Online appendix to "A general approach to measuring electoral competitiveness for parties and governments"

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Appendix I: Modelling government formation

Having surveyed much of the literature on government formation, we have identified 32 factors that have been claimed to be important in government formation processes. While we have tried to include as many factors as possible, we have omitted factors that either are irrelevant to the Swedish local context, do not vary between municipalities, or are impossible for us to measure.[18] The 32 factors are all operationalized as a variable x_{jiy} of the potential government coalition j in the government formation opportunity occurring in municipality i following the election in year y. Below, we divide the factors into four different groups. The number of each factor corresponds to that reported in Table 1 in the paper.

[18]Examples include the formally appointed formateur, of which there are none in Swedish municipalities (Bäck 2003), the existence of an investiture vote, for which there is no variation in the sample (Martin and Stevenson 2001), or the circumstances that ended the tenure of the previous cabinet, for which there is little data at the local level (Martin and Stevenson 2010).

The factors in the first and largest group are related to the size and ideological proximity of the parties in the potential government. Among the earliest hypotheses is that potential governments are less likely to form if they control only (1) a *minority* of the seats (see Martin and Stevenson 2010). An early refinement to this hypothesis suggests that those majority cabinets are more likely to form that are (2) *minimal-winning coalitions*, meaning a coalition from which no partner is unnecessary to the majority status of the coalition (Morgenstern and Von Neumann 1953). In such cabinets, the benefits associated with being in power are shared by as few partners as possible. As there are often more than one minimal-winning coalition, several further refinements have been made to this theory. Among them is that minimal-winning coalitions are more likely to form if they are (3) *connected*, in the sense that they contain only ideologically adjacent parties (Axelrod 1970), if they have (4) the *narrowest ideological range* (De Swaan 1973), if they contain (5) the *fewest parties* among available minimal-winning coalitions, or if they are (6) the *minimum-winning coalition* meaning that they control the smallest share of seats among available minimal-winning coalitions (Laver and Schofield 1990).

As regards cabinet size, Glasgow and Golder (2015) include the two variables (7) *cabinet seat share* and (8) *cabinet seat share squared* to capture an idea strongly related to the minimal-winning coalition theory, namely that both small minority cabinets and large surplus majority cabinets are less likely to form than cabinets whose seat share is slightly above 50 percent. As far as (9) *number of parties* are concerned, the standard account suggests that, ceteris paribus, cabinets are more likely to form the fewer parties they include (Glasgow and Golder 2015).

Later policy-centered theories, in the vein of Axelrod and Swaan, have suggested that irrespective of their size, ideologically divided cabinets should be less attractive to potential coalitions partners than more compact ones. Following Martin and Stevenson (2001), we account for this by including a measure of (10) the *ideological range* between the two most distant parties in the potential government along the

left–right continuum.[19] A related theory by Laver and Schofield (1990) holds that potential minority cabinets should be more likely to form the larger the ideological divisions within the majority opposition they would face (Martin and Stevenson 2001). We capture this by including a measure of the (11) *ideological range between the most distant parties in the opposition* and (12) by *interacting* that measure with the minority cabinet variable mentioned above.

A more recent theory about the relevance of the cabinet's ideological composition is provided by Glasgow and Golder (2015). They suggest that as the ideological distance of the partners in a potential coalition to the median left–right position in the parliament increases, the probability that these coalitions will form decreases. Following Glasgow and Golder (2015), we therefore include a measure of (13) the *ideological distance from the median* computed as the weighted mean ideological distance between the partners in the coalition and the median, with the weights for each party based on its seat share.

Several theories suggest that potential governments are more likely to form if they contain particular parties that have a strong bargaining position. Among those most frequently occurring in the literature are (14) the party that controls the *median seat* on the left–right dimension, and (15) the *largest party*. For obvious reasons, the potential government with the strongest bargaining position of them all is one that consists of (16) a *single majority party*. This is not a rare phenomenon in Swedish municipalities; out of the approximately 1,700 coalitions in place between 1998 and 2018, 6 percent were single party majority governments (SKL 2018).

The literature has also considered that certain parties may make potential governments less attractive to join, because doing so will incur high electoral costs to prospective partners. This is particularly the case with parties that promote 'anti-system' political views (Martin and Stevenson 2010). In the context and period studied here, this phenomenon should be properly captured by a variable

[19] This variable scores a 0 for single-party cabinets.

indicating whether or not the potential government includes the radical right party (17) the *Sweden Democrats (SD)*. In a local setting such as ours, it also makes sense to include a variable on whether or not the potential government includes (18) a *local party*, since these are often elected on an anti-establishment agenda.

A second set of factors relate to the incumbent and to its recent electoral performance. First, incumbency theory holds that for a number of reasons a potential government is more likely to form if it is constituted by the same set of parties that formed (19) the *incumbent government* (see Martin and Stevenson 2001). Considering the greater discretion that comes with leading a government, the same logic would suggest that a potential government is more likely to form if it includes (20) the *party of the chief executive* (Martin and Stevenson 2010); in our case, the Mayor. In a recent contribution to the incumbency theory, Glasgow and Golder (2015) distinguishes between the incumbent coalition and the incumbent parties. Their analysis specifically links the incumbency advantage to the coalition; in case it does not re-form as a whole, other potential coalitions that include (21) *one or more but not all incumbent parties* are less likely to form.

Martin and Stevenson (2010) have also hypothesized that the recent electoral performance of the incumbent affects its prospects of returning into office because parties should be more willing to join or re-form a coalition that has performed well, even after considering the ways that the election may have changed the seat distribution. As a measure of (22) *electoral performance*, we calculate the average seat change experienced by each potential government between the most recent election and the election prior to that. Because this effect is expected to matter particularly for the incumbent government, we include (23) an *interaction* between the electoral performance measure and the incumbent government indicator.

A third set of factors have to do with parties' pre-electoral relationships. Martin and Stevenson (2010) have shown that parties who have governed together in the past are more likely to do so again, presumably because cooperation promotes

mutual trust and understanding. Accordingly, we construct a measure of the (24) *familiarity* of the partners in each potential coalition, following the approach developed by Martin and Stevenson (2010) in which past governing partnership is discounted relative to more current partnership. A related but distinct factor is discussed by Bäck and Lindvall (2015), who create a measure of a coalition's (25) *commitment potential*, based on the historical patterns of cooperation among the involved parties. In short, coalitions that include parties who have recently been in government with a different set of coalition partners or who have recently governed alone are conceived as having lower commitment potential. Whereas Bäck and Lindvall (2015) do not use their measure to study government formation, we include it here because we might expect that potential coalitions with a low commitment potential are associated with higher costs and are less likely to form.

Martin and Stevenson (2010) furthermore hypothesize that if parties make pre-electoral commitments to form certain coalitions, these coalitions are more likely to form. Lacking data on actual statements on the local level, we resort to including dummy variables for the two long-standing political blocs within Swedish politics, namely (26) the *right-wing bloc* consisting of the Center Party, the Christian Democrats, the Conservative Party, and the Liberal Party, and (29) the *left-wing bloc* consisting of the Social Democrats and the Left Party.[20] Inspired by Skjæveland et al. (2007), we also include two additional variants of each of these bloc dummies. The (27, 30) *bloc-plus* variables score 1 if the coalition contains all parties from the bloc, including cases where it contains all parties from the bloc and one or more other parties. The (28, 31) *bloc-minus* variables score 1 if the coalition contains some but not all parties from the bloc, as well as one or more other party. The expectation is that breaking a pre-electoral coalition is a less appealing option in a government formation process than extending a pre-electoral

[20]In recent years, the Green Party has moved closer to the left-wing bloc, especially so at the national level. However, at the municipality level the Green Party is best perceived as bloc independent (Folke 2014).

Table A1: A reduced government formation model

	(1)	
1. Minority cabinet	-0.645^{***}	(0.165)
2. Minimal-winning coalition	1.039^{***}	(0.100)
3. Seatshare	0.473^{***}	(0.044)
4. Seatshare squared (/100)	-0.414^{***}	(0.040)
5. Number of parties	-0.424^{***}	(0.048)
6. Ideological range	-0.555^{***}	(0.019)
7. Opposition ideological range	-0.303^{***}	(0.020)
8. Median party	0.460^{***}	(0.080)
9. Incumbent government	2.223^{***}	(0.096)
10. Right-wing bloc	2.373^{***}	(0.115)
Observations	409,113	
Government formation opportunities	1,719	
Pseudo R^2	0.489	

Standard errors in parentheses (clustered by government formation opportunity). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

bloc with a party from the outside. In addition, we include a variable indicating a (32) *bloc-transcending coalition* that includes parties from both blocs.

A reduced model of government formation

Reported in Table 1 in the paper, a conditional logit model that includes these 32 factors conducted on data from the 1,719 government formation opportunities in our dataset provides a reasonably good fit to the data, as indicated by the Pseudo R^2 parameter of 0.58. However, many of these variables are computationally demanding and require data that might be difficult for researchers to get a hold of. Therefore, as a robustness check reported in Table A1, we run a reduced version of our model that includes no more than 10 key variables that should be comparably easy to compile. A comparison shows that the predictive power of the model decreases, as the Pseudo R^2 drops from 0.58 to 0.49. Further analyses reported in Appendix III demonstrate that our approach performs better the more data is used in this step, but that also the reduced model represents a significant improvement over previous measures in terms of predicting re-election.

Appendix II: Electoral competitiveness measures

This appendix gives an overview of the 18 measures of electoral competitiveness to which our measure is compared in Section 4 of the paper. For exact definitions and scales, we refer the reader to the respective refered study.

To begin, we include four measures of electoral competition that are derived from the vote share (or the seat share) of the partisan majority, the incumbent, the ruling coalition, and the largest party, respectively, developed by Clingermayer and Wood (1995), Canes-Wrone and Park (2012), Boyne (1998) and Vanhanen (2000).

In addition, we include three measures that capture the closeness between the two major parties in the parliament: The *two-party margin*, the *two-party ratio*, and the *raw vote margin* (in percentage points) separating the two major parties. These measures are described in detail by Fauvelle-Aymar and François (2006). A related measure by Aidt et al. (2011) of the win-margin of the *mayor's party* over the largest opposition party, is also included. Applicable specifically to the Swedish case, Högström (2017) proposes a measure of electoral closeness defined as the difference between the two major *blocs* in Swedish politics (see Footnote 20). Here, we include both versions of Högström's closeness measure, one based on *ex-ante* vote shares and one based on (the more problematic) *ex-post* vote shares.

Next, we include three more advanced indexes based on vote shares, designed more specifically for multi-party systems: Kirchgässner and co-authors' (1992) *entropy index*, which is a measure of the instability in the election; Endersby and co-authors' (2002) *competition index*, and Capron and Kruseman's (1988, p. 33) *fractionalization index*, which "measures the probability that any two voters randomly chosen from the electorate have voted for different parties". For definitions, see Fauvelle-Aymar and François (2006).

We also include a *volatility* measure proposed by Boyne (1998), applied, in our case, on the changes in vote shares of the Mayor's party over three most recent

elections. In a similar vein, following Hübscher and Sattler (2017), we also include a logarithmized measure of the *replacement risk* of the largest incumbent party, which is a function of its closeness to the second party in the parliament as well as changes in vote shares among all parties over the five past elections. In addition, we include a measure of the plurality party's likelihood of losing plurality status, created following the approach outlined by Kayser and Lindstädt (2015).

Finally, we include two measures of *electoral pressure* and *political protection*, developed by Immergut and Abou-Chadi (2014). The two measures are derived from a factor analysis performed on six variables related to electoral competition: voter volatility, the disproportionality of the electoral system (LSQ index), the effective number of parties, the fraction of electoral winners in government, the size of government majority, and the size of government majority relative to the number of governing parties.[21]

In Figure 4 in the paper, the 18 measures described above are compared to the measures constructed using our approach, with regards to their capability to predict re-election of the incumbent. As an alternative way to explore this issue, we follow Kayser and Lindstädt (2015, appendix) by considering visually how the distributions of the tested measures vary between two sub-samples of the data, one with municipality-elections after which re-election took place and one with municipality-elections after which it did not. If a measure is to have predictive capability, we should expect its scores to be unevenly distributed across the two sub-samples. Our main outcome indicator – the weighted re-election of the incumbent – is not dichotomous, thus we resort here to the indicator on re-election (or ejection) of the largest incumbent party.

The box plots reported in Figure A1 show how the scores of the 22 compared

[21] Immergut and Abou-Chadi (2014) first apply a varimax rotation to the results of the factor analysis, and then create their two variables. We skip rotation, because the factors generated on our sample appeared unsuitable for rotation and because the unrotated versions perform better in the comparisons.

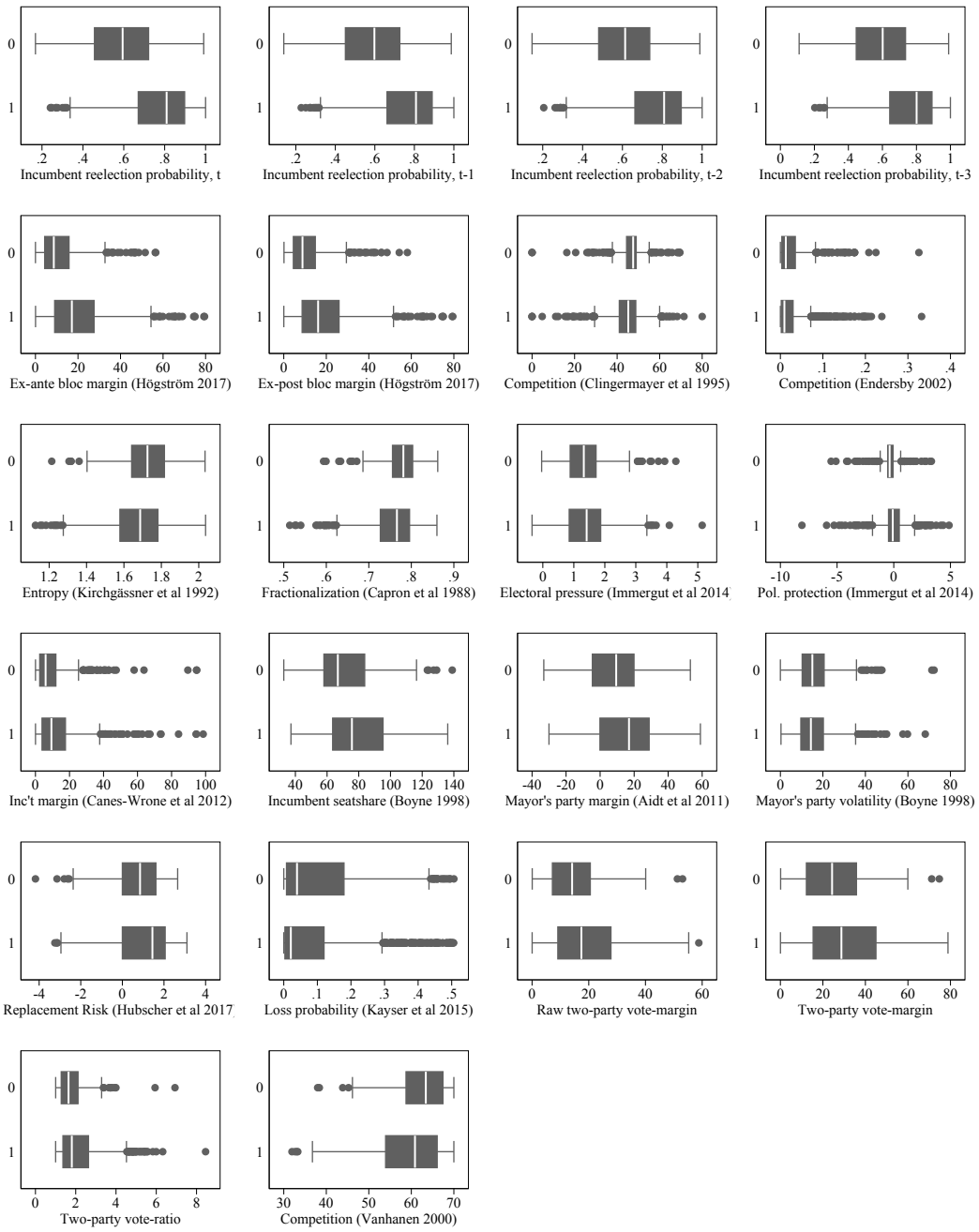

Figure A1: Boxplots for re-election of the largest incumbent party

measures are distributed across the two sub-samples. Plotted in the top row, the four versions of our re-election probability turn out to be the ones for which the distribution of the predictor varies most clearly across the two realized outcomes. Consider, for instance, that for elections after which the largest incumbent party remained in office, the re-election probability as measured in May of the year of the election was around or above 66 percent in 75 percent of the cases, whereas little more than 25 percent of the probabilities were that high for elections after which the largest incumbent party was ousted. Also, consider that the difference in the median predicted probability across the two outcome is more than 20 percent of the full range of values. An inspection of the plots for the 18 existing measures reveals that none of them comes close to being that much differently distributed across the two outcomes. Indeed, for several measures the two distributions are largely indistinguishable.

Appendix III: Simplified measures

Admittedly, to code each and every step of the approach presented in this paper is a time-consuming task. To make our approach more appealing to researchers whose main interest is not in the estimation of reelection prospects, we will now present and evaluate a number of possible simplifications to our approach.

We have investigated three different simplifications of how we generate the simulated election outcomes in Step I. First, we have used a reduced model for the election forecast, with previous election results being the only predictor. Compared to the large set of variables in Equation 2, this is a huge simplification. Second, we have simplified the simulation procedure, by simply drawing party-specific residuals without the blocs and clusters described in Section 3.2.2. This simplification means that we do not model the inter-party correlation or the relation between party size and residual variance in our re-sampling. Third, we have skipped the re-sampling altogether, effectively assuming that the election forecast will be realized, which leads us to underestimate the pre-electoral uncertainty.

As was mentioned in Appendix I, we have tried two different sets of explanatory variables in the coalition formation model used in Step II. Our main model includes 32 independent variables, of which some are computationally demanding or require data that may be difficult to get hold of. We have therefore ran a coalition formation model that only includes ten variables, chosen because they are central in the literature, have high explanatory power, and are easy to calculate.

By combining the four varieties of Step I with the two varieties of Step II, we end up with eight versions of our measure, seven of which are simplifications. The rest of this appendix evaluates these simplifications. As in the paper, we will begin by assessing the accuracy of the uncertainty estimations, and then evaluate the predictive capability. In addition, because all our measures are estimated probabilities, we are also able to evaluate the simplifications using Brier scores.

Accuracy of uncertainty estimation

Throughout the paper, we argue that it is important to model the electoral uncertainty, or else the probability estimates will be biased away from full uncertainty ($p = 0.5$). In Figure A2 we test this claim by showing binned scatter plots, with the share of elected observations on the y-axis and the estimated office probability on the x-axis, for the eight different versions of our measure described above. For the probabilities to be correctly estimated, they should line up along the 45° line, where the share of elected observations equal the estimated election probability.

The left-hand and right-hand columns contain the four versions that include the full and the reduced government formation model, respectively. The measures in the top row apply our preferred full election model. As illustrated by the close resemblance between the left-hand and right-hand plot, the estimated probabilities are well calibrated also when using the reduced government formation model.[22]

The measures in the second row use the reduced election model that relies only on previous election results. This reduces the accuracy of our uncertainty estimations, as evidenced by the larger spread of the bins away from the 45° line in both plots. Moving on to the third row, we find that the simplification of the procedure for re-sampling the residuals results in a minor deterioration of accuracy, which is most visible when combined with the full government formation model.

In the bottom row, we report the measures for which there is no re-sampling. Here, particularly the left plot reveals a clear pattern of underestimated uncertainty, as the share of elected observations is much higher than estimated for low probabilities, and vice versa for high probabilities. This result confirms that the simulation is necessary in order to produce correctly calibrated probability estimates.[23]

[22] This should not come as a surprise. While the probabilities in the left-hand plot will be estimated with greater precision, thanks to a larger number of relevant variables in the coalition formation model, there is no reason for why fewer variables should provide more biased estimates.

[23] This finding is intuitive: When we use the predicted election outcomes as if forecasts were perfect, we fail to model one of two sources of uncertainty: pre-electoral uncertainty. Thus, predicted election losses (or wins) will be taken for granted, when in fact they should not.

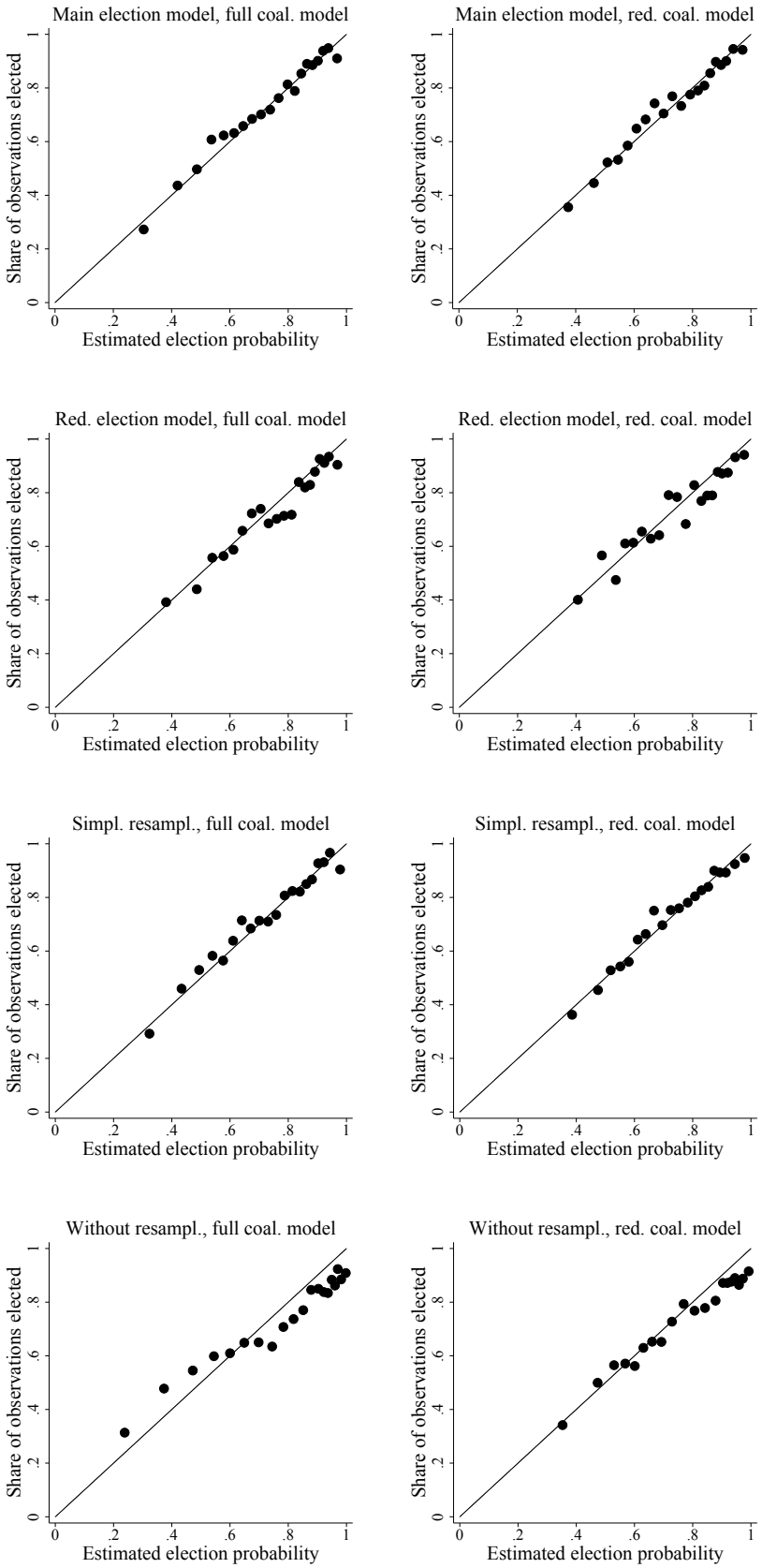

Figure A2: Comparison between predicted probabilities and average outcomes

Capability to predict re-election into office

The second part of the evaluation investigates how the various simplifications of our measure affect its capability to predict re-election. Here we follow the approach used in Section 4.2 in the paper by running, for each of the eight measures, an OLS regression of the seat share weighted re-election of the incumbent parties (see Footnote 16 in the paper) with that measure as the single predictor. To conserve space, we only construct our measure for one point in time, namely the month of May of the election year.

Figure A3 reports the results. For each of the four variants of Step I, two bars with Adjusted R^2 scores are presented, one that applies the full coalition formation model in Step II, and one that applies the reduced variant. As also reported in Figure 4 in the paper, the measure produced using our preferred election model and the full coalition formation model account for 23.5 percent of the variation in re-election of the incumbent. As expected, when applying the reduced coalition formation model the Adjusted R^2 score of the measure drops considerably; by 4.0 percentage points or 17 percent in the case at hand. The deterioration that comes with using the reduced model in Step II is smaller for the three simplified variations of Step I – ranging from 7 to 14 percent – but is still considerable in each case. Yet, this loss in predictive power is far from dramatic, and in some applications it may be a price worth paying.

The figure furthermore shows the added value of carefully modelling the pre-electoral uncertainty – for each of the simplified variations of Step I, we notice a considerable reduction in predictive capacity. For the worst-performing variation, where the election model is based solely on previous election results, around one third of the predictive capacity is lost. Combining that variation of Step I with the reduced government formation model in Step II yields the lowest Adjusted R^2 score among the eight models, at 0.134.

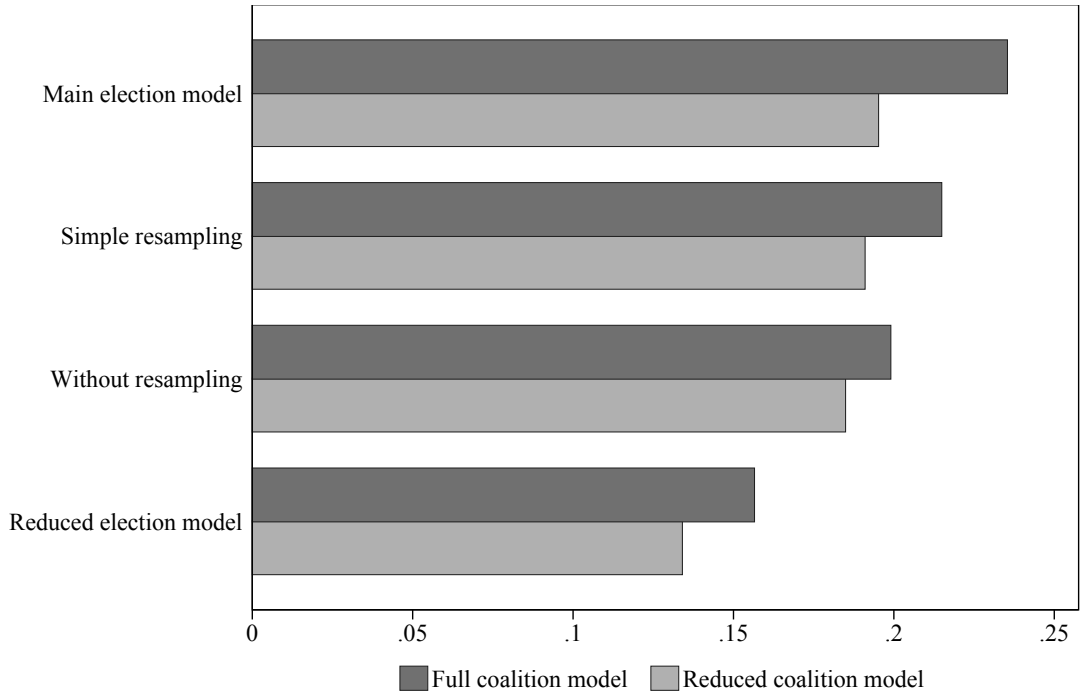

Figure A3: Capacity to predict re-election of incumbent government (Adjusted R^2)

In sum, the implication of the results reported in Figure A2 and Figure A3 is two-fold. On the one hand, it demonstrates that efforts to improve the quality of the models – in both steps of our approach – are likely to pay off in terms of the accuracy of the uncertainty estimations and/or predictive capability of the produced measures. On the other hand, it shows that even a simple election forecasting model in Step I, based solely on the previous election results, combined with a fairly limited government formation model in Step II, produces a measure of the re-election probability of the incumbent that substantially outperforms all previous measures of electoral competitiveness in terms of its capacity to predict re-election; our worst model's Adjusted R^2 score of 0.134 is still 80 percent higher than that of the best-performing previous measure reported in Figure 4 in the paper, while also conforming to Kayser and Lindstädt's 2015 six criteria for a useful measure of electoral competitiveness. This, in our view, demonstrates the added value of considering both pre-electoral and post-electoral uncertainty when devising measures of electoral competitiveness for parties and governments.

Brier scores and their decomposition

It is difficult to evaluate the accuracy of probability forecasts, because the true probability of a positive outcome can never be observed. Instead, forecasters or forecasting models are typically evaluated using a 'scoring rule', where repeated probability measures are compared with the observed outcomes. The most frequently used scoring rule is the Brier score (Brier 1950), which measures the average squared distance between the estimated probability of a positive outcome (in our application the office probability $p(O)_i$) and the actual outcome (a binary indicator measured as 0 or 1):

$$BS = \frac{1}{N} \sum_{i=1}^{N} (p(O)_i - O_i)^2 \tag{6}$$

The Brier score takes on a value between 0 (all negative outcomes are assigned a probability of 0 and all positive outcomes a probability of 1) and 1 (all positive outcomes are assigned a probability of 0 and all negative outcomes a probability of 1). The lower the Brier score is, the better the predictions are considered to be.

A useful feature of Brier scores is that they can be decomposed into three additive terms (Murphy 1973), which captures different attributes of the prediction: reliability (REL), resolution (RES) and uncertainty (UNC). These terms relate to the Brier score as follows, which means that to get a low Brier score, forecasts should have low scores on reliability and uncertainty, but high scores on resolution:

$$BS = REL - RES + UNC \tag{7}$$

Reliability, commonly also referred to as 'calibration', concerns whether the estimated probabilities are actual probabilities, such that for any set of predictions, the average probability estimate equals the expected share of positive outcomes. In other words, reliability is the same thing as we evaluate in Section 4.1 in the paper

and the previous section of this appendix. To compute the reliability component used in the decomposition above, one first sorts the predictions into K number of groups, based on the estimated probability, and then calculates the average squared deviation between the share of positive outcomes and the estimated probability in each group:

$$REL = \sum_{k=1}^{K} \frac{n_k}{N}(p(O)_k - \bar{O}_k)^2 \tag{8}$$

The resolution component measures how much variation there is in the estimated probabilities. In other words, this measure is similar to the regression sum of squares used when calculating the R^2 for a regression model. The resolution is calculated as the average difference between the conditional event frequencies, given the groupings, and the global share of outcomes:

$$RES = \sum_{k=1}^{K} \frac{n_k}{N}(\bar{O}_k - \bar{O})^2 \tag{9}$$

Lastly, the uncertainty component measures the global uncertainty of the outcome. It equals zero if an outcome always or never occurs, and can reach a maximum of 0.25 for outcomes that occur half the time.

$$UNC = \bar{O}(1 - \bar{O}) \tag{10}$$

We have calculated Brier scores for our preferred approach as described in the paper, but also for the four other variants where we i) use a reduced set of variables in the coalition formation model, ii) use a reduced set of variables in the election prediction model, iii) skip the blocs and clusters in the re-sampling procedure, and iv) skip the simulation step altogether. The scores have been calculated for two actors where the outcomes are binary: election of any specific party and the re-election of the largest party in the incumbent coalition.

Table A2: Brier scores

	BS	REL	RES	UNC
All parties				
Main model	0.144	0.000	0.085	0.229
Reduced coalition model	0.156	0.001	0.074	0.229
Reduced election model	0.149	0.001	0.080	0.229
Simple resampling	0.146	0.001	0.084	0.229
Without resampling	0.156	0.005	0.077	0.229
Largest incumbent party				
Main model	0.157	0.003	0.037	0.192
Reduced coalition model	0.162	0.003	0.032	0.192
Reduced election model	0.167	0.007	0.031	0.192
Simple resampling	0.159	0.003	0.035	0.192
Without resampling	0.170	0.010	0.032	0.192

The columns represent Brier scores (BS), reliability (REL), resolution (RES) and uncertainty (UNC). Lower scores on BS and REL, and higher scores on RES, indicate a better forecasting model. UNC is unaffected by the predictions.

The results are presented in Table A2. As indicated by the lower Brier score, our main approach performs better than the four alternatives. The worst performer is the variant without re-sampling, which receives the largest Brier score for both outcomes. Skipping the simulation step leads to a worse reliability (higher REL score), in line with expectations and the visual evidence in Figure A2. However, doing so also turns out to reduce the resolution of the prediction model. A much better result is achieved if the re-sampling procedure is instead replaced with the simplified version without blocks and clusters. In fact, this variant performs almost as good as our main model. However, it should be kept in mind that the two re-sampling methods yielded larger differences when the outcome was the weighted share of re-elected government parties (Figure A3).

The two variants with fewer variables in the regression models manages better than the variant without re-sampling, but not as good as the other two. When we analyze all parties, it is primarily the reduction in the coalition formation

model which affects the Brier score, while the reduced election model actually performs pretty well. On the other hand, the tables are turned when we restrict the sample to the largest incumbent party. This difference implies that the pre-election uncertainty is relatively more important for large incumbent parties, while it becomes more important to accurately model the coalition prospects when we are interested in smaller parties who to a larger extent are dependent on ruling with others.

Simply comparing the two alternative outcomes, we see large differences with regards to uncertainty and resolution, that jointly result in a much smaller difference in the Brier score. The difference in uncertainty reflects the fact that by guessing the most common outcome, we would be right in 75 percent of the cases with respect to the largest incumbent party (they are elected after 75 percent of the elections), but in only 64 percent of the cases with respect to all parties (they have a baseline office probability of 36 percent). However, because our prediction model does a very good job of resolving the differences between large incumbent parties and other parties, the predictions for the latter group end up slightly more accurate.

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