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Research Report

The role of social media ads for election outcomes: Evidence from the 2021 German election

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Abstract

Social media ads have become a key communication channel in politics. However, the relationship between political ads from social media and election outcomes is not fully understood. Here, we aim to estimate the association between online political advertising and election outcomes during the 2021 German federal election. For this, we analyze a large-scale dataset of 21,641 political ads from Facebook and Instagram that received ≈126 million impressions. Using regression analysis, we show that political advertising on social media has a positive relationship with a candidate's election outcome and may even sway elections. All else equal, ≈200,000 additional impressions are predicted to increase a candidate's votes by 2.1%. We further use a causal sensitivity analysis to evaluate how unobserved confounding may affect our estimates. We find that the estimated impact of ads cannot be reasonably explained away, highlighting the significance of social media for election outcomes.

Keywords: elections, social media, political campaigns, online political advertising, voting behavior

Significance Statement

Social media has transformed political campaigning, allowing advertisers to reach a broad audience at comparatively low cost and specifically target certain voter groups. In this study, we analyze a large-scale dataset of 21,641 political ads from Facebook and Instagram with ∼126 million views during the 2021 German federal election. This allows us to study the countrywide influence of social media on elections across the full political spectrum. We find that online political advertising significantly influences election outcomes and may even sway elections. Our findings offer valuable insights for researchers, candidates, and policymakers, emphasizing the necessity of transparency in online political advertising to ensure fair elections.

Introduction

The rise of social media led to a large shift in political advertising during elections (1–4). For example, in the United States, spending on online political advertising rose from only USD ∼70 million in 2014 to USD ∼1.8 billion in 2018 (5). In Germany, a majority of candidates (≈80%) running in the 2021 German federal election believed that social media could influence voters and consider social media platforms such as Facebook important tools for political campaigning (6). This shift has raised concerns about political advertising on social media. For example, political advertising may have reinforced political polarization on social media during the 2020 US presidential elections (7). Furthermore, foreign actors such as the Russian Internet Agency have strategically used social media with the aim of manipulating elections (8, 9). However, the impact of political ads on social media for election outcomes remains unclear.

There are good reasons why political advertising on social media may be effective. A particular benefit of social media is that it allows candidates and political parties to run ad campaigns with wide reach at comparatively low costs (3). For example, in the United States, an average ad on Facebook generates 7,500 impressions at a cost of only USD 224 (10). Such low costs for political advertising are especially helpful for campaigns with smaller budgets and, thereby, can help to democratize electoral competition (5). Compared to traditional advertising channels (e.g. TV, radio, and newspapers), another benefit of social media is the opportunity to target specific user groups (11–16), which has been shown to be highly effective in survey experiments and various areas of advertising, but outside of elections (12–15, 17). Targeting further allows campaigns to send tailored political messages to receptive audiences. For example, candidates can tailor ads to small spatial areas (18) that correspond to their

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constituency and, thus, directly communicate with their voters. Moreover, social media advertising is particularly flexible in that it allows for rapid adaptations to new events and changes in the political discourse (18, 19), for example, to respond directly to attacks from opponents.

In contrast, political advertising on social media has several restrictions because of which it may be ineffective in persuading voters. In general, many voters have strong prior beliefs such that influencing elections through social media is generally considered to be difficult (20–22). Furthermore, the mass of content by different accounts such as media outlets and other politicians may bury political ads (9) and thus only provide limited visibility to candidates. Most social media users are also not interested in politics or rather follow in-group instead of out-group political accounts (23), and, as a result, political advertising would mostly reach supporting voter groups but cannot sway voters from other parties. This hypothesis is supported by empirical evidence that even the massive foreign influence campaign of the Russian Internet Agency during the 2016 US presidential election was eventually unrelated to people's voting behaviors (9), which suggests that political advertising on social media may be ineffective.

Overall, it thus remains unclear whether political advertising on social media is effective in influencing electoral outcomes. Previous research has extensively studied the effectiveness of campaign spending (24–29) and TV ads (26, 30–36) on election outcomes and repeatedly documented that political advertising is effective (26, 30–36) (see Background for a comprehensive overview of the literature). Still, the countrywide impact of political advertising on social media across the full political spectrum is unknown. Here, research is needed to evaluate the influence of political advertising on social media.

To analyze the relationship between social media ads and election outcomes, a hindering factor in previous research was limited data availability from social media platforms. Political advertising on social media is oftentimes perceived as intransparent and publicly inaccessible (37). In contrast to TV ads that are publicly accessible, it was previously extremely challenging, if not impossible, for research to systematically collect and analyze political ads from social media (37). Especially, two key pieces of information for analyzing political advertising—the number of impressions and cost per ad—have been previously unknown to researchers. In an attempt to foster transparency, public pressure (5) and legislative initiatives (e.g. the Digital Services Act in the European Union (38)) have committed major social media platforms to make such key information on political ads accessible to the public. Owing to this, major social media platforms (e.g. Facebook, Instagram) have begun publishing public archives that document political advertisements sold on their services (39). Here, we leverage a unique—and previously unavailable—data source to quantify the relationship between political ads and election outcomes.

In this paper, we analyze the relationship between online political advertising and election outcomes using a large-scale dataset of 21,641 political ads published on Facebook and Instagram during the 2021 German federal election (for details on the election and the electoral system in Germany, see Supplementary Material A). Specifically, we use regression analysis in combination with a comprehensive set of controls and fixed effects. Thereby, our approach accounts not only for multiple sources of endogeneity such as party characteristics (e.g. campaign budget, popularity) and constituency characteristics (e.g. unemployment rate) but also candidate-specific heterogeneity (e.g. a candidate's effort and the quality of her/his campaign). Importantly, this allows us to study the *countrywide* role of political advertising across the *full* political spectrum.

To quantify the effectiveness of political campaigns, it is essential to measure exposure to political ads. In this study, we use impressions—the number of times an ad is rendered on a user's screen (40)—as a direct measure of exposure on social media platforms. In traditional campaign settings, such as TV or radio, an analogous measure would be viewership or listenership of a broadcast ad. While both impressions and traditional exposure metrics indicate the opportunity for exposure rather than active engagement, impressions offer a significant advantage: they are a precise, direct measure of ad delivery, eliminating biases associated with proxies used in previous studies like the number of ads aired or the estimated exposure of TV ads (32, 33, 35, 36). This reduces the risk of measurement errors, providing a more accurate basis for estimating the role of political ads in election outcomes.

Generally, estimating the causal impact of political advertising on election results is challenging (32, 33, 35, 36, 41, 42). Endogeneity due to unobserved confounding can lead to biased regression estimates. This has led researchers to apply different identification strategies to identify the causal relationship between political campaigns and election outcomes, such as randomized controlled trials (RCTs) (e.g. (43–45)), exploiting exogenous variation due to particular market features that create natural experiments (e.g. (35, 36, 42)), or instrumental variable approaches (e.g. (32, 33)). Although RCTs are considered the gold standard for identifying causal effects, they may be problematic in the realm of political advertising. Typically, RCTs are limited to a specific population that may not be representative of the real world. More importantly, ethical considerations may limit their applicability for political advertising as they might involve withholding campaign information from a control group or disproportionately favoring one political candidate or party, which undermines fair elections. Exploiting exogenous variation influencing the allocation of political ads, such as unique market features (e.g. the design of market areas for TV advertising in the United States) can create natural experiments to identify causal effects. However, these natural experiments are often limited to specific settings (e.g. uniquely structured broadcasting markets) and typically cannot provide a countrywide evaluation of ad effects, negatively affecting the external validity of the results (35). Identification strategies using instrumental variables rely on strict assumptions, such as the instrument's exogeneity, making it challenging to find and justify an appropriate instrument (46).

In the observational design of our study, using instrumental variables might seem appropriate to estimate the effects of political advertising on social media. However, the reliability of this approach hinges on strict assumptions, especially the instrument's independence from unobserved confounders (46). For example, research on the impact of television advertisements has utilized the prior year's advertising costs as an instrumental variable (32, 33). Yet, in the dynamic pricing environment of social media, advertising rates vary significantly by advertiser, compromising this independence assumption. Nevertheless, we examine the use of political advertisements by candidates in neighboring constituencies as a potential instrument (see Supplementary Material L for details). Since voters can only cast votes in their own constituencies, we assume that advertising decisions of candidates in neighboring constituencies are unrelated to another candidate's characteristics. However, the strict conditions necessary to validate the instrumental variable assumptions preclude us from applying such an approach in our main analysis.

Because of the above, fully addressing endogeneity concerns and establishing causality between social media ads and election outcomes in a countrywide setting is also challenging in our study. Here, we employ a causal sensitivity analysis, which allows us to evaluate how unobserved confounding may affect our results and provides empirical evidence to reasonably argue for the causality of our findings (see Materials and methods). The causal sensitivity analysis is beneficial in our setting as it shifts our discussion toward the strength of potential confounding and how it relates to observed variables (47), rather than solely justifying the strict assumptions required for identification strategies such as instrumental variables. Overall, the causal sensitivity analysis provides more transparency on the conditions under which unobserved confounding cannot reasonably explain away the effect of social media ads on election outcomes.

Our results establish a statistically significant positive coefficient for the relationship between online political advertising and a candidate's election outcome. Specifically, our regression analysis predicts that an additional ~200,000 impressions increase a candidate's number of votes by 2.1%. The estimates are robust across different model specifications and when controlling for various sources of heterogeneity. In addition, our causal sensitivity analysis provides empirical evidence unobserved confounding cannot reasonably explain away our findings. Notably, political advertising can be considered cheap with an estimated average price per vote of only EUR 4, and may even sway elections. As such, our results highlight the significance of social media for politics and have both practical and policy implications for elections worldwide due to the growing importance of social media.

Background

The widespread use of political advertising on social media raises the question about its (in)effectiveness in influencing election outcomes. While previous research has studied the effectiveness of campaign spending (24–29) and TV ads (26, 30–36, 42, 48) on election outcomes and repeatedly documented that political advertising is effective (26, 30–36, 42, 48), the crucial differences between online and offline political ads (3) suggest that previous findings may not generalize to political ads on social media. In the following, we provide an overview of previous research on campaign effects for electoral outcomes and review the literature on political ads on social media.

A large stream of literature has studied the effect of campaign spending on election outcomes (24–29). Typically, these studies measure the effect of an additional unit of spending on a candidate/party's election outcome. Here, scholars have found a consistent but small effect of a candidate's or party's expenditure on their electoral success across various types of elections (13, 24, 25, 28) and geographical contexts (25). However, measuring advertising effects from campaign spending suffers from important limitations: First, equating campaign spending with the effectiveness of various campaign strategies leads to an oversimplified understanding, as it fails to isolate the impact of specific campaign efforts such as political advertising on social media on election outcomes. Second, campaign spending does not reflect the actual reach or engagement with an election campaign but is an indirect measure of exposure, hence inducing measurement errors that may lead to bias when estimating campaign effects. To alleviate this, we estimate the effect of online political advertising based on impressions and thus actual views of political ads. This allows us to measure the direct effect of a candidate's political ads on their election outcome.

Another stream of literature has focused on how TV ads affect election outcomes (32, 33, 35, 36, 42, 48). Again, these studies report modest yet statistically significant effects of TV ads on electoral outcomes. Typically, researchers estimate the impact based on the total number of TV ads broadcast by candidates or parties, or by estimating the exposure to these ads and thus the effect of an additional ad or additional unit of exposure on electoral success. However, such methodologies are prone to inaccuracies in measuring actual viewer exposure, potentially leading to measurement errors and biased outcomes (49). Furthermore, political advertising exhibits significant differences online and offline (3). For instance, online political ads often exhibit greater partisanship and utilize precise targeting (3, 18), which renders it likely that both offline and online ads have a different impact on election outcomes. Therefore, previous results on the effectiveness of TV ads may not be directly applicable to political advertising on social media. Therefore, research is needed that empirically evaluates how political advertising on social media influences election outcomes.

Social media has led to a large shift in political advertising. Research in this area has predominantly concentrated on analyzing the content, strategy, and unique characteristics of political advertisements on social media. For example, researchers have analyzed the difference between political advertising online and offline (3), how politicians advertise on climate change (50) and immigration (51, 52), address Spanish vs. English-speaking audiences (53). Further works have compared political ads by populist and mainstream parties during the 2019 European elections (54), studied political advertising during the 2022 Italian election (55), and analyzed the targeting strategies of different campaigns (11, 16). Overall, this shows that campaigns adopt unique strategies to run political ads on social media (11) that are different from traditional offline campaigns (3). For example, online political ads are less issue-focused (3) and tend to be directed to one's base (3) which may mobilize voters but not necessarily persuade diverse parts of the electorate. Additionally, different targeting strategies have been found to influence the cost-effectiveness of campaigns, leading to variations in the number of views (11). Despite these findings, a gap remains in our understanding of the direct impact of political ads on electoral outcomes.

There is some recent evidence that suggests that social media can influence elections (56), however, not with a focus on political advertising. Since parties develop distinct messaging strategies for organic and paid content (57), a more detailed view is crucial to evaluate how political ads affect electoral outcomes. Here, recent work suggests that online political advertising affects voter turnout (43) and vote choice (45, 58) but with key limitations. Specifically, these studies are restricted to a limited number of voters from a specific geographical area and only consider political ads by one party. Hence, these studies capture specific idiosyncrasies in the political landscape, which is problematic for making general claims as advertising effects are likely to differ across regions and parties. For example, in the United States, certain states are considered predominantly Democratic or Republican (59) such that online political advertising by the opposite party may have little effect. In addition, parties employ different online advertising strategies (57), which likely vary in their effectiveness in persuading voters. Others have also shown the persuasiveness of online political ads in survey experiments (60). However, this approach may suffer from an opt-in bias and merely collects preferences rather than actual votes. Hence, empirical evidence as presented in this work is needed to measure the *countrywide* effect of online political advertising across the

full political spectrum, providing a holistic perspective on the role of online political advertising in electoral processes.

Social media has increasingly become a pivotal tool in election campaigns, extensively used by candidates for disseminating political messages and by voters for gathering political information. Despite its importance for electoral processes, the effect of online political advertising for election outcomes remains unclear. While previous studies show small but consistent effects of campaign spending and TV ads for electoral outcomes, important differences between political advertising online and offline render it likely that previous results do not generalize to online political advertising. Additionally, current studies on online political advertising tend to be focused on examining content and campaign strategies or are limited to specific regions or political parties and thus are unable to provide a countrywide perspective on the impact of online political advertising on elections across the full political spectrum. To bridge this gap, we aim to estimate the countrywide impact of online political advertising on election outcomes by leveraging a comprehensive data source providing detailed information on real-world exposure to election campaigns on social media.

Results

Political advertising on social media in Germany

We analyzed the effect of political advertising on social media during the 2021 German federal election. The election marked a turning point in German politics as Angela Merkel did not stand for re-election. Overall, >60 million Germans were eligible to vote, of which eventually 76.6% cast their ballot (61). Voters were assigned to one of the 299 constituencies and cast two votes: The first vote (also called "direct vote") elects a constituency representative, while the second vote represents a party vote and is thus unrelated to a specific candidate. Here, we focused on the first vote to evaluate the effect of political advertising on a candidate's vote share. For more details on the electoral system, see Supplementary Material A.

To evaluate the effect of political advertising on election outcomes, we matched political ads published on Facebook and Instagram with official election data from the six major political parties in Germany (i.e. *SPD*, *Union*, *Grüne*, *FDP*, *AFD*, and *Die Linke*). Facebook and Instagram were—by far—the most popular social media platforms in Germany and account for a total market share of 77% (62). Moreover, ∼80% of the candidates consider Facebook as an important tool for their election campaign and a majority believes that advertising on Facebook can influence voters' opinions (6). Here, we collected political ads via the Meta ad library (39), which provides comprehensive information on all political ads published on Facebook and Instagram. In addition, we retrieved official election data from the Federal Returning Officer (see Materials and methods).

Our data comprise 21,641 political ads published on Facebook and Instagram by all 1,785 candidates of all major parties that ran as constituency representatives in the 2021 German federal election. In sum, all candidates have spent EUR ∼1.4 million on political ads, which received ∼126 million impressions. This implies that an average ad generated 5,844 impressions, for which a candidate paid an average price of EUR,65.00. Put differently, this amounts to approximately EUR 0.01 per impression.

We first studied where candidates generated impressions with political ads to explore regional differences in political advertising. Figure 1a shows the distribution of impressions across all German constituencies. We find that political ads were viewed in almost all constituencies (286 out of 299) and were rather equally distributed (median: 254,985, interquartile range [IQR]: 95,682 to 522,729). Hence, political advertising was relevant across all constituencies and did not exhibit notable regional differences.

To explore regional variations in a party's advertising efforts, we also analyzed a party's number of impressions across districts. We observe that impressions were generally distributed relatively evenly across constituencies for all parties, with some notable regional variations. For instance, ads by the *Grüne* received a higher concentration of impressions in the southwest of Germany, while *Die Linke* garnered a considerable number of impressions in constituencies in eastern Germany. Additionally, both the *SPD* and *Union* recorded higher impression counts across most areas in Germany, reflecting their prominence as the two leading political parties in the country. Details are in Supplementary Material D.

We also analyzed which parties are particularly engaged in political advertising on social media. To do so, we compared the impressions generated by political ads of each party (see Fig. 1b). We find that comparatively large parties (i.e. *SPD* and *Union*) had a larger viewership on social media as compared to their smaller opponents (i.e. *Grüne*, *FDP*, *AFD*, and *Die Linke*). *SPD* and *Union* received the most impressions (∼48 million and ∼47 million, respectively), followed by *FDP* (∼15 million), *Grüne* (∼8 million), *AFD* (∼6 million), and *Die Linke* (∼2 million). Next, we examined whether the number of impressions generated by parties in each constituency was associated with their performance in the 2017 German Federal Election. However, we observe only a weak relationship between the number of impressions and the election results in 2017 (see Supplementary Material G for details).

In the next step, we studied how impressions of political ads on Meta were distributed across platforms (see Fig. 1c). We find that parties used all platforms to publish political ads on social media. The majority of impressions (∼79 million) were generated with ads published on *both* Facebook and Instagram, followed by ads that were published on Facebook only (∼38 million). In contrast, political ads on Instagram have only received ∼10 million impressions. Evidently, Facebook was thus more relevant for candidates than Instagram.

Furthermore, we analyzed *who* was advertising on Meta during the 2021 German Federal Election. To do so, we explored the characteristics of candidates advertising on Meta. We find that incumbents as well as candidates with a higher campaign budget and time investment for their campaign were more likely to advertise on Meta. In contrast, older candidates were less likely to publish social media ads. In terms of party affiliation, we observe that candidates running for the *SPD*, *Union*, and *FDP* were relatively more likely to run ads on Meta. However, candidates running for *Die Linke* tended to advertise less on Meta. Details are in Supplementary Material H.

Estimation results

We used regression analysis to analyze the association between the number of impressions of candidates' political ads on Meta and their election outcome. In multiparty elections, as is the case for Germany, the vote shares of candidates running in the same constituency are interdependent. Hence, the success of one candidate implies a lower vote share for others. To estimate the link between political advertising and election outcomes, we thus used a discrete choice model in the form of a conditional logit model, which has been used by previous literature estimating the effect of campaign spending in multiparty elections (25). The discrete choice model

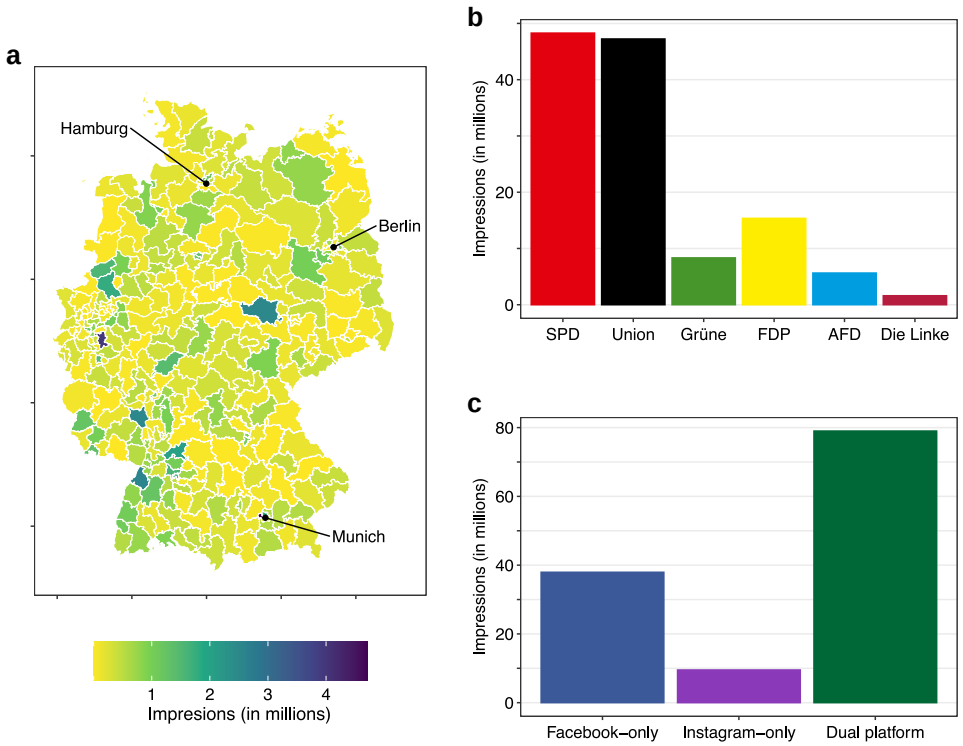

Fig. 1. Impressions of political ads. a) The map shows the distribution of impressions across all 299 constituencies in the 2021 German federal election. b) The bar chart shows the distribution of impressions across the six major political parties in Germany (i.e. *SPD*, *Union*, *Grüne*, *FDP*, *AFD*, and *Die Linke*). c) The bar chart shows the distribution of impressions across different platforms, that is, political ads either published on Facebook (Facebook-only), Instagram (Instagram-only), or on both platforms simultaneously (Dual-platform).

Table 1. The table shows the regression results for our discrete choice model where our dependent variable is the ratio of a candidate's votes over abstentions.

Intercept	−1.952***
	(0.170)
Impressions	0.021***
	(0.005)
Vote share: Party vote	5.561***
	(1.169)
Vote share: Previous election	1.444
	(1.320)
Incumbent	0.065***
	(0.019)
Quality/effort FE	YES
Party FE	YES
Constituency FE	YES
Adj. R^2	0.923
Obs. (*N*)	1,785

Note: SEs in parentheses.
***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.
SEs are clustered at the party level to account for dependencies between candidates, and the number of impressions is z-standardized for better interpretability. Quality/effort refers to a set of control variables measuring time investment, budget, team size, and whether a candidate was supported by a professional consulting company. Abbreviations: FE, fixed effects; Adj. R^2, Adjusted R^2; Obs. (*N*), Number of observations.

accounts for the interdependence between vote shares by modeling the voters' choices for a certain candidate over a reference category. We thus regressed the number of impressions of a candidate's political ads on Meta on the log-transformed ratio of a candidate's votes over the number of abstentions in a constituency (see Materials and methods). We chose the number of abstentions as a reference category (instead of the number of votes of another party) as this allowed us to estimate the effect of online political advertising across *all* candidates and constituencies.

To account for various sources of heterogeneity, we included a comprehensive set of control variables in our model. Informed by political science literature (35, 57, 59, 63), we controlled for the following: (i) the party vote share in a constituency (*Vote share: Party vote*) to account for overall party preferences; (ii) the direct vote share of candidates in the previous election, that is, the 2017 German federal election (*Vote share: Previous election*), to account for election preferences of constituencies over time; (iii) a dummy (*Incumbent*) indicating whether a candidate is an incumbent (=1) or contender (=0) to account for incumbency advantage (63); (iv) the quality/effort of a candidate by including a candidate's time investment, budget, team size, and whether a candidate was supported by a professional consulting company during the campaign; (v) party fixed effects to account for unobserved party factors (e.g. to account for campaign budgets, party popularity, and also differences in TV/radio advertising); and (vi) constituency fixed effects to account for constituency-specific heterogeneity (e.g. unemployment rate). Details are in the Materials and methods.

The estimation results for the conditional logit model are reported in Table 1. We report the standard error (SE) and confidence interval (CI) of each estimated coefficient. We find a positive and statistically significant coefficient for the link between the total number of impressions of a candidate's political ads on social media and the ratio of the number of votes obtained by a candidate over abstentions (coef: 0.021, SE = 0.005, $t = 4.365$, $P < 0.001$, 95% CI = [0.011, 0.030]). To facilitate the interpretability of our results, we z-standardized the number of impressions before estimation. Hence, all else equal, a 1 SD increase in impressions predicts a 2.1% increase in the number of a candidate's votes over abstentions. This allows for intuitive interpretation when assuming that abstentions are constant (e.g. assuming that abstentions are from voters without political interests so that changes in votes come

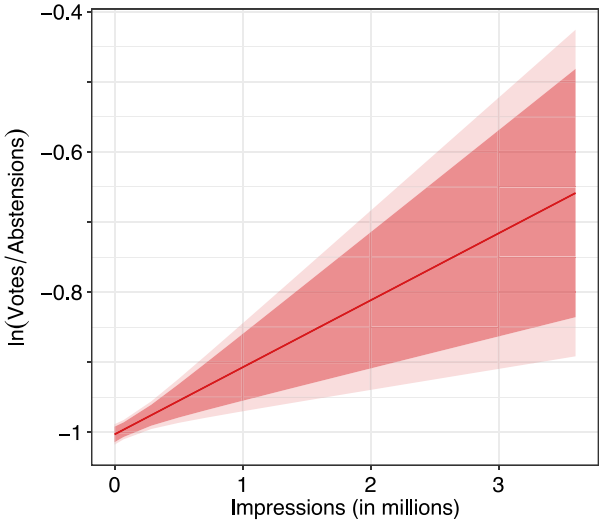

Fig. 2. Predicted marginal effect of ad impressions on a candidate's vote share. The figure shows the predicted marginal effect of ad impressions on a candidate's log-transformed ratio of votes over abstentions as estimated via the discrete choice model (N = 1,785). Effect sizes are computed by averaging the effects over the observed values of the variables in our model. Shaded areas indicate $\alpha = 95\%$ (dark) and 99% (light) CIs.

solely from other candidates' voters). Here, an additional ~200,000 impressions predict a 2.1% increase in a candidate's number of votes. Figure 2 shows the predicted marginal effect of political ads. We find that the number of impressions is positively associated with the ratio of a candidate's votes over abstentions and thus a candidate's election outcome. In addition, the high adjusted R^2 of 0.923 shows that the conditional logit model explains a large share of the variance of a candidate's election outcome.

Robustness checks

Causal sensitivity analysis

Our regression model addresses multiple sources of endogeneity through a comprehensive set of controls and fixed effects. However, there may remain some endogeneity concerns related to unobserved confounding, in particular, with regard to unobserved candidate characteristics (e.g. some candidates could be better versed in using Meta to publish political ads). Since such information was unavailable to us, we performed a causal sensitivity analysis following the approach in (47). frequently used in political science literature (64, 65) and allows us to (i) quantify the degree of unobserved confounding required to invalidate our results and (ii) evaluate whether unobserved confounding as strong as the association between observed covariates with the treatment and outcome would explain away the estimated effect.

As a result, we find that not even unobserved confounding three times as strong as a candidate's incumbency advantage or quality/effort (as measured through a candidate's time investment, budget, team size, and whether a candidate was supported by a professional consulting company during the campaign), which have been identified as important drivers of electoral success by political science literature (63, 66), can explain away our result of a positive and statistically significant effect of political advertising on social media on election outcomes. Overall, this corroborates our finding of a statistically significant relationship between political advertising on social media and a candidate's election outcome. Details are in Supplementary Material I.

Additional checks

To ensure the robustness of our results, we further performed an extensive series of checks regarding the (i) estimator (e.g. we used a linear model and an SUR model (67)), (ii) control variables (e.g. we included additional control variables such as a candidate's age, gender, and job, and we also controlled for opponents' spending), and (iii) data sample (e.g. we checked different campaign periods). Across all checks, our findings remained robust. That is, we found a positive and statistically significant coefficient for a candidate's impressions. Details are in Supplementary Material J.

Price per vote

The cost of running a political campaign on social media is considered to be comparatively cheap (3). To offer a quantification, we thus calculated the price per vote. For an intuitive interpretation, we assume that abstentions are constant (i.e. assuming that abstentions are from voters without political interests so that changes in votes come solely from other candidates' voters). Further, in our sample, the average price per impression on Meta is EUR 0.01, and our discrete choice model from above predicted that keeping abstentions constant, ~200,000 additional impressions increase a candidate's number of votes by 2.1%, which implies, on average, ~500 additional votes. Then, the average price per vote is approximately EUR 4 (=2, 000/500).

We now evaluate whether political advertising could reasonably influence election outcomes. To this end, we assume that a candidate publishes political ads on social media that generate an additional 200,000 impressions (i.e. one standard deviation). Based on our analysis from above, we estimate that an additional 200,000 impressions would lead to 500 additional votes at a total cost of EUR 2,000, which accounts for less than 10% of the average budget of a candidate in the 2021 German federal election (6). Even in a conservative setting, where we assume that the results of all other candidates remain unchanged, an increase of 500 votes for the second candidate would have changed the election outcome in 12 constituencies (out of 299) in the 2021 German federal election. Overall, this highlights the significance of social media in driving—and even swaying—election outcomes.

Additional analysis

Ad spending and number of political ads

We repeated our main analysis to further study (i) ad spending and (ii) the number of political ads on social media during the 2021 German federal election. We first inspected the distribution of (i) ad spending and (ii) the number of ads across constituencies, parties, and platforms. Consistent with our main analysis, we find that (a) there are no notable regional patterns in the distribution of (i) ad spending and (ii) the number of ads across constituencies, (b) the largest parties (i.e. *SPD*, *Union*) had a larger ad spending and also published more ads as compared to their opponents, and (c) candidates primarily make use of ads that are published on *both* Facebook and Instagram. For details, see Supplementary Material K.1.1.

To examine how (i) ad spending and (ii) the number of ads are linked to a candidate's election outcome, we re-estimated our discrete choice model from our main analysis but used (i) ad spending or (ii) the number of ads as our independent variable instead of the number of impressions. Following our main analysis, we included the same comprehensive set of controls to account for various sources of party-, constituency-, and candidate-specific heterogeneity (see Materials and methods) and z-standardized both variables. The results are as follows: (i) For ad spending, we

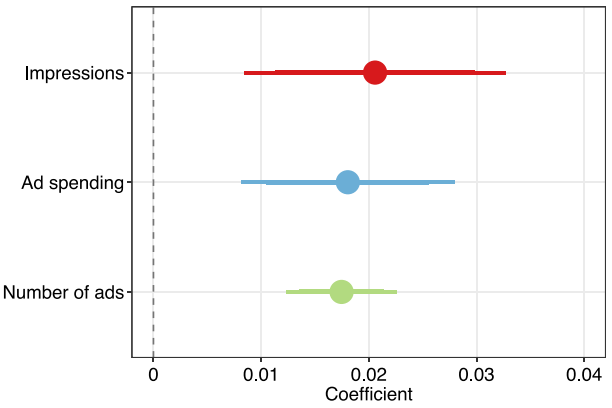

Fig. 3. Estimation results for ad spending. Estimated coefficient for a candidate's impressions from the main analysis and additionally (i) ad spending (in EUR) and (ii) the number of ads. We find a positive and statistically significant coefficient of political advertising on a candidate's vote share for all three variables. We used the same discrete choice model from our main analysis and the same comprehensive set of control variables at the party, constituency, and candidate level. Shown are the estimated coefficients for a candidate's impressions (top), ad spending (middle), and the number of ads (bottom). Reported are mean (dot) as well as $\alpha = 95\%$ (thick bars) and 99% CIs (thin bars).

find a positive and statistically significant coefficient (coef: 0.018, SE = 0.004, $t = 4.701$, $P < 0.001$, 95% CI = [0.011, 0.026]). (ii) For the number of ads, the estimated coefficient is also positive and statistically significant (coef: 0.017, SE = 0.002, $t = 8.770$, $P < 0.001$, 95% CI = [0.014, 0.021]). In addition, considering the z-standardization, the coefficients of both (i) ad spending and (ii) the number of impressions are of similar size compared to that of our main analysis as indicated by overlapping CIs (see Fig. 3). Details are in Supplementary Material K.1.2.

To evaluate how unobserved confounding would affect our estimates, we again performed a causal sensitivity analysis (47). We find that unobserved confounding cannot reasonably explain away our findings of a positive and statistically significant coefficient for a candidate's (i) spending and (ii) number of ads. Details for the causal sensitivity analysis are in Supplementary Material K.1.3.

Political advertising across platforms

Advertisers on Meta can decide whether they want to publish an ad only on Facebook (Facebook-only), only on Instagram (Instagram-only), or simultaneously on both platforms (Dual platform). While we focused on the overall effect of online political advertising across platforms in our main analysis, we further conducted three additional analyses studying political ads across platforms. For this, we re-estimated our main model but included an additional variable in form of a dummy indicating whether (i) a candidate published *"Facebook-only"*, (ii) *"Instagram-only"*, and (iii) *"Dual platform"* ads, respectively. We find a positive and statistically significant coefficient for *"Facebook-only"* and *"Dual platform"* but not for *"Instagram-only"*. The coefficient of impressions is still positive and statistically significant across all models and of similar size to our main analysis. Details are in Supplementary Material K.2.

Political advertising in East- and West-Germany

Following the historical division of Germany after World War II, there still prevail differences between the former East and West Germany. To account for this, we re-estimated our main regression model but included an additional dummy variable indicating whether a candidate is running in East Germany. Here, we find no statistically significant coefficient. Still, the coefficient of a candidate's impression is positive, statistically significant, and in good agreement with our main analysis. Details are in Supplementary Material K.3.

Goals of political advertising on social media

Political campaigning follows various goals (11, 18, 68–70). On the one hand, campaigns may, for example, publish ads that mobilize voters close to the candidate's position and call them to vote. On the other hand, candidates may use ads to persuade voters of their political position. We have thus explored the goals of political ads on social media during the 2021 German Federal Election. To do so, we classified all ads based on whether they are designed to persuade, mobilize, inform, promote events, or call for donations using Llama-3.3-70 B-Instruct-Turbo, a state-of-the-art large language model developed by Meta (71). Following best practices (72), we performed a validation against human annotators and found an agreement rate of 83% with the labels assigned by Llama. Additionally, we calculated Cohen's kappa to assess inter-rater reliability. We find a substantial inter-rater reliability (Cohen's $\kappa = 0.75$), supporting the robustness of our approach.

We find that a majority of ads published on Meta during the 2021 German Federal Election are designed to persuade (38%) and mobilize (31%) voters. Only a few ads are informational (19%), promote events (12%), or call for donations (0.2%). The latter is not surprising since parties in Germany are mostly funded publicly or via membership fees and would rarely call for donations.

We also assessed whether candidates who rely on persuasion or mobilization ads are more successful using regression analysis. Specifically, we re-estimated the regression model from our main analysis but also included a candidate's share of impressions from persuasion or mobilization ads. We do not find evidence for a statistically significant relationship between a candidate's share of impressions from persuasion or mobilization ads and electoral success in our data. Importantly, the positive and statistically significant effect of a candidate's total number of impressions remains robust. This suggests that electoral success is driven more by the overall reach of a candidate's ads rather than their specific goal. Details are in Supplementary Material K.4.

Diminishing returns to advertising effects

Advertising returns are fairly constant in ground (73) and TV campaigns (35). However, differential advertising effects for social media ads in the United States (43) may suggest diminishing returns to political advertising on social media. To test for this, we re-estimated our main regression model but included a quadratic term of a candidate's impressions as an additional variable. We find a negative but not statistically significant coefficient for the quadratic term and thus limited evidence for diminishing returns of political advertising on social media. Details are in Supplementary Material K.5.

Discussion

Social media has a widespread impact on online and offline behavior of individuals and society (3, 14, 23, 74–77). With around 4.95 million users worldwide (78), social media has become an important factor in politics (2, 3, 5). Political campaigns thus spent substantial amounts of their budget on social media ads (5). Here, we aimed to estimate the countrywide effect of political

ads from Facebook and Instagram on election outcomes during the 2021 German federal election and found robust evidence that election campaigns on social media influence election outcomes.

Previous literature has extensively analyzed the effectiveness of *offline* election campaigns (28, 30–33, 35, 36, 42, 48). In particular, prior research has estimated the effect of campaign spending (28) and TV ads (30–33, 35, 36, 42, 48), both of which have a consistent and significant impact on election outcomes, which may even swing elections (32). However, due to differences in offline vs. online political advertising (3, 18), the effect of political advertising on social media may differ from that of offline advertising. In this regard, prior works have shown that political advertising on social media affects voter turnout (43) and vote choice (45), yet these works are limited in that they only consider political ads published by only one party and in a specific area (see Background for an overview of the literature). Others have also shown the persuasiveness of online political ads in survey experiments (60). However, this approach may suffer from an opt-in bias and merely collects preferences rather than actual votes. In contrast, large-scale evidence that is representative of the whole population and different parties is missing. Here, we add a novel analysis studying the *countrywide* effect of political advertising using social media on election outcomes across the *full* political spectrum.

Our result that political ads influence election outcomes may be explained by two characteristics that are unique to advertising on social media. On the one hand, election campaigns on social media can reach a wide audience at comparatively low costs (3). Thus, the sheer volume of social media ads might allow election campaigns to approach and influence a substantial number of voters. On the other hand, political ads on social media can be targeted to specific user groups with tailored messages (14, 15, 17) and, further, offer flexibility to quickly respond to new events as well as to changes in the political discourse (18, 19). Notably, our finding that political advertising on social media is effective was not self-evident. First, influencing election outcomes through social media is generally considered to be difficult as many voters have strong prior beliefs (20–22). Second, a substantial proportion of social media users are not interested in politics (23) and will thus have a low receptiveness to political ads. Third, social media use is especially pronounced in comparably young and tech-savvy audiences (79), which may dampen the overall effectiveness of political ads at the societal level. Despite these potentially limiting factors, our results empirically confirm the effectiveness of political advertising on social media.

The real-world effect of political advertising on election outcomes is subject to discussion (21, 22, 33, 36, 43–45). Nevertheless, in close races, even small advertising effects can be meaningful and may even sway elections (32). Our regression model predicts that keeping abstentions constant, ~200,000 additional impressions increase a candidate's votes by 2.1%. Our results further imply an average price per vote of EUR 4. Although a 2.1% increase may seem small, our estimation suggests that a 2.1% increase would only cost EUR 2,000 and would have swayed the election outcome in 12 constituencies (out of 299) during the 2021 German federal elections.

Due to the observational nature of our study, a careful research design is needed to alleviate endogeneity concerns. Our main results are based on regression analysis, where we counter endogeneity concerns through a comprehensive set of controls and fixed effects. However, there may remain a potential endogeneity issue related to further unobserved candidate characteristics, which we addressed using causal sensitivity analysis (47). Causal sensitivity analysis can alleviate endogeneity concerns by quantifying the strength needed for unobserved confounders to overturn our findings and thus establish that our effects cannot be explained away at a reasonable level of unobserved confounding. Overall, our results thus offer robust empirical evidence to reasonably argue for a statistically significant relationship between political advertising and a candidate's election outcome.

A particular strength of this study is that we examine the role of political advertising using a unique and large-scale dataset of political ads from the Meta ad library (39). Following public pressure (5) and legislative initiatives (38), social media platforms committed to more transparency, which has led Meta to release a comprehensive library of all political ads published on their platforms. Importantly, the Meta ad library provides information on real-world impressions, which are otherwise not accessible. On this basis, we can—for the first time—use actual impressions in an empirical analysis, instead of the number of ads or estimated advertising exposure as in prior works on TV ads (32, 33, 35, 36, 42, 48). In addition, the global dominance of Facebook and Instagram, which manifests in a global market share of 78.5% (62) and ~5 billion active users a month (78), contributes to that our results are representative and generalize well to other social media platforms.

As with other research, ours is not free of limitations that offer opportunities for future research. First, our results may be specific to the 2021 German federal election. However, the federal structure in Germany with its direct election of constituency representatives is similar to those of other countries, and, furthermore, the election is comparatively large with more than 60 million eligible voters and candidates from multiple parties across the political spectrum (61). The German federal election should therefore be representative of elections in various other democracies. Second, we analyzed political advertising on Facebook and Instagram, which are—by far—the largest social media platforms and were deemed effective by a large share of candidates (6). Nevertheless, future research may also extend our analysis to other platforms. Third, our analysis relies on the Meta Ad Library, which has been the subject of some scrutiny, particularly at its launch (80, 81). Concerns include the possibility of incomplete inclusion of political ads and the potential for advertisers to circumvent detection (80, 81). These issues may be particularly pronounced in contexts like the United States, where private organizations play a larger role in campaign funding, making transparency more challenging. In contrast, the structural features of the 2021 German Federal Election may help mitigate these risks. Political campaigns in Germany are primarily managed by parties and candidates themselves, ensuring greater transparency and reducing the likelihood of undetected ads. Moreover, the Ad Library has been extensively utilized in publications across disciplines such as computer science (52, 54, 55), communication science (82, 83), and political science (3, 11, 84).

Finally, while our analysis leverages impressions from the Meta ad library as a direct measure of ad exposure, we acknowledge that impressions indicate only the opportunity for users to see an ad and do not guarantee cognitive engagement or message retention. This is inherent to most measures of exposure across advertising channels, such as TV, radio, or the web (32, 33, 35, 85–87). However, previous research demonstrated that impressions from social media ads increase the success of commercial advertising campaigns (85, 88), which is likely to transfer to political campaigns. Impressions further provide a unique advantage by eliminating estimation errors associated with indirect proxies

(e.g. estimated exposure to TV ads). Future research could explore methods to better distinguish between passive exposure and active processing of social media ads to further refine our understanding of their effectiveness.

The importance of social media for political advertising has grown tremendously over the last years (5, 18). This has implications for policymakers and society. One concern is that ads from social media platforms could be used to manipulate elections (20). Here, past examples such as the Cambridge Analytica scandal and the Russian interference during the 2016 US presidential election (9, 20) aimed to manipulate voting behavior show that social media ads can affect elections. To allow for more transparency, new legislative initiatives are underway to promote data access and thereby enable empirical evidence on the role of political advertising on social media. Monitoring political advertising on social media will thus be crucial to ensure fair and democratic elections.

Materials and methods

German federal election

In this paper, we analyze political advertising on Meta (i.e. the platforms Facebook and Instagram) during the 2021 German federal election. Overall, votes were cast in 299 constituencies of roughly equal population size. Each voter casts two votes: The first vote (also called "direct vote") elects a constituency representative for parliament. In contrast, the second vote represents a party vote and is thus unrelated to a specific candidate. Here, we focus on the first vote and thus election outcomes at the candidate level. For details about the electoral system in Germany, see Supplementary Material A.

Data

Election data

We collected official election data via the Federal Returning Officer (http://bundeswahlleiter.de). In particular, we collected a candidate's vote share, which represents the dependent variable in the subsequent analysis, and data on whether a candidate is an incumbent or a contender. In addition, we collected the number of abstentions and various other variables at the party level for each constituency. For the latter, we retrieved (i) the vote share of the second vote for each party (*Vote share: Party vote*), and (ii) the vote share of the first vote for each party during the previous federal election in 2017 (*Vote share: Previous election*). Summary statistics are in Supplementary Material C.

We further collected data on candidate characteristics using the German Longitudinal Election Study (GLES) Candidate Study (6), which provides information on the campaigns of each candidate. The GLES is the central survey in Germany for high-quality data on German elections conducted by the GESIS Leibniz Institute for the Social Sciences (6).[a] Specifically, we collected data on a candidate's time investment (*Time investment (h/week)*), budget (*Budget ()*), team size (*Team size*), and whether a candidate was supported by professional consulting during the campaign (*Consulting* (=1 if yes)). Throughout our work, these variables are used to capture the effort of a candidate and the quality of her/his campaign. For simplicity, we refer to them as quality/effort. Motivated by prior literature, a candidate's quality is typically reflected by the funds a candidate can raise as well as her/his organizational skill during the campaign (89), which is necessary when managing larger teams or when interacting with professional consultants. In addition, a candidate's effort can be gauged by the financial and personal investments made into the campaign, which are related to factors such as their budget (including private funds) and the amount of time devoted to the campaign. Summary statistics are in Supplementary Material C.

Social media ads for political advertising

Our analysis is based on a large-scale dataset of 21,641 political ads published by all 1,785 candidates running as constituency representatives of all major parties (i.e. *SPD*, *Union*, *Grüne*, *FDP*, *AFD*, and *Die Linke*) on Meta, that is the social media platforms Facebook (http://facebook.com) and Instagram (http://instagram.com). We focus on online political advertising on Meta for the following reasons. First, Facebook and Instagram are highly popular among users in Germany with an overall market share of 77% in 2021 (62). Second, both platforms are considered to have a large influence on the political debate (90, 91). Third, Meta has several practical benefits for political advertising as it allows to run campaigns with far-reaching audiences, granular targeting, and comparatively low costs (3). Examples of political ads published on Facebook and Instagram are in Fig. S3.

The observation period was set to resemble the main campaign period of the election, i.e. from April 26 to the election day (i.e. 2021 September 26). In fact, the *Union* and *Grüne* nominated their candidates for chancellor in the week prior to the starting date of our observation period (see Supplementary Material A for details). Hence, our data should capture the main campaign activities leading up to the election. We also perform robustness checks with other observation periods (see Supplementary Material J.3.1).

We collected political ads via the Meta ad library (http://facebook.com/ads/library/). Importantly, the ad library contains all political ads published on Meta and provides detailed information about each ad, namely, (i) content, (ii) page name, (iii) ad spending (in EUR), (iv) sponsor, and (v) the number of impressions. An impression on Meta is recorded each time an ad is rendered on a user's screen (40) and thus provides a direct measure of exposure to political ads. The Meta ad library also includes information on how impressions were distributed across gender (i.e. female, male, diverse) and age (i.e. 18–24, 25–34, 35–44, 45–54, 55–64, 65+). In addition, the ad library indicates whether a political ad was published (i) only on Facebook (named "Facebook-only" throughout the paper), (ii) only on Instagram (Instagram-only), or (iii) simultaneously on both platforms (Dual platform).

Our analysis is based on the candidate level. For this, we first matched candidates with their political ads based on the candidate name, the page name, and the sponsor of the political ad. As such, we included political ads that (i) were sponsored by a specific candidate but published under a different page name (e.g. candidates sponsor political ads for the regional chapter of their party) and (ii) were not sponsored by the candidate, yet published on a candidate's page on Facebook or Instagram (e.g. a party sponsors a political ad for their candidate). This matching procedure guarantees a comprehensive sample of all political ads associated with each candidate. In cases where an ad was matched with multiple candidates, we manually assigned the ad to the correct candidate. Subsequently, we aggregated all political ads at the candidate level. Meta only reports ad spending and the number of impressions in discretized buckets (see Supplementary Material E for details). We averaged the maximum and minimum of each bucket to obtain conservative point estimates of the ad spending and the number of impressions per ad. As a result, we obtain the following variables at the candidate level: (i) total number of ads, (ii) total ad spending, and (iii) the total number of impressions. For candidates who did

not advertise on Meta, we set the total number of ads, total ad spending, and the total number of impressions to zero, thereby obtaining a complete sample of all candidates running for constituency representative. Summary statistics are in Table S1.

Some candidates ran ads across all parts of Germany. For example, the top candidates typically play a strategic part in the election campaigns of their parties and, therefore, use political advertising on Meta to reach voters in all parts of Germany. To account for this, we excluded impressions outside a candidate's home state as they are unrelated to their direct election but also implemented a robustness check including all impressions (see Supplementary Material J.3.4).

Regression analysis

We use regression analysis to estimate the association between a candidate's impressions and their election outcome. While this may generally be subject to unobserved confounding, we later address this concern by employing a causal sensitivity analysis. The main explanatory variable is the total number of impressions of a candidate's political ads on Meta. An important characteristic of multiparty electoral systems is the interdependence of vote shares between candidates running in the same constituency (67). The reasons for this are that (i) the vote share y_i of each candidate in a constituency is bounded by $y_i \in [0, 1]$ and that (ii) the vote shares of all candidates running in a constituency sum up to one (67). To account for this, we follow prior literature on multiparty elections (25, 92) and employ a conditional logit model to estimate the effect of a candidate's impressions on social media on their vote share. The conditional logit model is a form of discrete choice model that allows one to model a voter's choice for a certain candidate over another option.

We anticipate that a voter's choice to support a candidate is influenced by the number of times they see that candidate's political ads on Meta. This is rooted in previous research on digital marketing (17, 93, 94) suggesting that a higher number of impressions of political ads will affect voters' attitudes toward a candidate. For instance, a greater number of ad impressions could either persuade the voter to favor a particular candidate or mobilize them to vote. Additionally, increased ad exposure can inform voters about a candidate's agenda, potentially broadening their set of considered candidates when making a voting decision.

Formally, we thus assume that the utility U of a voter v voting for candidate i is a function of ϕ_{vi}, the total number of impressions of candidate i's political ads on Meta seen by voter v, and a vector of control variables X_i such that

$$U_{vi} = \beta\phi_{vi} + \gamma X_{vi} + \epsilon_{vi}, \tag{1}$$

where ϵ_{vi} are independent and identically distributed across voters and candidates and follow a type-I extreme value distribution. The probability of a voter v voting for candidate i can then be described by

$$P_{vi} = \frac{\exp(\beta\phi_{vi} + \gamma X_{vi})}{\sum_k \exp(\beta\phi_{vk} + \gamma X_{vk})} \tag{2}$$

with X_{vk} being the kth candidate characteristic observed by voter v. The discrete choice model then estimates the logarithm of the probability P_{vi} of voter v voting for candidate i compared to the probability of the same voter choosing a reference category (P_{v0}) via

$$\ln(P_{vi}) - \ln(P_{v0}) = \beta(\phi_{vi} - \phi_{v0}) + \gamma(X_{vi} - X_{v0}) + \varepsilon_v. \tag{3}$$

For our analysis, individual voting data were unavailable. We thus follow (25) and approximate the probabilities in Eq. 3 by the number of votes for each candidate (s_i) and use the number of abstentions (s_0) in a constituency as the reference category, which results in

$$\ln(s_i) - \ln(s_0) = \beta(\phi_i - \phi_0) + \gamma(X_i - X_0) + \varepsilon_v. \tag{4}$$

In contrast to choosing another party as our reference category, this specification allows us to model the effect of political advertising on social media across all constituencies and parties. Assuming that ϕ_0 and X_0 are equal to zero, we then model $\ln(s_i) - \ln(s_0)$ via

$$\ln\left(\frac{s_i}{s_0}\right) = \alpha + \beta\phi_i + \gamma X_i + \delta_i + \zeta_i, \tag{5}$$

where $\ln(\frac{s_i}{s_0})$ is the log-transformed ratio of a candidate's votes over abstentions, α represents the model intercept, β measures the effect of the total number of impressions of a candidate's political ads, γ refers to the effects of all control variables in X_i, δ_i are party fixed effects, and ζ_i represents constituency fixed effects.[b] Note, that our analysis is on the candidate level and there are multiple candidates running for a seat in the parliament in each constituency.

For our regression model, we use a comprehensive set of controls (i.e. X_i in Eq. 5) in combination with fixed effects at the party and constituency level (i.e. δ_i and ζ_i in Eq. 5) to address various sources of heterogeneity. Specifically, we control for the following: (i) Similar to the United States where certain states are considered as predominantly Republican/Democratic (59), regions in Germany also exhibit different party preferences (e.g. the *Union* is traditionally strong in Bavaria). Hence, we include the party vote share in a constituency (*Vote share: Party vote*) to account for overall party preferences. (ii) Party preferences can also vary over time (35). To account for election preferences over time, we thus include the direct vote share of candidates in the previous election, that is, the 2017 German federal election (*Vote share: Previous election*) as a control variable. (iii) Political science literature has demonstrated that incumbents have a significant advantage in winning an election over contenders (63). Therefore, we include a dummy (*Incumbent*) indicating whether a candidate is an incumbent (=1) or contender (=0) to control for the presence of an incumbency advantage. (iv) An important determinant of a candidate's electoral success is their quality and effort (66). Hence, we account for candidate quality/effort during campaigning by including a candidate's time investment, budget, team size, and whether they were supported by professional consulting (=1) or not (=0). (v) A party's election campaign depends on various party characteristics (57). To account for such unobserved party factors (e.g. TV ads, campaign budget, strategy, and popularity), we add party fixed effects by including a dummy variable for each party to our regression model. (vi) To account for constituency-specific heterogeneity (e.g. unemployment rate, migrant stock), we follow previous research (35) estimating the effect of TV ads in US elections and included constituency fixed effects by adding dummy variables for each constituency to our regression model. As part of our robustness checks (see Supplementary Material J), we control for further sources of heterogeneity. Therein, we add additional controls to account for the viewership (i.e. the share of ad impressions by age and gender) and content (i.e. the tone of an ad's content) of an ad, as well as further candidate characteristics (i.e. age, gender, job, popularity).

We z-standardize the number of impressions to facilitate the interpretability of our results. Hence, all else equal, a 1 SD increase in impressions predicts a β% increase in a candidate's vote share. We test whether the coefficients are significantly different from zero using two-sided t tests and impute missing values using median imputation. The statistical analysis was implemented in R 4.2.2. If not stated otherwise, we use the same approach and set of controls for all subsequent analyses.

Our conditional logit model is built upon the assumption of independence of irrelevant alternatives (IIA) (95). Although a violation of this assumption might compromise the accuracy of our results, the relevance of IIA to our study is limited as argued in previous research (95). Nevertheless, we provide a detailed discussion on IIA in Supplementary Material F and an additional robustness check that relaxes the IIA in Supplementary Material J.

Robustness checks

Causal sensitivity analysis

Our regression model addresses multiple sources of endogeneity through a comprehensive set of controls and fixed effects. However, there may remain some endogeneity concerns related to unobserved confounding. To alleviate remaining endogeneity concerns related to unobserved confounding, in particular, with regard to unobserved candidate characteristics (e.g. some candidates could be better versed in using Meta to publish political ads), we conducted a causal sensitivity analysis (47, 96, 97).

Causal sensitivity analysis is frequently used in political science literature (64, 65) and allows us to (i) quantify the degree of unobserved confounding required to invalidate our results and (ii) evaluate whether unobserved confounding as strong as the association between observed covariates with the treatment and outcome would explain away the estimated effect. Here, we follow the approach described in (47). Our causal sensitivity analysis suggests that unobserved confounding may not reasonably explain away this estimated effect, hence, corroborating the reliability of our findings. Details are in Supplementary Material I.

Additional checks

We further performed a series of checks to ensure the robustness of our results. In particular, we performed robustness checks regarding the (1) estimator (e.g. we used a linear model and a SUR model (67)), (2) control variables (e.g. we included additional control variables such as a candidate's age, gender, and job), (3) data sample (e.g. we checked different campaign periods). Across all checks, our findings remained robust. That is, we found a positive and statistically significant coefficient for a candidate's impressions. Details are in Supplementary Material J.

(1) Estimator: We checked the robustness of our results with regard to our estimation technique. Specifically, we performed the following checks: (i) We used a linear regression model, which allows for better interpretability but cannot account for the interdependence of vote shares of candidates that run in the same constituency. (ii) We used a seemingly unrelated regression (SUR) model as outlined in (67). Thereby, we relaxed the IIA assumption of the conditional logit model but could not estimate a joint coefficient across all parties. (iii) We changed our dependent variable and estimated the effect of a candidate's impressions on their over-/underperfomance (i.e. the difference between a candidate's vote share [*Direct vote share*] and the corresponding party vote share [*Vote share: Party vote*]). (iv) We re-estimated our model but now clustered standard errors on the constituency level to control for dependencies within a constituency.

(2) Control variables: We also accounted for additional sources of heterogeneity by including different control variables. Here, we conducted the following checks: (i) We added control variables to account for candidate heterogeneity. Specifically, we re-estimated our regression model but this time included a candidate's age, gender, job, and whether the candidate is on an election list by the corresponding party. This accounts for the fact that, for example, older candidates might be perceived as more experienced or that certain jobs signal a higher competency, thus resulting in larger vote shares. (ii) Candidates may receive different levels of attention by the media. To control for this, we relied on the GLES Candidate Study (6) and included an additional variable in our regression model that measured how often a candidate was mentioned by the media. (iii) Previous research has shown that advertising effects differ across genders for online purchase decisions (98). To control for such gender effects, we included the share of views by women of a candidate's political ads on Meta into our regression model. In a similar vein, voters of different age groups might react differently to political ads. Hence, we also estimated a model including the share of views by different age groups (i.e. 18–24, 25–34, 35–44, 45–54, 55–64, 65+). (iv) Ad tone of TV ads (i.e. negative vs. positive ads) was found to have a significant impact on election outcomes (33, 42). We thus control for positive/negative tone in political ads on Meta. For this, we computed the average tone of a candidate's political ads using the German SentiWS dictionary (99) following best practices (72). Subsequently, we re-estimated our regression model from the main analysis and included the average tone of a candidate's political ads as an additional control variable. (v) Candidates may change their advertising behavior based on their competitors' campaign efforts. To control for this, we re-estimated our discrete choice model from the main analysis and included the total spending of other candidates running in their constituency. As an alternative specification, we used a candidate's expenditure share for political ads on Meta relative to the total expenditure of other candidates running in their constituency. (vi) To control for all effects outlined in (i)–(v) at once, we also re-estimated our regression model including all of the above control variables. Summary statistics for the additional control variables are in Table S1.

(3) Data sample: We checked whether our results are sensitive to our data collection. (i) We repeated our analysis for different observation periods. Specifically, we used five different observation periods. Thereby, we account for different campaign lengths. By in/excluding the week prior to the election, we further account for the effect of mail-in ballots. (ii) We repeated the analysis including all candidates from other parties or running as independents that were previously excluded. (iii) We conducted three additional analyses to check for the influence of outliers on our results: First, we winsorized our data and excluded candidates with the top/bottom 1% and 5% of impressions, thereby controlling for the influence of candidates who barely/extensively advertise on Meta. Second, we excluded the top candidates of each party (i.e. Olaf Scholz (*SPD*), Annalena Baerbock (*Grüne*), and Christian Lindner (*FDP*); the top candidates of the other parties did either not run as constituency representatives or did not publish political ads on Facebook and Instagram), as they might profit from their high popularity and visibility during the election. (iv) We repeated our analysis but included impressions outside a candidate's home state.

Overall, we found a robust and statistically significant coefficient for our impression variable. In particular, our results are robust across different model specifications, additional control variables, and different data samples.

Notes

[a] Further details on the survey and corresponding survey methods are available at https://doi.org/10.4232/1.14100.

[b] Due to the logarithmic dependent variable, the regression coefficients should be interpreted as follows: A one-unit shift in the explanatory variable of interest is associated with a $(e^{coef} - 1) \times 100\%$ increase in the ratio of a candidate's votes over abstentions.

Supplementary Material

Supplementary material is available at *PNAS Nexus* online.

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Author Contributions

D.B. analyzed the data. D.B., N.P., and S.F. conceived and designed the experiments, contributed to results interpretation, and manuscript writing. All authors approved the manuscript.

Preprint

This manuscript was posted on a preprint: https://osf.io/preprints/osf/q8mxj.

Data Availability

Election data and advertising data for this study are publicly available via the Federal Returning Officer (61) and the Meta ad library (39), respectively. Materials to replicate our results are available at https://github.com/DominikBaer95/SocialMediaElections. The raw data can be retrieved from D.B. upon reasonable request to protect the privacy of the candidates. Access to the data of the German Longitudinal Election Study (GLES) Candidate Study (6) must be requested via https://doi.org/10.4232/1.14100 and cannot be shared by the authors due to data protection agreements.

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