown movement, the Querdenken, has been very active in spreading conspiracy theories ranging from the idea that masks are deadly to vaccines being able to alter your DNA (BBC Trending [40]).

In Great Britain, the government faces criticism because of their vaccination policy, which has yet to approve the COVID-19 vaccine for 12–15-year-olds. This means sending children back to schools with inadequate mitigations for COVID-19 in place, which could lead to widespread infections and more disruptions to learning. Additionally, trust in the ability of the government to see this pandemic through has decreased since the announcement of their so-called 'Freedom Day' (Donovan [41]). Freedom Day brought with it a lifting of any remaining COVID-19 restrictions and came amidst 47,000 new cases of COVID-19 being reported in the previous 24 hours (Donovan [41]). The decision of Freedom Day brought with it 1,200 scientists worldwide criticising the decision to open up, saying it could pose a threat to the entire world if daily cases increased exponentially and vaccine-resistant mutations of the virus were allowed to develop (Ball [42]). The downward trend in the VPAI is likely (figure 6) a product of all the accumulated issues.

In France, introducing a stringent vaccination policy known as 'COVID-19 vaccine passports' has decreased the positive attitude towards the COVID-19 vaccine (The Economist [43]). The news that movie theatres, museums and sports venues have begun asking visitors to provide proof of a COVID-19 vaccination or a negative test has many French nationals angry but willing to take the vaccine simply to return to their once normal way of living.

Italy, the second-worst Northern-hemisphere country with regard to people who have not been fully vaccinated, namely 58.42 per cent, has faced an uphill battle since the start of their vaccine rollout on 27 December 2020. By April 2021, the Rome government was faced with a lacklustre uptake in COVID-19 vaccines. They decided to take a tough stance, approving emergency legislation to make

COVID-19 vaccines mandatory for all healthcare workers, including pharmacy staff (Roberts [44]). This likely contributed to the decreasing trend in the VPAI (see figure 6). Individuals who refused would be transferred to another job or suspended without pay for up to a year. This emergency legislation faced fierce resistance from the country's deeply rooted anti-vaccine movement**,** which has been fostered in part by populist political forces. These included the 5 Star Movement, which entered government in 2018 promoting vaccine hesitancy. Public trust in the vaccine has also taken a hit after the country temporarily decided to suspend the use of the Oxford/AstraZeneca vaccine after several deaths (Roberts [44]).

In New Zealand, the COVID-19 rollout has been described as a 'shambles'. This is due to the government of the day not delivering the promised vaccines because they and the country as a whole became complacent (Vance [45]). At the time of writing this paper, New Zealand found itself in a level-4 lockdown (the most stringent level of lockdown) and had not had a positive COVID-19 case during the previous six months. New Zealand's zero COVID-19 strategies were successful until the first Delta-variant positive person was announced. Soon the government realised that they did not have enough vaccines to vaccinate everyone fully, as previously promised. This government failure has driven an increased mistrust in institutions and anger towards capacity issues in New Zealand. Additionally, people expressed anger towards the government's vaccination policy, making it mandatory for all 'frontline' staff to be fully vaccinated or removed from their positions. All of the above can affect the downward trend in the VPAI.

South Africa's woes are almost too many to count, ranging from capacity issues, mistrust in the government to anti-vaccination campaigns, all of these creating a decrease in positive attitude towards the COVID-19 vaccines (see figure 6). From as early as December 2020, it was clear that the country had no COVID-19 strategy apart from its dependency on their fragile COVAX arrangement. After receiving their first delivery of the AstraZeneca vaccine on 1 February 2021, it became clear that the government also did not have a clear vaccination policy (van den Heever et al. [46]). The Health Minister created confusion in the public arena when he announced that the AstraZeneca vaccine did not demonstrate efficacy against mild to moderate COVID-19 and placed the rollout of the vaccine on hold.

The announcement by the Health Minister caused a decrease in trust in the COVID-19 vaccine and likely contributed to the downward trend in the VPAI. The decision was criticised by local scientists and not supported by the World Health Organisation. This move guaranteed that South Africa would face a winter epidemic wave with most of the 17 million or so high-risk population unvaccinated (van den Heever et al. [46]). During the winter months from June to September 2021, South Africa lost 25,660 lives to COVID-19. This probably could have been avoided if the South African government had not been plagued by corruption and mismanagement during its response to the pandemic. By August 2021, South Africa saw 'vaccine apathy' or 'vaccine fatigue', with the number of people coming forward to be vaccinated dropping below 200,000 a day, falling short of the set target of 300,000. According to a study conducted by the Human Sciences Research Council and the University of Johannesburg (Cooper et al. [47]), the vaccine-hesitant cite three primary concerns: side effects, effectiveness, and distrust of the vaccine and institutions.

To summarise, the downward trend in positive attitudes is partly due to a fear of the side effects, but many other factors also contribute. These include dissatisfaction with governments' rollout plan, procurement, and corruption.

4.2 POLS, FE and IV regression results

This section discusses the results of those covariates that are significantly related to the VPAI and, therefore, when addressed, could increase the uptake of COVID-19 vaccines.

In table 3, the results of the POLS estimation controlling for a month and a country fixed effect are similar to the results of the FE model and the IV regression. The covariate 'trust in the COVID-19 vaccine' is statistically significant and positively related to VPAI across all the estimated models. Therefore, we believe that this result on the correlation between trust and the VPAI is robust. We assume that when trust in the vaccine increases, the fear of negative side-effects decreases and that the positive attitude towards vaccines improves.

506 **Table 3: Results from POLS with FE and IV**

Variable	POLS		FE		IV	
VPAI	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Lagged trust in the COVID-19 vaccine	0.2938***	(0.0281)	0.2938***	(0.0193)	0.3127***	(0.0999)
Lagged compliance	-0.0176***	(0.0060)	-0.0176***	(0.0037)	-0.0170***	(0.0064)
Lagged anger towards the government # Daily vaccinations	-0.0274***	(0.0073)	-0.0274***	(0.0073)	-0.0273***	(0.0072)
Lagged new daily vaccinations	0.0055***	(0.0013)	0.0055***	(0.0014)	0.0055***	(0.0014)
Lagged new daily cases	-0.0032***	(0.0080)	-0.0032***	(0.0011)	-0.00324***	(0.0080)
Log vacc tweets	-0.0049*	(0.0029)	-0.0049*	(0.0029)	-0.0047*	(0.0029)
Vaccine policy (Reference – Level 0)						
Level 1	0.0598***	-0.0125	0.0598**	-0.0232	0.0596***	(0.0123)
Level 2	0.0451***	-0.0091	0.0451**	-0.0227	0.0454***	(0.0105)
Level 3	0.0476***	-0.0088	0.0476**	-0.0228	0.0480***	(0.0092)
Level 4	0.0536***	-0.0092	0.0536**	-0.0227	0.0542***	(0.0103)
Level 5	0.0473***	-0.0102	0.0473**	-0.0233	0.0477***	(0.0109)
Country FE	Yes		Yes		Yes	
Month FE	Yes		Yes		Yes	
N	1727		1727		1727	
Adjusted R^2	0.867		0.422		0.866	
Hansen J-Statistic of overidentification					p = 0.6544	

507 Source: Authors' calculations
508 Robust Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

509

Compliance, the act of complying with government-mandated regulations to curb the spread of COVID-19, is statistically significant and negatively related to the VPAI. When people are unwilling to comply with the regulations, their attitude towards vaccines is more positive. Unwillingness to comply likely motivates people to get vaccinated. This finding is important for policymakers because it is necessary to emphasise that the regulations can be less strict once people are vaccinated, returning to a more 'normal' way of life, encouraging people to take the vaccine.

The variable 'anger towards the government' interacted with the new daily vaccinations per 1000 is statistically significant and negatively related to VPAI. Therefore, when people's dissatisfaction with the government increases, given the incompetence regarding the vaccine rollout, the relationship with the VPAI decreases. Analysing the negative sentiment and emotion tweets that reflect anger, we find that people are angry with governments due to the lack of procurement, procurement of the correct vaccine, the rollout of the vaccination plan and corruption within governments. This anger directed at governments due to a lack of access to vaccines sabotages the positive attitude towards vaccines and hinders the uptake of vaccines.

The relationship between VPAI and the number of daily new vaccinations is inversely proportional, significant and positively related. This implies that when the daily number of vaccines administered are very low, the positive attitude is high, but as the number of vaccines administered per day increases, the positive attitude starts to plateau. Also, using the vaccine rollout or the lack thereof, as a proxy for constraints in information campaigns, the physical availability of vaccines or a lack of geographical accessibility, we can see how important it is to overcome any barriers which might impede the intention to be vaccinated (Cylus & Papanicolas [48]).

We find that daily new cases, a proxy for the evolution of the COVID-19 pandemic across all ten countries, is statistically significant and negative. If the daily cases are high, the positive attitude towards the vaccine is relatively low, but as the daily cases start increasing, the positive attitude improves.

Controlling for the vaccination policy, thus the groups that can access the COVID-19 vaccine, we find that when more groups of people can access the vaccine, for example, all age groups compared to fewer groups, it is positively related to the VPAI. Once again showing that when more people have access to the COVID-19 vaccine, positivity towards the vaccine is enhanced.

The number of vaccine-related tweets is statistically significant and negatively related to the VPAI in all the estimated models. This implies that, as the tweets related to vaccines increase, the attitude towards vaccines decreases. This may likely be because many of the tweets contain misinformation or conspiracy theories rather than campaigns and information to encourage being vaccinated - and, therefore, decreases positive attitudes towards vaccines. From this, we can derive that calculation (individuals' engagement in information searching or sharing) plays a significant role in evaluating the risks of infections and receiving vaccinations when making good decisions (Brewer et al. [49]). Depending on the sources of information consulted, high levels of information searching could lead to non-vaccination, due to the abundance of anti-vaccination sources, for instance, on the internet (Kata [50]).

In summary, we see that those variables that can improve the positive attitude towards vaccines are related to information about the safety and side-effects of the vaccines (increased trust in vaccines) and a balance between the strictness of regulations and access to vaccines. Additionally, increased trust in the governments' capabilities, honesty of governments and capacity constraints can decrease the dissatisfaction with governments and increase vaccine uptake. Better information about the COVID-19 vaccines in general also disseminated via social media can increase positivity towards the COVID-19 vaccine. Misinformation about COVID-19 vaccines and social media should be monitored, and campaigns against this misinformation should be launched. Vaccines should also be made accessible to all groups of people.

5. Conclusions

In this study, we constructed a real-time Vaccine Positive Attitude Index (VPAI) derived from Big Data, to illustrate the evolution of people's positive attitudes toward the COVID-19 vaccine across ten

561 countries. Our descriptive analysis showed that the VPAI generally indicates a decline in attitude over
562 the time period investigated. When we consider the different hemispheres, the trend is downwards in
563 the Northern and Southern hemispheres. When we examined the ten individual countries, we saw that
564 only Belgium and the Netherlands experienced a positive trend in the VPAI, whereas the other countries
565 experienced a negative trend.

566 Using POLS, FE and IV regression models, we determined which variables are significantly related to
567 the VPAI and, therefore, could increase the uptake of COVID-19 vaccines if addressed by policy
568 measures. We found that those variables that could improve people's attitudes towards vaccines were
569 information related to the safety and side-effects of the vaccines, increased confidence in governments
570 in conducting the vaccine rollout and handling procurement and capacity issues, cognisance of the
571 compliance versus the vaccine up-take decision, and better information about the COVID-19 vaccines
572 in general, but especially disseminated via social media.

573 These results give policymakers the necessary information on how to increase positive attitudes towards
574 the COVID-19 vaccine. Policymakers should focus on increasing trust in the COVID-19 vaccines. They
575 could more openly disseminate information regarding the vaccine, do it in layman's terms, and
576 acknowledge people's fears, anger, and other negative emotions while emphasising the stringent safety
577 and efficacy standards of the COVID-19 vaccine development process thus fostering individuals' self-
578 efficacy through vaccination. All of this may increase vaccine confidence. Additionally, addressing the
579 lack of accessibility to vaccination clinics could be overcome by following countries such as the United
580 States of America by creating mobile vaccination clinics, to reach people in remote areas.

581 Additionally, policymakers should implement policies to increase people's sense of collective
582 responsibility. This can be done by raising awareness of emotional manipulations by anti-vaccine
583 disinformation efforts and activating positive emotions such as altruism and hope as part of vaccine
584 education endeavours. Another potential strategy is to elicit positive emotions toward helping one's
585 community restore health and well-being, when deciding to vaccinate against what is called the most
586 consequential disease of our time.

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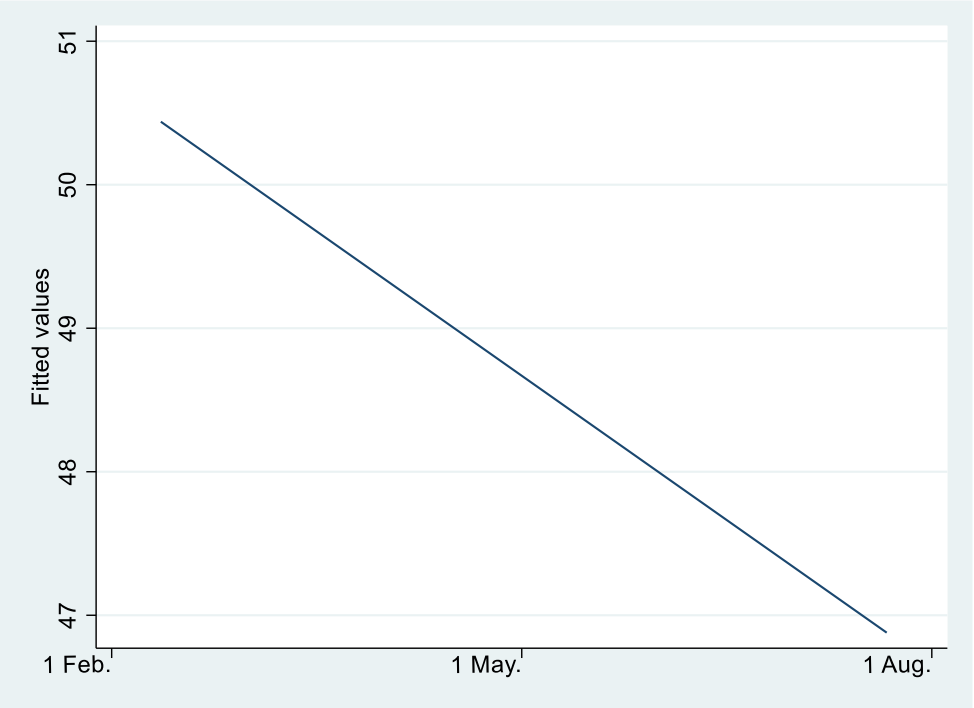
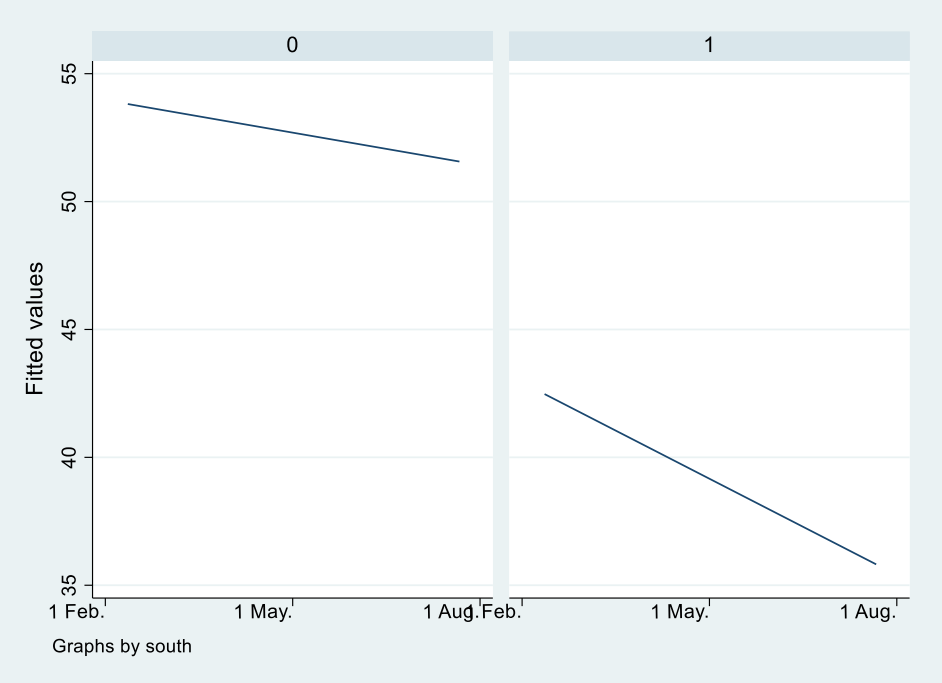
Appendix A: Results on the trends in VPAI using sentiment 140



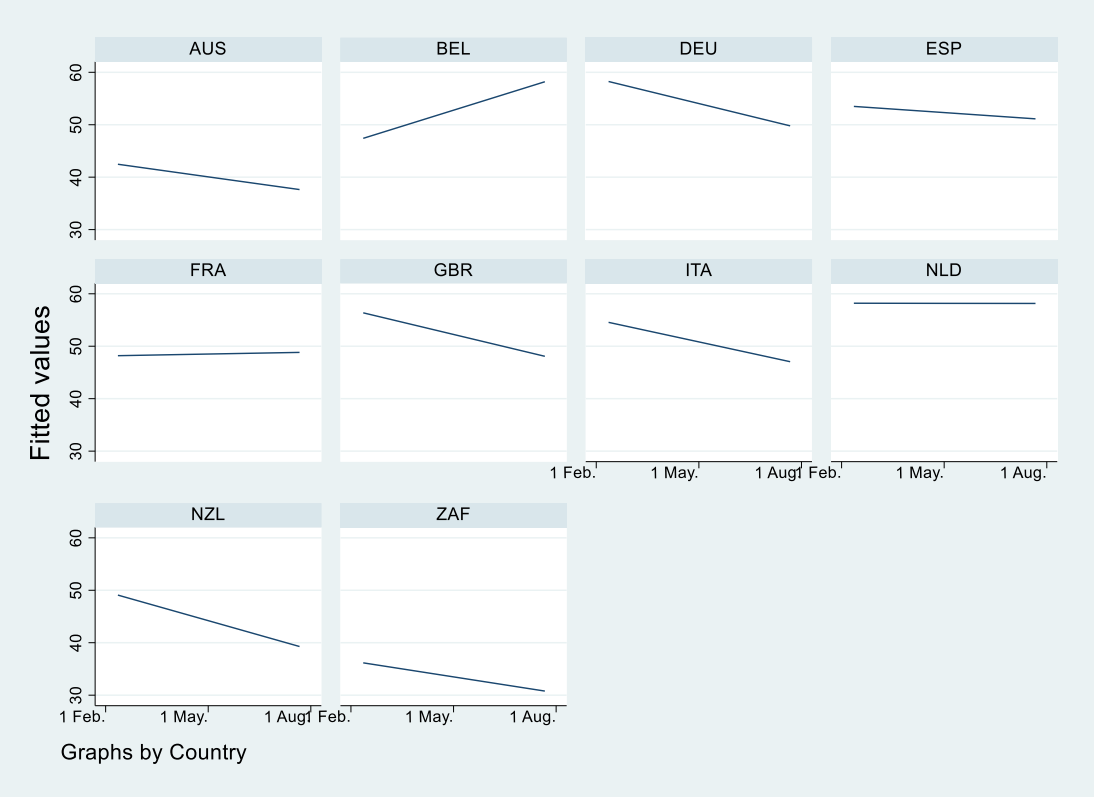
Source: Authors' calculations

Figure 7: Trend in positive attitude from February 2021 to August 2021 for the whole sample, using Sentiment 140



Source: Authors' calculations

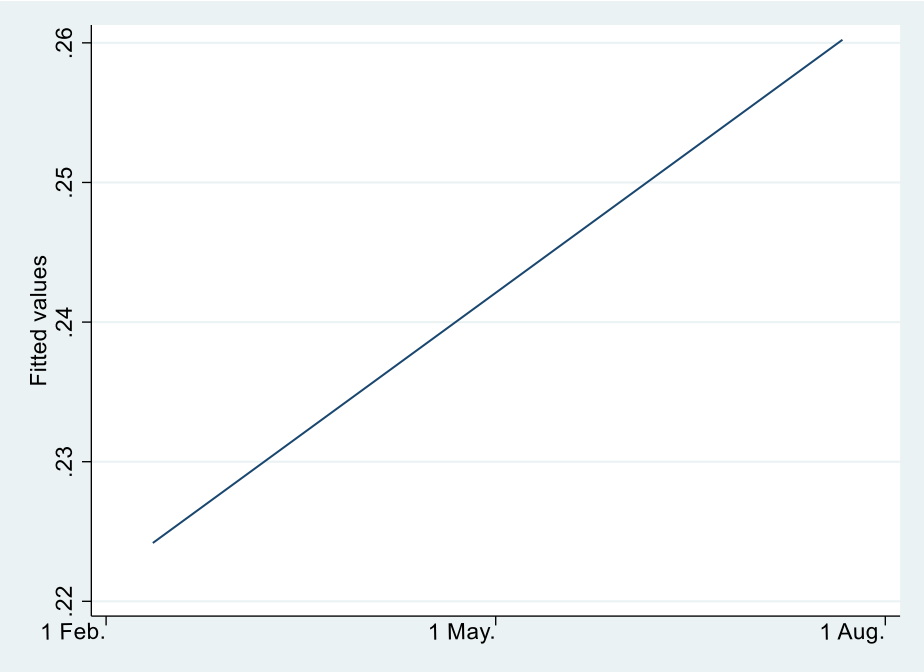
Figure 8: Trend in positive attitude from February 2021 to August 2021 per hemisphere, using Sentiment 140



Source: Authors' calculations

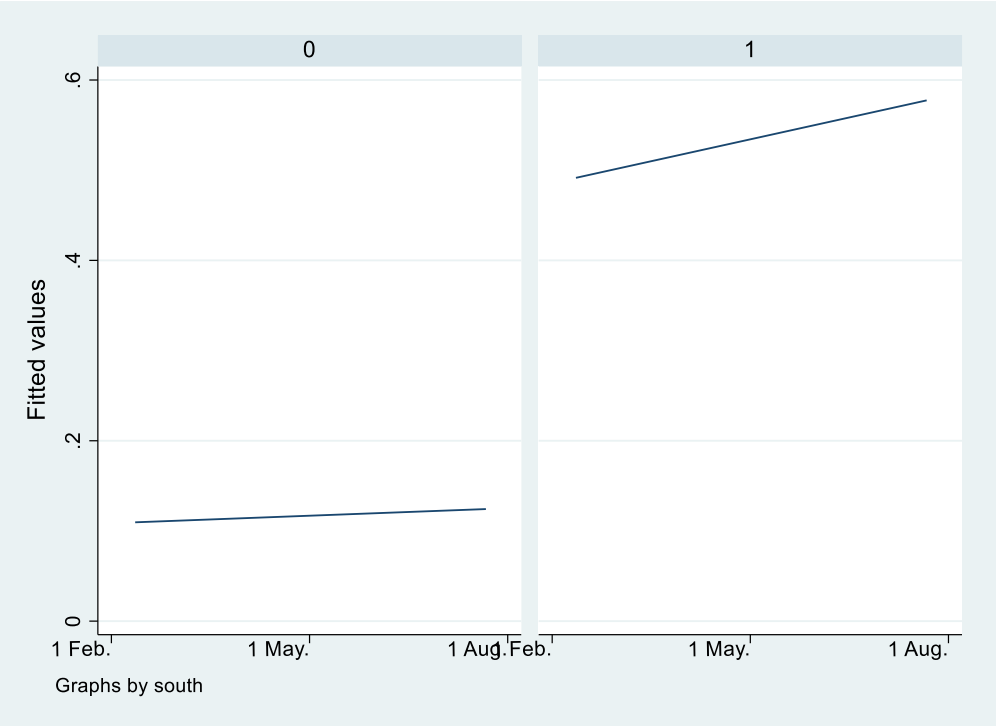
Figure 9: Trend in positive attitude from February 2021 to August 2021 per individual country, using Sentiment 140

Appendix B: Results on the trends using VPAI2



Source: Authors' calculations

Figure 10: Trend in positive attitude including false negatives related to governments (VPAI2) for the whole sample from February 2021 to August 2021



Source: Authors' calculations

Figure 11: Trend in positive attitude including false negatives related to governments (VPAI2) for the different hemispheres from February 2021 to August 2021

Source: Authors' calculations

Figure 12: Trend in positive attitude including false negatives related to governments (VPAI2) for the individual countries from February 2021 to August 2021