Abstract

In this study we approach the vaccine debate from a new and comprehensive perspective, by taking into account all the main elements that make it a particularly complex social phenomenon. Focusing on the Italian context, which has always been the scene of heated discussions on vaccination even before Covid-19, we examine almost all the online information produced in the 2016-2021 timeframe by both sources that have a reputation for misinformation and those that do not.

Although reliable sources can rely on larger newsrooms and cover more news than misinformation ones, the transfer entropy analysis of the corresponding time series reveals that the former have not always informationally dominated the latter on the vaccine subject. Indeed, the pre-pandemic period sees misinformation establish itself as leader of the process, even in causal terms, and gain dramatically more user engagement than news from reliable sources. Despite this information gap was filled during the Covid-19 outbreak, the newfound leading role of reliable sources as drivers of the information ecosystem has only partially had a beneficial effect in reducing user engagement with misinformation on vaccines. Our results indeed show that, except for effectiveness of vaccination, reliable sources have never adequately countered the anti-vax narrative, specially in the pre-pandemic period, thus contributing to exacerbate science denial and belief in conspiracy theories. At the same time, however, they confirm the efficacy of assiduously proposing a convincing counter-narrative to misinformation spread. Indeed, effectiveness of vaccination turns out to be the least engaging topic discussed by misinformation during the pandemic period, when compared to other polarising arguments such as safety concerns, legal issues and vaccine business.

Thus, the inability of reliable sources to address issues that are particularly sensitive and important to the public seems to be the biggest contributor to the spread of false narratives, even more than the sizeable presence of misinformation in the news ecosystem. By highlighting the strengths and weaknesses of institutional and mainstream communication, our findings can be a valuable asset for improving and better targeting campaigns against misinformation on vaccines.

Introduction

The chronicles of recent years have shown that we have to get used to address global emergencies, in which communication plays a pivotal role in the representation of reality and strongly affects the formation of opinions and the orientation of individual behaviour, specially on the web [11, 2, 3, 4]. Internet and social media, while providing a great capacity for the public to interact, represent indeed important vectors for the spread of potentially erroneous or intentionally false information [5, 6, 7] that may have tremendous impact on society, especially when the subjects discussed are sensitive and emotional [8] such as those health-related [9, 10], in particular vaccination [11, 12, 13]. For instance, exposure to information questioning the safety and effectiveness of vaccines may worsen people’s attitudes toward vaccines and be difficult to refute [14]. Vaccination hesitancy has indeed been an important public health issue even before Covid-19, to the point of being named one of the top ten threats to global health in 2019 by the World Health Organization (WHO) [15]. However, the proliferation of anti-vaccination misinformation through social media has recently given it new urgency due to the unprecedented scale of Covid-19 pandemic and the resulting need for rapid administration of the approved vaccines [16, 17, 18].

In this study we approach the public debate (or “public sphere” using Habermas’ term) on vaccines from a new and comprehensive perspective, by taking into account all the main elements that make it
The design, approval and enforcement of the legislative framework on mandatory paediatric vaccinations has been employed institutionally for monitoring disinformation and has been validated at international level. The same source classification has been employed institutionally for monitoring disinformation and the methodology used has been validated at international lev[e](2).

Aside from assessing the coverage of vaccine subject from both the sourcesets throughout the period analysed, we also adopt the Transfer Entropy approach to estimate the strength and direction of information flow between the corresponding daily time series.

Surprisingly, to a low pre-pandemic coverage of the vaccine subject by Reliable sources is opposed a great deal of attention from the Questionable counterpart and a slight dominance, even in causal terms, of its asset in the information transmission between the two sourcesets. On the contrary, the Covid-19 outbreak marked a significant increase in vaccine coverage from Reliable sourceset, to the point of decreeing its transition from dependent to independent variable in the Transfer Entropy model describing its causal relationship with the Questionable counterpart. However, the observed narrowing of the user engagement gap with the Questionable counterpart is only partially attributable to the newfound leading role of Reliable sources as drivers of the information ecosystem, and seems more likely to be an endogenous effect of the Covid-19 infodemics. Indeed, vaccine-related content from Questionable sources out-engage those from Reliable sources by a factor of twenty before the pandemic, which drops to seven during the Covid-19 outbreak, whereas on the days when the vaccine coverage from Reliable sources outperforms that from Questionable sources, it does so by a factor between one and two, regardless of the period considered.

To point out the key features of the observed audience engagement differences and dynamics, we also build a very accurate machine learning model capable to individually classify vaccine-related content according to the opinion conveyed and the specific topic discussed. The analyses reveal that diametrically opposing opinions, anti-vax for Questionable sources and pro-vax for Reliable sources, are the most engaging views. By comparing the levels of coverage conveying such opinions on the most polarising topics, we show that, except for effectiveness of vaccination, Reliable sources have never adequately countered the anti-vax narrative, specially in the pre-pandemic period, thus contributing to science denial and belief in conspiracy theories. At the same time, however, we find confirmation of the efficacy of assiduously proposing a convincing counter-narrative to misinformation spread (21). Indeed, effectiveness of vaccination turns out to be the least engaging topic within the Questionable sourceset during the pandemic period, when compared to other polarising arguments such as safety concerns, legal issues and vaccine business.

Hence, our findings highlight some new evidence that appears to be very interesting from both research and policy perspectives. Trust in science as well as in institutions is an emotional process that takes place through a long and complex path and may adversely affect social response, not only in relation to vaccine acceptance. In this context, institutional and mainstream communication play a pivotal role (22). The spread of false narratives among the public is indeed due not only, and not so much, to the presence of misinformation sources, but also to the inability of institutional and mainstream communication in addressing issues that are particularly sensitive and important (23), at least for a portion of the population.
Results and discussion

Questionable vs Reliable sources: Which one drives the media attention on vaccines?

Over the past few years, the evolution of the vaccine debate has undergone a few phases that emerge clearly from the data. Figure 1 shows the daily time series of the percentage of vaccine-related content from Questionable (Q) and Reliable (R) sources, respectively. To bring out trends more clearly, we display a 30-days simple moving average \[24\], i.e. the data-point at time \( t \) is given by the mean over the last 30 datapoints (see Supplementary Table 3 and Supplementary Figure 1 for descriptive statistics of both the two time series and their corresponding first difference; see Supplementary Table 4 for stationarity tests).

As expected, the two time series show an evident degree of correlation. Indeed, few major vaccine-related events have driven the media attention throughout the time span analysed, regardless of the type of news source.

During the first phase, the debate was particularly vibrant in 2017 when by law [Law n.119 of July 31] anticipated by the [Decree Law n.73 of June 7] hereafter Vaccination Act) the Italian Government extended from four to ten the free and mandatory vaccinations for children 0-16 years old\(^4\) and introduced fines and admission bans for unvaccinated children at school. In this regard, it should be noted that full implementation of the Vaccination Act did not occur until September 2019 due to exemptions and extensions (see Law n.108/2018).

During the last phase, the vaccine debate has been almost completely monopolised by the pandemic outbreak: first by the Covid-19 vaccine race and roll out, later by the administration of authorized vaccines and the resulting safety concerns, especially regarding the AstraZeneca vaccine (March 5 and June 6 2021) leading to vaccination hesitancy [25].

Figure 1 also suggests that the role of Covid-19 pandemic in the vaccine debate was twofold. On the one hand, regardless of the source (Questionable or Reliable), it has raised media attention on vaccines to levels never reached in previous years. On the other hand, it has clearly influenced the dynamics of the cross-correlation between the two time series. A more pronounced trend of Questionable than Reliable is indeed evident before the Covid-19 outbreak, where the debate appears to have been heated almost among page communities that were sceptical about the introduction of mandatory

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\(^4\)These are: anti-polio; anti-diphtheria; anti-tetanus; anti-hepatitis B; anti-pertussis; anti-Haemophilus influenzae type b; anti-morbillius; anti-rubella; anti-parotitis; and anti-varicella.

\(^5\)As of March 15, 2021, the Italian Medicines Agency (AIFA) suspended the administration of the vaccine nationwide to shed light on potential serious side effects on blood coagulation reported in the previous days in Italy and in several other European countries within a short time of inoculations. The vaccination campaign with the AstraZeneca vaccine resumed in Italy from the afternoon of March 19, 2021, following clarifications provided by the European Medicines Agency (EMA).

\(^6\)On June 3, 2021, AIFA (Italian Medicines Agency) publishes an update information note on the risk of thrombosis occurrence in combination with thrombocytopenia. On June 8, 2021, the Liguria healthcare company Alisa suspends a batch of AstraZeneca’s vaccine following a report of a suspected adverse reaction.
On the contrary, the two variables proceed with comparable intensity and very similar monotonicity during pandemic (see Supplementary Table 3). Hence, aside from performing an overall analysis of the vaccine debate in Italy throughout the time span under investigation, we identified the date of the first confirmed cases of Covid-19 in Italy (30 January 2020) as a watershed event between pre-pandemic and pandemic periods, and we also analysed these two sub-periods separately. The choice of this date is motivated by the fact that, although the start of vaccinations dates back to 27 December 2020 when Italy received 9,750 doses of the Pfizer–BioNTech vaccine, the vaccine debate has been almost totally monopolised by the Covid-19 vaccines since the early stages of the pandemic.

Table 1 shows the cross-correlation function (CCF) score, i.e., the ratio of covariance to root-mean variance, between Questionable and Reliable time series with respect to any of the aforementioned periods.

| Period     | CCF Overall | CCF Pre-pandemic | CCF Pandemic |
|------------|-------------|------------------|--------------|
|            | 0.840       | 0.457            | 0.905        |

Table 1: Cross-Correlation Function (CCF) between Questionable and Reliable time series with respect to the three period analysed.

Consistent with what inferred graphically, these scores confirm that during the pandemic the degree of correlation between the two time series is roughly double that of the pre-pandemic period (See Supplementary Figure 2 for the lag analysis of CCF).

The different cross-correlation scores observed between the two sub-periods naturally raise questions. Is the vaccine news production from Reliable sources that drives the production of vaccine-related content from Questionable sources, or vice-versa? Does this dynamics depend on the analysed period or does it maintain a constant direction throughout the time-span? To answer these questions, we study the direct causal relationship between the two time series by evaluating the Transfer Entropy (TE) of one to the other for the overall period and both the pre-pandemic and pandemic sub-periods. TE [27] is an information-based measure based on the Shannon’s formula [28] that can appropriately detect the information flows between time series and identify its sources. Since a straightforward implementation of TE could lead to biased estimates under conditions that may be peculiar to the observed phenomenon, we relied on the bias correction provided by the concept of Effective Transfer Entropy (ETE). The ETE estimates for the overall period and the two sub-periods (pre-pandemic and pandemic) are reported in Table 2, together with the corresponding net information flow (NIF) from Reliable to Questionable, meaning that when this quantity is positive, the Reliable source set informationally dominates the Questionable one, whereas when it is negative, the Questionable source set leads [29].

| Period     | ETE_R→Q SE | ETE_Q→R SE | NIF    |
|------------|------------|------------|--------|
| Overall    | 0.052**    | 0.003      | 0.012** 0.003 0.040 |
| Pre-pandemic | 0.006**    | 0.002      | 0.012*** 0.002 -0.006 |
| Pandemic   | 0.047***   | 0.009      | 0.000   0.009 0.047 |

Table 2: Effective Transfer Entropy (ETE) estimates for both the possible information flow directions during the three analysed periods, respectively, together with associated Standard Error (SE). The net information flow (NIF) column represents the difference between ETE_R→Q and ETE_Q→R.

As far as the overall period is concerned, there is a significant bi-directional information flow between Questionable and Reliable source sets (1% and 5% significance level for the direction R→Q and Q→R, respectively), whereas the NIF shows a larger information transmission from Reliable to Questionable. Hence, the results suggest that the production of vaccine news from Reliable sources dominates that from Questionable sources. This is rather expected as Reliable sources on average have larger newsrooms and cover more news, while Questionable sources often pick up on news that has already been circulated, changing their perspective and narrative [30].

Surprisingly, albeit with a much smaller NIF, a reverse trend concerns the pre-pandemic sub-period. Indeed, although the interactions between the two source sets are significant in both directions (1% and

7Debate on these issues occurs within distinct, non-communicating communities. In fact, conspiracists (and other communities) need for cognitive closure, i.e., they are more likely to interact with conspiracy based theories and have a lower trust in mainstream sources [26].
5% significance level for the direction Q→R and R→Q, respectively), the information flow from R to Q undergoes a net downsizing, while it remains constant in the opposite direction, when time is limited to before the Covid-19 outbreak. Therefore, the NIF returns a slight dominance of Questionable sources on Reliable sources. With this respect, the very different levels of attention paid by the two sourcesets to the paediatric vaccination obligation, from entry into force of the Vaccination Act to its full implementation (see Figure 1), could have played a role in determining the Questionable asset as the leader sourceset. As observed above, the low pre-pandemic coverage of the vaccine subject by Reliable sources is contrasted by a vibrant debate among the community of Questionable news outlets.

On the contrary, the Covid-19 outbreak marked a significant increase in attention on the vaccine subject from Reliable media, to the point of decreeing its transition from dependent to independent variable in the Transfer Entropy model describing its causal relationship with the Questionable counterpart. Suffice it to say that the ratio of Reliable to Questionable content went from 2 to 1 in the pre-pandemic period to 9 to 1 in the pandemic period. Moreover, although the duration of the pandemic period is roughly half that of the pre-pandemic period analysed, Questionable and Reliable sources increase their overall news production on vaccines by about 500% and 1700%, respectively (See Table 4).

In this new framework, the situation is practically reversed compared to pre-pandemic period: the information flow in the direction Q → R (0.000) is not found to be statistically significant, whereas the communication from Reliable sources (re)gains its leading role in the information ecosystem and the NIF reaches its maximum (0.047), with 1% significance level for the direction R→Q.

**Questionable vs Reliable sources: Which one sees more engagement with vaccine news?**

The overabundance of information - some accurate and some not - during Covid-19 outbreak led WHO to coin the term infodemics for describing a situation that makes it hard for people to find trustworthy sources and reliable guidance when they need it [31]. The perils of misinformation phenomena during the management of disease outbreaks have been widely investigated [32, 33, 34, 35], since they could even speed up the epidemic process by influencing and fragmenting social response [36, 37]. For instance, vaccination hesitancy has been an important public health issue even before Covid-19 [38, 39]. At its core, vaccination hesitancy is a perception concern, rooted in the information individuals receive [40, 41]. Several studies relied on the behaviour of user on social media, in terms of interactions with vaccine-related content, as a proxy for the collective attitude towards vaccination [42, 43, 44, 45, 46, 47, 48].

With respect to our data, identical trends to those of the produced content concern the number of interactions. Namely, the significant increase in content on vaccines during pandemic is matched by a proportional increase in user interactions (see Table 4 and Supplementary Figure 3). To understand whether the pandemic only played a role on the information flow between the two sourcesets or also on the corresponding user engagement, we study the out-engage factor defined by 5.

Denoted with $X$ the vaccine subject and with $X^c$ the totality of other subjects covered during day $d$, left panel of Figure 2 shows the distribution of the out-engage factor $P(R; X, X^c; d)$ ($P(Q; X, X^c; d)$) for the days $d$ when it is in favour of the vaccine subject compared to the rest of subjects discussed within the R (Q) sourceset. Right panel shows instead the distribution of the out-engage factor $P(R, Q; X; d)$ on vaccine subject for the days $d$ when it is in favour of one sourceset to the other. Distributions are broken down by period analysed and $n$ indicates the corresponding number of days.

Namely, on a daily basis, we compare the user engagement with the vaccine-related content of the two sourcesets from two different points of view:

- the inside perspective, that is the ratio between the per-content interactions, where content is binary divided into vaccine-related and any other subject discussed within the same sourceset;
- the outside perspective, that is the ratio between the per-content interactions normalized by followers of one sourceset to the other, where content is exclusively vaccine-related.

8Some outliers up to 6 concerning the inside perspective and up to 75 concerning the outside perspective are not shown.

9For both sourceset, engagement on vaccine subject is evaluated by means of $\frac{E}{E}$ as per-content interactions normalized by followers. While normalization by followers does non affect the out-engage factor formula from the inside perspective (it contributes twice equally but inversely), it has a huge impact on the same formula from the outside perspective, either by reducing the contribution of news content from sources with a large follower base, or by amplifying the contribution of news content from sources with a small follower base [49]. Due to the risk of confusing scale effects with the real user engagement (i.e., mainstream information has more audience than alternative information and therefore triggers more user interactions, all things being equal), we decided to consider the normalized version of this latter as standard for the calculation of social engagement.
The vaccine subject appears to be slightly more engaging among the Questionable rather than Reliable sources, when compared to the totality of the other subjects covered. Such an overall gap (Q: median 1.866, mean 2.633; R: median 1.549, mean 2.210) is achieved almost exclusively during the pandemic period (Q: median 1.829, mean 2.499; R: median 1.291, mean 1.546), whereas the pre-pandemic distributions are practically overlapping (Q: median 1.913, mean 2.791; R: median 1.815, mean 2.757). Hence, while the out-engage factor from the inside perspective remains somewhat constant with respect to vaccine-related content and narratives of the Questionable sourceset, the Covid-19 infodemics has made the consumption of vaccine news from Reliable sources more complex compared to the pre-pandemic period (See Supplementary Table 6).

The differences in how users engage with vaccine news from Questionable and Reliable sources are definitely more evident when we investigate the outside perspectives, namely when we compare the per-content engagement normalized by followers of one sourceset to the other. The audience engagement distribution for Questionable sources clearly dominates that for Reliable sources during the overall period (Q: median 12.385, mean 110.217, R: median 1.647, mean 3.107). This is essentially due to the enormous gap observed during the pre-pandemic period, when Questionable sources reached as a whole a median out-engage factor of $\sim 20.6$ (mean 163.814) compared to $\sim 1.7$ (mean 3.229) for Reliable sources. Naturally, because of outliers, averages are considerably higher than the medians. The low engagement gained by Reliable sources is clearly the result of the low level of attention paid to the vaccine issue prior to the Covid-19 outbreak and observed in the previous section. The latter could also explain the unreadiness of the news ecosystem to address a crisis communication such as that which has accompanied the pandemic since its early stages. Ambiguous communication about the disease origin, transmission and treatment, disjointed narratives and mixed messages about the side effects and clots caused by the AstraZeneca vaccine - just to name a few - have fostered confusion and distrust in some communities, and also added to the skepticism in the entire vaccination system. As a matter of fact, only nine days of the pandemic see vaccine news from Reliable sources overperform the same subject from Questionable sources. Nevertheless, contrary to the inside perspective, while the out-engage factor from the outside perspective remains almost constant for the Reliable sourceset (median 1.433, mean 1.862), Questionable sources lose much of the engagement advantage (median 6.971, mean 14.933) achieved during the pre-pandemic period (See Supplementary Table 7 for more statistical details). Hence, although the news narratives of Reliable sources on the vaccine subject were never particularly successful throughout the period analysed, the Covid-19 outbreak
had a levelling effect on the disproportion of engagement between sources that have a reputation for misinformation and those that do not.

**Polarising topics and the engaging power of extreme opinions**

To point out the key features of the social media communication dynamics on vaccines, we study the opinions expressed and the topics discussed by Questionable and Reliable sources.

To this aim, a state-of-the-art neural model is trained to distinguish between three different perspectives on vaccination (anti-vax, neutral, pro-vax) and six different topics (administration of vaccines, vaccine business, effectiveness of vaccination, legal issues, safety concerns, other), respectively. Both models are trained on a manually annotated set of contents, representing \( \sim 10\% \) of the total dataset, and reach 0.88 as accuracy score on the evaluation set (see Materials and Methods for details).

Figure 3 (left panel) shows a substantial time-invariance of the distribution of vaccine-related content from Reliable sources among the three opinion classes. As expected, the neutral perspective is dominant, exceeding 65% in both the pre-pandemic and pandemic sub-periods, followed by pro-vax opinion and a more marginal percentage of content conveying anti-vax views, which however exceeds 10% during Covid-19 outbreak\(^1\). Differently, the Covid-19 outbreak seems to have had a significant impact on the communication choices of the Questionable counterpart. The anti-vax perspective, which was clearly dominant throughout the pre-pandemic period, loses about 25% in favour of uplifting views during the pandemic and drops from 65% to 40% (See Supplementary Figure 4 for the percentage of vaccine coverage by each news source analysed with respect to the different opinion classes).

| Overall | Pre-pandemic | Pandemic | Overall | Pre-pandemic | Pandemic |
|---------|--------------|----------|---------|--------------|----------|
| Anti-vax | Neutral      | Pro-vax  | Anti-vax | Neutral      | Pro-vax  |
| Questionable | 1233 | 589 | 644 | 481 | 427 | 54 |
| Reliable | 1397 | 297 | 961 | 98 | 436 | 199 |

**Figure 3**: Opinion percentage distribution with respect to vaccine-related content from Questionable and Reliable sourcesets, respectively (left panel). User engagement with vaccine-related content from Questionable and Reliable sourcesets, respectively, conveying the corresponding opinion (right panel). Figure reports both the inside and outside perspectives. Distributions refer distinctly to the overall period, and both the pre-pandemic and pandemic sub-periods.

In order to investigate the user engagement dynamics corresponding to different narratives, we study the distribution of the out-engage factor from both the inside and outside perspectives. With respect to the former perspective, denoted with \( X \) the vaccine-related content conveying the opinion \( x \), \( X^c \) in \( P(R; X, X^c; d) \) (\( P(Q; X, X^c; d) \)) will indicate the remaining vaccine-related content, i.e., those conveying any opinion other than \( x \).

Figure 3 (right panel) shows a clear degree of symmetry with respect to the axis identified by the neutral distribution between Questionable and Reliable source sets from the inside perspective, regardless of the period considered. Namely, if the most engaging content among those produced by Questionable sources convey an anti-vax opinion (Overall: median 4.000, mean 16.798; Pre-pandemic: median 5.875, mean 22.316; Pandemic: median 2.744, mean 10.164), then the high-engagement content from Reliable sources corresponds to pro-vax opinion (Overall: median 3.502, mean 23.289; Pre-pandemic: median 6.094, mean 38.584; Pandemic: median 2.587, mean 4.307). On the contrary, pro-vax opinion from Questionable sources (Overall: median 2.800, mean 7.406; Pre-pandemic: median 3.984, mean 12.943; Pandemic: median 2.744, mean 10.164) was significantly lower than its equivalent in Reliable sources.

\(^1\)As proof of the extent to which mainstream information is involved in the dissemination of anti-vax views, it is worth noting that, partly due to the limited number of Questionable sources (161) compared to the Reliable ones (521), the anti-vax content from the latter (30,622) numerically accounts for \( \sim 1.6 \) times those from the former (18,994) throughout the overall period.
Pandemic: median 2.370, mean 4.901) and anti-vax opinion from Reliable sources (Overall: median 2.319, mean 7.141; Pre-pandemic: median 3.668, mean 5.940; Pandemic: median 1.904, mean 3.165) perform worse on average or in the median, both roughly comparable to the neutral one.

Even from the outside perspective, sorting the opinions according to their out-engage factor results in opposite rankings for the two sourcesets, regardless of the period considered. Moreover, when comparing the same opinion from one sourceset and the other, respectively, the greater engaging power of alternative narrative over the mainstream one is much more evident, specially concerning those content conveying anti-vax opinion (Overall: Q median 17.800, mean 940.100; R median 2.309, mean 5.586). Nevertheless, as observed without dividing the content according to the opinion conveyed (see Figure 2), while the out-engage factor from the outside perspective remains somehow constant for any opinion conveyed by the Reliable sourceset (median value drops from 2.497 in the pre-pandemic period to 1.717 in the pandemic period for anti-vax opinion, and from 3.383 to 2.349 for pro-vax opinion), the shock effect of the Covid-19 outbreak has significantly reduced the engaging power of Questionable sources (median value drops from 64.600 to 10.050 for anti-vax opinion, and from 11.026 to 4.860 for pro-vax opinion). See Supplementary Tables 8 and 9 for more statistical details.

To better understand why audience engagement follows different dynamics depending on whether the content is produced by disinformation sources or not, it is essential to analyse the nature of the vaccine debate, and thus the different topic coverage over time. Figure 4 shows, for both the sourcesets, the coverage distribution among the six topic categories identified. The inner bar refers to the percentage of content conveying anti-vax opinion (red) for Questionable sourceset and pro-vax opinion (azure) for Reliable sources, these being the most engaging views, respectively, both from the inside and outside perspectives.

Regarding Questionable sources, while two-thirds of the vaccine news produced during the pre-pandemic period is about safety concerns, legal issues and vaccine business, most of them (∼ 80%) conveying anti-vax opinion, the same topics is covered by “only” two-fifths of the vaccine-related content during the pandemic, and “only” 60% of the time with an anti-vax opinion. As a consequence, Questionable sources have lost much of the engaging power with the Covid-19 outbreak, also because the drastic reduction in coverage of the most polarising arguments was balanced by the increase in content on two trending topics of the pandemic period: administration of vaccines and effectiveness of vaccination. Daily bulletins on the number of vaccines administered and infection trends, on the one hand, and data on the percentage and duration of vaccination effectiveness, on the other, are, however, topics where it has been much more difficult to impose a conspiracy narrative, especially from a strictly anti-vax perspective.

Regarding Reliable sources, while most topics receive constant attention throughout the period analysed, even with respect to the percentage of pro-vax opinion conveyed, administration of vaccines and legal issues have opposite trends both among themselves and in relation to the sub-period analysed. Content on vaccines administered drop from accounting 24% of vaccine coverage in the pre-pandemic period to 55% with the Covid-19 outbreak. Legal issues concerning the implementation of the Vaccination Act are discussed in ∼ 28% of content, while the debate on whether or not compulsory enforcing vaccination
against Covid-19 accounts for only \(\sim 6\%\). Moreover, by comparing the levels of pro-vax coverage by Reliable sources and anti-vax coverage by Questionable sources on the most polarising topics, it is evident that, except for effectiveness of vaccination, Reliable sources have never adequately countered the anti-vax narrative, specially in the pre-pandemic period. Confirming the efficacy of assiduously proposing a convincing counter-narrative on polarising arguments, effectiveness of vaccination was the least engaging topic within the Questionable sourceset during the pandemic period, when compared to safety concerns, legal issues and vaccine business (See Supplementary Table 10 for the percentage distribution of vaccine-related content among the six topics).

To analyse the relationship between different types of vaccine-related content, both with respect to news source provider, opinion conveyed and topic discussed, and the corresponding user engagement, we also rely on some econometric models. Given the nature of the problem (analysis of differences between information of different quality) and the data available (unbalance panel), we focus on the following models:

\[
y_{it} = \alpha + \beta x_i + \gamma z_{it} + \theta_i + \epsilon_{it}, \quad i = 1, 2, \ldots, N, \quad t = 1, 2, \ldots, T
\]

where \(i\) is the index of news source, \(t\) is time (days since January 1th, 2016), \(y_{it}\) is the user engagement on vaccine-related content from source \(i\) on day \(t\), \(x_i\) is a vector of time-independent source-related variables (e.g., the reliability category: Reliable vs. Questionable), \(z_{it}\) are time-dependent factors (e.g., number, type and topic of news content), and \(\theta_i, \epsilon_{it}\) are the error terms (with the auto-correlated component). Random effects regressions with AR(1) disturbance have been estimated\(^{[49, 50, 51]}\). Results are presented in Table 3.

| Model Variable | Opinion (I) | Opinion (II) | Topic (III) | Topic (IV) |
|----------------|-------------|-------------|-------------|-------------|
| Source’s quality | Questionable (D) | .000778 (0.000245)*** | .000464 (0.000241)* | .000849 (0.000246)*** | .000567 (0.000242)** |
| Content | Anti-vax (ln) | .000540 (0.000128)*** | .000349 (0.000161)*** | | |
| | Quest-Anti-vax (D-ln) | .013400 (0.00262)*** | .00125 (0.00008)*** | .000125 (0.00038)*** | .000317 (0.00007)*** | .000035 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** |
| | Pro-vax (ln) | -.000282 (0.000111)** | .000680 (0.000117)*** | | |
| | Quest-Pro-vax (D-ln) | -.000280 (0.00038)*** | .00222 (0.000173)*** | .000292 (0.000189)*** | .000363 (0.00031)*** | .000000 (0.00000)*** | .000000 (0.00000)*** | .000000 (0.00000)*** |
| Topic | Administration (ln) | | | -0.00317 (0.00007)*** | .000355 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** |
| | Quest-Anti-vax (D-ln) | | | .000946 (0.000227)*** | .000000 (0.00000)*** | .000000 (0.00000)*** | .000000 (0.00000)*** | .000000 (0.00000)*** |
| | Business (ln) | .000946 (0.000227)*** | .000000 (0.00000)*** | .000000 (0.00000)*** | .000000 (0.00000)*** | .000000 (0.00000)*** | .000000 (0.00000)*** | .000000 (0.00000)*** |
| | Legal (ln) | .000179 (0.000052)*** | .000292 (0.000189)*** | .000125 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** |
| | Quest-Legal (D-ln) | .000179 (0.000052)*** | .000292 (0.000189)*** | .000125 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** | .000355 (0.00008)*** |
| | Effectiveness (ln) | .000000 (0.000015) | .000034 (0.000125)*** | .000357 (0.000130)*** | .000249 (0.000151)* | .0125 (0.000297)** | .000125 (0.00004)*** | .000125 (0.00004)*** |
| | Quest-Effectiveness (D-ln) | .000000 (0.000015) | .000034 (0.000125)*** | .000357 (0.000130)*** | .000249 (0.000151)* | .0125 (0.000297)** | .000125 (0.00004)*** | .000125 (0.00004)*** |
| | Safety (ln) | .000034 (0.000012)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** |
| | Quest-Safety (D-ln) | .000034 (0.000012)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** | .000012 (0.000003)*** |
| Controls | Time (weekday, month, year) | YES | YES | YES | YES |
| Summary stats | Observations | 1,378,129 | 1,378,129 | 1,378,129 | 1,378,129 |
| | Number of sources | 680 | 680 | 680 | 680 |
| | Chi-squared (df) | 1961.98 (26)*** | 4609.65 (28)*** | 1218.21 (29)*** | 4035.04 (34)*** |
| | R² between | .1135 | .0797 | .0787 | .2141 |

The estimates refer to random effects models with AR(1) disturbance. The baselines of the estimates are for models on stance (I and II) "neutral opinions", and for those on topics (III and IV) "other topics" on vaccines (e.g., events, related news). The dependent variable is the natural logarithm of the engagement. For each variable, the coefficient, the standard error (in parentheses), and the level of significance (*** 1%; ** 5%; * 10%) are reported.

Table 3: Random effects regressions with AR(1) disturbance.

First, Questionable sources significantly increase vaccine news engagement in all estimates. This result seems to highlight the greater emotional reaction to the vaccine topic from the anti-vax community. In fact, content conveying anti-vax opinion increases engagement while pro-vax content decreases it (Model I). The elasticity of the former is positive and significant (equal to 0.05%), while the elasticity of the latter is negative (-0.03%), and increases significantly when anti-vax content is proposed by Questionable sources. In addition, the unbalanced nature of the panel and the fact that \(T\) is greater than \(N\) led to choose a model with autocorrelated disturbances. In any case, random effects regressions with robust estimator of variance were also estimated and the results presented in the paper are confirmed.
sources (1.34%, Model II, coefficient of the interactive variable). Conversely, when Questionable sources convey pro-vax opinion, engagement drops by 0.03%. In essence, the polarisation highlighted above about the narrative on vaccines of the news sources (pro-vax for those Reliable, and anti-vax for those Questionable) is reflected on the emotional reactions of the corresponding communities of users. If we focus on the vaccination topics (Models III and IV), those that elicit the greatest reactions are business and legal issues, as well as those related to safety concerns (with an elasticity of 0.4%). Again, if we distinguish topics by quality of information, a clear polarisation emerges. Questionable sources arouse strong emotional reactions in the case of narratives linked to business and legal aspects of vaccinations, as well as to the safety of vaccines (with an elasticity that reaches 1.3%). Engagement drops instead for administration of vaccines and, confirming the importance of assiduous counter-narratives to highly polarising content, effectiveness of vaccination.

Materials and methods

Data collection

We collected about 350K vaccine-related contents published on Facebook, Instagram, Twitter and YouTube by almost all Italian news sources in the 6-year period that goes from 01/01/2016 to 31/12/2021. Data from Facebook and Instagram were collected through Facebook’s CrowdTangle API, whereas data from Twitter and YouTube were gathered by means of their official APIs.

With the only exception of the instant messaging services Whatsapp and Facebook Messenger, the four analysed platforms represent the most used social media in Italy during 2021: YouTube was used by 85.3% of Internet users aged 16 to 64, Facebook 80.4%, Instagram 67%, and Twitter 32.8% (source: GWI)

To ensure the most representative picture of both traditional and new media, we considered a wide range of national/local newspapers, radio/TV channels and online news outlets that were active in Italy during the aforementioned period. Namely, we selected:

- 96 out of the 121 major Italian newspapers that in 2021 reached 30 million Italians, i.e., ~60% of the population aged more than 18 (source: GfK Mediamonitor);
- 462 online-only news outlets that in 2021 monthly reached 40 million Italians, i.e., ~96% of the total internet audience (source: ComScore);
- 89 TV channels, including all RAI newscasts (3 national and 20 regional), that in 2021 monthly reached 8 million Italians, i.e., ~54% of the TV audience (source: Auditel);
- 35 radio channels that in 2021 daily reached 26 million Italians, i.e. ~77% of radio listeners (source: RadioTER - Tavolo Editori Radio).

Then, limited to the 682 selected sources (see Supplementary Table 1 for the list), we performed a keyword search for content that matched an exhaustive list of vaccine-related keywords, including general terms (e.g. vaccine, vaccination) and vaccine brands/names, both mandatory (e.g. Hexyon, Menjugate), recommended (e.g. Bnt162b2, Gardasil, Janssen, Twinrix) and others available (e.g. Vaxchora, Ervebo). See Supplementary Table 2 for the complete list of keywords. Hence, the data collected can reasonably be considered as the whole vaccine-related information provided to Italian citizens during the period under investigation.

We assigned a binary label to each news source to distinguish between two categories: Questionable - i.e., a source producing mainly unverified or false content - and Reliable. The list of Questionable news sources was gathered by merging the lists from independent fact-checking organizations - i.e., bufale.net, butac.it, facta.news, newsguardtech.com, and pagellapolitica.it. The remaining sources were labelled as Reliable. Table 4 shows a breakdown of the dataset. Data are divided by sourceset and period analysed (Pre-pandemic 01/01/2016 - 29/01/2020, Pandemic 30/01/2020 - 31/12/2021, Overall 01/01/2016 - 31/12/2021), and concern the number of sources, contents and corresponding user interactions (understood as the algebraic sum of all possible actions/reactions performed on the four platforms analysed).

Time series and causality analysis

The correlation functions for testing and measuring causality (e.g. Granger causality [52]) have been applied in a number of fields, including social media [53, 54]. Despite the widespread, their use is limited
Table 4: Breakdown of the dataset.
respectively. Let now $X$ be a universe of pairwise disjoint features and $X \subset X$. We write $C(S; X; T)$ and $I(S; X; T)$ for denoting that the aforementioned quantities concern the set of features $X$.

We compute the total user engagement with the $X$-related content published by $S$ during $T$ as the real number

$$E(S; X; T) = \frac{I(S; X; T)}{C(S; X; T) \cdot F(S; T)}$$

(4)

where $F(S; T)$ represents the average number of followers of the social media accounts of $S$ which were active during $T$. In other words, if $s \in S$ did not publish any content on any of the analysed platforms throughout $T$, its contribution $E(s; X; T)$ to $E(S; X; T)$ is 0. If $s$ was only active on Facebook during $T$, then $F(s; T)$ counts only the average number of its fans on Facebook during $T$.

To assess the importance of the $X$-related content published by $S$ throughout $T$ in terms of user engagement, we investigate two different points of view: the out-engage factor of $X$ to $X'$, that is the complement of $X$ in $X$ (inside perspective); the out-engage factor of $X$ in $S$ to itself in $S'$, that is the complement of $S$ in $U$ (outside perspective). Namely, we refer to the factor of proportionality of $E(S; X; T)$ to $E(S^c; X; T)$ in the former case, and to the factor of proportionality of $E(S; X; T)$ to $E(S^c; X; T)$ in the latter case. To these aims, we consider the function with codomain $\mathbb{R} \setminus [-1,0] \cup (0,1]$ defined by

$$P(S, S'; X, X'; T) = \delta(S, S'; X, X'; T) \left( \frac{E(S; X; T)}{E(S', X; T)} \right)^{\delta(S, S'; X, X'; T)}$$

(5)

where $S'$ is another set of sources, $X'$ another set of subjects, and $\delta$ stands for the sign function of the difference $E(S; X; T) - E(S'; X'; T)$:

$$\delta(S, S'; X, X'; T) = \begin{cases} 1 & \text{if } E(S; X; T) > E(S'; X'; T) \\ 0 & \text{if } E(S; X; T) = E(S'; X'; T) \\ -1 & \text{if } E(S; X; T) < E(S'; X'; T) \end{cases}$$

(6)

It is straightforward to notice that $P(S, S'; X, X'; T) = 0$ if and only if the user engagement on $X$-related content from $S$ during $T$ equals the user engagement on $X'$-related content from $S'$ during the same time span. Otherwise, if $P(S, S'; X, X'; T) \in [1,\infty]$ then the user engagement on $X$-related content from $S$ is higher than the user engagement on $X'$-related content from $S'$, and we say that $X$ is overperforming in $S$ with respect to $X'$ in $S'$ during $T$. Conversely, if $P(S, S'; X, X'; T) \in [-\infty,1)$ we say that $X'$ is overperforming in $S'$ with respect to $X$ in $S$ during $T$.

For $S' = S$ and $X' = X^c$ the absolute value returned by (5) responds to the inside perspective, and we also write $P(S; X, X^c; T)$. For $S' = S^c$ and $X' = X$ it responds to the outside perspective, and we also write $P(S, S^c; X; T)$.

In the analysis, we consider the partition of the selected sourceset into Questionable and Reliable subsets, and we study the distribution of the daily out-engage factor of the vaccine subject from both the perspectives. Limited to vaccine-related content, we also investigate both the perspectives in the universe of possible opinions conveyed: anti-vax, neutral, pro-vax.

**Modeling opinion conveyed and topic discussed in vaccine-related content**

One of the goal of this study is to build a deep learning model capable of predicting whether the text of social media content conveys anti-vaccine, neutral or pro-vaccine opinion. We first manually annotated $\sim 10\%$ of the content gathered. Despite the sample was intentionally selected to contain as much extreme opinion as possible, approximately half of the annotated data concerns neutral opinion. To make the model more balanced between opinion classes and more confident with the local space around extreme opinions, we applied text data augmentation techniques to content annotated as conveying anti- or pro-vaccine opinion. The augmented dataset was then split into two parts to produce a dataset for training and a dataset for evaluating the model. We then apply the model to all the collected data and study the relationship between source category (Questionable or Reliable) and content opinion (anti-vax, neutral or pro-vax).

The annotation process also concerned the identification of the topic discussed: one of administration of vaccines, vaccine business, effectiveness of vaccination, legal issues, safety concerns, other. Then we used the same training and test datasets also to build a deep learning model capable of predicting the topic discussed in vaccine-related content.

Deep learning models based on Transformer architecture outperform other approaches to most automated natural language processing (NLP) tasks, especially when data comes from social media [62, 63].
Hence, we followed the Google’s pre-trained language model [64], which represents the state-of-the-art for semantic text representation in most languages [65], to train our Italian models.

**Data selection, annotation and augmentation.** The content to be annotated were sampled from the collected data. To get a training set as rich as possible with both anti-vaccine and pro-vaccine opinion, we intentionally annotated about three-quarters (9,071) of content published by those news sources that mainly cover topics concerning medicine, science and technology, both Questionable (the more likely to convey anti-vaccine opinion) and Reliable (the more likely to convey pro-vaccine opinion). Other 25,232 contents to be annotated were randomly selected from the data produced by the remaining sources. The data to annotate was split among the authors. The splitting procedure was optimised to get ∼20% overlap between the authors. This allowed us to compare the annotator agreement results with the model performance (see Classification). The total annotated data consist of 34,303 contents, divided according to the opinion conveyed in 9,902 anti-vaccine, 17,258 neutral, and 7,143 pro-vaccine.

Since anti-vax and pro-vax opinions are only conveyed by about half of the annotated contents, we applied a text data augmentation technique to make the model more balanced between opinion classes and more familiar with the local space around non-neutral opinion. Namely, we relied on the nlpaug Python library [66] to get 11,712 augmented contents. Augmented contents were obtained by inserting words in a selection of data annotated as anti-vaccine or pro-vaccine through the contextual word embedding of BERT, i.e, the pre-trained language model then fine tuned to the annotated data. The data to be augmented were chosen randomly but preserving the topic distribution of the whole annotated dataset.

The augmented dataset was then split into two parts to produce a dataset for training (80%) and a dataset for evaluating (20%) the model, by ensuring on both sets the same class distribution with respect to both opinions and topics. To assure proper model evaluation, neither the annotated content used as a basis for the augmentation nor the augmented content were included in the evaluation set.

The annotation results with respect to opinion and topic for the training and evaluation sets are summarised in Table 5.

|       | Adm | Bus | Eff | Leg | Oth | Saf | ∑    |       |
|-------|-----|-----|-----|-----|-----|-----|------|-------|
| A     | 941 | 1,019 | 1,895 | 929 | 238 | 6,664 | 11,686 | (31%) |
| N     | 6,733 | 311 | 1,816 | 1,379 | 1,121 | 2,351 | 13,711 | (38%) |
| P     | 1,734 | 320 | 5,664 | 491 | 435 | 2,681 | 11,325 | (31%) |
| ∑     | 9,408 | 1,650 | 9,375 | 2,799 | 1,794 | 11,696 | 36,722 | (100%) |

(a) Training set.

|       | Adm | Bus | Eff | Leg | Oth | Saf | ∑    |       |
|-------|-----|-----|-----|-----|-----|-----|------|-------|
| A     | 235 | 254 | 474 | 232 | 59 | 1,666 | 2,920 | (31%) |
| N     | 1,808 | 78 | 454 | 344 | 280 | 587 | 3,551 | (38%) |
| P     | 433 | 80 | 1,415 | 122 | 108 | 670 | 2,828 | (31%) |
| ∑     | 2,476 | 412 | 2,343 | 698 | 447 | 2,923 | 9,299 | (100%) |

(b) Evaluation set.

Table 5: Annotation results for both (a) training and (b) evaluation sets. Rows refer to opinion classes: A = anti-vaccine, N = neutral, P = pro-vaccine. Columns refer to topic classes: Adm = administration of vaccines, Bus = vaccine business, Eff = effectiveness of vaccination, Leg = legal issues, Saf = safety concerns, Oth = other.

**Classification.** A state-of-the-art neural model based on Transformer language models was trained to distinguish between the three opinion classes. We used the pre-trained BERT multilingual cased model [64] consisting of 12 stacked Transformer blocks with 12 attention heads each. We attached a linear layer with a softmax activation function at the output of these layers to serve as the classification layer. As input to the classifier, we take the representation of the special [CLS] token from the last layer of the language model. The whole model is jointly trained on the downstream task of three-class opinion identification. According to the BERT reference paper [64], fine-tuning of the neural models was performed end-to-end. We used the Adam optimizer with the learning rate of 5e−5 and weight decay...
set to 0.01 for regularization [67]. The model was trained for 4 epochs with batch size 64 through the HuggingFace Transformers library [68].

The same pre-trained architecture and hyperparameters were also used to train a model for distinguishing between the six topics.

Table 6 reports the performance of the trained models compared with the inter-annotator agreement by using the same measure: accuracy (Acc) and the F1 score for individual classes, on both the training and the evaluation datasets. The confusion matrices for the evaluation set, used to compute all the scores of the annotator agreements and the model performance, are reported in Supplementary Tables 11 and 12.

| Performance and agreement | Overall Acc | A F1 | N F1 | P F1 |
|---------------------------|------------|------|------|------|
| **Model**                 |            |      |      |      |
| Training                  | 0.93       | 0.93 | 0.91 | 0.94 |
| Evaluation                | 0.88       | 0.88 | 0.86 | 0.90 |
| **Inter-annotator**       |            |      |      |      |
| Training                  | 0.89       | 0.90 | 0.86 | 0.89 |
| Evaluation                | 0.89       | 0.90 | 0.87 | 0.89 |

(a) Opinion model.

| Performance and agreement | Overall Acc | Adm F1 | Bus F1 | Eff F1 | Leg F1 | Oth F1 | Saf F1 |
|---------------------------|------------|--------|--------|--------|--------|--------|--------|
| **Model**                 |            |        |        |        |        |        |        |
| Training                  | 0.94       | 0.94   | 0.85   | 0.94   | 0.88   | 0.79   | 0.95   |
| Evaluation                | 0.88       | 0.88   | 0.83   | 0.89   | 0.80   | 0.73   | 0.92   |
| **Inter-annotator**       |            |        |        |        |        |        |        |
| Training                  | 0.91       | 0.89   | 0.83   | 0.92   | 0.81   | 0.78   | 0.95   |
| Evaluation                | 0.87       | 0.86   | 0.78   | 0.89   | 0.78   | 0.70   | 0.92   |

(b) Topic model.

Table 6: Performance of our vaccine (a) opinion and (b) topic classification models on the training set and the evaluation set, in comparison to the inter-annotator agreement on the same datasets. The overall performance is measured by accuracy (Acc), and performance for individual classes by F1 score.

**Conclusions**

In this article we analysed the public debate on vaccines over the past six years. We did this by (i) examining the news production of the main Italian generalist and specialized news outlets, binary divided into sources that have a reputation for misinformation (Questionable) and those that do not (Reliable), (ii) categorizing the vaccine-related content by topic discussed and opinion conveyed, and (iii) comparing the corresponding engagement of the audience that follow the two source sets. The results highlight a complex picture that needs to be illustrated in all its facets. Indeed, the information dynamic changes over time. At first, when the debate centered on the enactment and implementation of a paediatric vaccine law, Questionable sources provided more coverage of this topic by establishing themselves as drivers of the process, even in causal terms, and gaining dramatically more user engagement than news from the mainstream media. This information gap was filled during the pandemic period when established sources covered the topic more thoroughly. However, the newfound leading role of Reliable sources as drivers of the information ecosystem has only partially had a beneficial effect in reducing engagement with misinformation on vaccines.

Our results indeed show that, except for effectiveness of vaccination, Reliable sources have never adequately countered the anti-vax narrative, specially in the pre-pandemic period, thus contributing to science denial and belief in conspiracy theories. At the same time, however, they confirm the efficacy of assiduously proposing a convincing counter-narrative to misinformation spread. Indeed, effectiveness of vaccination turns out to be the least engaging topic within the Questionable source set during the pandemic period, when compared to other polarising arguments such as safety concerns, legal issues and vaccine business.
Summarizing, our findings render the spread ease of false narratives among the public as only partially attributable to the presence of misinformation sources, and more likely due to the inability of institutional and mainstream communication in addressing issues that are particularly sensitive and important, at least for a portion of the population. We therefore believe that the article brings some interesting and new insights to the scientific and policy debate but given the complexity of the phenomenon much remains to be explored. Specifically, the next step is to link this analysis to the actual behaviors of citizens. For example, the issue of vaccination hesitancy is a crucial topic to investigate. The challenge is to address the whole complex process from the public sphere to individual and social behaviors by analysing large and representative samples of citizens.

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Dynamics of information flow and engaging power of narratives in the polarised debate on vaccines

Supplementary Information

| Source name                                      | Sourceset       | Source medium | Source subject          |
|------------------------------------------------|-----------------|---------------|-------------------------|
| A Chi Sacciu                                    | Questionable    | Online        | Entertainment           |
| Accademia della Libertà                         | Questionable    | Online        | Culture & Society       |
| Agenpress                                       | Questionable    | Online        | General News            |
| Ambiente Bio                                    | Questionable    | Online        | Nature & Animals        |
| Apri la Mente                                   | Questionable    | Online        | Lifestyle               |
| ArticoloTre                                     | Questionable    | Online        | General News            |
| Associazione Comilva                            | Questionable    | Online        | Science & Technology    |
| Attivo Tv                                       | Questionable    | Online        | General News            |
| Autismo e Vaccini                               | Questionable    | Online        | Science & Technology    |
| Avvistamenti di Creature Mitologiche            | Questionable    | Online        | General News            |
| Avvistamenti E Contatti                         | Questionable    | Online        | Science & Technology    |
| Banda Bassotti                                  | Questionable    | Online        | General News            |
| Basta Bugie                                     | Questionable    | Online        | General News            |
| Benessere Feed                                  | Questionable    | Online        | Lifestyle               |
| Break Notizie                                   | Questionable    | Online        | General News            |
| Byo Blu - Claudio Messora                       | Questionable    | Online        | General News            |
| Caffecina Media                                 | Questionable    | Online        | Entertainment           |
| Catena Umana Attorno Al Parlamento Italiano     | Questionable    | Online        | Politics                |
| Centro Meteo Italiano                           | Questionable    | Online        | Weather                 |
| Che Succeed                                    | Questionable    | Online        | Entertainment           |
| Cogito ergo sum... Penso dunque sono            | Questionable    | Online        | Business/Finance        |
| Come Don Chisciotte                             | Questionable    | Online        | General News            |
| Come i treni a vapore                           | Questionable    | Online        | Politics                |
| Complottisti                                    | Questionable    | Online        | Science & Technology    |
| Condividilio                                   | Questionable    | Online        | General News            |
| Conoscenze al Confine                           | Questionable    | Online        | Science & Technology    |
| Contro la Massoneria e gli Illuminati           | Questionable    | Online        | Politics                |
| Controinformo                                   | Questionable    | Online        | General News            |
| Corvelva                                       | Questionable    | Online        | Science & Technology    |
| Coscienza Italiana                              | Questionable    | Online        | General News            |
| COSMO Fruttariano 3M                            | Questionable    | Online        | Lifestyle               |
| Curarsi Al Naturale                              | Questionable    | Online        | Lifestyle               |
| Destra di Popolo                                | Questionable    | Online        | Politics                |
| Dinamo Press                                    | Questionable    | Online        | General News            |
| Dionidream - Ricardo Lautizi                    | Questionable    | Online        | Lifestyle               |
| Diretta News24                                  | Questionable    | Online        | General News            |
| DirettaNews                                     | Questionable    | Online        | General News            |
| Disinformazione                                 | Questionable    | Online        | General News            |
| Disquisendo                                     | Questionable    | Online        | General News            |
| Eclissi Sociale                                 | Questionable    | Online        | Entertainment           |
| Eco(R)esistenza                                 | Questionable    | Online        | Nature & Animals        |
| ECplanet                                        | Questionable    | Online        | Nature & Animals        |
| Source name                      | Sourceset         | Source medium | Source subject        |
|----------------------------------|-------------------|---------------|-----------------------|
| Essere Informati It              | Questionable      | Online        | General News          |
| Etica Mente                      | Questionable      | Online        | General News          |
| Eurosalus                        | Questionable      | Online        | Lifestyle             |
| Evidenzialiena                   | Questionable      | Online        | Science & Technology  |
| FacecCaso                        | Questionable      | Online        | General News          |
| Fascinazione                     | Questionable      | Online        | General News          |
| Fonte Verificata                 | Questionable      | Online        | General News          |
| Fuori Di Matrix                  | Questionable      | Online        | General News          |
| Gli occhi della guerra           | Questionable      | Online        | General News          |
| Globalist                        | Questionable      | Online        | General News          |
| GOSPA News                       | Questionable      | Online        | General News          |
| Gruppo 'Gnazzzio                 | Questionable      | Online        | General News          |
| Gruppo AsSIS                     | Questionable      | Online        | General News          |
| GuardaCheVideo                   | Questionable      | Online        | General News          |
| Hack the Matrix                  | Questionable      | Online        | Science & Technology  |
| Howtodorefor                     | Questionable      | Online        | General News          |
| Igienista Mentale                | Questionable      | Online        | General News          |
| Il Faro Sul Mondo                | Questionable      | Online        | General News          |
| Il Giornale Italiano             | Questionable      | Online        | General News          |
| Il Meglio Del Web                | Questionable      | Online        | Lifestyle             |
| Il Mondo di Noi Donne            | Questionable      | Online        | General News          |
| Il Populista                     | Questionable      | Online        | General News          |
| Il Primato Nazionale             | Questionable      | Online        | General News          |
| Il sapere e’ potere 2            | Questionable      | Online        | General News          |
| iLMeleo                          | Questionable      | Online        | Weather               |
| Imola Oggi                       | Questionable      | Online        | General News          |
| I'News 24                        | Questionable      | Online        | General News          |
| Informa Italia                   | Questionable      | Online        | General News          |
| Informare Blog Over - Gianni Fraschetti | Questionable | Online        | General News          |
| Informare Per Resistere          | Questionable      | Online        | General News          |
| Informasalus.it - L'Indipendenza del Sapere | Questionable | Online        | Science & Technology |
| Infosanmini                      | Questionable      | Online        | General News          |
| Infovax - vaccini e informazione| Questionable      | Online        | Science & Technology  |
| IO VI Spengo                     | Questionable      | Online        | Lifestyle             |
| Italia Patria Mia                | Questionable      | Online        | General News          |
| Italeuropeo News                 | Questionable      | Online        | General News          |
| Jeda News                        | Questionable      | Online        | General News          |
| John Koenig Mb Koenig            | Questionable      | Online        | General News          |
| JulieNews                        | Questionable      | Online        | General News          |
| Ke Video                         | Questionable      | Online        | Lifestyle             |
| Killuminati Soldiers             | Questionable      | Online        | General News          |
| Kontrokultura                    | Questionable      | Online        | Entertainment         |
| L'Antidiplomatico                | Questionable      | Online        | Business/Finance      |
| L'Irresponsabile                 | Questionable      | Online        | General News          |
| La Finanza sul Web               | Questionable      | Online        | Business/Finance      |
| La Nuova Bussola Quotidiana      | Questionable      | Online        | General News          |
| La Verita di Ninco Nanco         | Questionable      | Online        | General News          |
| La Voce del Patriota             | Questionable      | Online        | General News          |
| Le notizie che non ti aspetti    | Questionable      | Online        | General News          |
| Leggilo.org                      | Questionable      | Online        | General News          |
| Letto Quotidiano                 | Questionable      | Online        | General News          |
| LiberaMente Servo                | Questionable      | Online        | General News          |
| Lo Sbuffo                        | Questionable      | Online        | Entertainment         |
| L'Alimentazione e Gli Illuminati | Questionable      | Online        | General News          |
| L'Antipolitica                   | Questionable      | Online        | Business/Finance      |
| Mafia Capitale                   | Questionable      | Online        | Entertainment         |
| Source name                                      | Sourceset  | Source medium | Source subject     |
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| Massimo Mazzucco - Luogo Comune                | Questionable | Online        | General News       |
| Mattino Online                                  | Questionable | Online        | General News       |
| Maurizio Blondet                                | Questionable | Online        | General News       |
| MEDNA T.news                                    | Questionable | Online        | General News       |
| Meteo Giornale                                  | Questionable | Online        | Weather            |
| MeteoWeb                                       | Questionable | Online        | Weather            |
| Neovitruvian                                   | Questionable | Online        | General News       |
| News Cronaca                                    | Questionable | Online        | General News       |
| Nexus Edizioni                                  | Questionable | Online        | General News       |
| No a Massoneria e Nwo Macerata                  | Questionable | Online        | General News       |
| No Censura                                     | Questionable | Online        | General News       |
| Notizie In Movimento                            | Questionable | Online        | General News       |
| Notizie Ora                                     | Questionable | Online        | General News       |
| Oltre.tv                                       | Questionable | Online        | General News       |
| Open Your Eyes                                  | Questionable | Online        | General News       |
| Operatori Di Luce                               | Questionable | Online        | Lifestyle          |
| Ora Zero                                       | Questionable | Online        | General News       |
| PandaPazzo.com                                  | Questionable | Online        | General News       |
| Pandora TV                                      | Questionable | Online        | General News       |
| Per Davvero                                     | Questionable | Online        | General News       |
| Per Una Nuova Medicina                          | Questionable | Online        | Science & Technology|
| Pianetablunews                                  | Questionable | Online        | General News       |
| Piccolo cuore1.blog                             | Questionable | Online        | Entertainment      |
| Piovegovernoladro - Dimissioni e tutti a casa   | Questionable | Online        | General News       |
| Prevenzione a Tavola                            | Questionable | Online        | Lifestyle          |
| Quello che i TG non dicono                      | Questionable | Online        | General News       |
| Rassegna Stampa                                 | Questionable | Online        | General News       |
| Rec News                                        | Questionable | Online        | Entertainment      |
| Rimani Informato                                | Questionable | Online        | General News       |
| Roba Da Pazzi                                   | Questionable | Online        | Entertainment      |
| Rosario Marcianò - Tankerenemy                  | Questionable | Online        | Science & Technology|
| Sa Defenza                                      | Questionable | Online        | Politics           |
| Sapere E’ Un Dovere                            | Questionable | Online        | General News       |
| Scenari Economici                               | Questionable | Online        | Business/Finance   |
| Scienze Chimiche: Informazione Corretta          | Questionable | Online        | Science & Technology|
| Scienza di Confine                              | Questionable | Online        | Science & Technology|
| Scienza e Conoscenza                            | Questionable | Online        | Science & Technology|
| Segni dal Cielo                                 | Questionable | Online        | Science & Technology|
| Segreto di Stato                                | Questionable | Online        | Politics           |
| Siamo La Gente                                  | Questionable | Online        | General News       |
| Signoraggio                                    | Questionable | Online        | Business/Finance   |
| Silenzi e Falsità                               | Questionable | Online        | Politics           |
| Sinistra Cazzate e Libertà                      | Questionable | Online        | Politics           |
| SocialTv Network - websocialtv                  | Questionable | Online        | Entertainment      |
| Sono Sena Parole                                | Questionable | Online        | Entertainment      |
| Sostenitori Forze Ordine                       | Questionable | Online        | General News       |
| Sovranità Monetaria & Debito Pubblico           | Questionable | Online        | Business/Finance   |
| Sputnik Italia                                 | Questionable | Online        | General News       |
| Stefano Montanari Nanodagonstico                | Questionable | Online        | Science & Technology|
| Stop alle scie chimiche                         | Questionable | Online        | Science & Technology|
| StopCensura.info                                | Questionable | Online        | General News       |
| Terra Real Time                                 | Questionable | Online        | Nature & Animals   |
| Tg 5 Stelle                                     | Questionable | Online        | General News       |
| Ticino Live                                     | Questionable | Online        | General News       |
| Umani In Divenire                              | Questionable | Online        | Nature & Animals   |
| Source name                          | Source set   | Source medium | Source subject           |
|-------------------------------------|--------------|---------------|--------------------------|
| Un male tutto italiano questo regime una vera piaga sociale | Questionable | Online        | Business/Finance          |
| Vaccini Basta                       | Questionable | Online        | Science & Technology     |
| VNews24                             | Questionable | Online        | General News             |
| Vox News                            | Questionable | Online        | General News             |
| Web Tg 24                           | Questionable | Online        | General News             |
| YesLife Magazine                    | Questionable | Online        | Lifestyles               |
| Zapping                             | Questionable | Online        | Culture & Society        |
| Zero Zero News                      | Questionable | Online        | General News             |
| 24Emilia                            | Reliable     | Online        | General News             |
| 24Finanza                           | Reliable     | Online        | Business/Finance         |
| 7per24                              | Reliable     | Online        | General News             |
| Adnkronos                           | Reliable     | Online        | General News             |
| Affaritaliani.it                    | Reliable     | Online        | General News             |
| Agenzia di Stampa DIRE              | Reliable     | Online        | General News             |
| Agenzia di Stampa Italpress         | Reliable     | Online        | General News             |
| Agi                                 | Reliable     | Online        | General News             |
| Agorà 24                            | Reliable     | Online        | General News             |
| AGR - Agenzia Giornalistica Radiotelevvisiva | Reliable | Online        | General News             |
| AgrigentoNotizie                    | Reliable     | Online        | General News             |
| AgrigentoOGGi                       | Reliable     | Online        | General News             |
| Alqamah                             | Reliable     | Online        | General News             |
| Altarimini                          | Reliable     | Online        | General News             |
| Ancona Notizie                      | Reliable     | Online        | General News             |
| AnconaToday                         | Reliable     | Online        | General News             |
| ANSA.it                             | Reliable     | Online        | General News             |
| ArezzoWeb.it                        | Reliable     | Online        | General News             |
| Argo Catania                        | Reliable     | Online        | General News             |
| askanews                            | Reliable     | Online        | General News             |
| Augustaonline                       | Reliable     | Online        | General News             |
| Avanti                              | Reliable     | Online        | General News             |
| Avellino Today                      | Reliable     | Online        | General News             |
| BagheriaNews                        | Reliable     | Online        | General News             |
| Bari Today                          | Reliable     | Online        | General News             |
| Basilicata Notizie                  | Reliable     | Online        | General News             |
| Beppe Grillo                        | Reliable     | Online        | Politics                 |
| Blasting News Italia                | Reliable     | Online        | General News             |
| Blitz quotidiano                    | Reliable     | Online        | General News             |
| Blog Sicilia                        | Reliable     | Online        | General News             |
| Blogo                               | Reliable     | Online        | General News             |
| Bologna2000                         | Reliable     | Online        | General News             |
| BolognaToday                        | Reliable     | Online        | General News             |
| BresciaToday                        | Reliable     | Online        | General News             |
| BrindisiReport.it                   | Reliable     | Online        | General News             |
| CalNews                             | Reliable     | Online        | General News             |
| CanicattiWeb                        | Reliable     | Online        | General News             |
| CastelloIncantato                  | Reliable     | Online        | General News             |
| Castelvetrano                       | Reliable     | Online        | General News             |
| Catania Oggi                        | Reliable     | Online        | General News             |
| CataniaToday                        | Reliable     | Online        | General News             |
| Catanzaro Informa                   | Reliable     | Online        | General News             |
| Cesena Today                        | Reliable     | Online        | General News             |
| ChartaBianca                        | Reliable     | Online        | General News             |
| Chieti Today                        | Reliable     | Online        | General News             |
| Ci Siamo - Notizie d'Italia         | Reliable     | Online        | Science & Technology     |
| CICAP                               | Reliable     | Online        | Science & Technology     |
| Source name                        | Sourceset | Source medium | Source subject         |
|-----------------------------------|-----------|---------------|------------------------|
| Citta della Spezia               | Reliable  | Online        | General News           |
| City News                         | Reliable  | Online        | General News           |
| Codcast Channel                   | Reliable  | Online        | Business/Finance       |
| COELUM Astronomia                 | Reliable  | Online        | Science & Technology   |
| Cor.Com corriere comunicazioni   | Reliable  | Online        | Business/Finance       |
| Corigliano_Calabro                | Reliable  | Online        | General News           |
| Corriere Calabria                 | Reliable  | Online        | General News           |
| Corriere Di Roma                  | Reliable  | Online        | General News           |
| Corriere di Sciacca               | Reliable  | Online        | General News           |
| Corriere Tv                       | Reliable  | Online        | General News           |
| Cronaca del Veneto                | Reliable  | Online        | General News           |
| Cronaca di Verona                 | Reliable  | Online        | General News           |
| Cronache Maceratesi               | Reliable  | Online        | General News           |
| Crotone24News                     | Reliable  | Online        | General News           |
| Curiosità Scientifiche            | Reliable  | Online        | Science & Technology   |
| Dagospia                          | Reliable  | Online        | General News           |
| Datasport.it                      | Reliable  | Online        | General News           |
| Dg Mag                            | Reliable  | Online        | Entertainment          |
| Diario Metropolitano              | Reliable  | Online        | General News           |
| Eco Di Basilicata                 | Reliable  | Online        | General News           |
| EconomyUp                         | Reliable  | Online        | Business/Finance       |
| Emilia Romagna News               | Reliable  | Online        | General News           |
| Estense                           | Reliable  | Online        | General News           |
| Everyeye.it                       | Reliable  | Online        | Entertainment          |
| EWTN Vaticano                     | Reliable  | Online        | Religion               |
| Fanpage.it                        | Reliable  | Online        | General News           |
| Ferrara24ore                      | Reliable  | Online        | General News           |
| FirenzeToday                      | Reliable  | Online        | General News           |
| FoggiaToday                       | Reliable  | Online        | General News           |
| Forlì 24 Ore                      | Reliable  | Online        | General News           |
| ForlìToday                        | Reliable  | Online        | General News           |
| Formiche                          | Reliable  | Online        | General News           |
| Galileo Giornale Di Scienza       | Reliable  | Online        | Science & Technology   |
| Gazzetta Dell'Emilia              | Reliable  | Online        | General News           |
| Gazzetta Jonica                   | Reliable  | Online        | General News           |
| Genova Today                      | Reliable  | Online        | General News           |
| GenovaQuotidiana                  | Reliable  | Online        | General News           |
| Giornale Del Cliente              | Reliable  | Online        | General News           |
| Giornale L'ora                    | Reliable  | Online        | General News           |
| Giornale Nisseno                  | Reliable  | Online        | General News           |
| Giornalettismo                    | Reliable  | Online        | General News           |
| GIPress                           | Reliable  | Online        | General News           |
| Grandangolo Agrigento             | Reliable  | Online        | General News           |
| Grande Napoli                     | Reliable  | Online        | Culture & Society      |
| Gravità Zero                      | Reliable  | Online        | Science & Technology   |
| HuffPost                          | Reliable  | Online        | General News           |
| Il Caffè Geopolitico              | Reliable  | Online        | Politics               |
| Il Corriere della Città           | Reliable  | Online        | General News           |
| Il Crotonese                      | Reliable  | Online        | General News           |
| Il Disappiccio                    | Reliable  | Online        | General News           |
| Il Dolomiti                       | Reliable  | Online        | General News           |
| il Fatto Nisseno                  | Reliable  | Online        | General News           |
| il Fatto Vesuviano                | Reliable  | Online        | General News           |
| Il Fogliettone                    | Reliable  | Online        | General News           |
| Il Giornale di Monza e della Brianza | Reliable | Online        | General News           |
| Il Lametino                       | Reliable  | Online        | General News           |
| Il NordEst Quotidiano             | Reliable  | Online        | General News           |
| Source name | Sourceset | Source medium | Source subject         |
|-------------|-----------|---------------|------------------------|
| Il Nuovo Giornale di Modena | Reliable | Online | General News |
| Il Paese Nuovo | Reliable | Online | General News |
| Il Pescara | Reliable | Online | General News |
| Il Piacenza | Reliable | Online | General News |
| il Post | Reliable | Online | General News |
| Il Quaderno.it | Reliable | Online | General News |
| Il Quotidiano Italiano | Reliable | Online | General News |
| Il Sicilia | Reliable | Online | General News |
| Il Sussidiario.net | Reliable | Online | General News |
| Il Telegrafo di Livorno | Reliable | Online | General News |
| Il Velino/AGV | Reliable | Online | General News |
| INFN - Istituto Nazionale Di Fisica Nucleare | Reliable | Online | Science & Technology |
| InfoAut | Reliable | Online | General News |
| InterNapoli | Reliable | Online | General News |
| IrpiniaNews | Reliable | Online | General News |
| Italia Notizie 24 | Reliable | Online | General News |
| Italia Unità per la Scienza | Reliable | Online | Science & Technology |
| Key4biz | Reliable | Online | Business/Finance |
| L’Adigetto | Reliable | Online | General News |
| L’Infiltrato.it | Reliable | Online | Lifestyle |
| L’Intraprendente | Reliable | Online | General News |
| L’Eco di Parma | Reliable | Online | General News |
| L’Immediato | Reliable | Online | General News |
| L’Indiscreto | Reliable | Online | General News |
| L’Occidentale-Orientamento quotidiano | Reliable | Online | General News |
| La Gazzetta Ennese | Reliable | Online | General News |
| La Nota 7 | Reliable | Online | General News |
| La Nuova del Sud | Reliable | Online | General News |
| La Sberia | Reliable | Online | General News |
| La Sicilia Web | Reliable | Online | General News |
| La Voce | Reliable | Online | General News |
| La Voce D’Italia | Reliable | Online | General News |
| Lamezia Click | Reliable | Online | General News |
| LaPresse | Reliable | Online | General News |
| Latina Quotidiano | Reliable | Online | General News |
| Latina Today | Reliable | Online | General News |
| LaVoce Del Trentino | Reliable | Online | General News |
| LaVocedelNordEst | Reliable | Online | General News |
| Le Cronache Lucane | Reliable | Online | General News |
| Le Scienze | Reliable | Online | Science & Technology |
| Lecce Cronaca | Reliable | Online | General News |
| Lecce Prima | Reliable | Online | General News |
| Leccenews24.it | Reliable | Online | General News |
| Lecco Today | Reliable | Online | General News |
| Lega Nerd | Reliable | Online | Entertainment |
| LegnanoNews | Reliable | Online | General News |
| Lettera43 | Reliable | Online | General News |
| Liberascienza | Reliable | Online | Science & Technology |
| Libero Reporter | Reliable | Online | General News |
| Live Sicilia | Reliable | Online | General News |
| Lo Spiffero | Reliable | Online | General News |
| Lo Strillone | Reliable | Online | General News |
| MadonieLive | Reliable | Online | General News |
| Magaze.it | Reliable | Online | General News |
| Marsala News | Reliable | Online | General News |
| Marsica Live | Reliable | Online | General News |
| Source name                                      | Sourceset  | Source medium | Source subject                      |
|-------------------------------------------------|------------|---------------|-------------------------------------|
| Med Bunker                                     | Reliable   | Online        | Science & Technology                |
| Mediaset Infinity                              | Reliable   | Online        | Entertainment                        |
| Medici Senza Frontiere                         | Reliable   | Online        | Science & Technology                |
| Megachip MegaTweet                              | Reliable   | Online        | General News                        |
| Meridio News                                   | Reliable   | Online        | General News                        |
| Messinaoggi                                    | Reliable   | Online        | General News                        |
| MessinaOra                                     | Reliable   | Online        | General News                        |
| MilanoToday                                    | Reliable   | Online        | General News                        |
| Minerva-Associazione Di Divulgazione Scientifica| Reliable   | Online        | Science & Technology                |
| Mitico channel                                 | Reliable   | Online        | Sports                              |
| Modena Today                                   | Reliable   | Online        | General News                        |
| Modena2000                                     | Reliable   | Online        | General News                        |
| Monza Today                                    | Reliable   | Online        | General News                        |
| MSN                                             | Reliable   | Online        | General News                        |
| Nanopress                                      | Reliable   | Online        | General News                        |
| NapoliToday                                    | Reliable   | Online        | General News                        |
| Newz.it                                         | Reliable   | Online        | General News                        |
| NeXt Quotidiano                                | Reliable   | Online        | General News                        |
| NordMilano24                                    | Reliable   | Online        | General News                        |
| Normanno                                       | Reliable   | Online        | General News                        |
| NovaraToday                                    | Reliable   | Online        | General News                        |
| NOW TV                                         | Reliable   | Online        | Entertainment                       |
| NtaCalabria.it                                 | Reliable   | Online        | General News                        |
| ntr24.tv                                        | Reliable   | Online        | General News                        |
| Nuova Cosenza                                  | Reliable   | Online        | General News                        |
| Nuova Società                                  | Reliable   | Online        | General News                        |
| Nuovo Sud                                      | Reliable   | Online        | General News                        |
| Oggi Milazzo                                   | Reliable   | Online        | General News                        |
| Oggi Treviso                                   | Reliable   | Online        | General News                        |
| OggiScienza                                    | Reliable   | Online        | Science & Technology                |
| Open                                            | Reliable   | Online        | General News                        |
| Ottopagine                                     | Reliable   | Online        | General News                        |
| Pachino News                                   | Reliable   | Online        | General News                        |
| PadovaOggi                                     | Reliable   | Online        | General News                        |
| Palermo Web                                    | Reliable   | Online        | Culture & Society                   |
| PalermoMania                                   | Reliable   | Online        | General News                        |
| PalermoReport                                  | Reliable   | Online        | General News                        |
| PalermoToday                                   | Reliable   | Online        | General News                        |
| Parma Quotidiano                               | Reliable   | Online        | General News                        |
| Parma Today                                    | Reliable   | Online        | General News                        |
| ParmaDaily                                      | Reliable   | Online        | General News                        |
| ParmaReport                                     | Reliable   | Online        | General News                        |
| PavaglioneLugo.net                              | Reliable   | Online        | General News                        |
| Perché vaccino                                  | Reliable   | Online        | Science & Technology                |
| Perugia Today                                   | Reliable   | Online        | General News                        |
| Piacenza Sera                                  | Reliable   | Online        | General News                        |
| Piacenza24                                     | Reliable   | Online        | General News                        |
| PicchioNews                                    | Reliable   | Online        | General News                        |
| Pisa Today                                      | Reliable   | Online        | General News                        |
| Piu Notizie                                    | Reliable   | Online        | General News                        |
| pomigliano LIVE                                 | Reliable   | Online        | General News                        |
| PositanoNews                                    | Reliable   | Online        | General News                        |
| Prima Pagina Reggio                             | Reliable   | Online        | General News                        |
| Pro-Test Italia                                | Reliable   | Online        | Science & Technology                |
| QtSicilia                                       | Reliable   | Online        | General News                        |
| Query                                           | Reliable   | Online        | Science & Technology                |
| Source name                        | Sourceset | Source medium | Source subject         |
|-----------------------------------|-----------|---------------|------------------------|
| Qui Mediaset                      | Reliable  | Online        | Entertainment          |
| QuiCosenza                        | Reliable  | Online        | General News           |
| Quotidiano della Sanità           | Reliable  | Online        | Science & Technology   |
| Radio Domina Nostra               | Reliable  | Online        | Religion               |
| Radio Nerazzurra                  | Reliable  | Online        | Sports                 |
| Ragusa Oggi                       | Reliable  | Online        | General News           |
| RagusaNews                        | Reliable  | Online        | General News           |
| Rai                               | Reliable  | Online        | General News           |
| RaiPlay                           | Reliable  | Online        | Entertainment          |
| Ravenna Notizie                   | Reliable  | Online        | General News           |
| Ravenna Today                     | Reliable  | Online        | General News           |
| Ravenna Web TV                    | Reliable  | Online        | General News           |
| Ravenna24Ore.it                   | Reliable  | Online        | General News           |
| Redacon Radionova                 | Reliable  | Online        | General News           |
| Reggio Nel Web                    | Reliable  | Online        | General News           |
| Reggio SERA                       | Reliable  | Online        | General News           |
| ResegoneOnline                    | Reliable  | Online        | General News           |
| Rete News 24                      | Reliable  | Online        | General News           |
| Reuters                           | Reliable  | Online        | General News           |
| RiminiToday                       | Reliable  | Online        | General News           |
| Riviera24                         | Reliable  | Online        | General News           |
| Rockit.it                         | Reliable  | Online        | Entertainment          |
| RomaToday                         | Reliable  | Online        | General News           |
| Salerno Notizie                   | Reliable  | Online        | General News           |
| Salerno Today                     | Reliable  | Online        | General News           |
| SanremoNews                       | Reliable  | Online        | General News           |
| Sardegna Oggi                     | Reliable  | Online        | General News           |
| Sardinia Post                     | Reliable  | Online        | General News           |
| Sassari Notizie                   | Reliable  | Online        | General News           |
| Sassuolo 2000                     | Reliable  | Online        | General News           |
| Sassuolo Oggi                     | Reliable  | Online        | General News           |
| Scetticamente                     | Reliable  | Online        | Science & Technology   |
| Scientificast.it                  | Reliable  | Online        | Science & Technology   |
| Scienza In Rete                   | Reliable  | Online        | Science & Technology   |
| Scienza Live                      | Reliable  | Online        | Science & Technology   |
| Scienze Naturali                  | Reliable  | Online        | Science & Technology   |
| Secolo Trentino                   | Reliable  | Online        | General News           |
| SempioneNews                      | Reliable  | Online        | General News           |
| Settesere                         | Reliable  | Online        | General News           |
| Si24.it                           | Reliable  | Online        | General News           |
| Sicilia Informazioni              | Reliable  | Online        | General News           |
| Sicilia News 24                   | Reliable  | Online        | General News           |
| Sicilia Today                     | Reliable  | Online        | General News           |
| Sicilia24h                        | Reliable  | Online        | General News           |
| Sicilians                         | Reliable  | Online        | General News           |
| Signoraggio: Informazione Corretta| Reliable  | Online        | Business/Finance       |
| Siracusa Live                     | Reliable  | Online        | General News           |
| Siracusa News                     | Reliable  | Online        | General News           |
| Siracusa Oggi                     | Reliable  | Online        | General News           |
| Stretto Web                       | Reliable  | Online        | General News           |
| Strill.it                         | Reliable  | Online        | General News           |
| Sudpress                          | Reliable  | Online        | General News           |
| TargatoCN                         | Reliable  | Online        | General News           |
| Telestense                        | Reliable  | Online        | General News           |
| TeleTermini Webtv                 | Reliable  | Online        | General News           |
| TempoStretto.it                   | Reliable  | Online        | General News           |
| Termometro Politico               | Reliable  | Online        | Politics               |
| Source name                                       | Sourceset | Source medium | Source subject         |
|--------------------------------------------------|-----------|---------------|------------------------|
| The Post Internazionale                          | Reliable  | Online        | General News           |
| The Social Post                                  | Reliable  | Online        | General News           |
| TiscaliNews                                      | Reliable  | Online        | General News           |
| Today.it                                         | Reliable  | Online        | General News           |
| TorinoToday                                     | Reliable  | Online        | General News           |
| TP24                                            | Reliable  | Online        | General News           |
| Trapani Oggi                                     | Reliable  | Online        | General News           |
| Trento Today                                    | Reliable  | Online        | General News           |
| TrevisoTodday                                   | Reliable  | Online        | General News           |
| TriestePrima                                    | Reliable  | Online        | General News           |
| TvLoft                                          | Reliable  | Online        | Entertainment          |
| Udine Today                                      | Reliable  | Online        | General News           |
| Umbria24                                         | Reliable  | Online        | General News           |
| UrbanPost                                       | Reliable  | Online        | General News           |
| VaccinarSI - Ulrike                              | Reliable  | Online        | Science & Technology   |
| VaccinarSI                                      | Reliable  | Online        | Science & Technology   |
| Vai Taormina                                    | Reliable  | Online        | General News           |
| VareseNews                                      | Reliable  | Online        | General News           |
| VeneziaToday                                    | Reliable  | Online        | General News           |
| Vera Scienza                                    | Reliable  | Online        | General News           |
| VeronaSera                                      | Reliable  | Online        | General News           |
| VesuvioLive                                     | Reliable  | Online        | General News           |
| Vicenza Today                                   | Reliable  | Online        | General News           |
| ViterboNews24                                   | Reliable  | Online        | General News           |
| Vivere Ancona                                    | Reliable  | Online        | General News           |
| ViviEnna                                        | Reliable  | Online        | General News           |
| Vivisezione e Sperimentazione Animale verità e menzogne | Reliable | Online        | Science & Technology   |
| Web Marte                                       | Reliable  | Online        | General News           |
| Wittytv                                         | Reliable  | Online        | Entertainment          |
| Alto Adige                                      | Reliable  | Print         | General News           |
| Avvenire                                        | Reliable  | Print         | General News           |
| Brescia Oggi                                    | Reliable  | Print         | General News           |
| Conquiste del Lavoro                            | Reliable  | Print         | Business/Finance       |
| Corriere Adriatico.it                           | Reliable  | Print         | General News           |
| Corriere Bologna                                | Reliable  | Print         | General News           |
| Corriere del Mezzogiorno                        | Reliable  | Print         | General News           |
| Corriere del Trentino                           | Reliable  | Print         | General News           |
| Corriere del Veneto                             | Reliable  | Print         | General News           |
| Corriere dell’Umbria                            | Reliable  | Print         | General News           |
| Corriere della Sera                             | Reliable  | Print         | General News           |
| Corriere delle Alpi                             | Reliable  | Print         | General News           |
| Corriere dello Sport                            | Reliable  | Print         | Sports                 |
| Corriere di Arezzo                              | Reliable  | Print         | General News           |
| Corriere di Como                                | Reliable  | Print         | General News           |
| Corriere di Romagna                             | Reliable  | Print         | General News           |
| Corriere di Siena                               | Reliable  | Print         | General News           |
| Corriere di Viterbo                             | Reliable  | Print         | General News           |
| Cronaca Qui                                     | Reliable  | Print         | General News           |
| Cronache di Caserta                             | Reliable  | Print         | General News           |
| Gazzetta del Sud                                | Reliable  | Print         | General News           |
| Gazzetta di Mantova                             | Reliable  | Print         | General News           |
| Gazzetta di Modena                              | Reliable  | Print         | General News           |
| Gazzetta di Parma                               | Reliable  | Print         | General News           |
| Gazzetta di Reggio                              | Reliable  | Print         | General News           |
| Giornale di Brescia                             | Reliable  | Print         | General News           |
| Source name                      | Sourceset | Source medium | Source subject    |
|---------------------------------|-----------|---------------|-------------------|
| Giornale di Sicilia             | Reliable  | Print         | General News      |
| Il Centro - Quotidiano d'Abruzzo| Reliable  | Print         | General News      |
| Il Cittadino                    | Reliable  | Print         | General News      |
| Il Dubbio                       | Reliable  | Print         | General News      |
| Il Fatto Quotidiano             | Reliable  | Print         | General News      |
| Il Foglio                       | Reliable  | Print         | General News      |
| Il Gazzettino                   | Reliable  | Print         | General News      |
| Il Giornale                     | Reliable  | Print         | General News      |
| Il Giornale d'Italia            | Reliable  | Print         | General News      |
| Il Giornale del Trentino        | Reliable  | Print         | General News      |
| Il Giornale Di Vicenza          | Reliable  | Print         | General News      |
| Il Giorno                       | Reliable  | Print         | General News      |
| il manifesto                    | Reliable  | Print         | General News      |
| Il Mattino                      | Reliable  | Print         | General News      |
| Il Mattino di Padova            | Reliable  | Print         | General News      |
| Il Messaggero.it                | Reliable  | Print         | General News      |
| Il Piccolo                      | Reliable  | Print         | General News      |
| Il Quotidiano del Sud           | Reliable  | Print         | General News      |
| Il Resto del Carlino            | Reliable  | Print         | General News      |
| Il Sannio Quotidiano            | Reliable  | Print         | General News      |
| Il Secolo XIX                   | Reliable  | Print         | General News      |
| Il Sole 24 ORE                  | Reliable  | Print         | General News      |
| Il Tempo Quotidiano             | Reliable  | Print         | General News      |
| Il Tirreno                      | Reliable  | Print         | General News      |
| Italia Oggi                     | Reliable  | Print         | General News      |
| L’Adige                         | Reliable  | Print         | General News      |
| L’Arena                         | Reliable  | Print         | General News      |
| L’Eco di Bergamo                | Reliable  | Print         | General News      |
| L’Osservatore Romano            | Reliable  | Print         | General News      |
| L’Unione Sarda                  | Reliable  | Print         | General News      |
| La Città di Salerno             | Reliable  | Print         | General News      |
| La Discussione Quotidiano       | Reliable  | Print         | Politics          |
| La Gazzetta del Mezzogiorno.it  | Reliable  | Print         | General News      |
| La Gazzetta dello Sport         | Reliable  | Print         | Sports            |
| La Nazione                      | Reliable  | Print         | General News      |
| La Notizia                      | Reliable  | Print         | General News      |
| La Nuova di Venezia e Mestre    | Reliable  | Print         | General News      |
| La Nuova Ferrara                | Reliable  | Print         | General News      |
| La Nuova Sardegna               | Reliable  | Print         | General News      |
| La Prealpina                    | Reliable  | Print         | General News      |
| La Provincia di Como            | Reliable  | Print         | General News      |
| La Provincia di Cremona         | Reliable  | Print         | General News      |
| La Provincia di Lecco           | Reliable  | Print         | General News      |
| La Provincia di Sondrio         | Reliable  | Print         | General News      |
| La Provincia di Varese          | Reliable  | Print         | General News      |
| La Provincia di Pavese          | Reliable  | Print         | General News      |
| la Repubblica                   | Reliable  | Print         | General News      |
| La SENTINELLA del Canavese      | Reliable  | Print         | General News      |
| La Sicilia                      | Reliable  | Print         | General News      |
| La Stampa                       | Reliable  | Print         | General News      |
| La Tribuna di Treviso           | Reliable  | Print         | General News      |
| La Verità                       | Reliable  | Print         | General News      |
| La Voce del Canavese            | Reliable  | Print         | General News      |
| La Voce di Mantova              | Reliable  | Print         | General News      |
| Latina Oggi                     | Reliable  | Print         | General News      |
| Leggo                           | Reliable  | Print         | General News      |
| Libero                          | Reliable  | Print         | General News      |
| Source name                          | Source set  | Source medium | Source subject       |
|-------------------------------------|-------------|---------------|----------------------|
| Libertà                             | Reliable    | Print         | General News         |
| Messaggero Veneto                   | Reliable    | Print         | General News         |
| Metro News Italia                   | Reliable    | Print         | General News         |
| Metropolis Quotidiano              | Reliable    | Print         | General News         |
| MF-Milano Finanza                  | Reliable    | Print         | General News         |
| Quotidiano del Molise               | Reliable    | Print         | General News         |
| Quotidiano di Puglia                | Reliable    | Print         | General News         |
| Quotidiano di Sicilia               | Reliable    | Print         | General News         |
| Quotidiano.net                      | Reliable    | Print         | General News         |
| Roma - Il Giornale di Napoli       | Reliable    | Print         | General News         |
| Secolo d’Italia                    | Reliable    | Print         | General News         |
| Tuttosport                          | Reliable    | Print         | Sports               |
| 24 Mattino                         | Reliable    | Radio         | General News         |
| Isoradio                            | Reliable    | Radio         | Entertainment        |
| Lo Zoo di 105                      | Reliable    | Radio         | Entertainment        |
| R101                                | Reliable    | Radio         | Entertainment        |
| Radio 105                           | Reliable    | Radio         | Entertainment        |
| Radio 24                            | Reliable    | Radio         | Entertainment        |
| Radio Antenna 1                     | Reliable    | Radio         | Entertainment        |
| Radio Bari 88.8fm                   | Reliable    | Radio         | Sports               |
| Radio Beckwith Evangelica           | Reliable    | Radio         | Religion             |
| Radio Bruno                         | Reliable    | Radio         | Entertainment        |
| Radio Capital                       | Reliable    | Radio         | Entertainment        |
| Radio Decijay                       | Reliable    | Radio         | Entertainment        |
| Radio G Giulianova                  | Reliable    | Radio         | General News         |
| Radio Globo                         | Reliable    | Radio         | Entertainment        |
| Radio Italia solomusicaitaliana    | Reliable    | Radio         | Entertainment        |
| Radio Kiss Kiss Napoli              | Reliable    | Radio         | Sports               |
| Radio KissKiss                      | Reliable    | Radio         | Entertainment        |
| Radio Maria                         | Reliable    | Radio         | Religion             |
| Radio Monte Carlo                   | Reliable    | Radio         | Entertainment        |
| Radio Number One                   | Reliable    | Radio         | Entertainment        |
| Radio Radicale                      | Reliable    | Radio         | Politics             |
| Radio Subasio                       | Reliable    | Radio         | Entertainment        |
| Radio Vaticana en Espanol          | Reliable    | Radio         | Religion             |
| Radiol1 Rai                         | Reliable    | Radio         | General News         |
| Radio2                              | Reliable    | Radio         | General News         |
| Radio3 Rai                          | Reliable    | Radio         | General News         |
| Radiom2o                            | Reliable    | Radio         | Entertainment        |
| Radionorba                          | Reliable    | Radio         | Entertainment        |
| radiosei                            | Reliable    | Radio         | Sports               |
| Radio Vaticana                     | Reliable    | Radio         | Religion             |
| Rai Radio Live                      | Reliable    | Radio         | Entertainment        |
| RDS 100% Grandi Successi            | Reliable    | Radio         | Entertainment        |
| Retesport 104.2                     | Reliable    | Radio         | Sports               |
| RTL 102.5                           | Reliable    | Radio         | Entertainment        |
| Virgin Radio                        | Reliable    | Radio         | Entertainment        |
| 50 news Versilia                    | Reliable    | TV            | General News         |
| Canale 58                           | Reliable    | TV            | General News         |
| Class CNBC                          | Reliable    | TV            | Business/Finance     |
| Comedy Central                      | Reliable    | TV            | Entertainment        |
| Discovery Channel                   | Reliable    | TV            | Nature & Animals     |
| Dplay                               | Reliable    | TV            | Entertainment        |
| Euronews Italiano                   | Reliable    | TV            | General News         |
| Eurosport                           | Reliable    | TV            | Sports               |
| Foggia TV                           | Reliable    | TV            | General News         |
| Fox Sports                          | Reliable    | TV            | Sports               |
| Source name               | Sourceset | Source medium | Source subject       |
|--------------------------|-----------|---------------|----------------------|
| FoxLife                  | Reliable  | TV            | Entertainment        |
| HISTORY                  | Reliable  | TV            | Culture & Society    |
| Horse TV HD              | Reliable  | TV            | Sports               |
| La Tua Tv                | Reliable  | TV            | Entertainment        |
| La7                      | Reliable  | TV            | General News         |
| La7 Attualit             | Reliable  | TV            | General News         |
| LazioTV                  | Reliable  | TV            | General News         |
| Mediaset Italia 2        | Reliable  | TV            | Entertainment        |
| Medical Excellence TV    | Reliable  | TV            | Science & Technology |
| MTV                      | Reliable  | TV            | Entertainment        |
| National Geographic Canale | Reliable | TV            | Nature & Animals     |
| NOVE                     | Reliable  | TV            | Entertainment        |
| Paramount Network        | Reliable  | TV            | Entertainment        |
| Rai Premium              | Reliable  | TV            | Entertainment        |
| Rai Scuola               | Reliable  | TV            | Culture & Society    |
| Rai Storia               | Reliable  | TV            | Culture & Society    |
| Rai1                     | Reliable  | TV            | General News         |
| Rai2                     | Reliable  | TV            | General News         |
| Rai3                     | Reliable  | TV            | General News         |
| Rai4                     | Reliable  | TV            | Entertainment        |
| Rai5                     | Reliable  | TV            | Entertainment        |
| Rainews.it               | Reliable  | TV            | General News         |
| RaiSport                 | Reliable  | TV            | Sports               |
| Real Time                | Reliable  | TV            | Entertainment        |
| redazione.tcabolziano    | Reliable  | TV            | General News         |
| Rete4                    | Reliable  | TV            | General News         |
| Rossini TV               | Reliable  | TV            | General News         |
| Siciliatv                | Reliable  | TV            | General News         |
| Sky Sport                | Reliable  | TV            | Sports               |
| Sky Sport MotoGP         | Reliable  | TV            | Sports               |
| Sky Sport NBA            | Reliable  | TV            | Sports               |
| Sky TG24                 | Reliable  | TV            | General News         |
| Sky Uno                  | Reliable  | TV            | General News         |
| SkySportF1               | Reliable  | TV            | Sports               |
| Spike TV                 | Reliable  | TV            | Entertainment        |
| Sport Channel 214        | Reliable  | TV            | Sports               |
| Sportitalia TV           | Reliable  | TV            | Sports               |
| SportMediaset            | Reliable  | TV            | Sports               |
| SuperTennis TV           | Reliable  | TV            | Sports               |
| Tele 8 TV                | Reliable  | TV            | General News         |
| Tele Occidente           | Reliable  | TV            | General News         |
| TELEBARI                 | Reliable  | TV            | General News         |
| Teleblu                  | Reliable  | TV            | General News         |
| Teleboario               | Reliable  | TV            | General News         |
| Telemova                 | Reliable  | TV            | General News         |
| TeleOne                  | Reliable  | TV            | General News         |
| Telesud Trapani          | Reliable  | TV            | General News         |
| Teleturria               | Reliable  | TV            | General News         |
| Tg La7 News              | Reliable  | TV            | General News         |
| Tg1                      | Reliable  | TV            | General News         |
| Tg2                      | Reliable  | TV            | General News         |
| Tg3                      | Reliable  | TV            | General News         |
| TgCom24                  | Reliable  | TV            | General News         |
| TGR Abruzzo              | Reliable  | TV            | General News         |
| TGR Basilicata           | Reliable  | TV            | General News         |
| TGR Calabria             | Reliable  | TV            | General News         |
| TGR Campania             | Reliable  | TV            | General News         |
| Source name                        | Sourceset | Source medium | Source subject       |
|-----------------------------------|-----------|---------------|----------------------|
| TGR Friuli Venezia Giulia         | Reliable  | TV            | General News         |
| TGR Lazio                         | Reliable  | TV            | General News         |
| TGR Liguria                       | Reliable  | TV            | General News         |
| TGR Lombardia                     | Reliable  | TV            | General News         |
| TGR Marche                        | Reliable  | TV            | General News         |
| TGR Molise                        | Reliable  | TV            | General News         |
| TGR Piemonte                      | Reliable  | TV            | General News         |
| TGR Puglia                        | Reliable  | TV            | General News         |
| TGR RAI - Trentino                | Reliable  | TV            | General News         |
| TGR Sardegna                      | Reliable  | TV            | General News         |
| TGR Sicilia                       | Reliable  | TV            | General News         |
| TGR Toscana                       | Reliable  | TV            | General News         |
| TGR Trentino Alto Adige BZ        | Reliable  | TV            | General News         |
| TGR Umbria                        | Reliable  | TV            | General News         |
| TGR Valle d’Aosta                 | Reliable  | TV            | General News         |
| TGR Veneto                        | Reliable  | TV            | General News         |
| TRC - Tele Radio Canicattì        | Reliable  | TV            | General News         |
| TV PRATO                          | Reliable  | TV            | General News         |
| Tv2000                            | Reliable  | TV            | General News         |
| TV8                               | Reliable  | TV            | Entertainment        |
| Tvsette Benevento                 | Reliable  | TV            | General News         |

Supplementary Table 1: List of news providers gathered. Table also report the corresponding source set (Questionable or Reliable), medium (Online, Print, Radio, TV) and main subject (Business/Finance, Culture & Society, Entertainment, General News, Lifestyle, Nature & Animals, Politics, Religion, Science & Technology, Sports, Weather).
| Vaccine type                       | Searched keywords                                                                 |
|-----------------------------------|-----------------------------------------------------------------------------------|
| General                           | vaccin* OR vax OR no-vax                                                         |
| Covid-19                          | pfizer OR pfizer/biontech OR mrnabut162b2 OR bnt162b2 OR mrna-pfizer OR biontech OR bnt-162b2 OR mrna-bnt162b2 |
|                                   | astrazeneca OR vaxzevria OR vaxzevria/covid-19 OR chadox1 OR chadox1-s OR azd1222 OR (chadox1 ncov-2019) |
|                                   | moderna AND (covid OR coronavirus) OR spikevax OR mrna-1273                       |
|                                   | juussen OR (johnson & johnson) OR johnson&johnson OR jnj-78436735 OR ad26.cov2.s OR j&j OR (j and j) OR (johnson and johnson) |
|                                   | sputnik OR gam-covid-vac OR gamaleya                                             |
|                                   | reithera OR grad-cov2                                                             |
| Mandatory (Law 119/2017)          | (imovax polio) OR (imovax tetano) OR (engerix b) OR hbvaxpro OR varilrix OR varivax OR acthib OR hiberix OR diftetall OR revaxis OR boostrix OR triaxis OR tribaccine OR m-m-rvaxpro OR priorix OR polioboostrix OR polioinfanrix OR tetravac (triaxis polio) OR (priorix tetra) OR proquad OR hexyon OR (infanrix hexa) OR vexelis |
| Recommended (Law 119/2017)        | bexsero OR trumenba OR menjugate OR neisvac-c OR pneumovax OR (prevenar 13) OR synflorix OR rotatex OR rotarix OR |
| Other authorized and marketed      | dukoral OR vaxchora OR ervebo OR dengvaxia OR (typhim vi) OR vivotif OR antivac OR ixiaro OR (agrippal s1) OR fluad OR (influpozzi subunità) OR (influvacc s) OR effueda OR (fluad tetra) OR (fluarix tetra) OR (flucelvax tetra) OR (fluenz tetra) OR (influvac s tetra) OR (vaxgrip tetra) OR avaxim OR havrix OR vaqta OR (twinrix adulti) OR (twinrix pediatrico) OR fendrix OR rabipur OR shingrix OR zostavax OR stamaril OR menveo OR nimenrix OR cervarix OR (gardasil 9) |

Supplementary Table 2: List of keywords used for filtering vaccine-related content. Table reports keywords divided by vaccine type: General, Covid-19 vaccines, Mandatory and Recommended vaccines (Law 119/2017), Other authorized and marketed vaccines. The special character * stands for zero or more non-whitespace characters. The list does not include the term immunizzazione (immunization) and its variations, since anti-vaccination contents almost never talks about immunization [13]. Obviously, this is expected since anti-vaccination groups tend not to believe that vaccines confer immunity.
| Source Set   | Period        | Mean TS | St.Dev. TS | Min TS | Max TS | Mean FD | St.Dev. FD | Min FD | Max FD |
|--------------|---------------|---------|------------|--------|--------|---------|------------|--------|--------|
| Questionable | Overall       | 2.051   | 0.002      | 2.074  | 1.061  | 0.000   | 0.000      | -4.525 | 16.346 |
|              | Pre-pandemic  | 1.308   | 0.001      | 1.230  | 1.023  | 0.000   | 0.000      | -4.525 | 11.679 |
|              | Pandemic      | 3.627   | 0.005      | 2.563  | 1.138  | 0.134   | 0.013      | -3.700 | 6.719  |
| Reliable     | Overall       | 0.921   | -0.009     | 1.700  | 0.499  | 0.000   | 0.000      | -9.316 | 16.344 |
|              | Pre-pandemic  | 0.159   | 0.000      | 0.235  | 0.224  | 0.000   | 0.000      | -1.925 | 2.458  |
|              | Pandemic      | 2.536   | 0.005      | 2.251  | 0.821  | 0.017   | 0.017      | -9.316 | 16.344 |

Supplementary Table 3: Descriptive statistics for the daily time series (TS) of the percentage of vaccine-related content from questionable and reliable sources, respectively, and the corresponding first difference (FD). The measures are reported for the overall sample (1 January 2016 –31 December 2021), together with the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods.
| Sourceset   | Period  | Levels  | FD       |
|------------|---------|---------|----------|
|             | Overall | −8.802*** | −14.641*** |
| Questionable| Pre-pandemic | −11.784*** | −12.140*** |
|             | Pandemic | −4.991*** | −4.587*** |
|             | Overall | −5.634*** | −8.475*** |
| Reliable    | Pre-pandemic | −16.735*** | −3.436*** |
|             | Pandemic | −4.186*** | −4.072*** |

***p < 0.001; **p < 0.01; *p < 0.05

Supplementary Table 4: Augmented Dickey Fuller (ADF) test statistics for daily time series of the percentage of vaccine-related content from questionable and reliable sources, respectively. The table reports the t-statistic of the ADF test statistics both in levels and on the first difference (FD). The ADF test is based on regressions with intercept. The null hypothesis for the test is non-stationarity. The estimates are reported for the overall period (1 January 2016–31 December 2021), together with the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods.
| SourceSet    | Period   | Bins     |
|-------------|----------|----------|
|             | (0,1]    | (1,2]    | (2,4]    | (4,8]    | (8,100]  |
| Questionable| Overall  | q38      | q67      | q83      | q98      | q100     |
|             | Pre-pandemic | q49      | q81      | q96      | q99      | q100     |
|             | Pandemic  | q14      | q37      | q77      | q94      | q100     |
| Reliable    | Overall  | q79      | q82      | q92      | q99      | q100     |
|             | Pre-pandemic | q98      | q99      | q100     | —        | —        |
|             | Pandemic  | q38      | q44      | q76      | q97      | q100     |

Supplementary Table 5: Correspondence bin upper bound - quantile for questionable and reliable time series, respectively. Bins refer to the symbolic encoding performed to calculate the transfer entropy. The measures reported refer to both the overall sample (1 January 2016 –31 December 2021), and the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods.
| Period           | Overperforming subject | Days | Median | Mean  | \( q_{10} \) | \( q_{90} \) |
|------------------|------------------------|------|--------|-------|--------------|--------------|
| Overall          | Vaccines               | 835  | 1.866  | 2.633 | 1.132        | 4.952        |
|                  | Other                  | 1357 | 3.007  | 11.773| 1.216        | 20.155       |
| Questionable     | Vaccines               | 385  | 1.913  | 2.791 | 1.154        | 5.366        |
|                  | Other                  | 1105 | 3.946  | 14.189| 1.308        | 24.602       |
| Pandemic         | Vaccines               | 450  | 1.829  | 2.499 | 1.120        | 4.456        |
|                  | Other                  | 252  | 1.554  | 2.072 | 1.075        | 3.382        |
| Reliable         | Vaccines               | 503  | 1.549  | 2.210 | 1.064        | 4.067        |
|                  | Other                  | 1689 | 3.704  | 17.724| 1.217        | 33.950       |
| Pre-pandemic     | Vaccines               | 276  | 1.815  | 2.757 | 1.099        | 5.362        |
|                  | Other                  | 1214 | 5.945  | 23.882| 1.442        | 46.183       |
| Pandemic         | Vaccines               | 227  | 1.291  | 1.546 | 1.045        | 2.311        |
|                  | Other                  | 475  | 1.780  | 3.113 | 1.094        | 4.771        |

Supplementary Table 6: Descriptive statistics for the out-engage factor of vaccine-related content to other content, and vice-versa, from questionable and reliable sources, respectively (inside perspective). The measures reported are median, mean, first \((q_{10})\) and ninth \((q_{90})\) deciles, and refer to both the overall sample (1 January 2016 –31 December 2021), and the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods. Days counts the number of times the corresponding subject overperformed the other in terms of user engagement.
| Period         | Overperforming sourceset | Days | Median | Mean | $q_{10}$ | $q_{90}$ |
|---------------|--------------------------|------|--------|------|----------|---------|
| Overall       | Questionable             | 1998 | 12.385 | 110.217 | 2.443 | 136.365 |
|               | Reliable                 | 180  | 1.647  | 3.107  | 1.098   | 6.570   |
| Pre-pandemic  | Questionable             | 1305 | 20.647 | 163.814 | 2.460  | 252.062 |
|               | Reliable                 | 171  | 1.690  | 3.229  | 1.099   | 6.740   |
| Pandemic      | Questionable             | 693  | 6.971  | 14.933 | 2.444   | 30.225  |
|               | Reliable                 | 9    | 1.433  | 1.862  | 1.120   | 2.861   |

Supplementary Table 7: Descriptive statistics for the out-engage factor of vaccine-related content from questionable sources to vaccine-related content from reliable sources, and vice-versa (outside perspective). The measures reported are median, mean, first ($q_{10}$) and ninth ($q_{90}$) deciles, and refer to both the overall sample (1 January 2016 –31 December 2021), and the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods. Days counts the number of times vaccine news from the corresponding sourceset overperformed vaccine news from the other sourceset in terms of user engagement.
| Period       | Overperforming opinion | Days | Median | Mean  | $q_{10}$ | $q_{90}$ |
|--------------|-------------------------|------|--------|-------|----------|----------|
| Overall      | Anti-vax                | 1397 | 4.000  | 16.798| 1.327    | 33.770   |
|              | Neutral                 | 589  | 2.651  | 12.236| 1.141    | 14.635   |
|              | Pro-vax                 | 297  | 2.800  | 7.406 | 1.221    | 16.098   |
| Questionable | Anti-vax                | 961  | 5.875  | 22.316| 1.452    | 43.800   |
|              | Neutral                 | 366  | 3.490  | 18.369| 1.185    | 36.122   |
|              | Pro-vax                 | 98   | 3.984  | 12.943| 1.468    | 26.395   |
| Pre-pandemic | Anti-vax                | 436  | 2.744  | 10.164| 1.247    | 15.110   |
|              | Neutral                 | 223  | 1.883  | 4.188 | 1.116    | 8.690    |
|              | Pro-vax                 | 199  | 2.370  | 4.904 | 1.196    | 10.989   |
| Pandemic     | Anti-vax                | 471  | 2.319  | 27.114| 1.131    | 14.672   |
|              | Neutral                 | 740  | 2.740  | 14.185| 1.139    | 30.026   |
|              | Pro-vax                 | 1230 | 3.502  | 23.289| 1.329    | 33.300   |
| Overall      | Anti-vax                | 204  | 3.668  | 59.409| 1.248    | 26.272   |
|              | Neutral                 | 571  | 3.734  | 18.985| 1.221    | 35.400   |
|              | Pro-vax                 | 728  | 6.094  | 38.584| 1.476    | 68.614   |
| Reliable     | Anti-vax                | 267  | 1.904  | 3.165 | 1.111    | 6.644    |
|              | Neutral                 | 169  | 1.622  | 3.674 | 1.083    | 5.423    |
|              | Pro-vax                 | 502  | 2.587  | 4.307 | 1.238    | 7.590    |

Supplementary Table 8: Descriptive statistics for the out-engage factor of vaccine-related content conveying the corresponding opinion to vaccine-related content conveying any other opinion from questionable and reliable sources, respectively (inside perspective). The measures reported are median, mean, first ($q_{10}$) and ninth ($q_{90}$) deciles, and refer to both the overall sample (1 January 2016 – 31 December 2021), and the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods. Days counts the number of times the corresponding opinion overperformed the others in terms of user engagement.
| Period | Opinion | Overperforming sourceset | Days  | Median | Mean | $q_{10}$ | $q_{90}$ |
|--------|---------|------------------------|-------|--------|------|--------|--------|
| Overall | Anti-vax Questionable | 1625 | 17.800 | 940.100 | 3.229 | 436.806 |
|         | Reliable | 89  | 2.309 | 5.586 | 1.153 | 8.100 |
|         | Neutral Questionable | 1233 | 10.115 | 150.338 | 2.366 | 156.743 |
|         | Reliable | 481 | 2.217 | 5.022 | 1.073 | 9.370 |
|         | Pro-vax Questionable | 670 | 5.697 | 97.088 | 1.468 | 62.428 |
|         | Reliable | 1044 | 2.760 | 13.589 | 1.168 | 23.102 |
| Pre-pandemic | Anti-vax Questionable | 957 | 64.600 | 2284.900 | 4.225 | 1429.222 |
|         | Reliable | 59 | 2.497 | 7.961 | 1.143 | 10.470 |
|         | Neutral Questionable | 589 | 21.127 | 293.565 | 2.510 | 450.093 |
|         | Reliable | 427 | 2.755 | 5.845 | 1.074 | 20.088 |
|         | Pro-vax Questionable | 217 | 11.026 | 198.860 | 1.672 | 478.696 |
|         | Reliable | 799 | 3.383 | 22.908 | 1.332 | 47.994 |
| Pandemic | Anti-vax Questionable | 668 | 10.050 | 118.376 | 2.898 | 99.865 |
|         | Reliable | 30 | 1.717 | 3.211 | 1.254 | 5.145 |
|         | Neutral Questionable | 644 | 7.199 | 31.353 | 2.304 | 32.542 |
|         | Reliable | 54 | 1.576 | 3.673 | 1.104 | 7.200 |
|         | Pro-vax Questionable | 453 | 4.860 | 57.824 | 1.419 | 29.596 |
|         | Reliable | 245 | 2.349 | 9.317 | 1.106 | 14.908 |

Supplementary Table 9: Descriptive statistics for the out-engage factor of vaccine-related content conveying the corresponding opinion from the corresponding sourceset to vaccine-related content conveying the same opinion from the other sourceset (outside perspective). The measures reported are median, mean, first ($q_{10}$) and ninth ($q_{90}$) deciles, and refer to both the overall sample (1 January 2016 –31 December 2021), and the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods. Days counts the number of times vaccine news conveying an opinion from the corresponding sourceset overperformed vaccine news conveying the same opinion from the other sourceset in terms of user engagement.
| Topic | Overall (%) | Pre-pandemic (%) | Pandemic (%) |
|-------|-------------|------------------|--------------|
|       | A  | N  | P  | A  | N  | P  | A  | N  | P  |
| Questionable |
| Adm   | 3.5 | 17.3 | 2.4 | 23.2 | 3.1 | 6.0 | 0.7 | 9.8 | 3.6 | 19.5 | 2.7 | 25.8 |
| Bus   | 4.7 | 1.9 | 0.4 | 7.0 | 8.0 | 0.8 | 0.1 | 8.9 | 4.0 | 2.1 | 0.5 | 6.6 |
| Eff   | 8.9 | 8.7 | 6.6 | 24.2 | 7.4 | 3.2 | 2.8 | 13.4 | 9.2 | 9.8 | 7.3 | 26.3 |
| Leg   | 4.1 | 5.0 | 0.7 | 9.8 | 8.2 | 7.4 | 0.4 | 16.0 | 3.3 | 4.5 | 0.8 | 8.6 |
| Saf   | 21.6 | 6.1 | 2.1 | 29.8 | 36.5 | 6.2 | 1.8 | 44.5 | 18.6 | 6.1 | 2.2 | 26.9 |
| Oth   | 1.3 | 3.7 | 1.0 | 6.0 | 2.3 | 4.8 | 0.3 | 7.4 | 1.1 | 3.5 | 1.2 | 5.8 |
| ∑     | 44.1 | 42.7 | 13.2 | 100.0 | 65.5 | 28.4 | 6.1 | 100.0 | 39.8 | 45.5 | 14.7 | 100.0 |
| Reliable |
| Adm   | 1.9 | 45.7 | 6.1 | 53.7 | 1.0 | 20.0 | 3.5 | 24.5 | 2.0 | 47.1 | 6.2 | 55.3 |
| Bus   | 0.9 | 2.1 | 0.6 | 3.6 | 0.6 | 1.3 | 0.7 | 2.6 | 0.9 | 2.2 | 0.6 | 3.7 |
| Eff   | 2.3 | 7.8 | 8.8 | 18.9 | 1.1 | 6.4 | 12.0 | 19.5 | 2.4 | 7.9 | 8.6 | 18.9 |
| Leg   | 0.7 | 5.4 | 0.8 | 6.9 | 1.5 | 24.0 | 2.0 | 27.5 | 0.7 | 4.4 | 0.6 | 5.7 |
| Saf   | 3.8 | 5.4 | 2.8 | 12.0 | 3.1 | 5.7 | 6.1 | 14.9 | 3.8 | 5.4 | 2.6 | 11.8 |
| Oth   | 0.3 | 3.6 | 1.0 | 4.9 | 0.5 | 8.8 | 1.7 | 11.0 | 0.3 | 3.3 | 1.0 | 4.6 |
| ∑     | 9.9 | 70.1 | 20.0 | 100.0 | 7.8 | 66.2 | 26.0 | 100.0 | 10.1 | 70.3 | 19.6 | 100.0 |

Supplementary Table 10: Percentage distribution of vaccine-related content among the six topics identified (Adm = administration of vaccines, Bus = vaccine business, Eff = effectiveness of vaccination, Leg = legal issues, Saf = safety concerns, Oth = other). Data are divided by source category (Questionable and Reliable) and period analysed (Overall 1 January 2016–31 December 2021, Pre-pandemic 1 January 2016–29 January 2020, Pandemic 30 January 2020–31 December 2021). Percentages are further divided according to the opinion conveyed by the corresponding content (A = anti-vax, N = neutral, P = pro-vax).
Supplementary Table 11: Confusion matrices for the evaluation set with respect to opinion: between the annotators and the model (a), and between annotators (b). The performance measures, Acc and F1, are calculated from these matrices. The axes show the possible labels (A = anti-vax, N = neutral, P = pro-vax).
| Label | Adm | Bus | Eff | Leg | Oth | Saf | ∑   |
|-------|-----|-----|-----|-----|-----|-----|-----|
| Adm   | 2150| 21  | 130 | 43  | 32  | 100 | 2476|
| Bus   | 23  | 350 | 18  | 5   | 5   | 11  | 412 |
| Eff   | 86  | 19  | 2108| 9   | 11  | 110 | 2343|
| Leg   | 53  | 22  | 17  | 538 | 31  | 37  | 698 |
| Saf   | 57  | 10  | 84  | 23  | 26  | 2723| 2923|
| Oth   | 40  | 5   | 18  | 23  | 318 | 43  | 447 |
| ∑     | 2409| 427 | 2375| 641 | 423 | 3024| 9299|

(a) Topic Model.

| Label | Adm | Bus | Eff | Leg | Oth | Saf | ∑   |
|-------|-----|-----|-----|-----|-----|-----|-----|
| Adm   | 213 | 4   | 14  | 5   | 4   | 4   | 252 |
| Bus   | 3   | 33  | 2   | 1   | 1   | 2   | 42  |
| Eff   | 9   | 2   | 211 | 0   | 2   | 12  | 236 |
| Leg   | 8   | 2   | 1   | 57  | 5   | 5   | 78  |
| Saf   | 4   | 0   | 8   | 2   | 2   | 279 | 295 |
| Oth   | 4   | 1   | 2   | 3   | 32  | 4   | 46  |
| ∑     | 241 | 42  | 238 | 68  | 46  | 314 | 949 |

(b) Annotators.

Supplementary Table 12: Confusion matrices for the evaluation set with respect to topic: between the annotators and the model (a), and between annotators (b). The performance measures, Acc and F1, are calculated from these matrices. The axes show the possible labels (Adm = administration of vaccines, Bus = vaccine business, Eff = effectiveness of vaccination, Leg = legal issues, Saf = safety concerns, Oth = other).
Supplementary Figure 1: Daily time series of the percentage of vaccine-related content from questionable and reliable sources, respectively, and associated first difference. Graphics are broken down by period: overall (1 January 2016–31 December 2021), pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021).
Supplementary Figure 2: Cross-correlation function (CCF), i.e., ratio of covariance to root-mean variance, for daily time series of the percentage of vaccine-related content from questionable (left panel) and reliable (right panel) sources, respectively, concerning the overall period (1 January 2016–31 December 2021) and the pre-pandemic (1 January 2016–29 January 2020) and pandemic (30 January 2020–31 December 2021) sub-periods, respectively. In the left (right) panel the lagged values refer to questionable (reliable) time series.
Supplementary Figure 3: Daily percentage of user interactions with vaccine-related content with respect to the totality of user interactions performed on content produced by questionable and reliable source sets, respectively.
Supplementary Figure 4: Percentage of vaccine coverage with respect to the different opinion classes (A=Anti-vax, N=Neutral, P=Pro-vax). The observations underlying each empirical Probability Density Function curve represent the single sources and their sizes the corresponding amount of vaccine coverage.