

APPENDIX

Tracking the Impact of Media on Voter Choice in Real Time: A Bayesian Dynamic Joint Model

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A

A.1 Results for Demographics and Social Issues

Parameter estimates for the impact of demographics and socio-political issues on voting intentions are presented next. It is clear from Table 1 that while social class and gender do not impact voting intentions, we find that age ($\gamma_{3,2}$ and $\gamma_{3,4}$) has a negative and significant impact on voting intentions for Labour and the Liberal Democrat party. The parameter estimates show that an increase in age decreases the odds of selecting one of three parties over ‘None’, suggesting that older swing voters had relatively lower intentions to turn out on election day and vote. Similarly, the coefficients for marital status ($\gamma_{4,3}$ and $\gamma_{4,4}$) suggest that marriage does not impact voting intentions for the Labour party. The variable ‘Kids’ takes two values with higher value implying no children. Therefore, $\gamma_{5,4}$ being negative and significant implies that people with children have a higher intention of voting for the Liberal Democrat party. The significant coefficients of “employment category”, i.e. a negative estimate for $\gamma_{6,3}$ and a positive one for $\gamma_{6,4}$, reflect that while non-earning swing voters

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Table 1: Demographics Parameter Estimation (Intention to Vote Model)

Description		Parameter	mean	2.50%	97.50%
Social Category	Labor	$\gamma_{1,2}$	0.156	-1.060	1.275
	Conservative	$\gamma_{1,3}$	1.450	0.296	2.573
	Liberal Democrat	$\gamma_{1,4}$	1.203	0.043	2.344
Gender	Labor	$\gamma_{2,2}$	0.266	-0.847	1.383
	Conservative	$\gamma_{2,3}$	0.967	-0.173	2.130
	Liberal Democrat	$\gamma_{2,4}$	0.912	-0.252	2.011
Age	Labor	$\gamma_{3,2}$	-0.213	-0.607	0.255
	Conservative	$\gamma_{3,3}$	0.017	-0.359	0.454
	Liberal Democrat	$\gamma_{3,4}$	0.101	-0.278	0.535
Marital Status	Labor	$\gamma_{4,2}$	0.427	-0.633	1.568
	Conservative	$\gamma_{4,3}$	-0.728	-1.904	0.369
	Liberal Democrat	$\gamma_{4,4}$	-0.556	-1.674	0.606
No of Kids	Labor	$\gamma_{5,2}$	0.553	-0.844	1.957
	Conservative	$\gamma_{5,3}$	0.009	-1.350	1.324
	Liberal Democrat	$\gamma_{5,4}$	-0.120	-1.407	1.247
Employment Category	Labor	$\gamma_{6,2}$	0.365	-0.779	1.529
	Conservative	$\gamma_{6,3}$	0.636	-0.503	1.754
	Liberal Democrat	$\gamma_{6,4}$	0.184	-0.943	1.307
Education Category	Labor	$\gamma_{7,2}$	0.462	0.055	0.877
	Conservative	$\gamma_{7,3}$	0.448	0.059	0.838
	Liberal Democrat	$\gamma_{7,4}$	0.371	0.039	0.768
Home Ownership	Labor	$\gamma_{8,2}$	-0.011	-0.039	0.018
	Conservative	$\gamma_{8,3}$	-0.012	-0.043	0.020
	Liberal Democrat	$\gamma_{8,4}$	-0.008	-0.034	0.022

would prefer to abstain rather than vote for the Conservatives, they intend to turn out and vote for the Liberal Democrats. However, the positive and significant coefficient for Education ($\gamma_{7,4}$) suggests that more educated swing voters tend to be more supportive of the Liberal Democrats.

Table 2: Parameter Estimates of Election Issues (Intention to Vote Model)

Description		Parameter	mean	2.50%	97.50%
The economy	Labor	$\eta_{1,2}$	0.024	-0.449	0.501
	Conservative	$\eta_{1,3}$	-0.087	-0.565	0.345
	Liberal Democrat	$\eta_{1,4}$	0.096	-0.343	0.516
Education	Labor	$\eta_{2,2}$	-0.851	-1.481	-0.275
	Conservative	$\eta_{2,3}$	-0.581	-1.203	0.015
	Liberal Democrat	$\eta_{2,4}$	-0.886	-1.463	-0.199
Tax & spend	Labor	$\eta_{3,2}$	0.698	0.191	1.180
	Conservative	$\eta_{3,3}$	0.270	-0.184	0.757
	Liberal Democrat	$\eta_{3,4}$	0.434	0.017	0.911
Family life and childcare	Labor	$\eta_{4,2}$	0.120	-0.422	0.727
	Conservative	$\eta_{4,3}$	0.052	-0.433	0.599
	Liberal Democrat	$\eta_{4,4}$	0.064	-0.434	0.601
Climate change	Labor	$\eta_{5,2}$	-0.257	-0.760	0.335
	Conservative	$\eta_{5,3}$	0.115	-0.367	0.686
	Liberal Democrat	$\eta_{5,4}$	-0.210	-0.750	0.404
International terrorism	Labor	$\eta_{6,2}$	-0.267	-0.822	0.187
	Conservative	$\eta_{6,3}$	-0.466	-0.983	-0.045
	Liberal Democrat	$\eta_{6,4}$	-0.097	-0.658	0.395
Housing	Labor	$\eta_{7,2}$	0.532	0.218	0.890
	Conservative	$\eta_{7,3}$	0.412	0.095	0.752
	Liberal Democrat	$\eta_{7,4}$	0.410	0.096	0.719

The results for the impact of social and political issues on voting intentions are presented in Table 2. We find that voters who think that “Economy” is a very important issue were more likely to vote for the Liberal Democrats. A quick look at the party manifesto reveals that the Liberal Democrats had a less stringent approach towards tackling economic problems, such as setting a

£400 pay rise cap (Page 16, Liberal Democrat Manifesto) in contrast to a one year public sector pay freeze proposed by the Conservatives (Page 8, Conservative Manifesto). In addition, education ($\eta_{2,2}$ and $\eta_{2,3}$) has a positive and significant effect for both Labour and the Conservative Party. This may reflect the fact that both these parties planned to give parents more power in selecting the school management (Page 0:5, Labour Manifesto) and freedom to parents to set up and run their own schools (Page 50, Conservative Manifesto). Interestingly, it appears that even after the controversial “Climategate” issue in Nov 2009, “climate change” remained an important issue for swing voters. The coefficients for climate change ($\eta_{5,2}$, $\eta_{5,3}$, $\eta_{5,4}$) all came out to be negative and significant implying that voters who considered “climate change” to be a very important issue were not likely to vote for any party. This “Climategate” issue, where it was alleged that scientists deliberately suppressed evidence against global warming, created shockwaves throughout the UK and might have created a significant level of distrust among the voters (?).

Finally, we consider the impact of demographics and voter attitudes regarding social issues on the final vote (Tables 3-4). The impact of gender is positive and significant for the Conservative and Liberal Democrat party, implying that females were more likely to vote for these parties. It is interesting to note that although more educated people had relatively higher voting intentions for the Liberal Democrats, all three parties were able to garner support from highly educated people when it came to the final vote, suggesting that the media communications strategy employed by the Conservative and Labour parties was successful in getting voters to show up at the polling booths on election day and vote for them. This may also relate to the Liberal Democrats progressively losing their early lead in exposure valence, and as we have seen, due to decay effects as well as increased voter attention, later exposures are particularly critical. With regard to social issues, education and housing policies were the most important predictors of the final vote. It is particularly important to note that although education policies had a positive impact on voting intentions they have a strong negative impact on actual voting behavior across all three parties. This suggests a large gap between the stated positions prior to the elections and the manner in which they were communicated to voters during the campaign; the feasibility of parties’ plans in these areas came under particular attack. Similarly, it appears that climate change has no impact on the final vote, despite having a strong, negative impact on voting intentions. Finally, although housing issues did not predict voting intentions, they had a strong positive impact on actual voting behavior. This ability to discern the differential impact of predictors on intentions versus the actual choice is one of the main advantages of our modeling approach.

Table 3: Demographics Parameter Estimates (Final Vote Model)

Description		Parameter	mean	2.5%	97.5%
Social Caegory	Labor	$\Gamma_{1,2}$	0.156	-1.060	1.275
	Conservative	$\Gamma_{1,3}$	1.450	0.296	2.573
	Liberal Democrat	$\Gamma_{1,4}$	1.203	0.043	2.344
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	Conservative	$\Gamma_{8,3}$	-0.012	-0.043	0.020
	Liberal Democrat	$\Gamma_{8,4}$	-0.008	-0.034	0.022

Table 4: Parameter Estimates of Election Issues (Final Vote Model)

Description		Parameter	mean	2.5%	97.5%
The economy	Labor	$\kappa_{1,2}$	0.024	-0.449	0.501
	Conservative	$\kappa_{1,3}$	-0.087	-0.565	0.345
	Liberal Democrat	$\kappa_{1,4}$	0.096	-0.343	0.516
Education	Labor	$\kappa_{2,2}$	-0.851	-1.481	-0.275
	Conservative	$\kappa_{2,3}$	-0.581	-1.203	0.015
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Tax & spend	Labor	$\kappa_{3,2}$	0.698	0.191	1.180
	Conservative	$\kappa_{3,3}$	0.270	-0.184	0.757
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	Conservative	$\kappa_{6,3}$	-0.466	-0.983	-0.045
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Housing	Labor	$\kappa_{7,2}$	0.532	0.218	0.890
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B

B.1 Simulation Results

We conduct a simulation study to evaluate the performance of our proposed model. The simulation is focused on evaluating the finite sample performance of the proposed Bayesian estimation when the data are generated, mimicking the real data we have. We generated data using the same model as in the paper as described below.

Let i denote individuals, k denote choices and t denotes time. We take; $i = 1, \dots, 100$; $k = 1, 2, 3$ and $t = 1, 2, 3$. Let $Y_{i,t}$ denote the choice of i^{th} individual at time t . He/she chooses one of the three available choices with respective probability $(p_{i,t}^1, p_{i,t}^2, p_{i,t}^3)$.

$$\begin{aligned}
Y_{i,t} &\sim \text{Multinomial}(p_{i,t}^1, p_{i,t}^2, p_{i,t}^3) \\
p_{i,t}^1 &\propto \exp(\gamma_1 \cdot \mathbb{1}_{\{Y_{i,t-1}=1\}}) \\
p_{i,t}^2 &\propto \exp(b_0 + \beta_{1,t} \cdot X_{i,t,2}^1 + \beta_{2,t} \cdot X_{i,t,2}^2 + \beta_{3,t} \cdot F_{i,t,2}^1 + \beta_{4,t} \cdot F_{i,t,2}^2 \\
&\quad + \ell_1(X_{i,t,2}^1 \cdot X_{i,t,2}^2) + \ell_2(F_{i,t,2}^1 \cdot F_{i,t,2}^2) + \gamma_2 \cdot \mathbb{1}_{\{Y_{i,t-1}=2\}} + b_{i,1}) \\
p_{i,t}^3 &\propto \exp(c_0 + \beta_{1,t} \cdot X_{i,t,3}^1 + \beta_{2,t} \cdot X_{i,t,3}^2 + \beta_{3,t} \cdot F_{i,t,3}^1 + \beta_{4,t} \cdot F_{i,t,3}^2 \\
&\quad + \ell_1(X_{i,t,3}^1 \times X_{i,t,3}^2) + \ell_2(F_{i,t,3}^1 \times F_{i,t,3}^2) + \gamma_3 \cdot \mathbb{1}_{\{Y_{i,t-1}=3\}} + b_{i,2})
\end{aligned} \tag{1}$$

Here, we consider two sets of time varying choice dependent covariates $(X_{i,t,k}^1, X_{i,t,k}^2, F_{i,t,k}^1, F_{i,t,k}^2)$, their interactions and random effects $(b_{i,1}, b_{i,2})$ to mimic the setup in the actual model.

We generate the data using the following steps :

1. $F_{i,t,k}^1, F_{i,t,k}^2$ are assumed to be count variables (as total number of encounters via two different media 1,2) and are generated from a Zero Inflated Poisson distribution for 3 time points over two choices. We assume the same arrival rate for both the Zero Inflated Poisson distributions across channels and choices, with encounter probabilities 0.65 and 0.5 for the two media.
2. $X_{i,t,k}^1, X_{i,t,k}^2$ are assumed to be continuous (as average valance) and generated from normal distribution $N(3, 1)$ to mimic the actual data.
3. Random effects $(b_{i,1}, b_{i,2})$ are jointly sampled from $N_2(\mathbf{0}, \mathbf{I})$.
4. We sample $\beta_{k,t} \sim N(\beta_{k,t-1}, 1) \forall k = 1, 2, 3$ and $t > 1$ and fix the initial values (at $t = 1$) as $\beta_{1,1} = 1.2, \beta_{2,1} = 1.6, \beta_{3,1} = 2.5, \beta_{4,1} = 1.2, b_0 = 2.7, c_0 = 1.5, \gamma_1 = 3, \gamma_2 = 2, \gamma_3 = 4$. Finally, we generate Y_i from $\text{Multinomial}(p_{i,t}^1, p_{i,t}^2, p_{i,t}^3)$ using equation 1.

5. We generate one hundred simulated data sets of size 200 each.

The details of simulation results are presented in Appendix B1. Based on the results, we find that the estimates under the proposed model reliably recovered the true estimates with reasonable coverage probability.

B.2 Out of sample prediction

We have now checked holdout performance. We attempted to test the predictive validity of our model by considering out-of- sample predictions. Out of 480 respondents, we used 400 respondents for the training sample and the rest of the 80 respondents were used to check the holdout sample prediction. Results are given below. As shown in the table, we are able to correctly predict the party voted in final vote for 66% of voters. We are able to recognize 71% of the Conservative voters and 77% of the Liberal Democrat voters. However, our model's recognition rate is 50% and 51% for Other parties and Labour party voters.

		Prediction Vote				
		Others	Labour	Cons.	Lib.Dem.	Total
Actual Vote	Others	6	3	2	1	14
	Labour	3	9	3	2	19
	Cons.	2	3	15	1	20
	Lib.Dem.	3	4	0	23	27
Total		15	16	18	31	80

Table 5: Confusion Matrix for Out of Sample Prediction