"In Gov We Trust!"
The Impact of the Compulsory Vaccination Law on Vaccine Hesitancy: Evidence from Italy

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Abstract

Over the last three years, Europe experienced a large measles outbreak. Italy was particularly hard-hit with over 5,000 cases and four deaths in 2017. 'Vaccine-hesitancy' has been blamed as the leading cause, with social media considered as the major source of misinformation and fake news on vaccines. To increase dramatically-low immunization rates, in 2017, the Italian Government introduced a mandatory vaccination-law ('No jab, No school'), against ten infectious diseases, including measles. This led to an increase in the MMR vaccination-coverage. However, these aggregate figures mask regional heterogeneities, with some areas still reporting dramatically-low coverage-rates. This work aims to quantify the 'No jab, No school' impact on i) MMR immunization rates at national and regional levels, ii) number of measles cases, iii) attitudes towards vaccination, derived from social-media data. To these ends, we use a RDD model on a compendium of epidemiological and social-media data covering the period January 2013-August 2019.

Keywords – Vaccine-hesitancy, Internet, Social Media, Immunization Rates
JEL codes – I12; I18; L82; L86

1. Introduction

In April 2019, the World Health Organization and UNICEF called the attention on the worldwide measles outbreak (Dyer 2019; Mahase 2019; McKee and Middleton 2019) and on the general upsurge in the overall number of reported cases. In Europe, for example, the number more than tripled in the last two years from 25,863 in 2017 to 82,596 in 2018 (WHO 2019). Low vaccination rates, year after year, have resulted in large numbers of unprotected youth and adults, creating large pockets of measles-susceptible individuals (Trentini et al., 2017, 2019). In response, the leaders of international organizations, among the others the European Commission, called for a global and coordinated action (European Commission 2019) to increase vaccination coverage.

Italy was particularly badly affected during the 2017 European outbreak. It was the country with the second highest incidence rate with four deaths and 5,098 cases reported, 4,042 of which were confirmed by positive laboratory results (Italian National Institute of Health, 2017; European Centre for Disease Prevention and Control, 2018). In response, the Italian Government approved the Law no. 119/2017, the so-called '*No jab, No school*', a mandatory vaccination policy for school-age children. Proof of vaccination against 10 vaccine-preventable diseases, including measles, is now required to enter kindergarten and nurseries (pre-primary) while parents face fines of up to €500 if they send their unvaccinated kids to school (Signorelli et al., 2018; D'Ancona et al., 2018; Italian Ministry of Health, 2017). The law also established a detailed vaccination schedule, with the administration of the first (second) dose at the age of 18 months (five years), and with routine catch-up campaigns to check for compliance with this two-dose schedule both at pre-primary and primary school. Therefore, children must have received one dose when entering pre-primary schools (at about three years of age) and two doses when entering primary schools (at about six years of age). The operating guidelines provided by the Ministry of Health also indicate the implementation during the transitional year 2017 of a catch-up campaign targeting all the defiant children aged 16 or below (D'Ancona et al., 2018).

Although highly debated and criticized, the introduction of the new law in Italy generated an upsurge in Measles, Mumps and Rubella (MMR) vaccination coverage which, in some Italian regions, almost reached the recommended 95% herd immunity level (Di Pietro et al., 2019). The law, however, triggered the debate both at the political and societal level on the possibility of having a counterproductive effect on vaccination coverage by lowering the level of trust on public institutions

(Guardian 2019). Such arguments were seized by antivaccine activists, who voiced their concerns through the Internet and the social media, in particular (McKee and Middleton 2019).

Despite anecdotal evidence shows an increase in the immunization levels post law introduction, quantitative analyses of its impact at both national and regional levels are still lacking. In this paper we try to fill these gaps by investigating the '*No jab, No school*' impact on short and long-term health outcomes. In parallel, we shed light on how mandatory vaccination policy is shaping the attitude and beliefs towards vaccination. In particular, we use a Regression Discontinuity Design model to exploit the discontinuity created by the enrollment of the law on i) measles cases (short-run) ii) MMR coverage (long-run) iii) social media beliefs, namely the proportion of neutral tweets. Our preliminary results, on a compendium of epidemiological and social data for the period January 2013-August 2019, show that the law increased significantly the MMR coverage, especially in those areas historically characterized by the lowest coverage. We also find that the attitude towards vaccination further polarized after the 'No jab, No school', with a significant increase towards negative opinion on vaccination. However, no significant effect on the number of measles cases was found.

The paper proceeds as follows, Sections 2 and 3 present the data and the methodology, respectively. Section 4 presents some preliminary results and finally section 5 concludes.

2. Data

Twitter Data collection

To evaluate the '*No jab, No school*' impact on the social media beliefs, we focus on Twitter posts related to vaccination. To this end, we constructed a list of keywords regarding opinion about vaccinations or measles following the strategy applied by Pananos and colleagues (Pananos et al. 2017). The words considered are the following: *vaccin*, vax, libertàdiscelta, libertadiscelta, ddl770, trivalente, #mmr. Stars were used to capture every possible declination and compounding of the selected keywords. In this way, the most widely used hashtags such as \#iovaccino (I vaccinate) or \#noobbligovaccinale (no compulsory vaccinations) were also identified by the downloading procedure. The tweets were collected using a web scraping methodology and covered the period January 2016 - August 2019, to have a similar pre and post time window.

Web scraping allows, through a HTTP GET request, to collect all the tweets matching the search criteria, similarly to perform the Twitter Search tool research available on the web.

To focus on posts expressing attitudes towards vaccinations, post with URLs only (or those likely to be advertisements), were filtered out prior to our primary analyses. We kept re-tweets (tweets re-shared from other users) as, in our opinion, they indicate that two or more individuals share the same attitude towards vaccination.

In the data cleaning process (Figure 1), we tokenized each tweet and we deleted useless meta information, such as mentions, numbers, stopwords and any other special character. Hashtags are only reduced into words (the # symbol was dropped) refraining us from losing any useful information. Finally, for each tweet we perform the stemming process, i.e. every word in the tweet is reduced to its root (*stem*), in other words two morphological variants of the same root would produce the same stem. Pre-processed tweets where then represented in vector, to this end we implemented the bag of words (BOW) method.

Finally, along with the post contents, we collected the date and time the posts were published as well as metadata regarding the Twitter accounts submitting the posts and, when available, geolocation information (latitude and longitude, available for 2.5 % of the sample).

Epidemiological data

Two distinct data sources made available by the Italian National Institute of Health (Istituto Superiore di Sanità, ISS) were used for the analysis. The first includes the number of measles cases on a monthly bases and covering the period between January 2013 and June 2019 (ISS, 2019) The second comprises MMR coverage rates at 24 months of age, so considering the first vaccine dose only, for Italy's 20 regions covering the period 2000–18 (GOV, 2019). For the purpose of analysis, the Provinces of Trento and Bolzano were classified as single regions, giving a total of 21 regions to be evaluated (Trento, Bolzano plus 19 standard regions).

3. Methods

Sentiment analysis

We classify the tweets in the following three categories i) vaccine hesitant ii) pro-vaccine iii) neutral. The tweets expressing views including universal opposition, opposition to contents of selected vaccines

or vaccination schedules, or a conviction that vaccine-related injuries occur at higher rates than commonly believed were classified as "vaccine hesitant". Individuals expressing views in favor of vaccination, of current policy, or simply expressing opposition to vaccine hesitancy were classified simply as "pro-vaccination". The residual category was defined as "neutral". To train the algorithm, three raters manually reviewed and catheterized the tweets in the three categories presented above. Each rater classified independently 1,000 tweets and determined for each of the corpus whether: the post either (1) clearly expresses vaccine hesitancy in whole or in part, (2) favors vaccination, or clearly criticizes vaccine hesitancy or "anti-vaxxers," (3) reference vaccination without clearly expressing or opposing vaccine hesitancy, or (4) irrelevant to the debate. To validate the annotator reliability, we randomly selected 200 common tweets to be rated by all the three raters.

Tweets were classified using a supervised classification model that we trained during the 'supervised' learning stage. To select the best fitting classification model, we run and compared four classification algorithms: Multinomial Naive Bayes, Linear Regression, Support-Vector Machines (SVM) and Random Forest.

For each of these algorithms we performed experiments using a 10-fold stratified cross validation (CV) procedure. We selected the Linear Regression model as it returns an average accuracy of 67,53 %. This performance is aligned to the one achieved in similar works (i.e. D'Andrea et al, 2019 ; Day et al, 2018)

Statistical model

To investigate the association between the implementation of the law and the outcomes namely i) number of measles–related cases (Cases) ii) MMR immunization coverage (MMR coverage) iii) percentage of neutral/negative/positive tweets (Neutral/Negative and Positive) we used a Regression Discontinuity Design, (Trochim, 1984) as follows:

$$(1)\ Y_t = \alpha + \beta\ Implementation\ Law_t + \gamma_1\ Time_t + \varepsilon_t$$

Here t is time-specific outcome. The outcome is measured as follows ii) Cases: number of measles cases ii) Coverage: Percentage of children below the age of two who have been immunized over the total number of children at the age of two iii) Neutral/Negative and Positive: percentage of tweets neither positive neither negative over the total of number of tweets. Implementation Law represents a

dummy which is equal to 1 from August 2017 and 0 otherwise. Subsequent models further adjust for secular time-trends, seasonality using monthly dummies, year dummies as well as regional dummies where we have geographical information. The main coefficient of interest is β, which estimates the average change in the outcome of interest after the Mandatory Vaccination Law was implemented

To gather evidence of the potential regional variation, the estimation results are also presented using the following model:

$$(2)\ Y_{it} = \alpha + \beta\ Implementation\ Law_{t} + \gamma_{I}\ Region_{i} + \delta\ Region_{i}\ Implementation\ Law_{t} + \eta_{it}$$

Our coefficient of interest is represented by δ, the percentage point increase in the MMR coverage at regional level associated with the introduction of the '*No jab, No school*'.
All data and models were estimated using Stata version 15. Robust standard errors were used to reflect non-independence of sampling.

4. Preliminary results

Twitter Data -Identified posts

A total of 6.910.764 unique records were collected from Twitter. The downloaded set of raw tweets has been cleaned with the aim of deleting duplicate tweets, i.e. tweets with the same tweet id and tweets written in other language. To this end language detection has been performed over the entire corpus of tweets using the Python open source library *fasttext* (Joulin et al 2017). Of the initial corpus of records, 88.518 were unique Italian tweets.

Figure 2.a shows the daily number of Italian tweets covering the period of interest. The dashed vertical lines represent four political events related to the law that might have triggered the discussion on the media. These are:

- May 19th, 2017: the Cabinet approved a decree reintroducing compulsory vaccination against 12 infectious diseases for children below 16 years of age to be admitted at school (Ansa, 2017).
- June 7th, 2017: the President of the Italian Republic signed the decree, from that moment on it started the process to enforce the law in the Italian legislative system.
- July 31st, 2017: the Chamber of Deputies approved the decree, changing the number of compulsory vaccinations from 12 to 10.

- August 3rd, 2017: the Senate of the Republic postponed the introduction of the law by one year from July 2019 to July 2020. The postponement applied only to pre-primary school-age kids. [

Starting from March 2017 the number of tweets related to vaccination significantly increased, as opposed to the flat trend that characterized the period before. This increase is particularly relevant between July and September 2017 when the number of tweets more than quadrupled, from a daily average of 19 tweets to a daily average of 88. Even starker is the comparison with the peaks under examination, on May, 19 (June, 7) [July, 31] we identified a total of 199 (201) [208] tweets, therefore a 10 times higher than the average before the introduction of the law.

Through the sentiment analysis, we classified 38 % as anti-vaxxers, 25% as *pro-vaxxers* and 37% as *neutral*. In particular, the number of anti-vaccine posts increased by 96% immediately after the enactment of the '*No jab, No school*', while pro-vaccine tweets increased by 77% in post-law period. Figures 2.b/c present graphically results from the preliminary sentiment analysis. The red color represents anti-vaxxers, the green one pro-vaxxers and the grey one are the neutral tweets. We can see that the enforcement of the law led to an increase in the antivax tweets, whereas its postponement led the pro-vax movement voiced their concerns.

Epidemiological Data

Figure 3 shows the trend in the number of measles cases for the period June 2013- June 2019. The red dashed line represents the introduction of the '*No jab, No school*' law, whereas the blue dashed lines represent the pre and post law trend. The picture shows that pre-law introduction the trend was slightly increasing, mainly driven by the spikes around July 2017. After the introduction of the law the trends appears to be slightly decreasing. Figure 4 presents the time trend in the MMR coverage between 2000 and 2018. MMR coverage was slowly rising, from 74.1% in 2000 to 90.6% in 2012. After this period, coverage levels fell to 85.2% in 2015. Since then and concomitantly with the 'No jab, No school' law MMR coverage started to raise again, assessing to a level of 93.2% in 2018.

Table 1 presents the results using the estimation strategy presented in equation 1. In column 1 the outcome is the number of measles cases, whereas in column 2 the outcome is the MMR coverage for the period 2013-2018. Our results show that the introduction of the '*No jab, No school*' law was accompanied with a significant increase in the MMR coverage by about 3.83 percentage points

[95%CI: 2.60 to 5.06 percentage points]. No significant effect was found when we look at the number of measles-related cases.

Table 2 presents the estimation results of model 2 indicating that indeed the estimated results mask some regional variation, more precisely Molise appears to be the most affected region with an increase in its MMR coverage by about 7.62 percentage points [95% CI: 0.24, 14.99 percentage points]. Then followed by Campania 7.54 percentage points [95% CI: 5.14- 9.94 percentage points] and Valle d'Aosta [6.70 percentage points, 95% CI: 3.45-9.94 percentage points]. Curiously, those three regions were the ones with the lowest MMR coverage rates in 2016 assessing to a MMR coverage rate level of 73.5% , 83.9% 83.4%. Therefore, at first glance it seems that the law was effective in increasing the coverage rate in the areas where the coverage rates was the lowest. An exception is represented by Bolzano, whose coverage level assessed to 67.5% and did not show any significant variations after the introduction of the '*No jab, No school*' law. Abruzzo, Friuli Venezia Giulia, Lombardia, Marche, Trento, Puglia, Sardegna, Sicilia and Umbria do not show any significant increase in their MMR coverage after the introduction of the law.

Twitter Data

Table 3 presents the estimation results of model 2 on the sentiment of the Twitter data we collected. We start presenting the impact on the percentage of neutral tweets (column 1), then to understand how the opinion shifted (if it shifted) we look at the percentage of negative (column 2) and positive tweets (column 3). It is worth noting that here we are examining the percentage point change in the tweets sentiment and not the variation in the number of tweets, which are reported in section 4.1. above.
Our estimation results show that the law led to a polarization of the individual opinion on social media. In fact, the percentage of neutral individuals decreased by about 14.5 percentage points (p.p) [95% CI: -18.8 to -10.2 p.p]. The shift was mainly towards negative tweets, which recorded an increase by about 10.6 p.p [95% CI: 5.9 to 15.3 p.p.]. Pro-vaxxers also voiced their concerns after the introduction of the law, our estimate show and increase in the percentage of positive tweets by about 3.9 p.p [95% CI: 0.03 to 7.5 p.p.]. These results appear to be in line with the previous literature showing that the antivaxxers seize the opportunity to raise the concerns on social media after the introduction of events connected to outbreaks or vaccination campaign (McKee and Middleton 2019).

5. Preliminary conclusion and future research

Our analysis suggests that the '*No jab, No school*' law led to a significant increase in the vaccination coverage. We estimated that the law led to a 3.83 percentage points [95%CI: 2.60 to 5.06 percentage points] increase in the MMR coverage and this increase was more pronounced in the regions with low coverage rates before its introduction. No effects were found on the number of measles-related cases. Our analysis on the Twitter data suggest that the '*No jab, No school*' led to a polarization of the individuals' opinion on vaccination. Our estimates show a decrease in the individuals with neither positive neither negative opinion on vaccination by about 14.5 percentage points (p.p) [95% CI: -18.8 to -10.2 p.p]. The shift was mainly towards negative tweets, which recorded and increase by about 10.6 p.p [95% CI: 5.9 to 15.3 p.p.].

Before analyzing potential implications for policy and research, we must note several limitations of our analysis. First and foremost, it is an ecological analysis. The law can impact on infection through two distinct pathways. First, the individual complies with the law and get vaccinated. Second, independent of the individual beliefs on vaccination, she is protected against measles as the community as a whole is affect by the law. In this paper we are primarily interested in the first one, however we cannot exclude the second one. Second, we cannot exclude the possibility that other changes, for example in the economy (Toffolutti et al., 2018), may have played a role. Although it is difficult to envisage what these might be at the regional level, they would have coincided with the different timings of the implementation of the Law.

Whether and to what extent a mandatory vaccination policy affects both vaccination coverage and individual's sentiment towards vaccination, might have significant implication for policies as they will cast long-shadow over the health of future generations. This is particularly relevant considering that antibiotic armamentarium is rapidly depleting, leading to considerable concerns for future policies. Further research is needed to understand what kind of policies, other than mandatory vaccination, might increase vaccination coverage, parental vaccination being one possibility (Marziano et al. 2019), and what monetary impact these policies might have. We also plan to investigate these processes by delving deeper into the analysis of vaccination beliefs.

Funding

VT received financial support from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n° 313590) project HRES - Health Resilience and Economic Shocks: Analysis of Quasi-Natural Experiments Using Multi-Level Modelling. A. Melegaro received financial support from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n° 283955) project DECIDE. The views expressed in this article do not necessarily reflect the European Union ones.

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Figures and Tables

Figure 1: Steps of the tweets elaboration

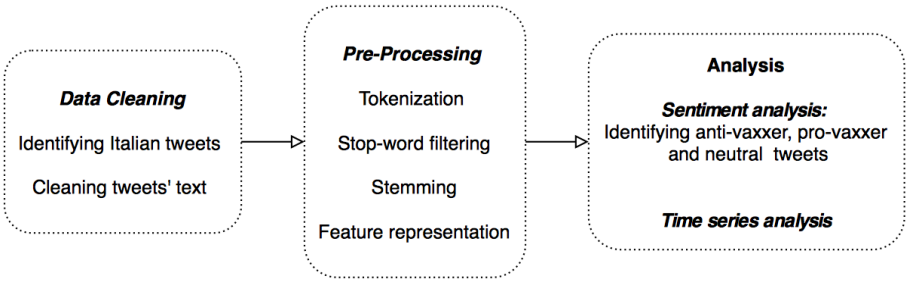
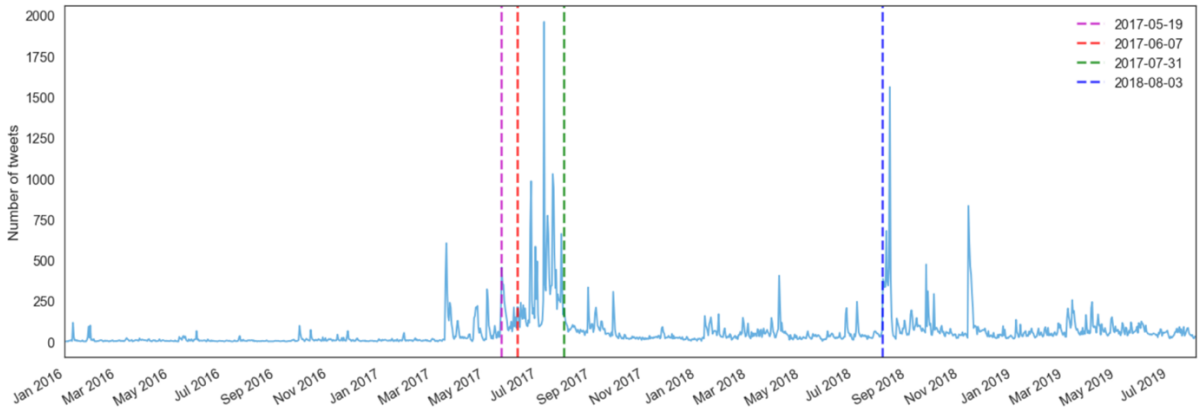
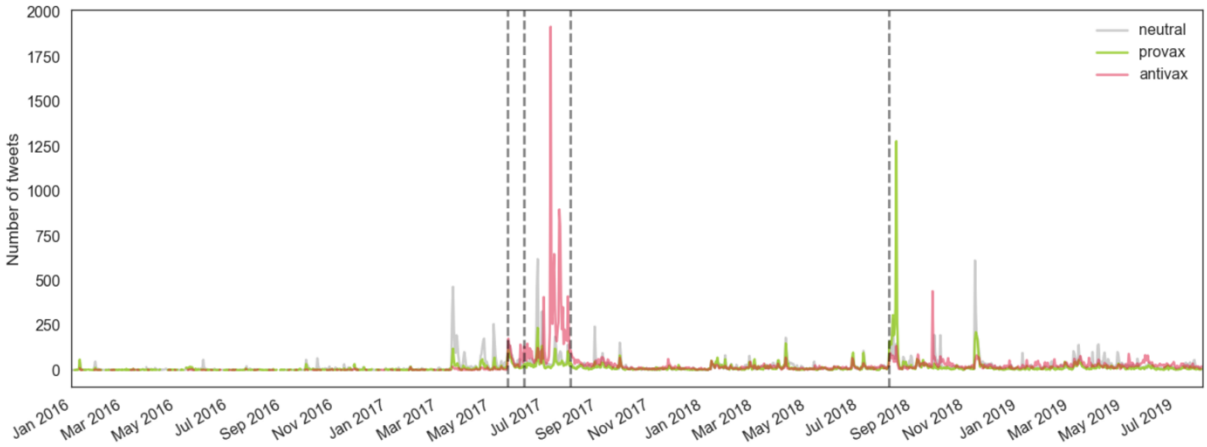


Figure 2a: Time-trend in vaccine-related tweets



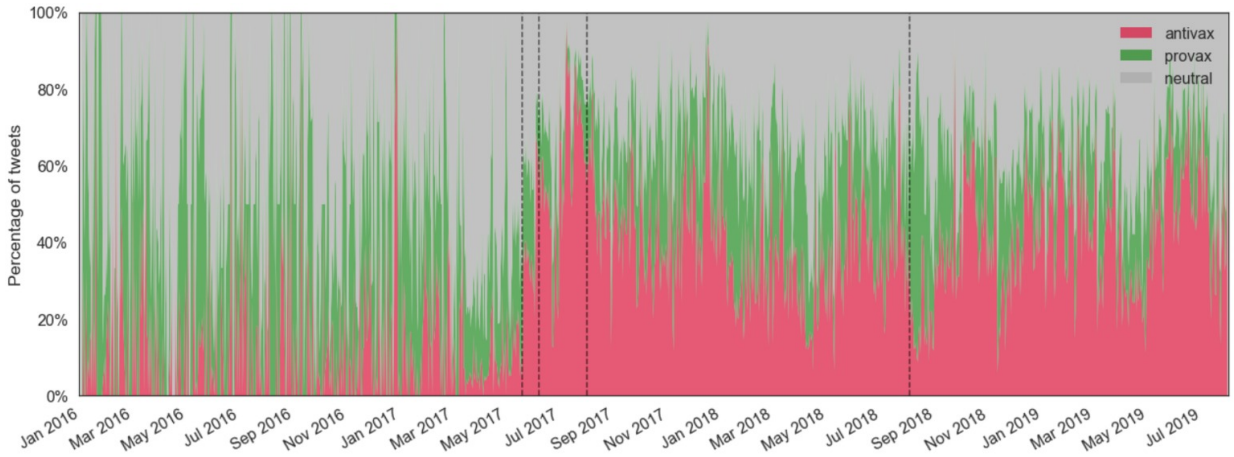
Source: Data represent total number of daily tweets covering the period January 2016- August 2019. The dashed vertical lines represent political events connected with the introduction of the 'No jab, No school' law.

***Figure 2b*:** Time-trend in pro-vax, anti-vax and neutral tweets



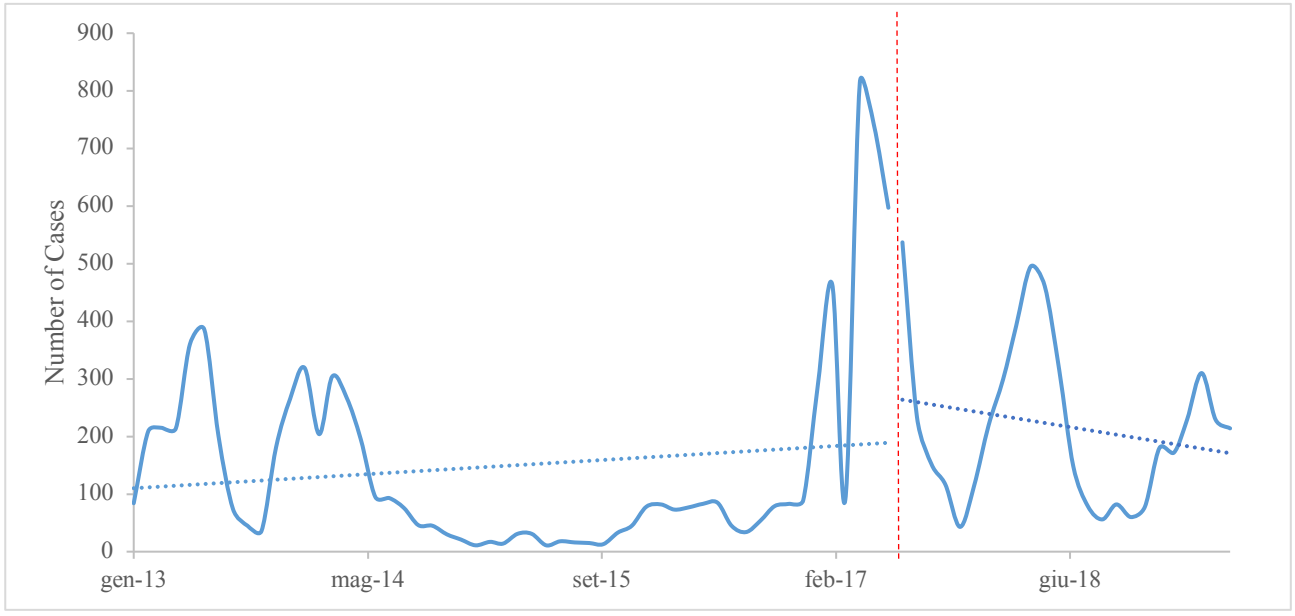
Source: Data represent total number of classified tweets *(neutral, provax and antivax*) by day from January 2016 to August 2019. The dashed vertical lines represent political events connected with the introduction of the 'No jab, No school' law (as in Fig 2.a).

***Figure 2c**:* Time-trend in pro-vax, anti-vax and neutral tweets



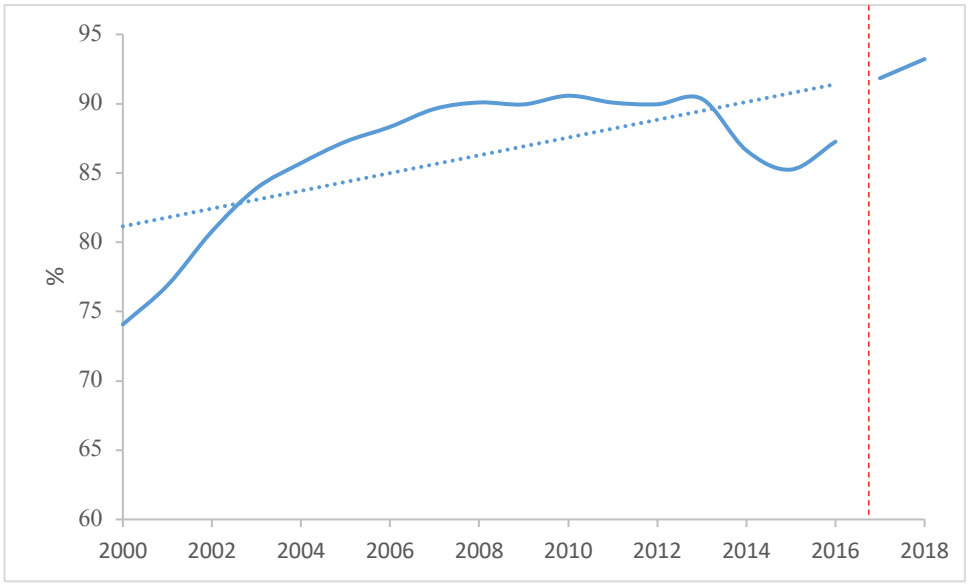
Source: Percentage stacked area chart of classified from January 2016 to August 2019 by day. The dashed vertical lines represent political events connected with the introduction of the 'No jab, No school' law (as in Fig 2.a).

Figure 3: Time trend in the number of measles-cases.



Source: Author's elaboration on monthly data from Infectious Diseases Epidemiology Unit (ISS) covering the period January 2013-June 2019.

Figure 4: Time trend in the MMR vaccination coverage



Source: Author's elaboration on yearly data from Infectious Diseases Epidemiology Unit (ISS) covering the period 2000-2018.

Table 1: Change in the MMR coverage and Number of measles-related cases associated with the '*No jab, No school*' Law Implementation.

	(1) Cases	(2) MMR coverage
Implementation of *No jab, No school*' Law	- 183	3.83
95% CI	[-413, 46.8]	[2.60, 5.06]
Regional dummies	Yes	Yes
Year Dummies	No	Yes
Number of Observations	76	125

Notes: Source: Data from ISS covering the number of measles-related cases for Italy at monthly level, covering the period January 2013 – June 2019 (column 1), MMR vaccination coverage rate at regional and year level for the period 2013-2018 (column 2). The dependent variable has been regressed through an OLS model on dummy variable equal to 1 after July 2017 (column 1) or since 2017 (column 1) and on a non-linear time trend. In column 2 we also used regional fixed effects. Robust standard errors have been used to compute the confidence intervals.

Table 2: Change in the MMR coverage associated with the '*No jab, No school*' Law Implementation, regional effects

	(1)
	MMR coverage
	Effect of the Policy at Regional Level
	b/ci95
Abruzzo	2.26 [-3.36,7.88]
Basilicata	2.40 [1.78,3.02]
Calabria	4.99 [2.75,7.23]
Campania	7.54 [5.14,9.94]
Emilia Romagna	2.65 [0.52,4.77]
Friuli-Venezia-Giulia	2.37 [-2.53,7.28]
Lazio	4.74 [1.84,7.65]
Liguria	6.98 [3.51,10.46]
Lombardia	0.20 [-1.88,2.27]
Marche	4.72 [-0.22,9.67]
Molise	7.62 [0.24,14.99]
Trento	3.03 [-0.89,6.95]
Bolzano	0.44 [-0.85,1.72]
Piemonte	2.60 [0.36,4.84]
Puglia	3.80 [-0.31,7.90]
Sardegna	0.84 [-1.02,2.70]
Sicilia	2.58 [-3.88,9.03]
Toscana	2.51 [0.93,4.08]
Umbria	2.32 [-0.25,4.89]
Valle d'Aosta	6.70 [3.45,9.94]
Veneto	2.17 [0.22,4.12]
N	125

Notes: Source: Data from ISS covering the MMR vaccination coverage rate at regional and year level for the period 2013-2018. The dependent variable has been regressed through an OLS model on dummy variable equal to 1 since 2017 (column 2), regional fixed effects and the interaction between the two. Robust standard errors have been used to compute the confidence intervals.

Table 3: Change in the percentage of neutral, negative and positive tweets associated with the '*No jab, No school*' Law Implementation

	(1) Neutral Sentiment	(2) Negative Sentiment	(3) Positive Sentiment
Implementation of *No jab, No school*' Law	-0.14	0.11	0.04
95% CI	[-0.18, -0.10]	[0.06, 0.15]	[0.003, 0.07]
Month dummies	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes
Number of Observations	1,290	1,290	1,290

Notes: Source: Tweets on vaccination collected by the authors through Web Scraping, covering the period January 2016 – August 2019. The dependent variable represents the percentage of neutral (column 1) negative (column 2) and positive (column 3) tweets at daily basis. The dependent variable has been regressed through an OLS model on dummy variable equal to 1 after July 201 and non-linear time trend. Robust standard errors have been used to compute the confidence intervals.