Local Sociostructural Predictors of COVID-19 Incidence in Germany

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Abstract: Socioeconomic conditions and social attitudes are known to represent epidemiological determinants. Credible knowledge on socioeconomic driving factors of the COVID-19 epidemic is still incomplete. Based on a linear random effects regression, a predictive model is derived to estimate COVID-19 incidence in German rural districts from local socioeconomic factors and popularity of political parties in terms of their share of vote. Thereby, time series provided by Germany's public health institute (Robert Koch Institute) of weekly notified 7-day incidences per 100,000 inhabitants per district from the outset of the epidemic in 2020 up to December 1, 2021, have been used to construct the dependent variable. Local socioeconomic conditions including share of votes, retrieved from the Federal Statistical Office of Germany, have been used as potential risk factors. Popularity of the right-wing party Alternative for Germany (AfD) bears a considerable risk of increasing COVID-19 incidence both in terms of predicting the maximum incidences during three epidemic periods and in a time-continuous sense. Thus, districts with high AfD popularity rank on top in the time-average regarding COVID-19 incidence. The impact of the popularity of the Free Democrats (FDP) is markedly intermittent in the course of time showing two pronounced peaks in incidence but also occasional drops. Socioeconomic parameters like *per capita* income, proportions of protection seekers and social benefit claimants, and educational level have negligible impact. A moderate risk emanates from popularities of the Green Party (GRÜNE) and the Christian Democratic Union (CDU/CSU) compared to the other parties with lowest risk level. In order to effectively combat the COVID-19 epidemic, public health policymakers are well advised to account for social attitudes and behavioural patterns reflected in local popularities of political parties, which are conceived as proper surrogates for these attitudes.

Keywords: COVID-19 incidence; SARS-CoV-2; socioeconomic risk factors; social determinants of health; public health policy;

1. Introduction

Socioeconomic conditions have long been known to constitute epidemiological determinants [1], which is also the case within the context of epidemiology of viral infections [2], including the recent COVID-19 pandemic with a focus on incidence [3–5] or on fatalities [6,7]. Within this latter context of the COVID-19 pandemic, researchers' attentions have additionally been drawn to sociobehavioural aspects and political attitudes as crucial predictors of the pandemic activity [8–11]. Here, the term "sociostructural" is used to comprise socioeconomic as well as behavioural and political aspects.

Apparently, Germany currently faces a prevalence of more or less unspecific gestures of political opposition [10], which resulted in the foundation of protest parties like the "Alternative for Germany" (Alternative für Deutschland, AfD). Recent studies suggest that regions with high popularity of the right-wing AfD exhibit higher COVID-19 incidences when being compared to regions with moderate or low AfD popularity [11]. Recent interview-based surveys confirm that radical opponents of anti-corona measures are over-proportionately attracted by the AfD [8–10]. However, another large fraction of these opponents is constituted by people with strong concerns with respect to modern medicine

or reject some medical interventions like vaccination completely as, e.g., anthroposophists [8–10]. Frequently, this group refers to the self-healing power of humans to express their reservations about medical research achievements. Often, this sub-population has an affinity towards the Green Party (Bündnis90/Die Grünen) or similar parties with an emphasis on environmental and bio-ecological aspects [9].

Previous analyses of socioeconomic determinants of COVID-19 incidences (and fatalities) exist for other countries like the USA [6], however, the results might not be applicable to Germany. Other studies have been conducted at an early pandemic phase and need to be updated to the recent epidemic activity [3,4,11]. In references [3,4], a single aggregated parameter, the so called German Index of Socioeconomic Deprivation (GISD), has been used as a predictor for COVID-19 incidence. Interestingly, the latter study revealed the more wealthy, i.e. less social deprivated sub-population as an early driver of the epidemic in Germany up to the so called "first wave," with a change to the opposite in the subsequent course of the epidemic. An obvious reason can be seen in ski tourism, which attracts more wealthy classes of society and which has been identified bearing an important epidemic driver function during the onset of the pandemic [12]. In a seroprevalence study restricted to one German region [5], the focus was on ethnicity and adjustments for possible socioeconomic confounders, however, leaving comparisons between regions pending. In the latter study, ethnicity as a significant risk factor has been concluded from an overproportionate seroprevalence of the corresponding subpopulation. Having said that, all sociostructural variables are strongly correlated, therefore, Ruck et al. [6] tried to shrink the set of variables down to the statistically most important subset using the least absolute shrinkage and selection operator (LASSO) regression method, however, with ambiguous meaning.

Here, we focus on a prediction model for COVID-19 incidence and refrain from using a score parameter and instead aim in separately assessing crucial sociostructural parameters. In addition, since previous quantitative analyses left some questions open with respect to possible socioeconomic confounders, we here show that multivariable linear random effects regression modelling yields popularity of the AfD (in terms of share of the vote) as a significant predictor of high incidence even after adjustment for several socioeconomic confounders and covariates. In contrast, an increasing percentage of votes for most of the other parties is associated with a reduced COVID-19 incidence with the exceptions of Christian Democratic Union (CDU/CSU) and the the Green Party (GRÜNE) whose percentage of votes are insignificant in absolute terms for predicting the incidence. However, due to the constraint that percentages of votes sum up to 100% the results have to be interpreted in a relative sense. Thus, in relative terms, popularity of the AfD bears high risk in increasing the incidence, whereas popularity of CDU/CSU or GRÜNE is associated with medium risk, respectively and the lowest risk emanates from the other parties.

2. Materials and Methods

2.1. Data

Publicly available data are used exclusively. Three age-stratified time series at the level of 411 rural German districts (Landkreise) of the registered COVID-19 7-day-incidence have been retrieved from the database provided by the Robert Koch-Institute [13]. Final retrieval date has been Dec 1, 2021. Thereby, the three age classes (in years) [0-14] (referred to as kids), [15-19] (juveniles), and >19 (adults) are used. Of note, due to unobserved COVID-19 cases, these data do not contain true incidences. For the analysis, three episodes of the epidemic time course are used spanning report weeks [41-60], [61-80], and [81-100], respectively, where the report weeks are counted from the first week of 2020 onward. These episodes enclose so called epidemic waves 2, 3, and 4, respectively. Since the peaks of the waves differ among districts, the maximum incidence within each of the periods is used as outcome to be predicted, whereby the period enters the model as one of the predictors. The age class is a further predictor.

Furthermore, socioeconomic data have been retrieved from the Regional German Database (Regionaldatenbank Deutschland) operated by Federal and State Government

Census Bureaus (Statistische Ämter des Bundes und der Länder) [14]. The following data, retrieved at the rural district level, have been used as predictors:

- share of the vote (percentages) resulting from the European election 2019 available for the following parties: CDU/CSU, SPD, GRÜNE, AfD, LINKE, FDP, and Other Parties (cf. list of abbreviations at the end of the article) focussing on eligible voters, voter turnout as well as valid second vote. The general vote statistic is established on a full census (Totalerhebung) and uses official transcripts as well as documents from electoral bodies (secondary statistics). In addition, the voter participation has been included to the set of predictors.

- unemployment rate (percentage) regarding the dependent workforce in 2020. The unemployment rate relates the numbers of registered unemployed people to the workforce (workforce and unemployees) as a quota given in percentage. The unemployment rate is focused on the dependent civil workforce, meaning all employees who are subject to social insurance including trainees (Auszubildende), minor (geringfügig) employees, and officials (Beamte) (excluding soldiers) including unemployed people. The data used is based on secondary statistics and gained through administrative processes by a complete survey (Vollerhebung) of regional employment agencies as well as registered people at the Jobcentre.

- graduates of 2019 within the population (percentages) holding particular degrees of education (w/o graduation, Hauptschulabschluss (lower degree secondary education), Mittelschulabschluss (middle degree secondary education), Hochschulreife (higher education entrance qualification)): The data is based on a full census (Totalerhebung) due to the duty of disclosure for public as well as private schools.

- proportion of the population with the status of protection seekers in 2019 based on data of the Central register of foreigners (Ausländerzentralregister AZR).

- proportion of the population receiving social assistance benefits in 2020 (Empfänger von Hilfe zum Lebensunterhalt) based on a complete survey (Vollerhebung), as well as secondary statistics since already gathered administrative data, is being prepared.

- *per capita* income

Moreover, the federal state to which a given district belongs serves as a further determinant.

2.2. Statistical Methods

Linear random effects regression modelling is used to predict the maximum incidence calculated at the rural district level within one of three pre-defined epidemic periods, depending on the share of the vote. In addition, a linear random effects regression is applied in increments at each point in time (i.e., weekly) during the entire observation time in order to obtain the temporal behaviour of the regression parameters. Predictors of the regression, i.e. possible risk factors, are the socioeconomic parameters and covariates listed above. The district index has been supplied as random variable. Statistical modelling has been performed using the "lme4" package of "R statistical programming language" (version 4.1.2) [15,16]. We report the estimates along with their p-values derived from t-statistics (two-sided). Models are compared using likelihood ratio tests. Significance level is $\alpha = 0.05$.

3. Results

The scatterplot Figure 1 depicts maximum incidence within epidemic period [81-100] of the adult population versus the share of vote of the AfD for the 411 rural districts. The AfD enjoys high popularity in East Germany which gives rise to well-separated point clouds corresponding to these two regions. A comparably strong difference in share of vote between East and West can be observed for the left-wing party "Die Linken" (LINKE), whereas differences in share of vote are more moderate for the other parties, although not negligible (see the full set of scatter plots in the supplement S1). The incidence of a rural district significantly increases with the district's percentage of AfD-vote as shown in Figure

1 by means of linear regression lines. Thereby, we fitted regression lines to the full set of data (yielding slopes s in Δ incidence per percentage point) ($s = 33.9$, $p < 0.0001$) as well as to the two subsets belonging to East ($s = 62.14$, $p < 0.0001$) and West Germany ($s = 16.72$, $p = 0.005$), respectively. It turns out, that the increase of incidence with increasing share of vote is by far stronger in East Germany, which suggests that the regions with their differing socioeconomic conditions might constitute confounders, which will be analysed in detail in the following.
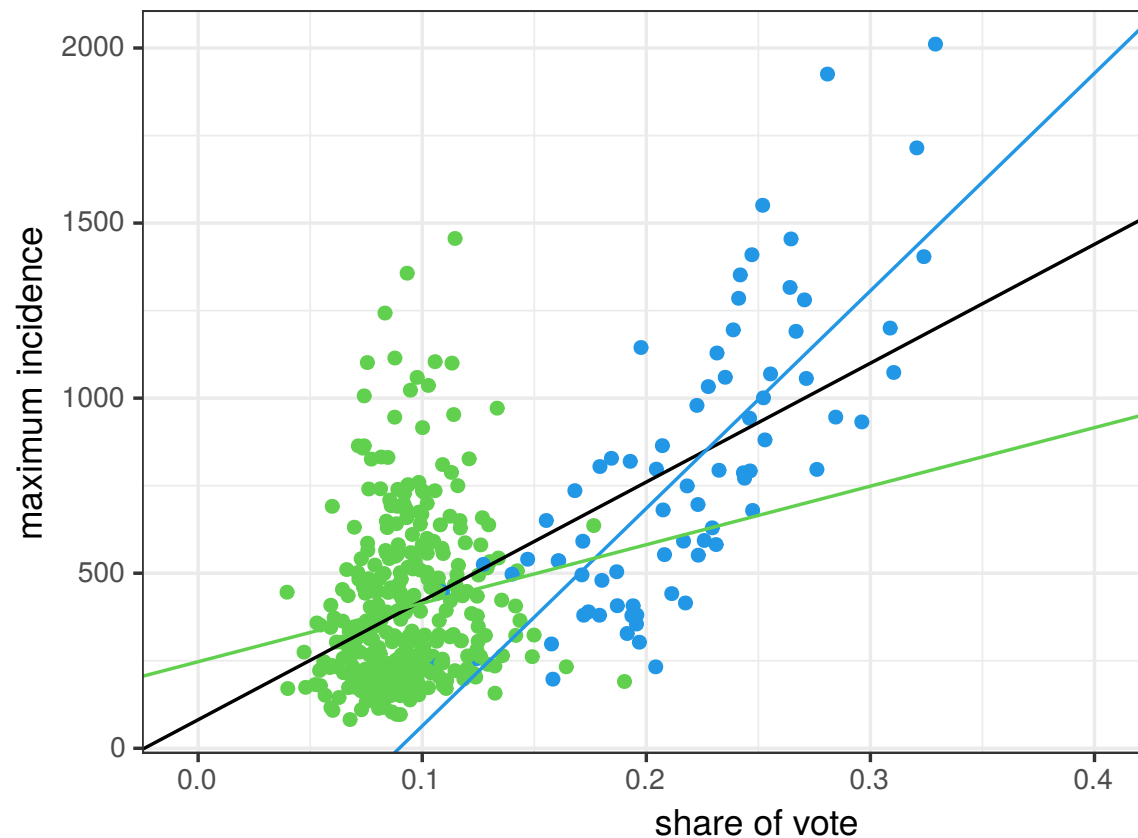
Figure 1. Maximum incidence within epidemic period [81-100] of the adult population by the AfD share of vote for the 411 rural districts. Data points corresponding to East German districts are depicted in blue, West German districts in green. Three linear regression lines are shown for the full set of points (black), only the East German (blue), and only the West German (green) parts, respectively.

In the same vein, we performed uni-variate linear regressions for all the other combinations of the triple set of predictors: party, epidemic period, age class. Please see the supplement S1 for the full set of scatterplots including regression lines. A qualitative assessment of the results strikingly reveals a dominant impact of the share of vote of the AfD. However, particularly the obvious differences observed for East and West Germany entail a rigorous multivariable regression including the required adjustments.

In a first step, a full multivariable linear random effects regression model including the following independent variables is fitted to the age-stratified (using three age classes) COVID-19 incidence data given at rural district resolution:

- share of vote per party excluding "other parties" (cf. Methods),
- federal state to which the district belongs with Bavaria as reference,
- age class with kids as reference,
- epidemic period with weeks [41-60] as reference,

- unemployment rate,
- proportion of protection seekers,
- proportion of social benefit claimants,
- proportion of population with with a given level of education excluding the group "w/o graduation",
- *per capita* income of private households in Germany from 1995 to 2019 provided by the task force "national accounts of federal states" (Volkswirtschaftliche Gesamtrechnungen der Länder) on behalf of 16 states' statistical offices, federal statistic office and registration office, Frankfurt. The data used focuses on the primary income of private households including non-profit organizations per inhabitant measured in Euro in 2019.

Instead of using the two-level predictor East/West we switched to the federal state with 16 levels, which proved necessary according to a likelihood ratio test ($p < 10^{-4}$). Thus, also North-South gradients in the percentage of votes for distinct parties as well as incidences can be observed. Thereby, unemployment rate, proportion of protection seekers, *per capita* income, as well as the proportion of social benefit claimants all turn out to constitute non-significant risks with $p > 0.5$ for all corresponding p-values. In addition, skipping these variables from the list of predictors and comparing full and reduced model fits yields $p = 0.7$ resulting from a likelihood ratio test. Likewise, the educational level does not pose a high risk of elevating the incidence above the average. However, the proportion of the population with a low degree graduation may be conceived as a relevant predictor with an estimate of $\beta = 5.85$ ($p = 0.09$), although below statistical significance. Therefore, education is kept within the list of relevant predictors, however, unemployment rate, proportion of protection seekers, and proportion of social benefit claimants are removed due to their irrelevance.

The reduced model resulting from the model reduction process described above yields the results listed in Table 1. The most striking result of the regression is the highly significant predictive power of the AfD's share of vote for the prognosis of COVID-19 incidence. Even after inclusion of several socioeconomic and epidemiological covariates, a strong risk of high incidences can be observed when being compared to the share of vote of other parties. Due to the constraint that the percentages sum up to 100%, the impact has to be interpreted in a relative sense. In this line, CDU/CSU as well as GRÜNE rank between AfD and the other parties in terms of the magnitude of risk. Obviously, rural districts with high percentages of votes of the AfD exhibit characteristics that constitute risk factors for COVID-19 incidence. The increasing risk resulting from an increasing popularity of CDU/CSU and GRÜNE is more moderate or neutral, whereas the increasing percentages of the other parties seem to unfold a lowering in risk of incidence. Independently, of whether the local characteristics that determine higher incidence rates are directly related to the political agenda of the corresponding parties or not, the very fact of increased incidences entails that the politicians are in charge to reflect these characteristics of their districts.

The impacts of most of the other predictors are not very surprising. Saxony (Sachsen) faced the by far highest incidence during the fourth wave (weeks [81-100]), whereas Schleswig-Holstein (SH) exhibited an incidence well below the country average, consistent with the observed statistical significance the two federal states and the epidemic period, respectively. Of note, an increasing vote participation turns out to statistically significantly lower the risk of COVID-19 incidence. A shared hostile stance with respect to public health and other policies between AfD voters and non-voters might by a possible, although speculative interpretation. To complete the report, the random effect of the rural districts yields a standard deviation of 31.4 for the intercept (262.4 residual), hence pointing to a considerable random variation between the rural districts not captured by the fixed effects of the model.

In a second approach, we applied the random effects linear regression at each instant of time in order to obtain time series of the regression parameters. The rational behind doing so is to reveal possible temporal effects with impact on the prediction. The result is shown

Table 1: Result of a linear random effects regression. Reference levels of the categorical predictors are: Bavaria (Bayern) for federal state, kids for age class, weeks [41-60] for epidemic period. The metric covariates are given in %, thus the corresponding βs have to be interpreted as Δincidence per percentage point. Due to the constraints that the percentages corresponding to share of vote and education, respectively, sum up to 100% we skipped the variables "Other Parties" and "w/o graduation" in order to avoid singularities.

	predictor	β	p-value
	(Intercept)	219.3572	0.6147
	Berlin	21.8472	0.6405
	Brandenburg	73.0680	0.1814
	Bremen	26.2201	0.7427
	BW	0.5616	0.9869
	Hamburg	-35.1745	0.7301
	Hessen	-81.2580	0.0452
	MV	-92.9675	0.1136
federal state	Niedersachsen	-66.3518	0.0974
	NRW	-14.6109	0.7172
	RP	7.6899	0.8410
	SA	106.4860	0.0789
	Saarland	99.5866	0.0947
	Sachsen	269.8220	0.0000
	SH	-188.4172	0.0000
	Thüringen	97.3940	0.1071
age class	juveniles	78.9686	0.0000
	adults	-112.7720	0.0000
period	[61-80]	-3.2528	0.7592
	[81-100]	445.5187	0.0000
education level	low edu	5.1997	0.1227
	middle edu	2.5696	0.3773
	high edu	3.3902	0.2381
	AfD	24.5496	0.0000
	SPD	-10.1267	0.0135
share of vote	CDU	0.7607	0.8418
	GRÜNE	4.5659	0.3228
	LINKE	-12.3950	0.0321
	FDP	-15.4975	0.0189
	vote participation	-5.6381	0.0001

in Figure 2. The dominant role of the AfD in predicting high incidences can be confirmed: the magnitude of the corresponding regression parameter almost persistently remains on top from end of 2020 on (Figure 2, second panel). This time-dependent regression also reveals a short period (around week 90) in which the Free Democratic Party (FDP) is on top. The moderate risk emanating from the GRÜNE and CDU/CSU can now apparently be attributed to the last episode roughly from week 90 onward.

The remaining two panels of Figure 2 are devoted to show the time courses of prediction parameters corresponding to federal state, age classes and unemployment rate. The latter predictor remains well below significance throughout the entire observation time and has here been chosen as a proxy for all the other socioeconomic determinants. All included socioeconomic parameters do not show any role on predicting COVID-19 incidence after week 40. The federal states as well as the age classes, however, turn out to be significantly predictive from this time-dependent version of regression modelling as well, as already shown above where we aggregated the incidence time series into maximum values of 3 dominating periods. Apparently, phases of higher and lower incidences alternate in an almost reciprocal way between West and East German states. Kids and juveniles play an
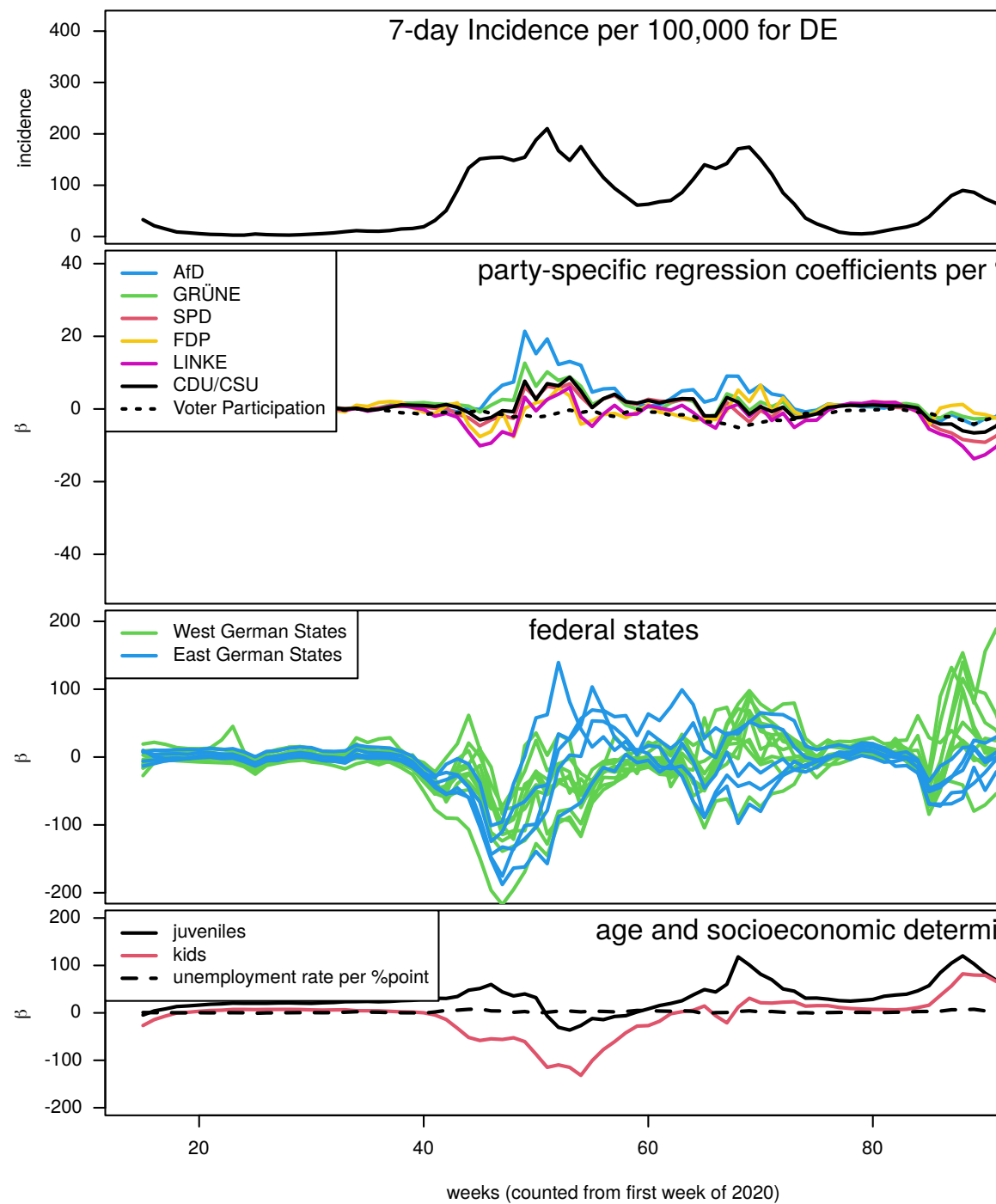
Figure 2. Time courses of regression parameters obtained from random effect linear regression modelling applied at all available time points during the observation time. Panel on top: the German COVID-19 incidence curve (to allow for a mapping of the results to the epidemic history). Other panels from top to bottom: regression parameters in units "per percentage point" corresponding to i) the share of votes (including voter participation), ii) the federal states (for a better visibility all West German states depicted in green, East German states in blue), iii) age classes (adults are reference) and percentage of unemployment.

increasing role in predicting high incidences, most likely due to the increasing vaccination rate of the adult cohorts, but periods of school closures and openings and unstable interventions may also play a decisive role.

4. Discussion

Conclusive inferences have to be drawn with utmost care. The presented analysis of sociostructural risk factors aims in informing public health and epidemiology policymakers. We refrain from any accusation which appears to be inappropriate due to unclear causality. We use the share of the vote of a particular party as an approximate surrogate parameter that presumably captures sociobehavioural aspects and correlates with COVID-19 incidence beyond other socioeconomic factors and we strongly advocate a subsequent reflection of our results from a sociopolitical perspective, including representatives of the corresponding parties.

Specifically, locally observed high COVID-19 incidences are associated with local popularity of the right-wing party AfD. Multivariable linear random effects modelling with adjustments for the most important socioeconomic public-health determinants and the inclusion of epidemiological covariates yields a high degree of reliability of this result. It is particularly worth of note that a set of the most important socioeconomic factors plays a minor role in driving the epidemic. Speculatively, social and antigovernmental attitudes play a more important role where the popularity of a party can be conceived as a proper surrogate measure (cf. [8,10]). One of the limitations of this analysis is the fact, that correlations do not allow to draw inferences on causality. However, a comprehensive sociological interpretation is beyond our aim which is driven by the demand to supply relevant information for public health policies. From this point of view it is crucial to be able to spot locally given conditions that are informative for epidemiological control strategies, whether these conditions have causal or mere correlative structures.

Local popularities of other parties by means of their share of vote lead to much better prognoses of COVID-19 incidences within the corresponding rural districts, with the exceptions of CDU/CSU and GRÜNE. In addition, during a short period of time the popularity of the FDP appears to pose a risk of increased COVID-19 incidence. Again, we refrain from comprehensive sociological analyses and refer to published work instead [8–11,17] where motivations of the protest movement have been discussed. In reference [17], the Austrian situation is discussed revealing an impact of the right-wing party FPÖ similar to the German AfD. In following the cited literature, the prevalence of conspiratorial attitudes is above average among the new protest movement which might in turn be intensified by the extensive use of new media communication tools (cf. [18,19] for a critical discourse, also see [17]).

Clearly, our analysis is limited by the fact that the officially registered incidences depend on local COVID-19 test policies and the corresponding infrastructural conditions. Policies with respect to opening of schools and corresponding test strategies are particularly important since the impact of kids and juveniles as possible epidemic drivers is controversially debated [20–25]. However, it seems more plausible that the average frequency of testing is even less in regions with a high "anti-corona attitude" prevalence, which thus would even amplify our result. Having that said, an in-depth analysis of the impact of both children-related policies and epidemic dynamics is encouraged.

Furthermore, the usage of aggregated data (proportions and population averages) might limit validity. Therefore, we engage the reader in relating our result with the insights gained by surveys based on individual interviews [8–10]. We focused on predicting local incidences, however, it is suggested to also include fatalities in future studies (for seminal work see [6,7]). Finally, we did not include vaccination coverage in our analysis due to unavailable high-quality data with required spatial resolution. However, rough estimates regularly published by the Robert Koch-Institute on their online COVID-19 dashboards suggest that incidence and vaccine coverage is negatively correlated. In addition, vaccine coverage might be predictive with respect to hospitalisation and severe COVID-19 illness, but considerably less important as protective factor for asymptomatic infections since the SARS-CoV-2 immunisation is generally not sterile. Importantly in our context, AfD-politicians officially propagate an anti-vaccination attitude consistent with findings in related surveys [8–10], which thus renders a significant impact of vaccination coverage

on our main result as very unlikely. In the same line, other locally differing COVID-19 containment strategies may play roles in predicting incidences. Once again, it is plausible that most of these differences are already contained in the popularities of certain parties as appropriate surrogate measures.

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Abbreviations

Abbreviations
The following abbreviations are used in this manuscript:

GISD	German index of socioeconomic deprivation
BW	Baden Württemberg
MV	Mecklenburg-Vorpommern
NRW	Nord-Rhein-Westfalen
RP	Rheinland-Pfalz
SA	Sachsen-Anhalt
SH	Schleswig-Holstein.
low edu	lower degree secondary education
middle edu	middle degree secondary education
high edu	higher education entrance qualification
AfD	Alternative for Germany
SPD	Social Democratic Party of Germany
CDU/CSU	Christian Democratic Union of Germany
FDP	Free Democratic Party
LINKE	The Left Party, Die Linke
GRÜNE	The Green Party, Bündnis 90/Die Grünen

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