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KOALA: A new paradigm for election coverage

An opinion poll based "now-cast" of probabilities of events in multi-party electoral systems

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Abstract 150 to 250 words
Common election poll reporting is often misleading as sample uncertainty is insufficiently addressed or not covered at all. Furthermore, main interest usually lies beyond the simple party shares. For a more comprehensive opinion poll and election coverage, we propose shifting the focus towards the reporting of survey-based probabilities for specific events of interest. We present such an approach for multi-party electoral systems, focusing on probabilities of coalition majorities. A Monte Carlo approach based on a Bayesian Multinomial-Dirichlet model is used for estimation. Sample uncertainty-based probabilities are estimated, assuming the election was held today ("now-cast"), not accounting for potential shifts in the electorate until election day ("fore-cast"). Since our method is based on the posterior distribution of party shares, our method can be applied for a variety of questions related to the outcome of the election. We also introduce visualization techniques that facilitate a more adequate depiction of relevant quantities as well as respective uncertainties. The benefits of our approach are discussed by application to the German federal elections in 2013 and 2017. An open source implementation of our methods is freely available in the `R` package `coalitions`.

Keywords 4 to 6 keywords Election analysis · Opinion polls · Election reporting · Multinomial-Dirichlet · Pooling

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1 Introduction

In multi-party democracies, approval of the government's and the opposition parties' work is usually measured by public opinion polls continuously conducted and published by various polling agencies. Reported quantities usually include the share of respondents that would vote for the respective political parties *if the election was held today* (party shares), the number of overall respondents and – often less prominent – information about sample uncertainty.

One party often does not obtain enough votes for a governance majority by itself if some kind of proportional representation is used. Thus, multiple parties form a so-called *coalition* to jointly obtain the necessary majority of seats in parliament. Media usually reports the results of such surveys by focusing on the reported voter shares while ignoring sample uncertainty. This is misleading, especially if shares are used to infer the possibility of a majority for a specific coalition. For example, in the prelude to the 2017 German federal election, a coalition was oftentimes stated to "lose" its majority just because the reported joint voter share dropped below 50% from one opinion poll to the next (cf. FAZ.net, 2017). Such interpretations are clearly inadequate as sample uncertainty (and often redistribution of votes) is not taken into account. This becomes especially problematic, when one or more parties are close to the country-specific threshold of votes that has to be passed in order to enter the parliament. This was the case in the 2013 German federal election, where the reported share of the Free Democratic Party (FDP) were close to but over the 5% threshold but the party in the end failed to pass the threshold. (cf. Section 1.2).

Beyond ensuring proper reporting of sample uncertainties, in our opinion, the focus in election poll reporting should in general be shifted away from the reported party shares. Instead, election coverage should focus on the most relevant question, i.e., how *probable* is a specific event or outcome, given the current political mood. As probabilities combine both, the reported shares and sample uncertainty in one number, they allow more precise as well as more adequate statements about specific events. Usually of interest before an election are the probabilities of events (**POE**) like:

- "Will a party obtain enough votes to enter the parliament (pass the threshold)?"
- "Will a party obtain the most (second most, third most, etc.) votes?"
- "Will a specific coalition obtain enough votes (joint majority) to form a governing coalition?"

In this article, we present our approach for election and coalition analysis (in German: **Koal**itions-**A**nalyse (KOALA)) that estimates POEs and brings more value to opinion poll based election coverage. It is important to note that we quantify the contemporary political mood and the resulting event probabilities ("now-cast"), not taking into consideration potential shifts until election day ("fore-cast"). Approaches for predicting future election outcomes based on past information can, e.g., be found in Graefe (2017) or Norpoth and Gschwend (2010). A special focus is put on multi-party proportional representation electoral systems and the estimation of probabilities for (joint) majorities. Probabilities are estimated by Monte Carlo simulations of election outcomes from the Bayesian posterior distribution of party shares conditional on current observed opinion poll data. Prior to the German general elections 2013 and 2017, results based on (an earlier iteration of) our approach already entered media reporting (cf. ZEIT ONLINE, 2013; Gelitz, 2017).

All methods discussed in this article are implemented in `R` (R Core Team, 2017) and are available in the open-source package `coalitions` (Bender and Bauer, 2018). A `shiny`-based (Chang et al., 2017) website `koala.stat.uni-muenchen.de` visualizes estimated coalition probabilities and is used to communicate the results for German federal and state elections to the general public. Additionally, we applied our method to the Austrian general election 2017. The process of fetching new polls, updating the website and sending out Twitter messages based on the newest results is automated and allows for an immediate transfer of the estimated POE to media outlets as well as the general public.

1.1 Data basis

As data base for our calculations, we use opinion polls conducted by established polling agencies that quantify the electoral mood in a limited time frame (*if an election was held today*). For each of the two elections discussed in Section 3, we base the discussion on opinion polls published by major German polling agencies (i.e., Allensbach, Emnid, Forsa, Forschungsgruppe Wahlen, GMS, Infratest dimap and INSA), starting one year before each election. Opinion poll data from these polling agencies is collected by and made publicly available on `www.wahlrecht.de`. Application of our approach to other countries requires systematic access to respective polling data. For the Austrian general election in 2017 for example, we used the data base available at `https://neuwal.com/wahlumfragen/`.

1.2 Motivating example

In the last opinion poll conducted before the German federal election 2013 (Forsa, 2013), special interest was on whether the conservative "Union" – i.e., the union of the parties CDU (Christian Democratic Union) and CSU (Christian Social Union in Bavaria) – and the liberal FDP would together obtain enough votes to form the governing coalition (cf. Table 1).

Table 1 Reported voter shares in the Forsa opinion poll for the German federal election, published September 20th, 2013 with $n = 1995$ respondents.

Union	SPD	Greens	FDP	The Left	Pirates	AfD	Others
40%	26%	10%	5%	9%	2%	4%	4%

The German election system mandates a 5% vote share threshold for parties to enter the parliament. Votes for parties below this threshold without at least three successful direct candidates are redistributed (proportionally) to parties above it. Table 2 depicts the resulting redistributed voter shares given the poll in Table

1. It illustrates, that Union-FDP with its reported joint 45% voter share before redistribution, would obtain 50% of parliament seats after redistribution. Thus, ignoring uncertainty it could be concluded that a majority for this coalition is possible, if voter shares would improve slightly for one of the two parties.

Table 2 Redistributed voter shares based on the Forsa opinion poll for the German federal election, published September 20th, 2013 with $n = 1995$ respondents (cf. Table 1). Party shares marked with "–" indicate parties that would not pass the 5% threshold.

Union	SPD	Greens	FDP	The Left	Pirates	AfD	Others
44.44%	28.89%	11.11%	5.56%	10.00%	–	–	–

However, such a consideration completely ignores sample uncertainty and the probabilistic nature of the outcome. If the poll in Table 1 is representative for the election result, one would expect that the FDP enters the parliament (passes the 5% threshold) with a probability of about 50%. Thus, the (posterior) distribution of the joint voter share is bimodal and also depends on whether the other "small" parties close to the 5% threshold enter the parliament. The example also illustrates that discussion of reported party shares can become very complex, due to sample uncertainty and the multitude of different outcomes this uncertainty entails. We therefore argue that probability based reporting of opinion poll results can answer the actual question of interest ("Will a coalition of Union-FDP obtain enough votes to obtain a majority of seats in the parliament?") more directly, while adequately taking into account the inherent uncertainty.

The remainder of the article is structured as follows: Section 2 introduces the Bayesian method used to estimate event probabilities as well as some details on the aggregation of multiple opinion polls and the correction of rounding errors. Section 3 illustrates the application of the approach to opinion polls in advance of the 2013 and 2017 German federal elections. A summary and discussion are presented in Section 4.

2 Methods

In this section, we describe our method for the estimation of POEs based on reported party shares. Section 2.1 gives a general introduction to the Multinomial-Dirichlet model. In Section 2.2 our approach for the aggregation of multiple polls from different polling agencies is described. As most agencies report rounded voter shares, we perform rounding error adjustment, briefly discussed in Section 2.3.

2.1 Estimating event probabilities from reported voter shares

To estimate the POE conditional on opinion poll results we use the Bayesian framework to construct the *posterior* distribution of the party shares based on distribution of the reported shares and an assumption about their *prior* distribution.

Let $X_1, \ldots, X_P$ be the reported opinion poll count of respondents that would elect party $p,\ p = 1, \ldots, P$ (vote count). For example, in Table 1 the reported vote count for the *Union* is given by $X_1 = .40 \cdot 1995 = 798$. Assuming that $(X_1, \ldots, X_P)$ has a Multinomial distribution

$$(X_1, \ldots, X_k) \sim Multinomial(n, \theta_1, \ldots, \theta_P), \tag{1}$$

where n is the sample size of the opinion poll and $\theta_p,\ p = 1, \ldots, P$ indicates the probability of party p being selected. Assuming a representative random sample, θ_p represents the percentage of voters for party p in the general population (CITATION Stichproben Buch). Given one (pooled) survey, the distribution of the observed vote counts $\mathbf{x} = (x_1, \ldots, x_P)$ is denoted by $f(\mathbf{x}|\boldsymbol{\theta})$.

For the prior distribution of the true party shares $\boldsymbol{\theta} = \theta_1, \ldots, \theta_P$ we chose a flat, uninformative prior distribution (Jeffrey's prior; Gelman et al. (2013))

$$\begin{aligned} \boldsymbol{\theta} = (\theta_1, \ldots, \theta_P)^{\mathrm{T}} &\sim Dirichlet(\alpha_1, \ldots, \alpha_P), \\ \text{with} \qquad \alpha_1 = \ldots = \alpha_P &= \frac{1}{2}, \end{aligned} \tag{2}$$

denoted $p(\boldsymbol{\theta}|\boldsymbol{\alpha})$. As the Dirichlet distribution is a conjugate prior to the Multinomial distribution, the resulting posterior distribution of parameters $\boldsymbol{\theta}|\mathbf{x}$

$$f(\boldsymbol{\theta}|\mathbf{x}) = \frac{f(\mathbf{x}, \boldsymbol{\theta})}{f(x)} = \frac{f(\mathbf{x}|\boldsymbol{\theta})p(\boldsymbol{\theta}, \boldsymbol{\alpha})}{f(x)} \tag{3}$$

$$\propto f(\mathbf{x}|\boldsymbol{\theta})p(\boldsymbol{\theta}|\boldsymbol{\alpha}) \tag{4}$$

$$\propto \prod_{p=1}^{P} \theta_p^{x_p} \cdot \prod_{p=1}^{P} \theta_p^{\alpha_j - 1} = \prod_{p=1}^{P} \theta_p^{x_p + \alpha_p - 1}, \tag{5}$$

is again a Dirichlet distribution with

$$\boldsymbol{\theta}|\mathbf{x} \sim Dirichlet(x_1 + 1/2, \ldots, x_P + 1/2). \tag{6}$$

Given the multivariate posterior (6) and using Monte Carlo simulations, POEs can be deduced for many types of events by simulating election results from (6) and calculating the percentage of simulations in which the event of interest occurred. This includes the probabilities for specific majorities derived from a complex, country-specific system of rules for the calculation of seats in the parliament (Sainte-Lague-Schepper in Germany; CITATION). E.g., given the Forsa poll introduced in Section 1.2, the coalition of Union-FDP obtained a majority of seats in 2 633 of 10 000 simulations, which equals an estimated probability of 26% (see Section 3 for more details).

If it is known that estimates of specific party shares are biased for some opinion polls/agencies, this information could be included in the model by using an informative prior distribution. The prior parameters α_p would then be adjusted to have higher or lower values, respectively. However, such biases of polling agencies are hard to quantify as the true party share in the electorate is only known on election days. For our analyses, we therefore use the uninformative prior (2).

2.2 Aggregation of multiple polls (Pooling)

In the presence of multiple published opinion polls, pooling is used to aggregate multiple polls in order to reduce sample uncertainty. To ensure a reliable pooling regarding the current public opinion, we only use polls published within the last 14 days and only use the most recent survey published by each polling agency.

Considering a single poll i, the observed numbers of votes X_{ip} for each of P parties follow a multinomial distribution with sample size n_i and underlying, unknown party shares θ_p in the population.
Pooling over multiple such polls as independent random samples leads to another multinomial distribution for the summed number of votes $\sum_i X_{ip}$:

$$\sum_i X_{i1}, \dots, \sum_i X_{iP} \sim Multinomial\left(\sum_i n_i, \theta_1, \dots, \theta_P\right). \tag{7}$$

Further analyses, however, showed that polls from different (German) polling agencies are correlated and the independency assumption does not hold. Therefore, we adjust the resulting multinomial distribution by using an *effective sample size* (Hanley et al., 2003), reflecting that the aggregation over multiple correlated polls does not contain information of a sample with $\sum_i n_i$ observations.

Quantification of pairwise correlation is done based on the variance of the party share difference between two polls for a specific party. The following equation holds for two independent random samples from poll A and B:

$$\begin{aligned} & Var(X_A - X_B) = Var(X_A) + Var(X_B) - 2 \cdot Cov(X_A, X_B) \\ \Leftrightarrow \quad & Cov(X_{Aj}, X_{Bj}) = \frac{1}{2} \cdot \left(Var(X_{Aj}) + Var(X_{Bj}) - Var(X_{Aj} - X_{Bj})\right). \end{aligned} \tag{8}$$

We take $Var(X_{Aj})$ and $Var(X_{Bj})$ as the theoretical variances of the binomially distributed, reported voter numbers and estimate $Var(X_{Aj} - X_{Bj})$ based on the observed differences between the reported party shares. Having done so, it is possible to estimate the covariance $Cov(X_{Aj}, X_{Bj})$ and accordingly also the correlation. As the binomial variance is directly proportional to sample size, the effective sample size n_{eff} can be defined as the ratio between the estimated variance of the pooled sample and the theoretical variance of a sample of size one:

$$n_{\text{eff}} = \frac{Var(\text{pooled})}{Var(\text{sample of size 1})},$$

with, in the case of two surveys,

$$Var(\text{pooled}) = Var(X_A + X_B) = Var(X_A) + Var(X_B) + 2 \cdot Cov(X_A, X_B)$$

and Var(sample of size 1) the theoretical variance of the pooled share.

Considering the party-specific correlations between 20 surveys conducted by the two German polling agencies that provide updates most regularly, Emnid and Forsa, we on average end up with a medium high positive correlation, using mean party shares and sample sizes per institute for the theoretical variances. Comparisons of other agencies were not performed as too few published surveys that cover comparable time frames were available. For simplicity, we do not recalculate the correlation for each simulation, but rather set the correlation used in our calculations to 0.5, i.e., a medium positive correlation. For convenience, the calculation of n_{eff} is based on the party with most votes, as the specific party choice only marginally affects the results.

Considering for example two polls with 1 500 and 2 000 respondents, respectively, and a pooled share of 40% for the strongest party, the method leads to an effective sample size of $n_{\text{eff}} = 2\,341$. Thus, the method reduces sample uncertainty compared to using a single poll, while being quite conservative compared to the assumption of independence between the polls and using an aggregate sample size of $1\,500 + 2\,000 = 3\,500$.

As noted above, in practice we use a time window of 14 days, i.e., all surveys published in the last 14 days are included in the calculation of the pooled sample. For some elections (e.g., state elections), opinion polls are updated very rarely. In such cases the time window and pooling procedure could be further modified, e.g., by including all surveys published within 14 days with full weight (using their reported sample size), and all surveys that were published between 15 and 28 days ago with halved weight (using the halved sample size).

2.3 Correction of rounding errors

Polling agencies usually only publish rounded party shares and raw data is not available. Therefore, we adjust the reported data by adding uniformly distributed random noise to the observed voter shares x_j in order to avoid potential biases caused by the use of rounded numbers:

$$\begin{aligned} x_{p,adj} &= x_p + r_{\gamma,p}, \\ \text{with} \qquad r_{\gamma,p} &\sim U[-\gamma, \gamma]. \end{aligned} \tag{9}$$

The correction coefficient γ is chosen according to rounding accuracy. E.g., for data rounded to 1% steps we use $\gamma = 0.5\%$. After random noise was added the adjusted shares are rescaled to ensure a sum of 100%. Overall, instead of using rounded numbers and simulating n_s values from the resulting posterior, we perform n_s simulations where we first adjust the voter shares using individually drawn random noise and then simulate one observation from each resulting posterior.

3 Application

As previously mentioned, (an earlier iteration of) our method entered media reporting before the German federal elections 2013 and 2017 (cf. ZEIT ONLINE, 2013; Gelitz, 2017). In the following, we will revise these two elections in order to underline the differences between standard media coverage of election polls – focused on the interpretation of the reported party shares – and our approach based on estimated POEs. Reported party shares as described in Section 1.1 were used as data basis. Polls from different agencies published within a time window of 14 days were aggregated (cf. Section 2.2). For the estimation of POEs $n_s = 10\,000$ simulations were performed.

3.1 German federal election 2013

In the legislative period from 2009 to 2013, the German government was formed by a coalition of the conservatives (Union) and the liberals (FDP). Before the election on September 22nd, 2013, the question whether the coalition could sustain its majority was therefore of main interest. A key role played the FDP, which had to successfully pass into parliament, i.e., achieve at least the minimum voter share of 5% for the coalition to even be possible. Figure 1 summarizes the reported party shares for the one year period prior to the election.

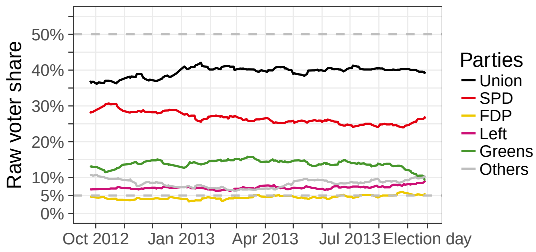

Fig. 1 Course of the pooled party shares from October 2012 until election day on September 22nd, 2013, based on a pooling time window of 14 days. As specific voter shares for AfD were only sparsely reported before the election in 2013 the party is contained in "Others".

POE: FDP passing the 5% threshold

The poll-based prospect of FDP to successfully pass into parliament is visualized in Figure 2. As can be seen, the reported voter share of the party only exceeded the necessary share of 5% over short periods of time and only once reached a maximum value of 6% (top left pane in Fig. 2). Similarly, the probability for the party to pass the threshold rarely rose over 50% (bottom left pane). However, starting at the end of August 2013 until election day, the pooled voter shares and the corresponding probabilities consistently were over 5% and 50%, respectively, stating that – shortly before election day – a parliament entry of the FDP was more probable than a failure.

Comparing voter shares and probabilities, Figure 2 shows that small changes in the overall share of a party can dramatically influence event probabilities, depending on the base level of the voter share and – in this example – its closeness to the 5% threshold. In this regard, probabilities make it easier to deduce *relevant* information from opinion polls as they incorporate both the closeness of the reported shares to the relevant threshold and sample uncertainty. E.g., the probability corresponding to voter shares of 4% and 6% correspond to very definite probabilities of near 0% and 100%, respectively, and communicating such probabilities leads to a much clearer perception of the current public opinion compared to the reported FDP voter share and survey sample size only.

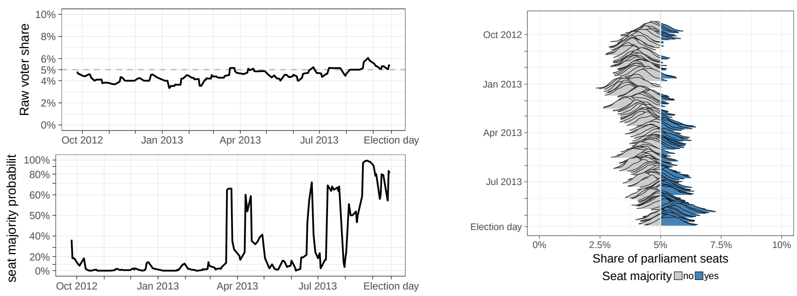

Fig. 2 Development of the prospect of FDP to pass the 5% threshold before the German federal election in September 2013 based on pooled opinion polls. Top left: Reported party shares before redistribution. Bottom Left: Probabilities to pass the 5% threshold, based on 10 000 simulations. Right: Densities of simulated FDP vote shares based on 10 000 simulations over time. Areas under the density depicted colored blue indicate the percentage of simulations in which the FDP would pass the 5% threshold.

POE: Union-FDP coalition majority

Figure 3 shows the simulated parliament seat shares for the coalition Union-FDP, based on the reported voter shares in Table 1. The estimated density is clearly bimodal as the reported FDP share before redistribution equals exactly 5% and therefore the FDP only enters the parliament in about 50% of the simulations. In this case, a majority was observed in about one quarter of the simulations, leading to an estimated POE of 26%.

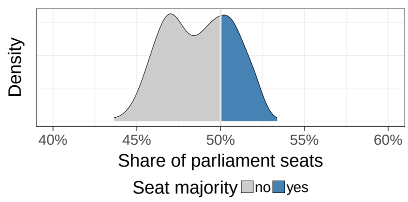

Fig. 3 Density of 10 000 simulated parliament seat shares for the coalition Union-FDP before the German federal election in September 2013 based on the Forsa opinion poll in Table 1. The area under the density colored blue indicates simulations with a Union-FDP majority, resulting in a POE of about 26%.

Such density plots depict both the probability and the underlying uncertainty for specific events. Therefore they are well suited to communicate probability estimates as well as the uncertainty underlying opinion polls. To visualize the *development* of such probabilities for a specific event, e.g., a coalition majority, we recommend extending the visualization in Figure 3 by using so-called *ridgeline plots* (Wilke, 2017) that depict the estimated densities. In Figure 4 this plot type and the development of majority probabilities is compared to the joint, redistributed shares of Union-FDP, which are usually reported in media.

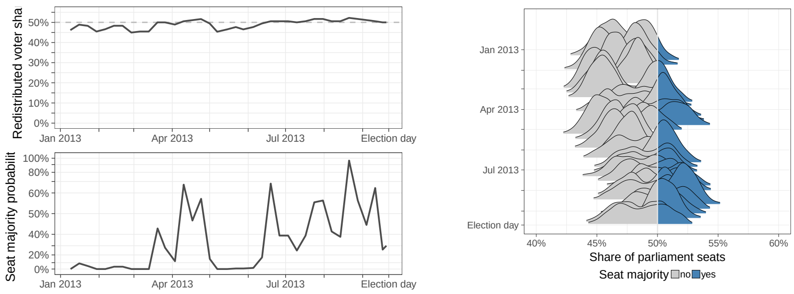

Fig. 4 Development of the POE that the coalition Union-FDP has a government majority before the German federal election in September 2013 based on Forsa opinion polls. Top left: Reported joint voter shares for Union-FDP after redistribution. Bottom left: Probabilities to reach a majority of seats in parliament, based on 10 000 simulations each from the posterior. Right: Densities of simulated parliament seat shares based on 10 000 simulations each. The area under the density colored blue indicates simulations with a Union-FDP majority.

Comparing the redistributed voter shares and the seat majority probabilities in Figure 4 it is clear that the probabilities contain a lot more information than the voter shares. Especially, even small changes in the redistributed voter share can make an immense difference regarding the probability of the coalition to form a government.

To focus on the most relevant changes in the majority probabilities, we propose the use of a skewed axis as shown in Figure 4. In this axis the range of values around 50% is stretched and the range of values near 0% and 100% is compressed. In this way, we put less weight on changes where an event is *still highly (im)probable* and emphasize more relevant changes after which an event gets more or less probable than 50%. Also, consistently using another axis for the estimated probabilities prevents confusion of probabilities and voter shares.

Finally, Figure 5 visualizes the results for the potential coalition Union-FDP based on *pooled* opinion polls (cf. Section 2.2). The redistributed, joint voter share was around 43% in October 2012, and rose steadily over time, reaching its maximum of ca. 51% about one month before election day. Only taking this development of the redistributed voter shares into consideration, one would conclude that – apart from a short time window in August/September of 2013 – a majority of the Union-FDP coalition would be slightly missed. In the best case, sample uncertainty would be reported, making a majority for the coalition *(highly) improbable*. A more precise and adequate quantification of the uncertainty however is usually not given.

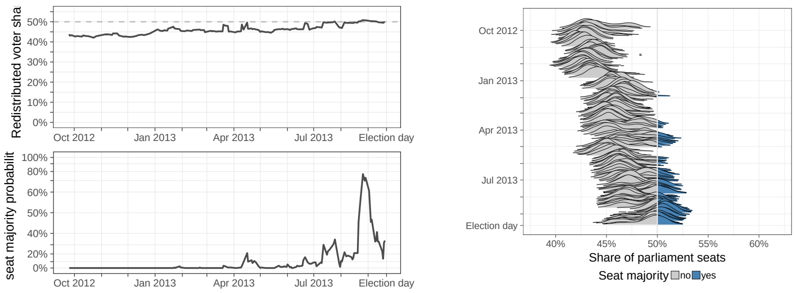

Fig. 5 Development of the prospect that the coalition Union-FDP would obtain the majority of parliament seats before the German federal election in September 2013 based on *pooled* opinion polls. Top: Observed joint reported voter shares after redistribution. Bottom: Probabilities to obtain the majority of parliament seats, based on 10 000 simulations each. Right: Densities of simulated parliament seat shares based on 10 000 simulations each. Areas under the density colored blue indicate the percentage of simulations with a seat majority for Union-FDP.

Considering the estimated seat majority probabilities together with the simulated seat share densities instead draws a more comprehensive picture of the situation. While the overall development of probabilities has the same structure as the redistributed voter shares, i.e., there is an increase over time, there are two points that clearly get more weight when shifting the focus in reporting towards discussing *how probable* events are: First of all, the impact of small changes in voter shares is more pronounced in the probability development. As discussed in context of Figure 2, the effect of changes in voter shares on a POE strongly depends on the base level of the voter shares. For example, a rise in voter shares from 45% to 48% in March 2013 only had a very small impact on the POE, as a seat majority was still very improbable. Instead, even very small changes near a voter share of 50% heavily influence the event probabilities. Secondly, probabilities do not only take into account the joint party shares and the sample uncertainty, but also implicitly cover the uncertainty regarding whether FDP passes the 5% threshold or not. Apart from the end of August 2013, the latter event is highly uncertain and thus overall majority probabilities of the coalition are comparatively small, even for pooled voter shares around 50%. The impact of the uncertainty regarding the FDP entering the parliament is directly noticeable in the ridgeline plot (right panel in Fig. 5), as the densities are bimodal or unimodal depending on whether the reported FDP share is close to 5% or not (see Fig. 2), respectively.

3.2 German federal election 2017

After the German federal election in 2013, none of the desired coalitions reached a seat majority and a "grand coalition" between Union and the social democratic SPD formed the government from 2013 to 2017. For the following election on September 24th, 2017, the goal of both Union and SPD was to obtain enough votes to form a governance coalition outside the grand coalition. Therefore, multiple potential coalitions were of interest before the election. In the following paragraphs, we will focus on the most prominently discussed coalitions, i.e., the Union-led coalition Union-FDP, and the SPD-led coalition of SPD, the Left party (Die LINKE) and the Green party, which – based on the joint voter share – was the strongest alternative to a Union-led government and was not clearly denied by the potential member parties until several weeks before election day. Also, after the rise of the right-wing party AfD major interest was in whether this party, which slightly missed the 5% threshold in 2013, would become the third strongest party in parliament after Union and SPD. The pooled party shares before the 2017 election are shown in Figure 6.

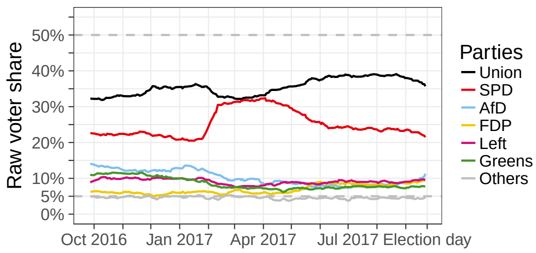

Fig. 6 Development of the pooled raw voter shares from October 2016 until election day on September 24, 2017, based on a pooling time window of 14 days.

POE: Union-FDP coalition majority
Compared to the German federal election in 2013, the situation for a coalition between Union and FDP before the election in 2017 was quite different as FDP voter shares were clearly above the 5% threshold (see Fig. 6) most of the time. However, as the share of Union was lower than in 2013, the joint redistributed voter share was mostly below 50%. As can be seen in Figure 7, the coalition had a joint, redistributed share of about 40% in October 2016 and reached its maximum share of nearly 49.8% about one month before election day.

Again, interpreting only the observed redistributed voter shares is hard for the general public as no easily accessible quantification of uncertainty is given. By comparison, the ridgeline plot in Figure 7 shows that parliament seat shares (or correspondingly voter shares) below 48% correspond to negligibly small success probabilities of $< 1\%$, based on pooled effective sample sizes of around 3000. On the other hand, based on comparable sample sizes, reported shares of 49% and 49.5% corresponded to probabilities of around 14% and 25%, respectively.

Overall, one month before election day the coalition had a good prospect reaching a seat majority based on a redistributed share of 49.8% and a probability of nearly 40%. However, until two days before the election the pooled share and the probability dropped again to 47.4% and 0.4%, respectively, making a success of the two parties highly improbable.

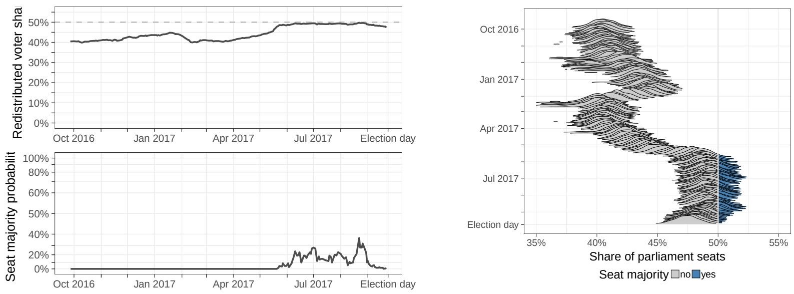

Fig. 7 Development of the prospect to form a government of the coalition Union-FDP before the German federal election in September 2017 based on pooled opinion polls. Top left: Reported voter shares after redistribution. Bottom left: POE to reach a majority of seats in parliament, based on 10 000 simulations each. Right: Densities of simulated parliament seat shares based on 10 000 simulations. The area under the density colored blue indicates simulations with a Union-FDP majority.

POE: SPD-Left-Greens coalition majority

Regarding the party share development of the SPD, the year before the general election in 2017 was shaped by an unusually fast increase, starting at the end of January 2017, when Martin Schulz was elected to be the SPD chancellor candidate and a subsequent, steady decline from April 2017 on (see Fig. 6). Accordingly, the coalition between SPD, the Left and the Greens had their best joint poll results between February and May 2017 as is shown in Figure 8. The maximum share was reached in April with a redistributed voter share of $\sim 50\%$, which corresponded to a probability of obtaining the parliament seat majority of $\sim 48\%$. Starting in April, the probability again dropped to negligibly small values. Shortly before election day, the joint share reached a value of around 41% and event probabilities of practically zero. The ridgeline plot in Figure 8 again nicely visualizes the uncertainty underlying the event of interest. This is not only limited to parties forming the potential coalition, but also includes information about all other causes of uncertainty in the data. For example, in November and December of 2016, the seat share distribution clearly is bimodal as in a relevant share of simulations FDP does not pass the 5% threshold and more votes are redistributed in these cases.

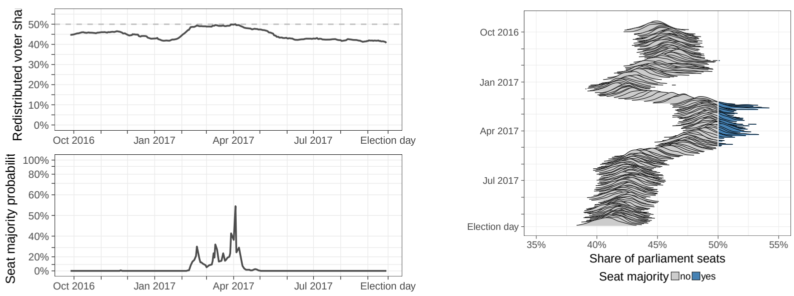

Fig. 8 Development of the prospect that the coalition SPD-Left-Greens will obtain a majority of parliament seats before the German general election in September 2017, based on pooled opinion polls. Top left: Observed reported joint voter shares after redistribution. Bottom left: Probabilities to obtain a seat majority based on 10 000 simulations each. Right: Densities of simulated parliament seat shares based on 10 000 simulations each. The area under the density colored blue indicates simulations with a seat majority.

POE: AfD becoming third strongest party
In the pretext to the 2017 election, special interest was given to the question which party would be the third largest party in parliament. With reported voter shares of over 8%, the right-wing AfD had a very good prospect to become a member of the German parliament for the first time (see Fig. 9) and was polling close to other smaller parties. Using our KOALA approach, estimating the POE that the AfD becomes the third largest party in parliament is straight forward, adequately summarizing this event probability that simultaneously depends on all reported party shares.

In the year before the general election in 2017, reported AFD party shares underwent strong fluctuations. In January 2017 the party had a 3.9% lead over Left and Greens (corresponding to an estimated probability of becoming the third largest party in parliament of 100%). Subsequently, the AfD share dropped 1.9 percentage points behind the Left in June (corresponding to a 1.2% probability) and rose back to a 1.7 percentage point lead (in voter shares) lead over the Left and FDP shortly before election day (corresponding to a 96.8% event probability).

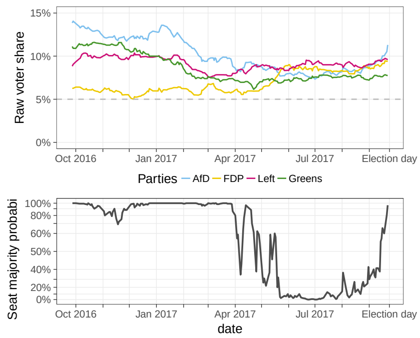

Fig. 9 Development of the prospect that AfD becomes the third largest party in parliament before the German federal election in September 2017 based on pooled opinion polls. Top: Reported voter shares before redistribution. Bottom: Probabilities to become third strongest party, based on 10 000 simulations each.

4 Conclusion

We present the KOALA (Coalition analysis) approach, i.e. a Bayesian, Monte Carlo based method to estimate POEs (probailities of events for specific election results) based on publicly available opinion polls. A pooling approach allows for the inclusion of information from multiple surveys and reduces sample uncertainty. As the examination of indivdiual polls from different pollster institutes showed that polling results in Germany are correlated, an effective sample size for the pooled sample is calculated to adjust for this issue. Rounding of the reported results is accounted for through the introduction of additional uncertainty in the simulation.

The estimated POEs are easy to communicate to the general public and prevent improper poll-based reporting as they include sample uncertainty in a natural way. Moreoever, the focus on the POE allows to easily capture complex situations like multiple parties close to a threshold, as the presented probability includes uncertainty in a natural way. Also, the POE not under focus at the beginning can be easily obtained through the posteriori distribution. Note that we only perform now-casting of the POE analysing the current politic mood and no fore-casting with the target to predict the election results in before.

Not covered by our method so far is structurell misreporting by the opinion polls, i.e. if the shares of certain parties are general under or overreported. While sampling uncertainty and rounding errors are covered in the method, and there is the hope that pooling reduces the effect of a structurell error of one polling agency, a general misreporting by the majority of the polling agencies would also affect our reporting. However, such a general error would also affect the traditional reporting.

A special focus was the visual presentation of the results. Different methods are used to make the results accessible to the general public and also to avoid a misinterpretation because of similiarity to existing plots. We visualize the results on a publicly available website for chosen elections and provide the open-source `R` package `coalitions` that allows for a straightforward application of the method to any multi-party electoral system. In this manner, our long-term goal is to make proper uncertainty assessment in general opinion poll-based reporting the rule, rather than an exception.

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