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Research article

A study of the relation between traffic accidents and election posters

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Abstract: Inattention in traffic is a risk factor for the occurrence of accidents. Elements surrounding traffic could potentially be a safety risk for road users. This study investigates the relation between election posters and traffic accidents using a seasonal autoregressive-moving-average model with exogeneous variables (seasonal ARMAX) correcting for variations in meteorological conditions and general traffic volume indicated through public holidays. Danish traffic accident micro data are used to construct a time series for daily number of accidents in city zones adjusted for probable known accident causes, namely drunk driving, narcotics, drivers deemed unfit to drive, and accidents related to low visibility. Model parameters are determined from Maximum Likelihood estimation on the period from 1 January 1997 to 15 December 2009 with an indicator for general election periods. The presence of general election posters is associated with an increased risk of traffic accidents ($p = 0.003$), when correcting for meteorological variables and public school holidays. While a causal relation between traffic accidents and the presence of election posters cannot be concluded from the analysis, we find distraction from election posters to be the most likely explanation for the associated increase in traffic accidents. On average, the model indicates that 1.18 additional daily accidents occur for general elections in Denmark. In total, that amounts to 127 additional accidents for the investigated period of time. This study shows that such sudden changes in traffic surroundings are significantly related to increased safety risks which could lead to a better discussion of relevant traffic legislation.

Keywords: ARMAX, election posters, risk assessment, time series analysis, traffic accidents

1 Statement of contribution

This research project was undertaken because we sought to investigate if a sudden and brief change of traffic settings leads to more traffic accidents. During election periods in Denmark, election posters transform the surroundings of traffic drastically with more distractions for drivers potentially decreasing traffic safety. This study is the first of its kind to document a statistically significant relation between traffic accidents and election periods, made possible by using advanced analytical methods. The study has the potential of impacting regulatory work on traffic safety with respect to election posters but also regulations on similar kinds of distractions such as campaigns or commercials. The public and relevant traffic safety authorities would be interested in these results both within and outside Denmark because a quantification of the effects of distractions of traffic could lead to a better discussion of which are reasonable, and which

are not.

2 Introduction

Inattention is a well-known risk factor for traffic accidents (Wang et al., 1996; Treat, 1980; Bucsuházy et al., 2020). Causes of traffic accidents are listed in registers, making cause-effect analysis possible. However, registers of causes of traffic accidents usually only concern the immediate action that led to the accident (Bucsuházy et al., 2020); one established cause of inattention is the use of mobile phones (Violanti, 1997; Nasar & Troyer, 2013; Lipovac et al., 2017). However, in many cases, the cause of the inattention remains unknown. While the problem of inattention has been dealt with in terms of legislation, intervention campaigns and indeed inattention monitoring systems for intelligent vehicles (Dong et al., 2010), it remains imperative to establish causes of inattention to direct such initiatives. The current paper investigates the presence of election posters as a potential source of inattention leading to traffic accidents. Election posters are an essential element of undertaking an election in Denmark where it is one of the primary channels for political parties and candidates to communicate policy and individual candidacies. In the weeks preceding an election, cities throughout the country change appearance as posters are hung up on street light poles, trees, bridges, etc.

The use of election posters in Denmark in the considered period is regulated by law (Retsinformation, 1989; DRD, 2021), in terms of when and where they are allowed. Election posters are allowed within a period of approximately three weeks preceding the election. Election posters are not allowed close to traffic signals, below a certain height, nor next to highways (Figure 1).

The use of election posters is common in many democratic societies (Holtz-Bacha & Johansson, 2017), and thus potential inattention due to these may apply in other settings than the Danish one. However, election posters as a risk factor in traffic is largely unexplored in the scientific literature. Wedel (2016) sought to investigate the effect of election posters on traffic accidents in Denmark but failed to find significant relations. However, this could be due to coarse comparisons, that the study did not consider autocorrelation, and only to a limited extent involved exogeneous information.

Figure 1 Election posters near the roads in Køge, Denmark, 2019 (photo: News Øresund, Johan Wessman)

The inclusion of exogeneous information in an analysis of election posters as risk factors in traffic accidents is central, to allow for the potential of causal conclusions. There are many published examples on exogeneous effects on traffic accidents. Fritz et al. (2020) showed a significant effect of daylight saving time on traffic accidents in the US, while Bergel-Hayat et al. (2013) found significant effects of rain and temperature on the number of traffic accidents, using time series models with exogenous variables. Martensen et al. (2016) conclude that the main reason for changes in the number of traffic accidents in different weather conditions is the change in traffic volume. A denominator for these results is sufficiently refined analytic tools and finding appropriate measures to account for external factors. In the analysis presented here, we will adopt a similar approach as Bergel-Hayat et al. (2013), in that we will use a time series framework to investigate the impact of election posters as a risk factor for traffic accidents, accounting for exogeneous information that includes season and various meteorological information.

3 Materials and methods

We used registers from Statistics Denmark on all Danish traffic accidents registered by the Danish police in the period between 1 January 1997 and 31 December 2019, giving location, time, and additional details for the accidents. For the analysis, we supplemented the accidents data with meteorological information.

To account for other possible reasons for an accident, to the extent possible in our data, we filtered the data to arrive at a more relevant subset. We first removed all accidents that did not happen in city zones, to focus the attention on areas without a minimal frequency

of election posters, as the concentration of election posters is much higher in cities than in rural areas. Second, we removed all accidents with drunk driving i.e. accidents where the driver of the car was registered with a blood alcohol level above 0.05%, and accidents where the driver was under the influence of narcotics or prescription drugs. Third, we removed accidents with people deemed unfit to drive by the police due to sickness or other related reasons. Lastly, we removed all accidents where the visibility was less than 100 meters at the place and time of the accident, as such weather conditions made it less likely that election posters are visible around the accident.

All meteorological data were obtained through the Danish Meteorological Institute's Open Data API (DMI, 2023). We registered information on temperature, precipitation, humidity, and dew point as a national daily average, using 5 different weather stations situated across the country. Summary statistics for these are presented in Table 1.

When modeling the daily number of traffic accidents, we included indicators for reoccurring periods over the year that may influence how people commute. These periods also affect the traffic volume which in turn may mirror the number of traffic accidents. We thus included public-school holidays as an explanatory variable, including Christmas, Easter, summer break, winter break, fall break, and several public holidays, based on the official vacation guidelines from the Ministry of Children and Education for all investigated years of traffic accidents (DME, 1999).

The variable of interest is the general election indicator. This variable is set to 1 when election posters are allowed to be put up (around 3–4 weeks before the election date, see DRD (2021) for more details) and 0 elsewhere from the day after the end of an election. The Danish experience is that election posters are put up instantly the moment it is allowed. In Figure 2, it is indicated when elections have taken place during the time from the 1 January 1997 to the 31 December 2019.

The resulting time series for the daily number of accidents within the filtered data is visualized in Figure 3 below.

4 Statistical analysis

We view the daily number of traffic accidents as a non-stationary time series. It is evident from Figure 3 that the series has a downward trend in the period 1997 to about 2010, and from 2010 and forward the expected number of traffic accidents is constant when accounting for seasonality. This yields two regimes. To find an optimal cutoff point for the trend, we smoothed the data to focus on the underlying structure. From the smoothed data, the 15 December 2009 was shown to be the optimal cutoff-point for a regime change, when using the L_1-norm to focus on absolute differences (inducing the Manhattan distance, see for example page 218 in Sharma (1996)).

By using one-lag differencing and a root transformation given by $f(x) = x^{1.65}$, the resulting transformed data from the first regime (i.e. between 1 January 1997 and 15 of December 2009) are stationary and normal distributed. The second regime (between 16 December 2009 and 31 of December 2019) could not pass model checks after optimal transformations and was hereafter excluded from the rest of the analysis. From the autocorrelation functions, a weekly seasonality in the data was identified. In general, there are fewer accidents during the weekend which supports the notion of less traffic volume when public schools are closed.

Figure 4 provides a complementary argument for the weekly seasonal effect, as there are fewer traffic accidents during the weekend. Considering the average number of daily traffic accidents per month, we see that the number of traffic accidents, in general, is larger during summer months. July is a special case, which can be explained by a long-lasting school summer break.

Let $\{Y_t\}$ denote the time series of the differenced and root-transformed number of daily traffic accidents. Further, let $\{X_{d,t}\}$ denote the time series of the exogeneous information of dimension d. We fitted a seasonal autoregressive moving-average model on $\{Y_t\}$ with a season of 7 days corresponding to weekly seasonality, and with exogenous input $X_{d,t}$ i.e. $SARMAX_d(p,q) \times (P,Q)_7$ is given by

$$\phi(B)\,\Phi\left(B^7\right) Y_t = \eta X_{d,t} + \theta(B)\,\Theta\left(B^7\right)\varepsilon_t$$

where B is the backshift operator, ϕ and θ are polynomials of orders p and q respectively, Φ and Θ are polynomials of order P and Q respectively, and η is a d-dimensional vector of parameters; finally, ε_t is white noise.

The initial set of the exogeneous information included indicators for public holidays and election periods in addition to meteorological information (namely temperature, precipitation, dew point, and humidity)

Table 1 Summary statistics of weather variables for each of the four yearly seasons

Weather variable	Fall	Spring	Summer	Winter
Daily precipitation (mm)	0.01 [0.00,0.92]	0.06 [0.00,0.75]	0.098 [0.00,1.48]	0.08 [0.00,1.09]
Temperature (°C)	9.65 [-5.85,20.7]	7.49 [-6.53,21.1]	16.1 [8.8,24.4]	1.99 [-11.3,10.7]
Dew point (°C)	7.68 [-7.67,17.0]	3.96 [-10.7,14.8]	12.5 [2.94,19.3]	0.60 [-13.6,9.15]
Humidity (%)	86.5 [64.6,99.5]	79.0 [43.5,98.7]	79.2 [54.5,96.6]	89.4 [52.7,100]

Numbers in the cells are on the format mean [minimum, maximum]).

Table 2 Number of seasonal holidays (average) and election days (total) for each of the four yearly seasons

Variable description	Fall	Spring	Summer	Winter
Number of school holidays in a year	7.21	15.3	43.9	21.1
Election days	135	102	112	134

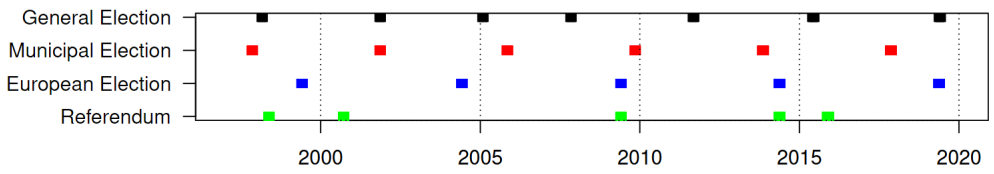

Figure 2 Overview of all Danish elections in the period explored in this article

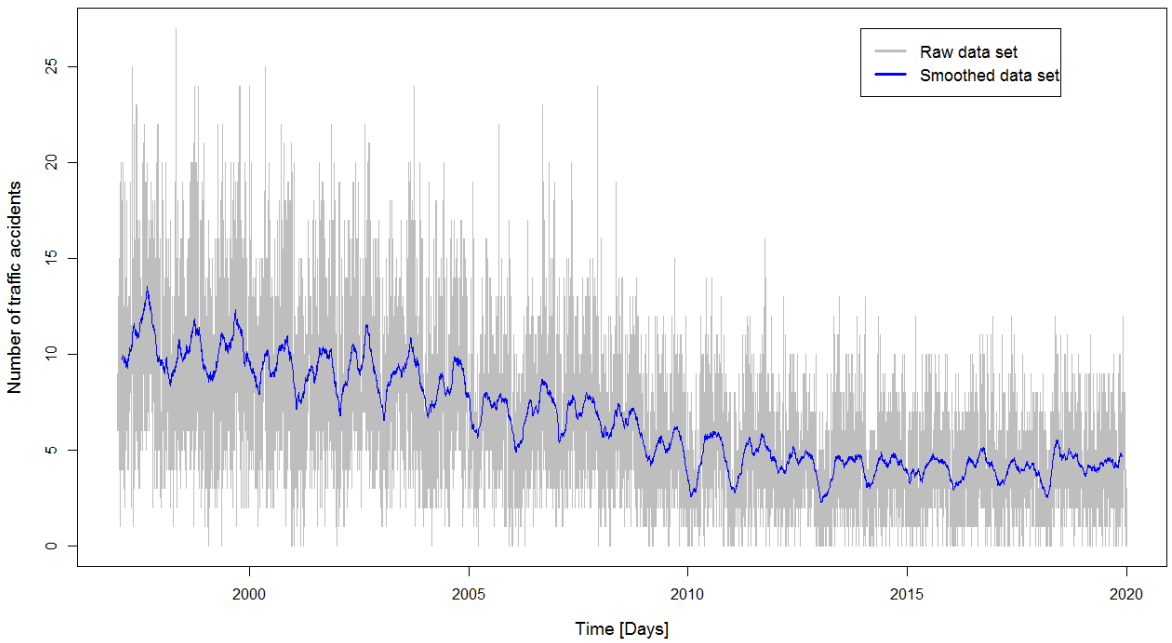

Figure 3 Daily number of traffic accidents including a simple moving average, using a window size of 75 days

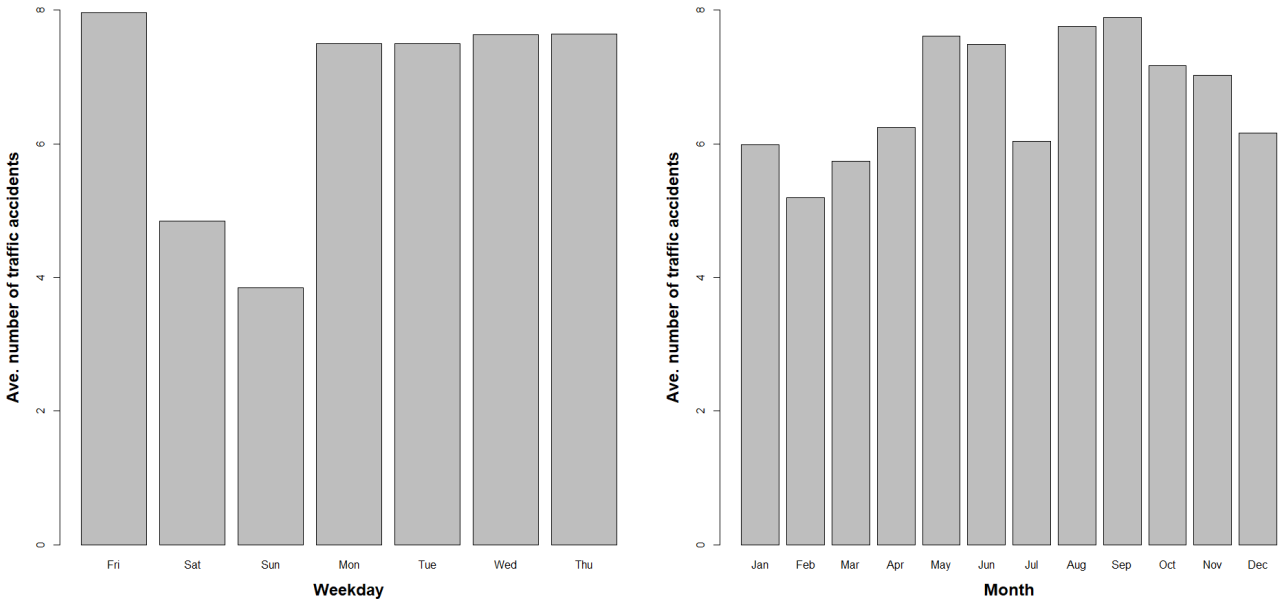

Figure 4 Average number of daily accidents for weekdays and months between 1 January 1997 and 15 December 2009

as well as a piecewise affine mapping describing the sliding seasonality of winter with maximum and minimum in February and August respectively; an equivalent summer mapping is constructed ensuring that the sum of the two mappings is always 1, taking leap years into account. Investigations on the nature of the data considered showed that it was not relevant to work with time-shifted explanatory variables. For the estimation of the SARMAX model, we consider polynomial orders p, q, P, and Q of up to 4, and performed a top-down model reduction from Maximum Likelihood testing, using a test-level of 5%. The appositeness of the initial model was investigated by verifying model assumptions i.e. gaussian residuals, variance homogeneity and temporal residual autocorrelations. Two-way interactions and squared effects of the exogeneous inputs were investigated but did not show any significance. All analytic programming was done in R (R Core Team, 2022).

5 Results

The model reduction process resulted in an $SARMAX_4(1,1) \times (1,1)_7$ on the traffic accidents between 1 January 1997 and 15 December 2009, including the explanatory variables temperature, dew point, public-school holidays, and general elections. Effect parameters and associated uncertainty quantification are provided in Table 3.

Table 3 Estimated parameters and significance level of an $SARMAX_4(1,1) \times (1,1)_7$ in transformed domain

Parameter	Estimate	Standard error	p-value
Ar1	- 0.0889	0.0154	< 0.0001
Ma1	- 0.975	0.005	< 0.0001
Sar1	- 1.00	7.37 1e-5	< 0.0001
Sma1	- 0.992	0.002	< 0.0001
Holiday periods	- 1.24	0.072	< 0.0001
Temperature	0.205	0.021	< 0.0001
Dew point	- 4.39	0.072	< 0.0001
General election periods	0.650	0.223	0.003

p-values are for Z-tests.

All resulting model parameters are significant on a 0.01 significance level, clearly indicating a relation between general election posters and traffic accidents. Humidity and precipitation were excluded from the final model due to non-significant parameters. The same holds true for European elections, municipal elections, and referendums. Squared terms and interaction terms of the explanatory variables were not proven significant either. The positive sign on the estimated general election parameter indicates an increase in the number of accidents during elections.

The estimated effect of a general election on the number of accidents was quantified to 127 additional traffic accidents between 1 January 1997 and 15 December 2009 amounting to 1.18 additional accidents per election day in this period. This quantification is obtained using the estimated model to compute the number of traffic accidents with and without the general election indicator for each of the four general election poster periods, work out the cumulated value over the entire period when the election indicator is included and not, transforming these quantities back to the natural domain (by an inverse root transformation) and computing the difference.

In Figure 5, the impact of a general election and public holidays is visualized in a time series plot between 9 December 2004 and 9 May 2005. From quick inspection, the average daily number of traffic accidents increases during the general election (indicated by the green area) whereas it decreases in weekends and during public holidays as expected. Qualitatively speaking, it can be said that the observed and estimated number of traffic accidents follow the same trend including the same seasonality. Both are reasonable within standard confidence intervals.

In Table 4, we provide summary statistics on the observed and estimated number of traffic accidents in average both before, during, and after a general election (27 days for each category).

6 Discussion

Naturally, the data are not integer after filtering and transformations (e.g. root transformations), but the raw data counting the number of accidents in traffic are indeed integer. Therefore, it could be argued that since we are dealing with integer data, we could apply integer time series modelling. For example, this could be an autoregressive Poisson regression model. We chose to use the (linear) SARMAX model anyway, because first that the level of number of accidents justified a continuous model approximation, and second because it was estimated that heterogeneity among the traffic accidents would compromise the variability assumptions from a Poisson process, leading to an overestimation of the variability unless suitably penalized. We believe that this may have been one of the factors contributing to the non-significances in the study of Wedel (2016). Similar considerations have been put forward in Fu et al. (2023).

It is a weakness of the results that modeling only applies to our 1st regime and not the 2nd, which is the most recent regime. The reason is the near non-stationarity of the data, which is apparent from Table 3, and which also applies to the 2nd regime. Yet, the main purpose of the paper is to evaluate the potential risk of election posters, which requires valid modeling. In the decade corresponding to the 2nd regime, we have not observed changes in neither the election poster tradition, nor the attitude towards election posters in the general public. We thus believe the results to remain valid to this day.

The model was corrected for meteorological variables and public-school holidays, both as direct effects, and as proxies for traffic volume. The fact that we filtered the accident time series to focus on election poster dense areas in cities does not necessarily mean that any causal effect that may be reflected in the positive association between presence of general election posters and traffic accidents is not present in rural areas. Rather, we presume that the effect is dissipated from the fewer election posters, but at the individual level the modeling reflects the same event that occurs in all areas in the country, rural or urban: That a driver encounters an election poster and may be distracted, increasing the risk of a traffic accident. While current legislation to some extent does handle potential inattention from election posters, our analysis points towards that excess risk remains, and authorities should reevaluate their measures of precautions. For future investigations, it would be interesting if a different representation of the volume of traffic could be obtained, for example GPS signals or estimates from satellite data. Such variables may provide information additional to what the regressors already included are capable of. We note that while the explanatory variables that we include may act as proxies for the changing volume in traffic, the exact same variables may have additional affects as to how people drive and thus the impact of traffic volume may counterbalance their initial effects. Thus, the parameter estimates of these variables should be interpreted with caution. The temperature regressor for instance can have several dampening and boosting effects on the number of traffic accidents. On the one hand, when the temperature rises, people living in Danish cities would be prone to use for example the bicycle for transportation, thus reducing the number of cars on the road. On the other hand, there is evidence that people drive less safely in perfect weather conditions, thereby increasing the number of accidents happening (Edwards, 1998).

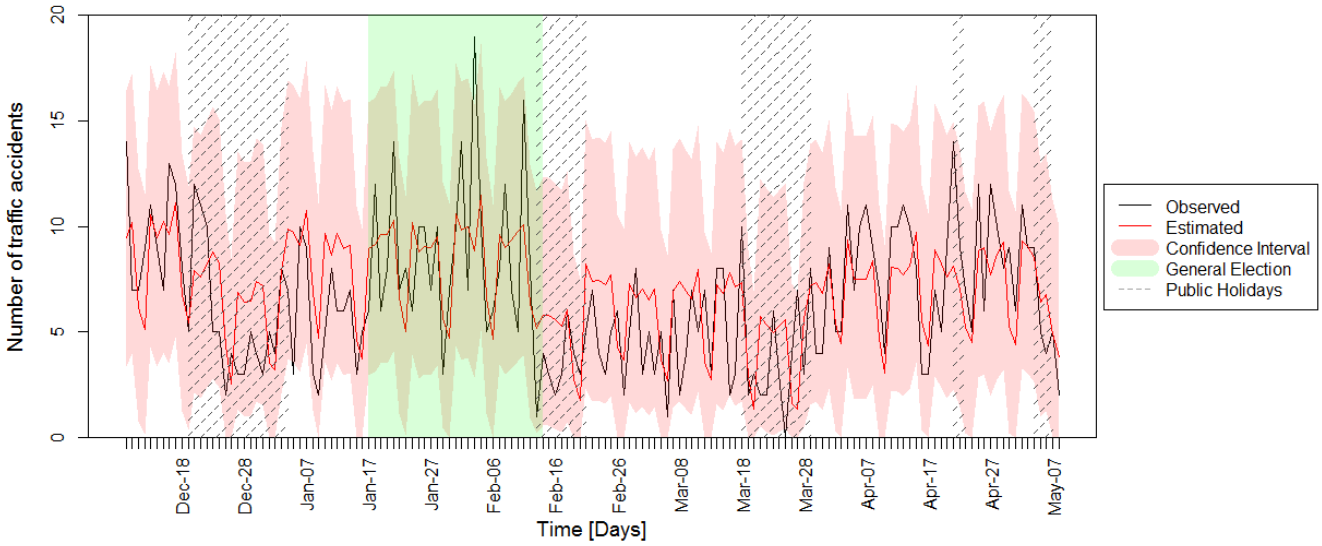

Figure 5 Daily number of observed and estimated traffic accidents between 9 December 2004 and 9 May 2005 including standard confidence intervals. A general election and public holidays are color indicated.

Table 4 Average number of traffic accidents before, during and after all general elections

Variable description	27 days before general election	During general election (27 days)	27 days after general election
Observed	207.5	248.5	201.5
Estimated	218.5	251.8	202.9

Moreover, the included meteorological explanatory variables are rough estimates of a national trend that is modelled, rather than reported local circumstances, which might explain why humidity and precipitation rate were not found to have a significant effect. The same does not hold for the holiday periods, where the effect is common all over the country, only perhaps moderated by demographics. The indicators of holiday periods are thus considerably more directly interpretable as cause-effect parameters. The same reasoning applies to why we used time series models that allows for autocorrelation and structured residuals from the moving average part. Naturally, the impact on the number of accidents in time t from the number of accidents in time $t-1$ is not causal but represents unmodelled trends in data that is not described by the exogenic information. Because the nature of traffic accidents is very complex, proxies must be applied to temporal effects that are not directly identifiable. The time series framework is tailored for such modeling, which is the main reason that we chose the time series ARIMA structure for the model work.

We note that the election poster variable only indicates whether it has been allowed to put up election posters at a given period. While election posters are always put up as soon as it is allowed, the concentration of election posters in the traffic is obviously heterogeneous. We have not been able to find any data on the heterogeneity of the concentration of election posters, nor discover any describing link between accidents and the poster concentration as the distracting effect. Nevertheless, the elimination of/correction for the included explanatory variables makes us conclude that there is no relevant evidence that the effect of general election periods we find should not be a causal effect of the visible change in the traffic room, i.e. election posters. This is particularly illustrated by Table 4, which indicates that within general election periods, both prior to and after the period in which election posters are allowed, the number of traffic accidents are lower than in the period where election posters are allowed. We note that no statistically significant effects on the daily number of traffic accidents were documented from other types of elections (i.e. European, municipal, or referendums). This is most likely due to that the concept of general elections is more deeply rooted in the mind of (Danish) citizens, with the most direct impact on everyday life and political philosophy. This

is also reflected in that Danish general elections have considerably higher participation rates than municipal elections, EU parliament elections and referendums, with the only noticeable exception within the study period being the referendum on the joining of the pan-European currency in the year 2000. A more deeply rooted concept may result in an increased incentive to look at the election poster, thereby causing potential inattention in the traffic.

For further studies, it could be interesting to investigate other kinds of traffic disturbances, and disturbances in other countries, to compare our findings, and see if e.g. commercials or visual campaigns can be said to play a similar role for traffic safety. The problem with investigating these other kinds of disturbances is that they will typically not be re-occurring in the same form for a specific campaign, making it more difficult to obtain a suitable period to compare with. Nevertheless, the framework developed here is applicable to other kinds of traffic disturbances.

A source of such inattention, somewhat similar to election posters, is bill-boards. While there is extensive evidence that bill-boards impact on drivers' behavior, there is no solid evidence that bill-boards in general also pose a risk for accidents (Decker et al., 2015; Wallace, 2003; Dukic et al., 2013). Gitelman et al. (2019) showed that at a specific highway in Israel, the removal and subsequent restoration of bill-boards pointed towards an increased risk of accidents when bill-boards were present. However, this study concerned a specific highway and specific bill-boards, and did not account for changing meteorological circumstances. In fact, we were not able to identify studies that combined the impact of meteorological circumstances and bill-boards. Additionally, lack of legislation on where to place bill-boards makes comparisons problematic. One example is placement at ground level (Wallace, 2003; FRA, 2004), forcing the driver to lower the gaze in order to view it. As noted, Danish legislation prohibits this kind of placement for election posters.

Another well established source of inattention is the use of mobile phones, which has been investigated by many authors. Violanti (1997) reported inattention to be by far the most common cause of accidents among drivers who were using mobile phones. However, in the review by Lipovac et al. (2017) on accidents where mobile phones were used, including more than 60 studies, none of these were reported to take any meteorological variables into account. While the relationship in risk between meteorology and the use of mobile phones may be different than for election posters, the inclusion of meteorological variables is important for separating effects, and the stand-alone effect of meteorological variables on accident risk is well documented.

In general, the analysis of the effect of election posters in the literature is scarce, and comparable sources of inattention like the above are difficult to analyze internationally, both because of lack of appropriate data (Yannis et al., 2007), and because the impact of meteorological variables differs with climate (Bergel-Hayat et al., 2013). It is a strength of our study that Danish databases on accidents can be and are combined with detailed meteorological knowledge, even at the national level. That the meteorological data are on national levels should be held up against the size of Denmark, which is less than 43 000 km^2. For larger countries like e.g. Germany, this will correspond to knowledge at a regional level.

7 Conclusion

We have shown that the presence of general election posters is associated with an increased risk of traffic accidents ($p = 0.003$), when correcting for meteorological variables and public school holidays. While a causal relation between traffic accidents and the presence of election posters cannot be concluded from the analysis, we find distraction from election posters to be the most likely explanation for the associated increase in traffic accidents. We estimate an additional 1.18 additional accidents per day with election posters present. In total, this amounts to 127 additional accidents for the investigated period of time.

CRediT contribution statement

Albert Skovgaard Bisgaard: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing—original draft, Writing—review & editing. **Magnus Hamann Poulsen:** Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing—original draft, Writing—review & editing. **Anders Stockmarr:** Funding acquisition, Investigation, Methodology, Supervision, Validation, Visualization, Writing—review & editing.

Declaration of competing interests

The authors declare that they have no competing interests.

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Albert Skovgaard Bisgaard and Magnus Hamann Poulsen contributed equally to this manuscript.

Availability of data

The register data from Statistics Denmark used in this study do not have public access, and do not have unpaid access. Danish scientific organizations can be authorized to work with data within Statistics Denmark, and such organizations can provide access to individual scientists inside and outside of Denmark. Requests for data may be sent to Statistics Denmark: https://www.dst.dk/en/kontakt.

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