The Electoral Effects of Voting Technology: Evidence from Bulgaria *

Milena Djourelova† Teodora Tsankova‡

September 2025

Abstract

Can voting technology improve the integrity of elections in developing democracies? We study this question in the context of Bulgaria's transition from paper ballots to direct-recording electronic machines – a measure intended to improve accuracy, enhance ballot secrecy and reduce opportunities for human interference in the voting process. Our empirical strategy leverages a sharp discontinuity in the allocation of voting machines across polling stations, and variation in their implementation across nine general elections. We document two main findings. First, in line with prior work, machine voting significantly increases the share of valid votes. Second, machine voting causes a large reduction in turnout, concentrated in poor, rural, and high–fraud-risk localities. This decline is driven by votes for parties that were locally dominant at baseline, while votes for other parties remain unchanged. Notably, the effect arises only when machine voting is fully implemented—but not when it is optional alongside paper ballots. Representative surveys suggest that a reduction in bought or fictitious votes is a likely mechanism, and provide little support for alternative explanations such as voters' technological aversion. Taken together, the findings indicate that, in settings with independent electoral authorities, voting technology can mitigate localized forms of electoral fraud, and inform ongoing debates over its implementation.

*We thank Yuliana Galyova and the team of Gallup International for leading the survey design and implementation in the field. We also thank Steve Coate, Claudio Ferraz, Thomas Fujiwara, Clement Imbert, Alessandro Lizzeri, Nathan Nunn, David Schindler, Jeff Weaver, and seminar and conference participants at Cornell, Tilburg, Utrecht, Nova SBE, MSU, USC, Brown, Princeton, the Bulgarian Council for Economic Analyses, IDB, the 2024 "Polarize" Workshop in Bergen, the 2024 UBC-Berkeley Political Economy Conference, the 2024 "Women in State Capacity" Workshop in Oxford, the 2025 IEB Workshop in Political Economy, and the 2025 Barcelona Summer Forum for helpful comments and suggestions.

†University of Southern California and CESifo. Email: milena.djourelova@usc.edu.

‡Tilburg University and IZA. Email: T.N.Tsankova@tilburguniversity.edu.

1 Introduction

The legitimacy and accountability of elected governments hinge on the implementation of fair and inclusive elections (Norris 2014). Yet, many democracies grapple with concerns over the integrity of their electoral processes. Between 2020 and 2024, one in five elections worldwide faced legal challenges over voting or vote counting procedures, and one-third of voters today live in countries with deteriorating electoral integrity (International IDEA 2024). Understanding whether, and which, electoral reforms can address these problems is therefore an important policy question.

In this paper, we ask whether voting technology can be instrumental in improving the integrity of elections in developing democracies. We study the effects of machine voting—a technology currently employed in about 20 countries, including Brazil, India, and the Philippines, to record and count votes electronically. By design, voting machines reduce ambiguities in how voter intent is captured, and there is robust evidence that they lower the incidence of invalid votes (Fujiwara 2015). Much less is known, however, about their broader impact on electoral integrity. Machines are hypothesized to enhance ballot secrecy, by limiting opportunities for tracking votes (e.g., through pre-filled ballots), and to curb interference by polling-station officials, since they generate real-time records of ballots cast.[1] Yet rigorous causal evidence on whether such mechanisms actually reduce electoral clietelism and fraud remains scarce—a question that is especially salient given recent political resistance to machine voting adoption in several countries.[2]

We study this question in the context of Bulgaria—a democracy with an independent electoral authority and strong electoral competition, yet persistent concerns over electoral integrity in recent decades. Numerous accounts document widespread vote-buying and coercion, including monetary incentives or threats used to mobilize voters in favor of a given

[1]There arguments assume that electoral results are not *centrally* manipulated, and thus apply to settings where electoral authorities are politically independent. They do not necessarily extend to autocracies or hybrid regimes where this condition is not met.

[2]For example, in Brazil, former president Jair Bolsonaro has repeatedly questioned the integrity of machine voting and sought to replace it with printed ballots. In Bulgaria, machine voting was scaled back to a mixed system in 2023 due to backlash from established parties.

party, as well as pressure on polling station officials to interfere with the voting process (e.g., through ballot stuffing). Throughout the paper, we use the term "vote-buying/coercion" to refer to both forms of interference.[3] According to a nationally representative Gallup survey, over 50% of Bulgarians report knowing of such practices in their locality. Only 10% express confidence in the honesty of elections—the lowest level globally and six times below the EU median (Gallup 2024).

In an attempt to reduce the share of invalid votes and the incidence of vote-buying, Bulgaria introduced direct-recording-electronic (DRE) machine voting in 2021. From an empirical perspective, the setting has several useful features that allow us to credibly evaluate the causal effects of the voting technology. First, Bulgaria had 7 general elections since 2021 with different versions of machine voting – either mandating it (a regime we refer to as "machine elections"), or giving voters the choice between machine and paper ballot (a regime we refer to as "mixed elections"). Second, in all of these elections, machine voting was only implemented in polling stations with 300 or more ex-ante registered voters, while polling stations below this cutoff continued to vote with paper ballots throughout. The threshold was introduced for cost and logistical reasons in distributing the machines, and no other policy employed the same cutoff. Under the assumptions of no manipulation of the running variable and continuity of potential outcomes around the threshold, this discontinuous rule allows us to estimate the causal effects of machine versus paper-ballot voting on polling-station level electoral outcomes in a regression-discontinuity framework. We provide evidence in support of these assumptions – the distribution of the number of ex-ante registered voters is smooth around the threshold, and we find that baseline electoral outcomes (prior to the introduction of machine voting), the baseline socio-economic characteristics of polling station localities and the total number of registered voters, are largely balanced around the threshold. Thus, we find no evidence of manipulation in either the assignment of voting machines or the composition of voter lists in response to this assignment.

[3]The corresponding Bulgarian term is also typically understood to encompass both practices. The results of our analysis are consistent with machine voting reducing opportunities for both types of manipulation, though we cannot disentangle their separate effects.

Our first result is that machine voting significantly increases the share of valid votes. This is driven by the almost full elimination of null votes (which account for about 6% of votes at baseline) – i.e., votes that cannot be unambiguously assigned to a party or are filled out improperly, and thus are not counted in the election results.[4] While this effect is ubiquitous, its magnitude varies depending on the socio-economic characteristics of polling station localities. It is significantly larger in localities with low education, a high share of ethnic minorities, or a high share of elderly population. We also document positive effects of the option of machine voting in mixed elections, with a magnitude roughly proportional to machine take-up.

Our second and novel result is that, despite improving accuracy, machine voting causes a sizable reduction in turnout. Pooling the three machine elections, we estimate a negative effect on turnout of about five percentage points. This is a sizable magnitude given the low turnout rate in Bulgaria in this period for stations close to the cutoff (about 41%). The decline is driven entirely by rural areas, by localities with low levels of education, and those with high unemployment. The decline is also significantly larger—reaching 12 percentage points—in localities with high baseline fraud risk, proxied by statistical anomalies in election returns identified by the Bulgarian Anti-Corruption Fund. In mixed elections, we find no significant impact of the machine option on turnout in any of the subsamples considered.

To assess the geographic scope of the effects and evaluate whether the RDD estimates might reflect spillovers in electoral activity across the machine assignment threshold, we implement an alternative empirical strategy: a difference-in-differences design at the municipality level–the level at which such spillovers are most likely to occur. This approach leverages cross-sectional variation in the share of registered voters assigned to polling stations with 300 or more ex-ante registered voters, and temporal variation in the implementation of machine voting. We complement this analysis by examining over-time changes in the electoral outcomes of below-threshold stations, as a function of the density of machine polling sta-

[4] We find that machine voting also leads to a significant but quantitatively small reduction in the share of blank votes – that is, votes explicitly indicating support for no one (an option available on both the paper and machine ballots).

tions near them (i.e. within the same municipality). Results from both tests suggest that spillovers are unlikely to account for the main findings, and that the turnout decline is driven by absolute changes in electoral activity above the machine assignment threshold.

Together, these results present a puzzle from a Downsian calculus-of-voting perspective. Despite increasing the probability of being pivotal – which should, if anything, increase voters' incentives to turn out – we find that machine voting has a strong negative impact on turnout. In fact, the second effect dominates the first in terms of magnitude resulting in a 10% reduction in the number of valid votes at the machine assignment threshold.

This pattern is consistent with the stated motivation behind the introduction of machine voting: to reduce the volume of bought and fictitious votes. Specifically, by preventing practices such as the distribution of pre-filled ballots and by reducing opportunities for tampering by polling station officials, the machine technology may directly reduce parties' willingness to pay for votes or hinder interference in machine polling stations.

We take two approaches to investigate this mechanism. First, we consider the implications of a reduction in vote-buying for the distribution of votes across parties. Given Bulgaria's proportional representation system in which strategic incentives play a limited role, we conjecture that the main determinant of the distribution of vote-buying activity is parties' ability to control brokers and/ or polling station committees. This leads to the prediction that a reduction in these practices should disproportionately weaken parties that were locally dominant under the paper ballot regime. We test this prediction by dis-aggregating the total valid votes received in each polling station into votes for parties that were most voted in that polling station at baseline (i.e., dominant parties), versus votes for other parties. We find that the reduction in total votes is driven entirely by votes for dominant parties (which decline at the threshold with more than 20%), while we find no effect for other parties. We show that this heterogeneity is not explained by a general reduction in turnout among supporters of established versus new parties, and that it is robust to alternative definitions of party dominance (e.g., a measure based on the party of the incumbent municipal mayor). Further disaggregating these effects, we find that vote losses in traditional strongholds are concentrated among parties typically associated with clientelistic practices.

Second, we partnered with Gallup International to implement a nationally representative, door-to-door survey that elicited retrospective reports of vote-buying and coercion in the period following the introduction of machine voting. We examine the relationship between these reports and respondents' self-reported polling station assignment—machine versus paper—controlling for individual and locality-level characteristics. Over half of respondents report having heard of vote-buying attempts in their locality between 2021 and 2024. However, consistent with the hypothesis that machine voting reduces this practice, the prevalence of such reports is lower among respondents assigned to machine polling stations. The difference is particularly pronounced in rural areas, where respondents assigned to machine stations are 23 percentage points less likely to report instances of vote-buying than those assigned to paper-based stations.

Finally, we consider an alternative mechanism: that turnout may be depressed by technology-related obstacles at the polling station or by voters' ex ante aversion to the technology. We view polling-station obstacles as an unlikely explanation for our results: we find no evidence of increased wait times or widespread technical malfunctions associated with machine voting. Other sources of aversion—such as security concerns—could, in principle, reduce participation if they affect the turnout decision ex ante and vary discontinuously at the assignment threshold; that is, if they are triggered by an individual's own assignment to a machine polling station rather than by broader electoral context. However, this explanation is difficult to reconcile with our finding that turnout declines even in the initial machine elections, when information about polling-station-level technology assignment was limited.

To assess this explanation more directly, our survey with Gallup included a question on self-reported discouragement from voting due to the use of machine technology. We find that, while 8% of respondents report being discouraged by the technology, this rate is statistically indistinguishable between individuals assigned to machine-voting and paper-ballot polling stations. If anything, in the rural subsample, the point estimates suggest that machine assignment is negatively associated with discouragement—though not significantly so. In other words, although some voters express aversion to machine voting, this aversion does not vary with assignment in a way that could explain the turnout discontinuity observed at the machine threshold.

This paper contributes to several strands of literature, most directly to work on the effects of voting technology. In line with existing evidence, we find that machine voting helps voters of lower socio-economic status cast valid votes, if they turn out (Fujiwara 2015; Hidalgo 2012; Aragón et al. 2025; Hanmer et al. 2010; Herrnson et al. 2012; Alters and Kooreman 2009).[5] Our main contribution is to show that machine voting has another important electoral effect – it can reduce localized electoral fraud. Although this mechanism has been hypothesized elsewhere, the empirical evidence in this regard remains sparse and debated. Hidalgo (2012) finds that the introduction of machine voting in Brazil led to a decline in votes for incumbent parties in three non-competitive states prone to fraud, while Schneider (2020) argues it increased voter registration fraud. In the context of India, Debnath et al. (2017) show that the rollout of electronic voting in state elections decreased turnout in states with high levels of fraud, whereas Desai and Lee (2021) find no such effect in national elections.[6]

Our setting allows us to more directly test the hypothesis that machine voting may be instrumental in reducing bought and fictitious votes. First, it features within-election and within-district variation in voting technology assignment, allowing us to examine its electoral effects holding constant candidate characteristics, constituency composition, and trends in political preferences. Second, we complement the administrative data with voter surveys to disentangle reductions in localized fraud from other possible mechanisms. Third, by comparing mandatory machine voting to partial adoption in mixed elections, we provide new causal evidence on which forms of implementation are effective in improving electoral accuracy and integrity.

[5]In contrast to our findings, Fujiwara (2015) and Aragón et al. (2025) find no economically significant effect of machine voting on voter turnout in Brazil and Peru, respectively. Unlike our setting, voting is compulsory in both countries, and turnout rates are roughly twice as high as in Bulgaria.

[6]In the context of the U.S., Card and Moretti (2007) test the hypothesis that touch-screen voting in the 2004 presidential election favored the incumbent Republican candidate due to deliberate manipulation. They find no evidence of manipulation and show that the observed patterns are explained by differential voter turnout. For a review of the adoption and effects of voting technologies in the United States, see Stewart (2011).

More broadly, our study contributes to a theoretical and empirical literature on vote-buying and coercion. Prior work has examined the effects of anti–vote-buying campaigns aimed at educating voters and reducing compliance with clientelistic practices (Vicente 2014; Schechter and Vasudevan 2023; Blattman et al. 2024). We instead study an institutional reform that changes the mechanics of how elections are conducted. This speaks to a central question in the literature: how vote-buying can persist under the secret ballot (Stokes 2005; Nichter 2008). Whereas existing explanations emphasize social networks and norms of reciprocity between brokers and voters (Finan and Schechter 2012; Duarte et al. 2023),[7] we highlight how procedural flaws—such as compromised secrecy—can sustain clientelism. In doing so, we relate to historical studies of the adoption of the secret ballot in the United States and Western Europe (Heckelman 1995; Aidt and Jensen 2016; Ferlenga and Knight 2025). In addition to enhancing secrecy, the voting technology reduces opportunities for polling station officials to tamper with votes. Our findings therefore relate to studies showing that increased monitoring of polling stations can reduce electoral fraud in high-risk environments (Enikolopov et al. 2013; Callen and Long 2015; Gonzalez 2021).

Finally, this paper relates to a literature on the impact of electoral rules on voter turnout – recently reviewed by Cantoni et al. (2024) – which has mostly focused on advanced democracies. Previous work has examined the electoral effects of various electoral procedures, including voter registration (Braconnier et al. 2017; Nickerson 2015), early or mail-in voting (Kaplan and Yuan 2020; Thompson et al. 2020), voter ID laws (Cantoni and Pons 2021), and ballot design (Shue and Luttmer 2009; Herrnson et al. 2012; Alles et al. Forthcoming). While the focus in this literature is on how electoral rules affect the cost side of voters' turnout decision or voter errors (in the case of ballot design), we investigate an additional channel that may operate in less established democracies – the effect of voting procedures on the mechanics of electoral clientelism and fraud.

The rest of this paper is organized as follows. Section 2 introduces the setting and the outline of Bulgaria's transition to machine voting. Section 3 introduces the data used in

[7] Related work examines how political parties monitor and incentivize brokers to enforce vote-buying agreements (Larreguy et al. 2016; Bowles et al. 2020).

our analysis. Section 4 presents our empirical strategy. Section 5 presents the main results. Section 6 presents evidence on the mechanism, and Section 7 concludes.

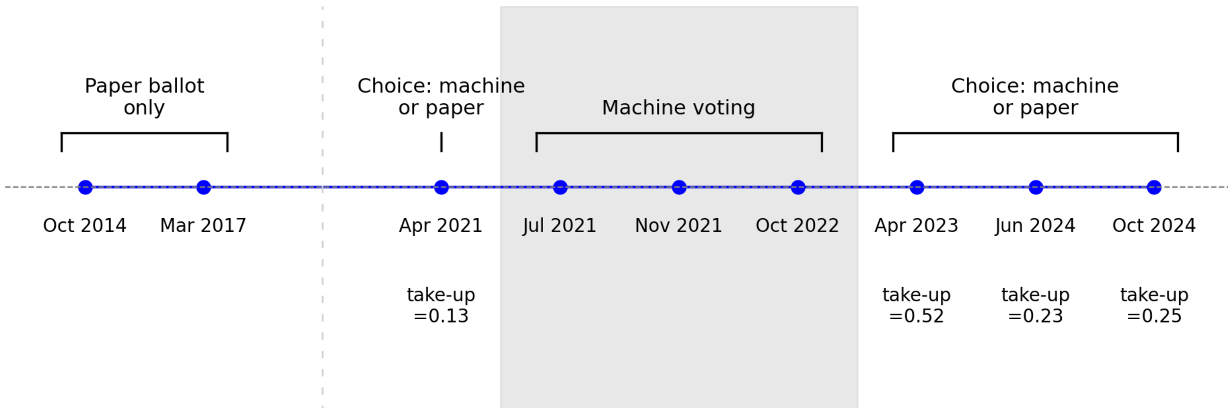
2 Background

Electoral system. Bulgaria has an open-list proportional representation system with 31 multi-member constituencies. Each constituency elects several representatives to the National Assembly, with the number of seats allocated based on population size. The overall distribution of seats is determined by the proportion of votes each party receives at the national level, with a minimum threshold of 4% vote share. The open-list element allows voters optionally to express preferences for candidates within the party list, which can lead to a re-ranking if one or more lower-ranked candidates surpass a threshold in preference votes (typically 7% of their party's total district votes). However, in practice, such re-ranking is a rare occurrence.

Election timeline and the introduction of machine voting. During the period of our study – and especially since 2021 – the Bulgarian political landscape is highly fragmented. For example, 19 parties and 9 coalitions participated in the general election of October 2024, with 8 making it to the National Assembly. Between 2021 and 2025, elected parties repeatedly failed to form a stable coalition government due to disagreements on major issues such as judicial reforms and Bulgaria's involvement in the war in Ukraine. This led to political deadlock and a series of snap elections. Several new parties entered in this period, and some established parties split up. As a result, party loyalty in our setting is quite low – exit poll data from Gallup suggests that in our sample period 35% of voters switch the party they vote for between consecutive elections.

The focus of this study are the nine parliamentary elections that took place during the period 2014-2024. Machine voting was first introduced in April 2021 on a voluntary basis – voters in polling stations with a machine had the choice between paper ballot and machine voting. After an amendment in the electoral law, machine voting became mandatory in polling stations with a machine. This was the case in the following three elections – July 2021, November 2021, and October 2022. Since April 2023, elections have reverted back to the earlier rules, offering a choice to voters. Figure 1 illustrates this timeline.

Figure 1: Timeline of elections



Notes: This figure reports the timeline of the nine general elections in our sample. These elections fall into three voting technology regimes: (1) Voting with paper ballot only; (2) Machine voting (in polling stations with ≥ 300 registered voters); (3) Mixed elections with choice between machine or paper (in polling stations with ≥ 300 registered voters). Polling stations below the 300 threshold continued to vote with paper ballot in all elections. For mixed elections, we report machine take-up (i.e., the share of machine votes) in polling stations close to the threshold, i.e., in the range of 300 to 400 registered voters.

Voting process. All eligible voters in Bulgaria are automatically registered to vote and assigned to a unique polling station based on their permanent address. In the polling station, the voter first presents their ID to a polling station official who verifies whether that voter is in the list of registered voters. Polling station officials are nominated by the political parties running in the election; each party has the right to appoint representatives to every polling station.

Figure A1 illustrates the voting process, comparing machine voting to voting with a paper ballot. In the case of paper-ballot voting, voters receive the ballot and mark their choice in a designated private area – typically behind a curtain or a paravent. In the machine voting case, the voter receives an electronic card that activates the machine, which is positioned such that the voter is visible to others but the machine screen is not. This layout further enhances ballot secrecy by increasing the visibility of any attempt to photograph the ballot—another common tactic used by vote brokers to verify bought votes.

Bulgaria uses Direct Recording Electronic (DRE) machines with a Voter-Verified Paper Audit Trail (VVPAT). This means that machine votes are recorded both electronically and physically: when a vote is successfully cast, the machine produces a printout that the voter checks and casts into a ballot box. Since 2023, official machine vote results are based on a manual tallying of these printouts. The machine interface has an identical format to the paper ballot, with parties listed on the left-hand side and candidates from the party lists listed on the right-hand side.

The arguments for machine voting. The motivation for the introduction of machine voting in Bulgaria was two-fold. The first explicit goal was to reduce the consistently high number of invalid votes (i.e. blank or null votes). In the 2017 parliamentary election, invalid ballots accounted for about 7% of all votes cast. Machine voting alleviates this issue as the machine interface makes it impossible to cast an ambiguous choice (though one can still cast a blank ballot by choosing the explicit ”support no one” option). For a vote to be valid, it must include a party choice, while choosing a candidate is optional.

The second explicit goal was to combat Bulgaria's persistent problem with vote-buying and voter coercion. The magnitude of this problem is difficult to quantify, but survey evidence from Gallup suggests that 11% of voters would be willing to sell their vote or would give in to coercion (an additional 8% state that they are unsure). These rates are higher among the poor, the less educated and among ethnic minorities – consistent with evidence that the susceptibility to clientelistic practices is linked to economic vulnerability (Bobonis et al. 2022; Fajury 2023).[8]

An example of a vote-buying scheme that machine voting was expected to impede is the so-called 'Indian string' scheme – an iterative process involving pre-filled ballots. The scheme begins with a broker handing a pre-filled ballot to a voter willing to sell their vote. The voter casts this ballot at the polling station and returns with the blank ballot as proof, allowing the cycle to continue. Machine voting disrupts this process, as the only 'ballot' cast is the real-time printout generated by the machine, which cannot be pre-filled.

[8] https://www.gallup-international.bg/42259/corrupted-vote-in-bulgaria/

Machine voting was also expected to limit opportunities for manipulation of the results by polling station officials. Unlike paper ballots, which can be added or altered during the counting process, machine printouts are generated in real time. Moreover, the dual recording of votes—both electronically and physically—may deter tampering by increasing the likelihood of detection.

On the other hand, there are other clientelistic practices that should not be affected by the technology. For example, while machine voting increases the secrecy of the vote, it does not necessarily affect the observability of turnout. Hence, we do not expect that pure turnout-buying strategies – i.e. the targeting of latent supporters conditional only on turning out and not on observing their votes (Nichter 2008) – will be directly impacted by the technology. In other words, using the terminology of Gans-Morse et al. (2014), enhanced vote secrecy should hinder pure vote-buying and double-persuasion, but not necessarily other strategies.

The arguments against machine voting. A number of concerns have been raised by opponents of machine voting, ultimately leading to the reintroduction of the mixed system in April 2023. The first argument was that the new technology may present an obstacle or inconvenience to some voters (e.g., to the elderly). In practice, the voting machine has an interface identical to the paper ballot and is no more difficult to operate than an ATM.

The second argument is about possible technical issues with the machines on election day. As insurance against such events, printed ballots are always supplied to all polling stations, to be used in case of a machine malfunction.

The third argument revolves around the security of the electronic system. In practice, machine votes in Bulgaria have been counted based on physical printouts since 2023 (electronically recorded votes are only used to verify this manual count). The security argument has nonetheless gained traction, culminating in the lead-up of the local elections of October 2023, when machine voting was banned 36 hours before election day because of a complaint about the documentation of the machines' certification. The Supreme Court later declared this ban unlawful.

Party stances on machine voting. Parties' positions on machine voting changed over time, but can be broadly categorized as follows (see Appendix Table A1). All three established parties in the pre-machine voting period — the center-right *Citizens for European Development of Bulgaria* (GERB), the ethnic-based *Movement for Rights and Freedoms* (DPS), and the *Bulgarian Socialist Party* (BSP) — expressed reservations about machine voting and voted in favor of reintroducing a mixed voting system in 2022. Critics dubbed these three parties "the paper coalition". The main proponents of full-scale machine voting were new parties established or gaining influence after 2017 – the reformist *We Continue the Change* (PP) and *Democratic Bulgaria* (DB), as well as the far-right *Revival* – which voted against reinstating a mixed voting system.[9] Voter preferences appear to align with these patterns, as reflected in machine take-up during mixed elections (Appendix Figure A2): supporters of established parties more often cast paper ballots, whereas supporters of new parties more often opt for machine voting.

Opposition to full-scale machine voting also tends to align with the extent to which parties are commonly perceived to engage in electoral clientelism or fraud, as shown in Appendix Table A1. To classify parties along the latter dimensions as systematically as possible, we use ChatGPT with the prompt: *"Classify parties in Bulgaria based on the extent to which they engage in electoral clientelism or electoral fraud. Base this assessment solely on evidence from official sources."*. The resulting classification—based primarily on OSCE/ODIHR election observation reports (OSCE Office for Democratic Institutions and Human Rights 2021, e.g.) and analyses by the Bulgarian Anti-Corruption Fund (Kraynova and Rusinov 2021)—identifies DPS and GERB as the parties most frequently implicated of such practices. These are two of the three parties in the "paper coalition" opposing machine voting in 2022. BSP – the third "paper coalition" party –is classified as occasionally implicated, while PP, DB, ITN, and Revival are not implicated in official sources. This classification broadly aligns with other classifications of clientelistic parties, such as the one

[9] The party *There is Such a People* (ITN), established in 2020, initially supported machine voting but raised concerns ahead of the 2023 local election. The party was not represented in the National Assembly at the time of the vote on reinstating the mixed system.

by the Democratic Accountability and Linkages Project (DALP).[10] Thus, in our analysis of party votes, we focus on the three established 'paper coalition' parties (DPS, GERB and BSP), but also single out the two parties flagged as clientelistic (DPS and GERB).

Case study. The hypothesized electoral effects of machine voting can be illustrated by the case of Bukovlak, a village in Northwest Bulgaria (the poorest region in the EU) with a documented history of electoral fraud over the years.[11] This case attracted media attention due to stark changes in electoral outcomes following the introduction of machine-only voting.

Appendix Figure A3 presents the evolution of electoral outcomes in Bukovlak. The three polling stations in the village exceed the 300-voter threshold and were thus all assigned at least one voting machine. The most notable pattern is that turnout collapsed from about 80% prior to the introduction of machine-only voting to about 20% after, picking up only when the mixed system was reintroduced. The decline was concentrated in votes for DPS and GERB – the two most voted parties in the 2014 and 2017 elections. Accounts from Bukovlak voters, cited in the media, suggest that this effect is due to a reduction in clientelistic mobilization efforts by vote brokers.[12]

Election recount. A partial recount of the October 2024 mixed election sheds light on the relative reliability of machine versus paper voting. The recount was mandated by the Constitutional Court in response to allegations of widespread electoral fraud. It covered 1,777 polling stations, in which machine take-up was 38%.

Appendix Figure A4 shows that nearly all revisions involved downward adjustments to the number of votes cast with paper ballots, typically due to missing ballots or other missing documentation. The largest adjustments affected two established parties – DPS–New Beginning

[10] The DALP classification is broader than ours: it reflects the propensity of parties to exchange material benefits for political support through policy promises and means other than direct electoral fraud. Nevertheless, the party ranking aligns with ours – DALP II, which is not publicly released but cited by Bliznakovski (2024), ranks DPS as most clientelistic, followed by GERB, BSP, Revival, ITN and PP-DB. DALP I, released in 2017, does not cover recently emerged parties which are relevant for our sample period.

[11] https://novini.bg/bylgariya/izbori/565227

[12] https://bntnews.bg/news/zhitelka-na-bukovlak-drug-pat-ni-davat-pari-da-glasuvame-sega-nishto-ne-zna html

and GERB. While payments to or coercion of voters may not be directly detectable through a recount, the pattern suggests that paper ballot votes are systematically more susceptible to tampering and inflation than machine-recorded votes.

3 Data

Electoral returns. We collect electoral returns by polling station from the Central Electoral Commission of Bulgaria for all general elections taking place between 2014 and 2024. For each of about 12,000 polling stations in the country, these data report whether the station had a voting machine or not, the number of registered voters (as of the election day), the number of total votes cast, the number of valid votes cast, as well as their breakdown by party. Following Fujiwara (2015), we define a vote as valid if it counts towards the vote share of a party or a candidate. This definition excludes blank votes (which indicate support for "No one"), as well as null votes (which do not comply with the rules of the electoral commission or cannot be uniquely assigned to a party/candidate). Turnout is defined as the total votes cast in a polling station (including blank and null votes), divided by the respective number of registered voters as of the election day.

For our running variable, we use information on the number of *ex-ante* registered voters (recorded several months before each election), which determines the allocation of machines to polling stations. Voting registration is automatic in Bulgaria and the assignment to polling stations is based on the address register, with each polling station having a geographically defined catchment area. This variable, and consequently the allocation of voting machines, varies over time as address registrations change between elections. However, because the elections in our sample are quite frequent, we find that these changes tend to be small, with only 2.2% of polling stations switching sides of the threshold between 2021 and 2024.

Table 1 reports summary statistics for the main outcomes of interest separately for paper, machine, and mixed elections. In paper elections the average turnout is 50% and the average share of valid votes is 93%. Comparing this baseline to the period after the introduction of machine voting, it is evident that the share of valid votes increases by around 2 percentage points in mixed elections and 5 percentage points in machine elections (driven by a decline in null votes). At the same time, turnout declined substantially after the machines were introduced by 12 to 13 percentage points. Yet, some of these changes over time may be attributable to reasons other than the voting technology – e.g., the very frequently held elections starting in 2021 likely led to significant voter fatigue. Thus, our empirical strategy will need to account for such time effects.

Table 1: Summary statistics

	N	Mean	Sd
Paper elections			
Turnout / num. reg. voters	23819	0.502	0.108
Valid votes / turnout	23818	0.932	0.044
Blank votes / turnout	23818	0.012	0.016
Null votes / turnout	23818	0.057	0.045
Machine elections			
Turnout / num. reg. voters	36887	0.373	0.129
Valid votes / turnout	36882	0.978	0.020
Blank votes / turnout	36887	0.020	0.017
Null votes / turnout	36887	0.002	0.011
Mixed elections			
Turnout / num. reg. voters	49054	0.384	0.134
Valid votes / turnout	49053	0.947	0.030
Blank votes / turnout	49057	0.029	0.020
Null votes / turnout	49057	0.024	0.028
Share machine votes	49057	0.396	0.245

Notes: Polling station-level summary statistics, weighted by number of registered voters, for the main outcomes of interest. *Paper elections* include elections in October 2014 and March 2017, *Machine elections* include elections in July 2021, November 2021 and October 2022, and *Mixed elections* include elections in April 2021, April 2023, June 2024 and October 2024.

Local socioeconomic characteristics. We add to the above polling-station dataset locality-level characteristics from the 2011 census (there are about 5,600 localities in Bulgaria). This includes the share of the population that is 65 years of age or older, the share without secondary education, the share of ethnic minorities (Turkish or Roma), the unemployment rate, and the type of locality (village versus town/city).

Baseline election fraud risk. We obtain a measure of baseline electoral fraud risk from the Bulgarian Anti-Corruption Fund (ACF)–a non-governmental organization dedicated to investigating and exposing corruption in Bulgaria. Since 2021, the ACF has published lists of polling stations deemed "risky" based on statistically irregular electoral returns.[13] These lists have recently been used by activists to draw attention to potential vulnerabilities (e.g, calling for volunteers to review video recordings of the vote-counting process in "risky" stations).

ACF's classification is based on statistical models flagging stations with abnormally high turnout, votes for the most-voted party, or share of invalid votes, relative to the local average. It also flags stations where election results change abruptly between consecutive elections.[14] We use the classification based on data from 2014 and 2017 (pre-machine) parliamentary elections that flags a total of 797 polling stations (approximately 6% of all stations).

Because the number of flagged polling stations is small for a reliable RDD analysis, we use a measure of "riskiness" aggregated to the locality level. Specifically, we compute the share of registered voters in each locality who were assigned to "risky" polling stations in the baseline March 2017 election. We label as "high risk" localities where this share exceeds 10%, though we obtain similar results using lower or higher thresholds (such as 5 or 15%). This procedure flags 522 localities and 1,355 polling stations.

Survey data. In order to understand the mechanisms behind our observational results better, we partnered with Gallup International to embed questions on attitudes toward machine

[13] `https://acf.bg/en/kontroliraniyat-port/`

[14] The classification was based on four statistical models. The first and second flag stations, which have a deviation in turnout or share of the winning party from the municipal average that is higher than the sum of the third quartile and the interquartile range. Additionally, the municipality needs to have a share of null or invalidated votes that is higher than the sum of the third quartile and the interquartile range. The third model flags stations where the difference between two consecutive elections in the deviation in turnout from the municipal average is higher than the sum of the third quartile and the interquartile range. The fourth model flags stations where the difference between two consecutive elections in the deviation in the number of votes for GERB, DPS or BSP from the municipal average is higher than the sum of the third quartile and the interquartile range.

voting and experiences with vote-buying in electoral surveys taking place before and after the election of June 2024. The survey was constructed by Gallup to be nationally representative and was administered to 1,811 respondents.

Our block of questions asked respondents to recall the general elections of the past three years (2021-2024), i.e. in the period since the introduction of machine voting. Respondents were asked whether they had voted in this period, and conditional on having voted at least once, whether their polling station had a voting machine or not. We further asked the following "Yes" or "No" questions: *"In this period (2021-2024), were you ever discouraged from voting due to the voting technology used?"* and *"In this period (2021-2024), have you ever heard about vote-buying attempts in your locality?"*. For the survey wave taking place before the June 2024 election, we also included a question on knowledge about the voting technology in the respondent's polling station in the upcoming election.

Finally, we have access to data from the Gallup Exit Poll Survey conducted for all elections between March 2017 and June 2024. Specifically, we use responses to questions related to machine voting, as well as information on the party for which the respondent voted in this and the previous election.

4 Empirical Strategy

4.1 Polling station-level RDD

The discontinuity in the allocation of voting machines. Our preferred empirical strategy exploits the rule set by the electoral commission for the allocation of machines across polling stations. In all elections since 2021, voting machines were distributed only to polling stations with 300 or more ex-ante registered voters, while smaller polling stations continued to vote with paper ballots throughout.[15] The motivation for this allocation rule was the limited number of machines available and economies of scale in their distribution to

[15]Rules regarding machine allocation differ in polling stations abroad, where registration is not required. Our sample excludes these polling stations, which account for less than 5% of all polling stations.

larger polling stations. About 22% of polling stations fall below the threshold of 300 ex-ante registered voters. To the best of our knowledge, no other electoral procedure varies at this threshold.

Figure B1 shows that compliance with the machine allocation rule is virtually perfect – the share of stations with a voting machine in any machine election is exactly zero for polling stations with fewer than 300 ex-ante registered voters, and exactly one for polling stations with 300 or more ex-ante registered voters (with only one deviation in April 2021). While exceptions exist, in practice, such polling stations have few registered voters and therefore almost always fall below the threshold.[16]

Estimation. To estimate the causal effects of machine voting, we use the polling-station-level cutoff and employ a sharp regression discontinuity design. We estimate specifications of the following form:

$$y_p = \alpha + \beta_1 1\{v_p \geq 300\} + \beta_2 v_p + \beta_3 v_p 1\{v_p \geq 300\} + \epsilon_p, \tag{1}$$

The dependent variable y_p indicates an electoral outcome in polling station p. The running variable v_p is defined as the number of ex-ante registered voters in polling station p. The treatment variable is $1\{v_p \geq 300\}$, i.e., a function that takes the value 1 if this number exceeds 300, with β_1 denoting the respective treatment effect. Our preferred specification pools all three machine and all four mixed elections together, controlling for electoral district $\times$ election fixed effects to account for any election- or candidate- specific shocks. We cluster standard errors by polling station.

The estimation samples are restricted to polling stations close to the cutoff, i.e., to stations with $v_p \in (300 - h; 300 + h)$. We consider two approaches when choosing the bandwidth h – using either the data-driven optimal bandwidth determined by the procedure of Calonico et al. (2015) or setting $h = 100$ (which happens to be close to the average optimal bandwidth). We

[16]Mobile polling stations, stations based in medical facilities, homes for the elderly and other specialized institutions for the provision of social services do not receive a machine regardless of their number of registered voters.

present robust estimates following Calonico et al. (2014a) throughout, applying local linear estimation with a triangular kernel.[17]

Identifying assumption. This empirical strategy identifies the causal effects of voting technology under the assumption that the running variable (i.e., the number of ex-ante registered voters) is not manipulated. We believe that this assumption is plausible because in Bulgaria voter registration and polling station assignment are automatic and based on the individual's permanent address in the national civil registry (or, under certain exceptions, their legal residential address). Both types of addresses are verified through cross-checks with government databases.

To assess further the validity of the assumption, we first examine the smoothness of the number of ex-ante registered voters around the threshold, implementing a formal sorting test for manipulation of the running variable following McCrary (2008). Figure B2 presents this test, pooling the three machine elections in panel (a), and the four mixed elections in panel (b). In both cases, we fail to reject the null hypothesis that the density of the number of ex-ante registered voters is continuous at the threshold of 300 (with a McCrary test p-val = 0.553 in panel (a), and 0.114 in panel (b)).

Second, we consider the possibility that machine assignment may influence subsequent voter registration, which would bias the interpretation of our main outcome variables. Hidalgo and Nichter (2016) argue that transfers of voter registration across electoral districts represent a quantitatively important channel of electoral fraud in Brazil, and Schneider (2020) present evidence that Brazilian states relying exclusively on machine voting had inflated registration figures. Such manipulation is likely more difficult in Bulgaria, where voter registration, address verification and polling station assignment are automatic. Table B1 shows no evidence of registration manipulation in our setting: we find no discontinuity in the number of registered voters (as of election day) at the machine assignment threshold, in either machine-only or mixed elections.

[17] Our main results are very similar if we apply the conventional or the bias-corrected estimator instead. They are also robust to different functional forms for the running variation, such as a quadratic instead of linear polynomial.

Third, we implement a placebo test for any baseline differences between polling stations below and above the threshold of 300 ex-ante registered voters. For this test we consider the 2014 and 2017 elections that took place *before* the introduction of machine voting. Table B2 shows that our main outcomes of interest – valid votes and turnout – are smooth around the threshold in this baseline period. We also find no discontinuities at the threshold in electoral outcomes of the 2023 local election (Table B3), in which machine voting was suspended days before the first round election.

Finally, in Table B4 we test whether polling stations on either side of the threshold differ with respect to the socio-economic characteristics of the towns or villages they are located in, as measured by the 2011 census. With the exception of a negative and marginally significant coefficient for log population, we fail to detect any discontinuity in socio-economic characteristics at the threshold.

4.2 Municipality-level difference-in-differences

The regression discontinuity strategy in Equation 1 has an important limitation – it does not allow us to distinguish between absolute changes in electoral outcomes, and a reallocation of electoral activity from machine to paper-ballot polling stations (or vice versa). To understand whether such spillovers are at play and to test the robustness of the RD results, we leverage the panel dimension of our data and adopt a difference-in-differences strategy at the municipality × election level.[18]

Specifically, we estimate event study regressions of the following form:

$$y_{me} = \sum_{e \neq Mar2017} [\theta_e ShareVoters^{\geq 300}_{mMar2017} \times 1\{Election = e\}] + \delta_m + \delta_{pe} + \epsilon_{me}, \tag{2}$$

where y_{me} denotes an electoral outcome in municipality m and election e, $ShareVoters^{\geq 300}_{mMar2017}$ is the share of ex-ante registered voters in municipality m assigned to stations with 300 or

[18] Bulgaria consists of 265 municipalities where a municipality has on average around 25,000 registered voters. The median number of polling stations per municipality is 23.

more registered voters in the March 2017 election, $1\{Election = e\}$ are a set of election indicators (with March 2017 as the omitted category), and δ_m and δ_{pe} are municipality and electoral district $\times$ election fixed effects, respectively.[19][20]

The coefficients of interest θ_e estimate the election-specific effects of the voting technology, under the assumption that, in its absence, municipalities with different levels of exposure would have followed similar outcome trends. Alternatively, we report difference-in-differences results pooling elections with the same technology regime. We further control for the second-order polynomial of the number of ex-ante registered voters at baseline interacted with election dummies, in order to account for the fact that larger and more urban municipalities tend to have larger polling stations. Standard errors are clustered at the municipality level.

5 Results

5.1 Share of valid votes

RDD results. We start by examining the effects of voting technology on the share of valid votes. Figure 2 compares polling stations below and above the threshold of 300 registered voters, pooling the three machine elections in panel (a), and the four mixed elections in panel (b). Figure 3 presents separate RDD coefficients for each of the nine elections we consider, estimated either using the optimal bandwidth suggested by the procedure of Calonico et al. (2015), or with a bandwidth uniformly set to 100.

In machine elections, the share of valid votes fluctuates around 95% in polling stations just below the machine-voting threshold, but jumps to 99% in stations just above (i.e., eliminating null votes in full and leaving a small fraction of blank votes). This discontinuity is statistically significant, with a similar magnitude in all three machine elections. For mixed elections, on the other hand, we find a smaller, but still statistically significant discontinuity

[19] We obtain similar results if, instead of using 2017 share of ex-ante registered voters assigned to stations with 300 or more voters, we use the contemporaneous election-specific share.

[20] Since Sofia municipality comprises multiple electoral districts, we pool them into a single analytical unit.

of about 0.8 percentage points. Since machine take-up in mixed elections is around 40% on average, this implies a treatment effect that is roughly proportional to the one estimated for machine elections. Indeed, Appendix Table C1 shows that the pooled effect for mixed elections is driven mostly by the two elections with the highest machine take-up (April 2023 and October 2024).[21]

We can further decompose these effects into a reduction in null votes and a reduction in blank votes (Appendix Tables C2 and C3). We find that the increased share of valid votes in both machine and mixed elections is almost fully accounted for by a reduction in null votes, which is due to a mechanical prevention of errors. We find a significant, but quantitatively small, reduction in blank votes.

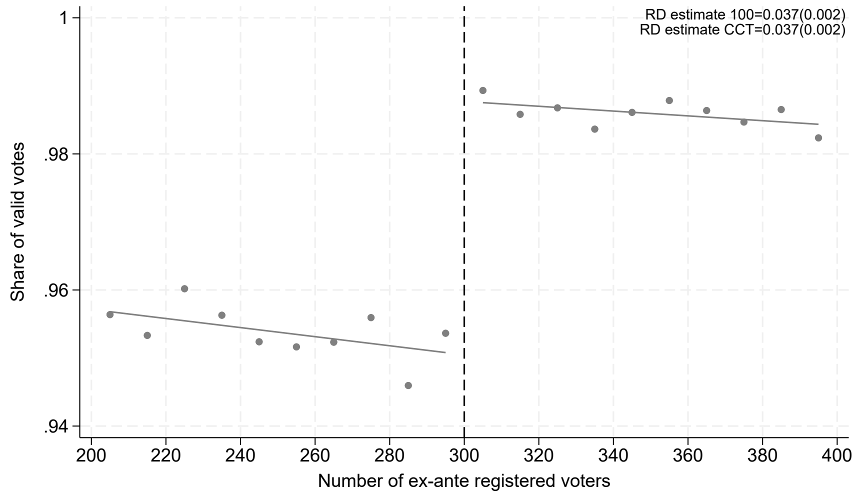
Heterogeneity. This mechanical effect can have a different bite for different types of voters, depending on their propensity to cast a null vote. We examine this heterogeneity in Appendix D.1, by estimating separate RDD regressions for polling stations in localities with different socio-economic characteristics. Specifically, we consider rural versus urban localities, and ones with below- versus above-median share of population without secondary education, share of ethnic minorities, share of individuals older than 65, and unemployment rate. The increase in the share of valid votes under machine voting is significant in all localities. However, it is significantly larger in magnitude in locations with lower educational attainment (p-val = 0.05), a higher share of ethnic minorities (p-val = 0.02), and a higher share of elderly population (p-val = 0.01). Interestingly, the effect is if anything smaller in magnitude in localities with high baseline election fraud risk according to the ACF measure, suggesting that the patterns in the share of valid votes are not necessarily linked to fraud. We find similar results for mixed elections, in which localities with lower socio-economic status fully account for the increase in the share of valid votes. This is despite the fact that machine take-up is much lower in localities with these characteristics (see Appendix Figure D1).

Overall, these results show that machine voting is most effective in preventing null votes

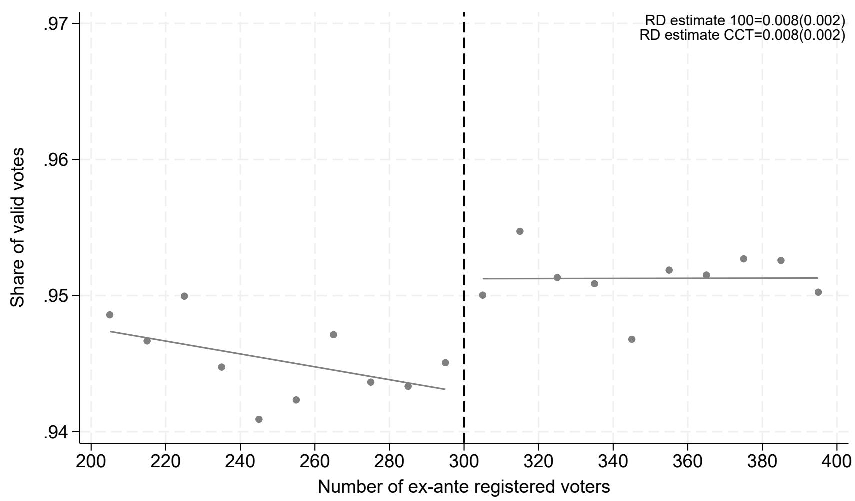
[21] Figure C3 focuses on mixed elections and shows how the share of valid paper and machine votes, respectively, vary with the number of ex-ante registered voters. There is no evidence that voter discretion above the threshold results in a change in the share of valid paper votes.

Figure 2: Share valid votes: RDD estimates

(a): Machine elections (pooled)



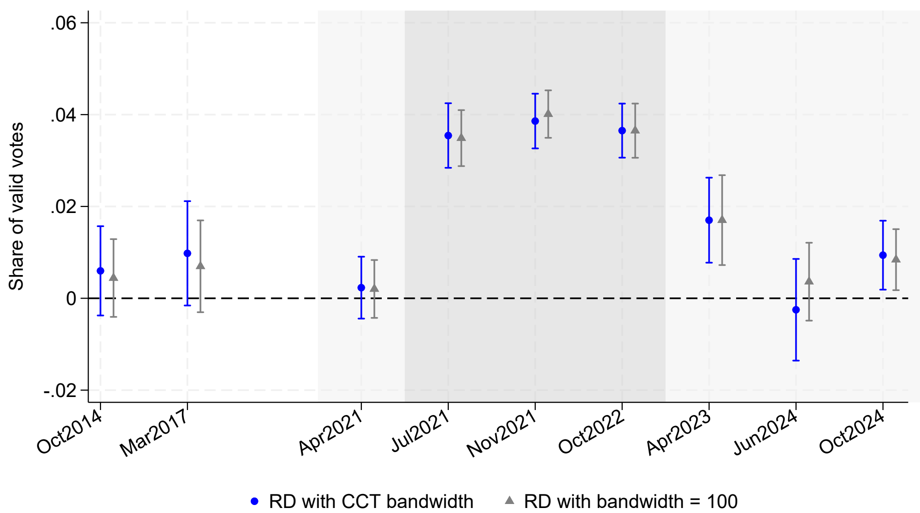
(b): Mixed elections (pooled)



Notes: Binned scatter plot: Share of valid votes over turnout by bin of the number of ex-ante registered voters. The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold.

among vulnerable groups and, thus, increases the likelihood that their preferences are reflected in the election results.

Figure 3: Share valid votes: RDD estimates by election



Notes: The plot shows RDD estimates of the effect of voting technology on the share of valid votes, estimated separately for each election. Estimates in the dark gray area show effects in machine elections and estimates in the light gray area show effects in mixed elections.

5.2 Turnout.

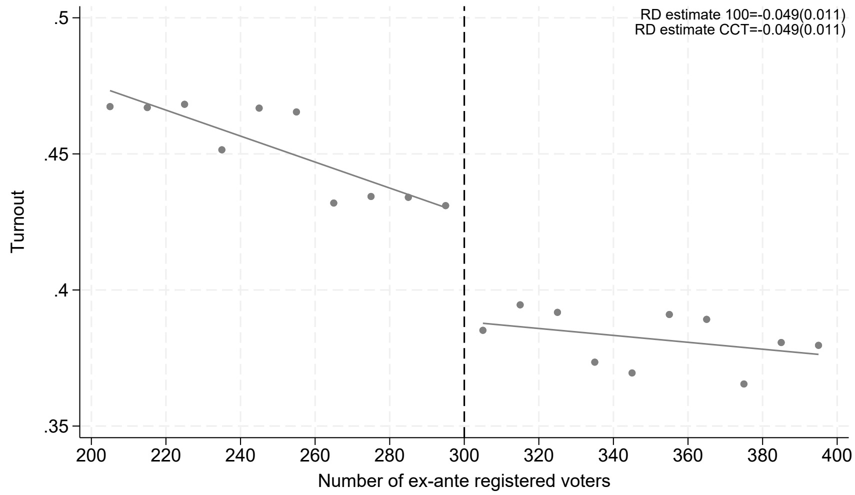
RDD results. Next, we turn to the effects of voting technology on turnout, defined as the total votes cast (valid or invalid) as a share of the number of registered voters. Figure 4 presents scatter plots of turnout around the machine-voting threshold, pooling machine elections in panel (a), and mixed elections in panel (b). Figure 5 presents separate RDD estimates for each election.

The results show a significant negative impact of machine voting on turnout – pooling the three machine elections, we find that turnout is, on average, 4.9 percentage points lower in polling stations just above the machine voting threshold compared to those just below. This corresponds to a 12% decline relative to the mean. The negative effect holds for each of the three machine elections, but is largest and most precisely estimated for the general elections of July 2021 and November 2021. Indeed, we find similar effects in the presidential election held in November 2021 with the same voting technology (Appendix Figure C2).[22]

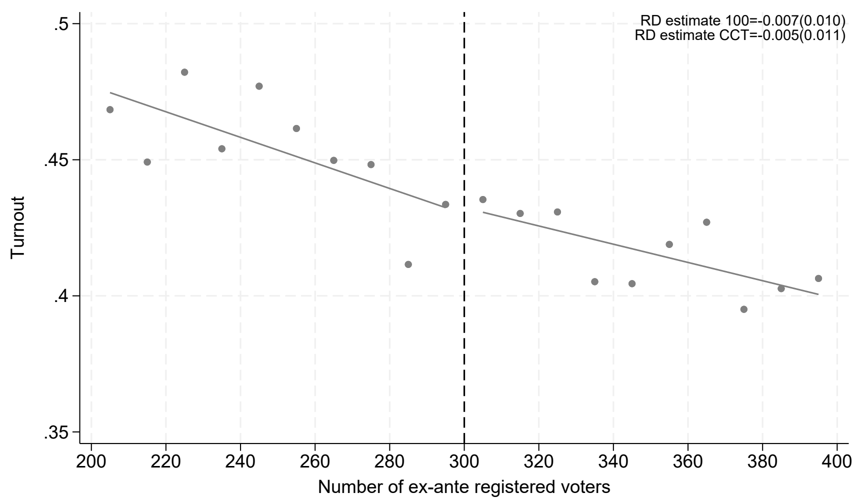
[22] The first round of the presidential election was held concurrently with the general election; the run-off was held one week later. We find similar effects in both rounds, suggesting that the result is not merely a mechanical artifact of concurrent voting. For an analysis of the effects of voting technology in concurrent races, see Villegas-Bauer (2024).

Figure 4: Turnout: RDD estimates

(a): Machine elections (pooled)



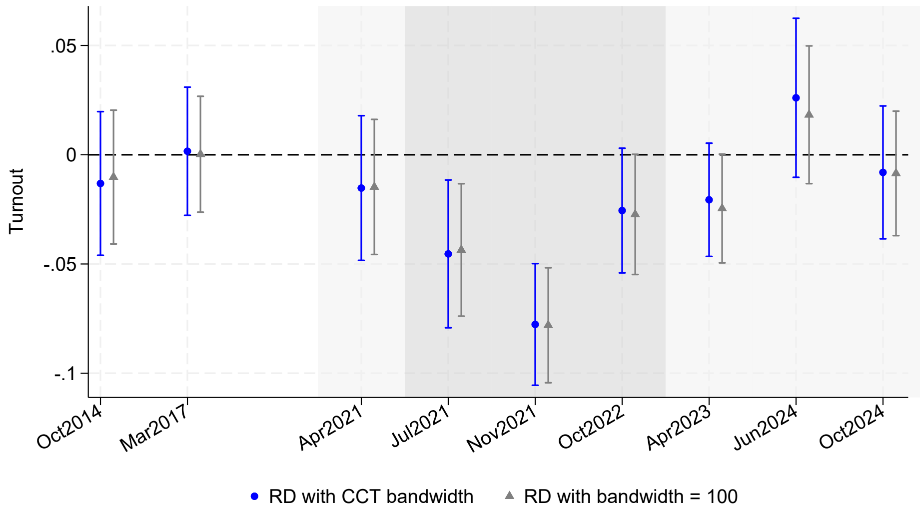
(b): Mixed elections (pooled)



Notes: Binned scatter plot: Share of turnout over registered voters by bin of the number of ex-ante registered voters. The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice between machine or paper voting in polling stations above the threshold.

Yet, giving voters the choice between machine and paper has no effect on turnout – the estimates for the four mixed elections are noisy and switch signs but are always insignificant, and the pooled sample estimate rules out a negative reduced form effect larger than 1.6 percentage points (Appendix Table C4).

Figure 5: Turnout: RDD estimates by election



Notes: The plot shows RDD estimates of the effect of voting technology on turnout, estimated separately for each election. Estimates in the dark gray area show effects in machine elections and estimates in the light gray area show effects in mixed elections.

Heterogeneity. Appendix section D.2 presents a heterogeneity analysis of these effects, splitting the sample based on the socio-economic characteristics of polling station localities. For machine elections, these results consistently show that the decline in turnout is driven by polling stations located in disadvantaged areas – it is driven by villages rather than towns or cities (p-val = 0.06), by localities with higher unemployment rates (p-val = 0.29), and by ones with lower educational attainment (p-val = 0.02). The decline in turnout is also substantially larger in localities with high baseline election fraud risk, as identified by the ACF: 11.7 percentage points, compared to 4.2 percentage points in other localities. This difference is statistically significant (p-value for equality of coefficients = 0.04), indicating that the overall impact is concentrated in higher-risk areas.

For mixed elections, the heterogeneity analysis supports the conclusion that giving voters a choice between machine and paper does not affect turnout – we find no significant effect in any of the sub-samples we examine.

5.3 Municipality-level DiD and spillovers.

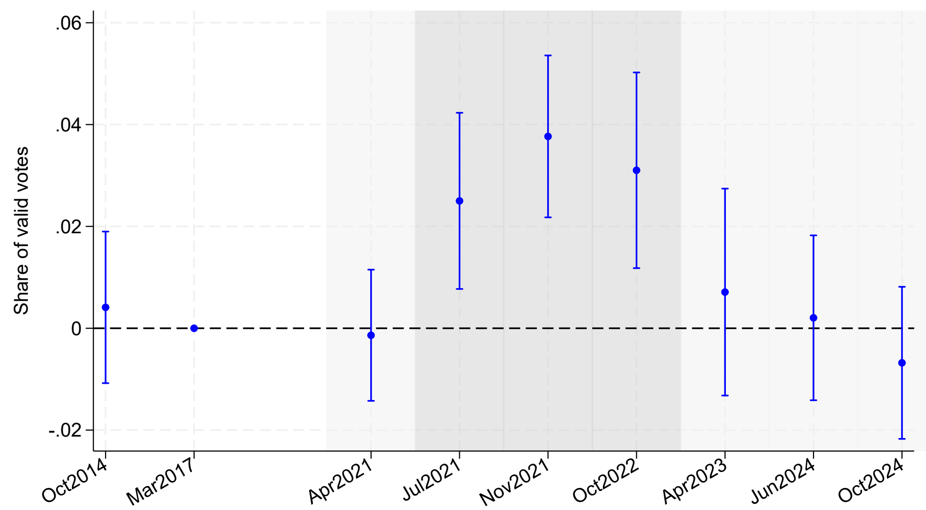
An important limitation of the RDD analysis is that it cannot distinguish between absolute changes in electoral activity above the threshold and a reallocation of activity from one side of the threshold to the other. This distinction is particularly relevant for the turnout result: it may reflect a shift in vote-buying activity with little aggregate effects.

To test for the presence of such negative spillovers, we implement a municipality-level difference-in-differences strategy leveraging variation in the share of voters assigned to polling stations exceeding the machine assignment threshold. Municipalities typically consist of a central town or city and all surrounding villages, forming a natural geographic unit within which spillovers are most likely to occur. If negative spillovers exist across the treatment threshold and operate locally—that is, within municipalities—then aggregating the analysis to this level should attenuate the estimated effects of the voting technology.

Figures 6 and 7 present municipality-level event-studies corresponding to Equation 2, and Appendix Tables E1 and E2 report estimates pooled by election type. The results mimic closely those from the RDD analysis. They suggest a 3 percentage point increase in the share of valid votes in machine elections (compared to a 3.7 percentage points increase estimated in the RDD analysis), though in this case we do not detect a significant municipality-level effect for mixed elections. For turnout they imply a decline by about 5 percentage points in machine elections (equivalent to the RDD estimate), and no impact on turnout in mixed elections. Thus, the estimated effects align closely in magnitude and significance with the RDD estimates.

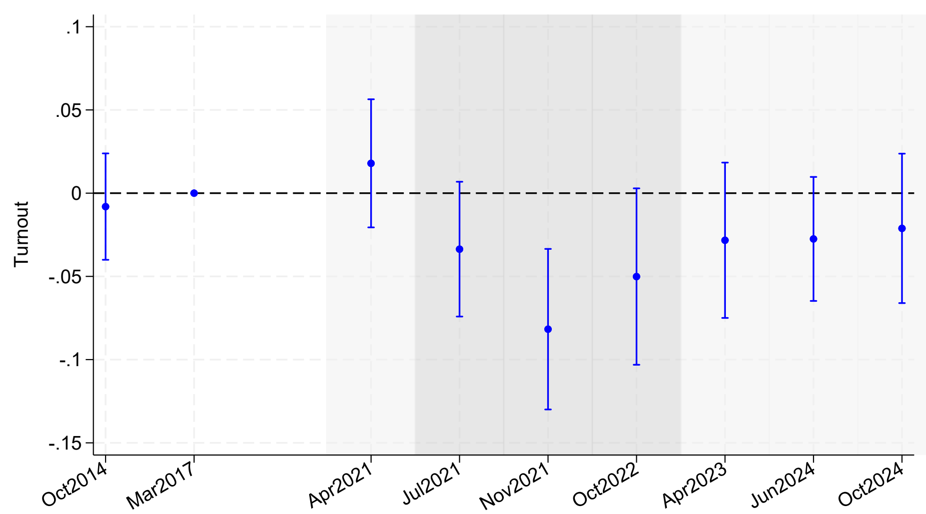
As an additional test for spillovers, we directly examine the evolution of electoral outcomes in the sample of below-threshold polling stations. The goal of this analysis is to assess whether over-time changes in the electoral outcomes of these stations vary with the local density of machine polling stations. We measure this density as the leave-one-out share of voters assigned to polling stations with 300 or more registered voters in the municipality during the baseline election of March 2017. The results, presented in Appendix Tables E3 and E4, indicate no significant spillovers on either valid votes or turnout.

Figure 6: Share valid votes: Municipality-level event study estimates (DiD)



Notes: The plot shows event-study estimates of the effect of voting technology on the share of valid votes. Estimates in the dark gray area show effects in machine elections and estimates in the light gray area show effects in mixed elections.

Figure 7: Turnout: Municipality-level event study estimates (DiD)



Notes: The plot shows event-study estimates of the effect of voting technology on turnout. Estimates in the dark gray area show effects in machine elections, and estimates in the light gray area show effects in mixed elections.

Taken together, these patterns suggest that machine voting generates absolute changes in electoral activity in treated polling stations, rather than merely reallocating activity across polling stations—at least not within the same municipality. One interpretation of this pattern is that clientelistic practices rely on local networks that exhibit limited geographic elasticity in the short term.

6 Mechanism

Our results thus far are surprising from a Downsian calculus-of-voting perspective: They suggest that, despite increasing the likelihood of votes cast being counted towards the election results and thus increasing the probability of being pivotal (conditional on turning out), machine voting leads to a significant reduction in turnout. In this section, we investigate two potential interpretations of this result.

6.1 Reduction in bought and fictitious votes

First, in line with the motivations behind the introduction of machine voting described in Section 2, the decline in turnout may reflect a reduction in bought or fictitious votes. In the absence of direct measures of electoral clientelism and fraud, we take an indirect approach to test the implications of this mechanism for (1) the distribution of votes across parties, and (2) for voters' reports of instances of vote-buying and coercion.

Votes for baseline dominant parties versus other parties. Bulgaria has a proportional representation system, which means that where within the 31 constituencies in the country parties get their votes has relatively little bearing on their overall seat share. Therefore, we conjecture that the main determinant of where and to what extent parties engage in vote-buying is the strength of their established local networks – i.e., their ability to control vote brokers and/or exert influence over electoral commissions. This leads to the prediction that, if machine voting reduces vote-buying (whether directed at voters or at polling station officials), we should expect a reduction in votes particularly for parties that were traditionally dominant locally.

We take this prediction to the data by decomposing the total number of valid votes cast on either side of the machine voting threshold into votes for parties that were locally dominant in the respective polling station under the paper ballot regime, versus votes for other parties. We do this classification using the two elections taking place prior to the introduction of machine voting (in 2014 and 2017), and consider as "dominant" the parties that were most voted in the polling station in either of these two elections. At the time, DPS, GERB, and BSP were the dominant political actors, and, as outlined in Section 2, DPS and GERB are most frequently identified as clientelistic in our context. For placebo checks looking at 2014 and 2017 election results, we consider the party that was most voted in the same election. Note that this classification is not party-specific – the same party can be a "dominant" party in one polling station, but fall into the "other" category in another station.

With this definition in hand, we apply the same RDD strategy as before to the two components of total valid votes: votes for "dominant" parties and votes for all other parties. We use an inverse hyperbolic sine (IHS) transformation to account for zeros in these disaggregated vote counts.[23] As an alternative, we express vote counts as a share of registered voters, which—as we show below—yields very similar results.[24]

Importantly, as before, the RDD strategy identifies within-election, within-district changes at the machine-assignment threshold, rather than changes over time. In the sample period of interest—i.e., following the introduction of machine voting—the means of the two components of votes are similar: the number of votes for "dominant" parties is 56, compared to 70 for other parties. As a result, the decomposition exercise is not mechanically biased toward either component of the vote total.

Table 2 presents the RDD results for the pooled sample of the three machine elections in panel (a), and for the pooled sample of the four mixed elections in panel (b). Column (1) reports the effects of machine voting on the total number of valid votes, and columns (2) and (3) break down this number into votes for traditionally dominant parties versus other parties. Figure 8 presents scatter plots corresponding to these outcomes pooling the elections in each technology regime, and Figure 9 presents the estimated effects for each separate election.

[23] Unlike the logarithmic transformation, the IHS is well-defined in the presence of zeros. That said, results are similar when using a log(1+x) transformation.

[24] We do not examine vote shares (i.e., relative to total valid votes) because the denominator would be endogenous, given the large effects of machine voting on turnout and valid votes.

Table 2: Votes for baseline dominant parties versus other parties: RDD estimates

(a): Machine elections

	(1) IHS(Total valid votes)	(2) IHS(Votes for dominant parties)	(3) IHS(Votes for other parties)
Machine voting	-0.103***	-0.245***	-0.0320
	(0.0359)	(0.0892)	(0.0655)
El. district × election FEs	Yes	Yes	Yes
Mean dep var (levels)	124.94	55.63	69.53
Effective observations left	1,314	1,721	1,168
Effective observations right	1,528	2,048	1,352
Bandwidth	86	114	79
p-value (2) = (3)			0.05

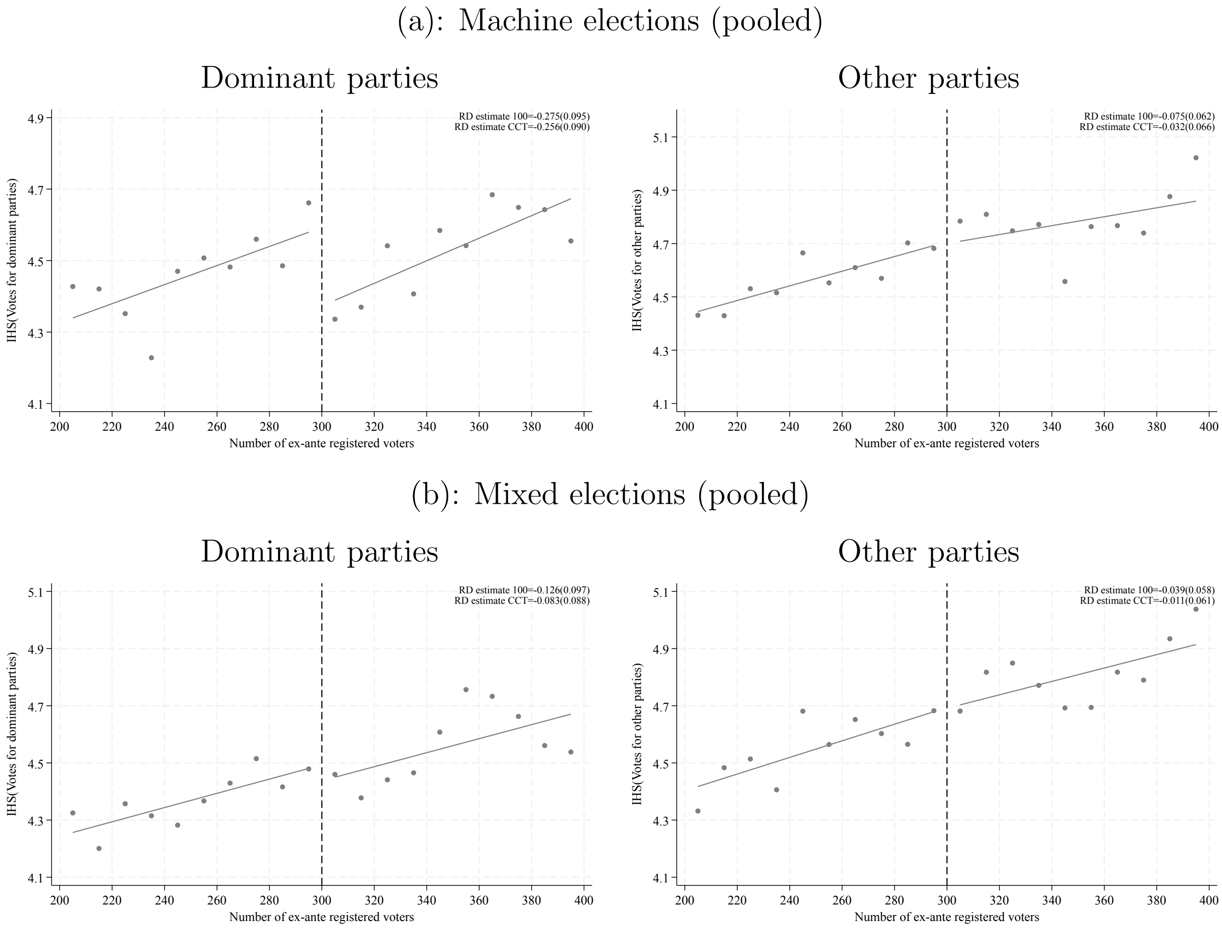
(b): Mixed elections

	(1) IHS(Total valid votes)	(2) IHS(Votes for dominant parties)	(3) IHS(Votes for other parties)
Choice machine or paper	-0.0299	-0.0832	-0.0113
	(0.0314)	(0.0883)	(0.0614)
El. district × election FEs	Yes	Yes	Yes
Mean dep var (levels)	128.01	57.49	70.29
Effective observations left	1,654	2,464	1,678
Effective observations right	1,828	2,963	1,864
Bandwidth	79	121	84
p-value (2) = (3)			0.50

Notes: RDD estimates of the effects of voting technology on the number of votes for parties that are locally dominant at baseline, versus other parties. The table presents β coefficients estimated from equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors clustered by polling station. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results show that, in machine elections, about 10% fewer valid votes are cast in polling stations above the machine voting threshold compared to the ones below, indicating that the negative turnout effect dominates the increase in the share of valid votes. This decline is not uniform across parties – it is driven entirely by a decline in votes for parties that were dominant in the respective polling station at baseline (a decline of 25%), while votes for other parties are unaffected. We reject the null hypothesis of equality of the coefficients estimated

Figure 8: Votes for baseline dominant parties versus other parties: RDD estimates

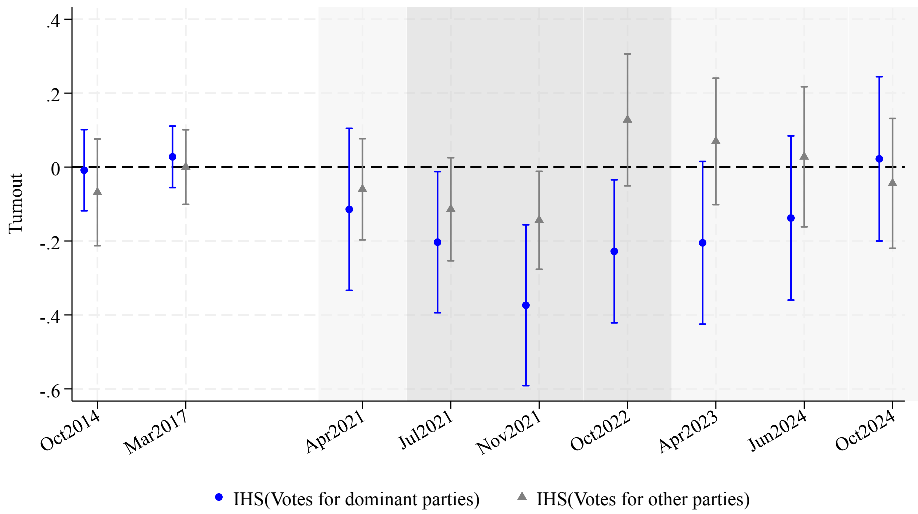


Notes: Binned scatter plot: The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold.

for these two outcomes at the 5% level. We find no significant effects looking at the pooled sample of mixed elections – neither on total valid votes cast, nor on votes for dominant or other parties, although we estimate a negative and marginally significant coefficient for votes for dominant parties in April 2023. Appendix Figure F1 and Table F1 show that these results are robust to expressing vote counts as share of registered voters instead of using an IHS-transformation.

Importantly, this heterogeneity is not driven by generally lower turnout among supporters of established versus new parties, which may be correlated with skepticism toward the new technology. Rather, established parties lose votes only in areas where they were initially

Figure 9: Votes for baseline dominant parties versus other parties: RDD estimates by election



Notes: The plot shows RDD estimates of the effect of voting technology on the number of votes for parties that are locally dominant at baseline, versus other parties, estimated separately for each election. Estimates in the dark gray area show effects in machine elections and estimates in the light gray area show effects in mixed elections.

dominant, but not elsewhere. We show this in Appendix Table F2 by disaggregating votes for non-dominant parties into those for established parties that were not dominant in the respective polling station at baseline, and those for new parties – i.e., parties that were either created or began receiving significant vote shares only after 2017. We find no significant effect of the voting technology on votes for either group.

Robustness. As a robustness check, we consider alternative definitions of party dominance. First, in Appendix Table F3 we define as locally "dominant" only parties that were *consistently* most voted in the respective polling station in both baseline elections. Second, in Appendix Table F4, we use the party affiliation of the incumbent municipal mayor. The latter measure has the advantage that it looks at the local government currently in power rather than at past election results.[25] We find similar results using both definitions – parties that were locally dominant in past general elections, as well as those currently holding the mayoral office, tend to lose votes under the machine voting regime. There is suggestive

[25] Note that local elections in the period of interest took place only with paper ballots, with the exception of runoffs in 2023.

evidence that parties holding the mayor office are affected in the mixed elections regime as well, but the effect in this case is less precisely estimated.

We also obtain similar results in a municipality-level difference-in-differences strategy (following specification 2), where we define dominant parties as those receiving the most votes in a given municipality in either 2014 or 2017. Table F5 presents the results. The estimates indicate a municipality-level decline in votes for dominant parties of 25–30 percent in machine elections. Votes for other parties show no significant change. These effects are consistent with the RDD estimates, which suggests no major spillovers of votes across the machine-assignment threshold.

Votes for clientelistic parties. The preceding analysis considers baseline party strength but remains agnostic about which parties are more likely to engage in electoral manipulation. Investigative and election observation reports, however, consistently identify DPS and GERB—two of the three established parties in the baseline period—as those most closely associated with electoral clientelism and fraud.

In Table 3, we examine whether these parties drive the overall results. We do so by reestimating our RDD specification separately for each party, restricting the sample to polling stations where that party was dominant at baseline. The table shows that machine voting causes a sizable reduction in votes for DPS in polling stations where DPS was dominant at baseline, amounting to a 43 percent decline. We find a smaller (17 percent) and less precisely estimated decline in votes for GERB in polling stations where GERB was dominant at baseline. We detect no effect on votes for BSP, nor any significant effects under the mixed election regime. These findings suggest that machine voting disproportionately reduces votes for the parties most commonly linked to electoral clientelism and fraud, particularly in areas where their clientelistic networks are likely to be strongest.

Survey evidence: Reports of vote-buying and coercion. Next, we turn to the survey data we collected in collaboration with Gallup, in which we elicit reports of vote-buying. The goal of this analysis is to test whether such reports differ between respondents assigned to

Table 3: Votes for baseline dominant parties: Breakdown by party

(a): Machine elections

	(1) IHS(Votes for DPS)	(2) IHS(Votes for GERB)	(3) IHS(Votes for BSP)
Machine voting	-0.429**	-0.171*	-0.0641
	(0.213)	(0.0875)	(0.0753)
Sample	DPS dominant	GERB dominant	BSP dominant
El. district × election FEs	Yes	Yes	Yes
Mean dep var (levels)	30.68	32.32	17.14
Effective observations left	420	691	716
Effective observations right	456	911	762
Bandwidth	74	97	113

(b): Mixed elections

	(1) IHS(Votes for DPS)	(2) IHS(Votes for GERB)	(3) IHS(Votes for BSP)
Choice machine or paper	-0.00144	-0.0660	0.0642
	(0.123)	(0.0771)	(0.0860)
Sample	DPS dominant	GERB dominant	BSP dominant
El. district × election FEs	Yes	Yes	Yes
Mean dep var (levels)	33.56	36.72	14.89
Effective observations left	838	909	861
Effective observations right	891	1,159	888
Bandwidth	109	94	100

Notes: RDD estimates of the effects of voting technology on the number of votes for parties that are locally dominant at baseline, broken down by party. The table presents β coefficients estimated from equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors clustered by polling station. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

machine versus paper-ballot polling stations. To do so, we use an indicator for self-reported polling station assignment, equal to one if the respondent reports to have been assigned to a polling station with a machine at least once since the introduction of machine voting, and equal to zero otherwise. This variable is available for respondents who have voted at least once since the introduction of machine voting (which is the case for 70% of all respondents). We assume that this assignment does not change over time, as the period of interest is relatively short (about 3 years) and switches of polling stations' status are rare in the electoral data.

While the survey data does not allow us to implement an RDD strategy, we can estimate linear probability models of the dependent variables of interest on an indicator for self-reported machine versus paper polling station assignment, conditional on respondent and locality characteristics. Specifically, we control for respondents' age, age squared, and indicators for gender, high school education, ethnic minority status, and employment (full or part-time). Locality-level controls include log population, share without secondary education, share of ethnic minorities, share of elderly population, and unemployment rate. In the full sample regressions, we also include indicators for whether the locality is a village, a small town, a large town, or the capital.

Table 4 reports the results. Conditional on answering the question about knowledge of vote-buying or coercion (and conditional on non-missing polling station assignment), 55% of respondents report such instances. The full sample estimates suggest that, other things equal, respondents assigned to machine polling stations are about 10 percentage points less likely to report vote-buying or coercion compared to those assigned to paper polling stations, though this correlation is imprecisely estimated (p-value = 0.131 in our preferred specification). The difference is more strongly pronounced in the subsample of rural areas, where respondents assigned to machine stations are 23 percentage points (about 46%) less likely to report vote-buying activity compared to respondents assigned to paper polling stations (p-value = 0.036). We find no such correlation in towns and cities – consistent with the fact that the turnout effect documented earlier is driven entirely by rural areas.

Table 4: Survey evidence: Reports of vote-buying or voter coercion

	Full sample		Villages		Towns/ Cities	
	(1)	(2)	(3)	(4)	(5)	(6)
	Heard of vote-buying					
Machine present in polling station	-0.095	-0.103	-0.261**	-0.230**	0.014	-0.007
	(0.067)	(0.069)	(0.105)	(0.108)	(0.080)	(0.086)
Respondent characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Locality characteristics	No	Yes	No	Yes	No	Yes
Locality type FEs	Yes	Yes	No	No	No	No
Observations	1,056	1,041	209	205	847	836
R^2	0.03	0.05	0.04	0.11	0.00	0.03
Mean dep var	0.55	0.56	0.50	0.49	0.57	0.57

Notes: This table presents respondent-level regressions of an indicator for self-reported knowledge of local vote-buying on an indicator for machine presence in the respondent's polling station. Respondent characteristics include gender, age, age squared, and indicators for high school, ethnic minority status, and being employed. Locality characteristics include log population, share without secondary education, share of ethnic minorities, share of elderly population, and unemployment rate. Locality type refers to village, small town, large town or the capital. Columns (1) and (2) report estimates for the full sample of survey respondents; Columns (3) and (4) report estimates for the sub-sample of rural areas; Columns (5) and (6) report estimates for the sub-sample of towns and cities. Robust standard errors in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6.2 Alternative mechanism: Discouragement

An alternative explanation for the negative effect of machine voting on turnout is that some voters are discouraged from participating because they expect the machines to be difficult to use or because they distrust their accuracy. In this case, abstention can be rationalized either by higher perceived costs of voting or by doubts that machine votes will be counted correctly.

Capacity constraints and technical difficulties. Although longer wait times or technical malfunctions associated with the new technology could, in principle, reduce turnout, such concerns are unlikely to be salient in small polling stations near the machine assignment threshold. Polling stations at the threshold record an average turnout of approximately 130 votes, while experimental evidence from the Central Election Commission indicates that a single voting machine can process up to 75 votes per hour.[26] Given the 13-hour duration of

[26] https://www.actualno.com/topnews/cik-po-75-izbirateli-na-chas-glasuvat-s-mashina-news_1599101.html#google_vignette

the election day, these stations should be operating well below capacity.

Nonetheless, as a test for the role of capacity constraints, we exploit a discontinuity in machine allocation between polling stations equipped with one versus two voting machines. The assignment of a second machine was based on a turnout threshold from the previous general election.[27] Figure F2 confirms that the thresholds – set at 425 voters in July 2021 and 350 voters in October 2022 – were binding: polling stations just above the cutoff received two machines, while those just below received only one. Despite the sharp increase in machine allocation at the threshold, we find no corresponding change in turnout. Thus, there is no evidence that capacity constraints induced by the technology played a meaningful role in driving the observed decline in voter participation.

We also find little evidence of widespread technical malfunctions. In exit poll surveys conducted by Gallup during the July 2021 and October 2022 elections, only 3.9% of voters assigned to machine stations report any problems with the machines.

Information on voting technology available to voters. Even in the absence of deterrence from wait times or technical malfunctions at the polling station, turnout may be negatively affected if voters factor the voting technology into their turnout decision ex ante. To generate the observed discontinuity in turnout at the machine assignment threshold, this mechanism would require that voters were informed in advance about the technology assigned to their polling station. However, such information was scarce during the initial phases of machine voting implementation.

Prior to the full-scale rollout of machine voting, the Central Election Commission launched an information campaign that included television advertisements and an online voting simulator disseminated to familiarize voters with the new technology. Notably, the campaign omitted any reference to the fact that small polling stations—constituting only a minor share of the electorate—would continue to use paper ballots. This implies that any potential disincentive effects on turnout would not systematically vary by station type.

[27] In the November 2021 election, polling stations with 320 or more voters in both the April and July 2021 elections received a second machine. Due to this double discontinuity, we do not report RDD estimates for this election.

To the best of our knowledge, the only polling-station specific information released by the Electoral Commission is a spreadsheet posted on its website in the weeks before each election, which lists the polling stations equipped with machines. Yet, given the lack of active dissemination, it is unlikely that voters—particularly those with limited digital literacy—accessed this list at a significant rate.[28] Consistent with this, in our June 2024 survey, conducted after five consecutive machine-based elections and just one week before the upcoming election, over 50 percent of respondents report that they do not know what voting technology would be used in their polling station.

Survey evidence: Self-reported discouragement. To more directly assess whether voter discouragement contributes to the negative effect of machine voting on turnout, we examine responses to a survey question on self-reported deterrence. Among respondents who answered this question, approximately 8%—and 10% within the estimation sample—report having been discouraged from voting at least once due to the use of voting machines. The two most commonly cited reasons are a mistrust in the reliability of machine voting and a perception that the technology is difficult to use.

However, the regression results in Table 5 indicate no significant difference in reported discouragement between individuals assigned to machine versus paper polling stations, conditional on covariates. If anything, the sign of the estimates in the rural subsample is negative, indicating that respondents assigned to machine polling stations are *less* likely to report discouragement than those assigned to paper polling stations (though the difference is not significant) – a direction inconsistent with our turnout results.

These findings suggest that while aversion to the new technology is not negligible and may contribute to lower turnout in machine elections overall, it is unlikely to generate the sharp discontinuity observed at the polling station assignment threshold.

[28] In contrast, voters can query the address of their assigned polling station based on their national ID number through a user-friendly online platform or through a free messaging service. Neither service includes information on whether the station is equipped with a voting machine.

Table 5: Survey evidence: Self-reported discouragement

	Full sample		Villages		Towns/ Cities	
	(1)	(2)	(3)	(4)	(5)	(6)
	Discouraged from voting					
Machine present in polling station	0.006	-0.001	-0.006	-0.076	0.001	-0.002
	(0.047)	(0.049)	(0.097)	(0.096)	(0.053)	(0.056)
Respondent characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Locality characteristics	No	Yes	No	Yes	No	Yes
Locality type FEs	Yes	Yes	No	No	No	No
Observations	1,050	1,035	204	200	846	835
R^2	0.03	0.03	0.03	0.09	0.02	0.03
Mean dep var	0.10	0.10	0.13	0.14	0.09	0.09

Notes: This table presents respondent-level regressions of an indicator for self-reported discouragement from voting due to the machine technology, on an indicator for machine presence in the respondent's polling station. Respondent characteristics include gender, age, age squared, and indicators for high school, ethnic minority status, and being employed. Locality characteristics include log population, share without secondary education, share of ethnic minorities, share of elderly population, and unemployment rate. Locality type refers to village, small town, large town or the capital. Columns (1) and (2) report estimates for the full sample of survey respondents; Columns (3) and (4) report estimates for the sub-sample of rural areas; Columns (5) and (6) report estimates for the sub-sample of towns and cities. Robust standard errors in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

7 Conclusion

In this paper, we examine the potential of voting technology to enhance electoral integrity in developing democracies. Using administrative data from Bulgaria and a regression discontinuity design, we show that the introduction of machine voting increases the share of valid ballots but also leads to a sizable decline in voter turnout. The decline in turnout is concentrated in poor and rural areas and arises only when machine voting is mandatory rather than optional. This effect is driven by a reduction in votes for parties that were locally dominant prior to the reform. Evidence from a nationally representative survey points to a decline in bought or fictitious votes as a plausible mechanism.

Our findings suggest several avenues for future research. First, our results capture the effects of machine voting over a relatively short horizon. How clientelistic parties adapt their strategies in the longer run remains an open question. For instance, Gans-Morse et al. (2014) argue that improved ballot secrecy may reduce pure vote buying (conditioned on verifying vote choice) but increase turnout buying—offering incentives to latent supporters conditional on turnout but irrespective of vote choice. To the extent that such substitution happens in the short run, our results may be underestimating the impact of the technology on the types of fraud it directly targets.

Second, while we conclude that voters' concerns about the accessibility and security of machine voting are unlikely to fully explain our results, we find that such concerns are non-negligible. Understanding the sources of these perceptions is an important area for future study.

Third, we note that our analysis applies to a setting characterized by independent electoral institutions and strong electoral competition. In such contexts, the main threats to electoral integrity stem from local-level practices such as vote-buying or interference by polling station officials, which voting technology can plausibly mitigate. By contrast, in autocracies or hybrid regimes where electoral authorities are captured by incumbents, technology could be deployed selectively or manipulated centrally. Understanding whether, and through what mechanisms, voting technology might be (mis)used under those conditions remains an important open question.

References

Aidt, T. S. and P. S. Jensen (2016): "From Open to Secret Ballot: Vote Buying and Modernization," *Comparative Political Studies*, 49, 636–667.

Alles, S., T. D. Barnes, and C. Tchintian (Forthcoming): *The Representational Consequences of Electronic Voting Reform: Evidence from Argentina*, Cambridge Elements in Campaigns and Elections, Cambridge University Press, university of San Andrés; University of Kentucky; CIPPEC.

Alters, M. A. and P. Kooreman (2009): "More evidence of the effects of voting technology on election outcomes," *Public Choice*, 139, 159–170.

Aragón, F. M., A. Chong, and A. Cozzubo (2025): "Electronic Voting and Invalid Votes: Evidence from a Natural Experiment in Peru," Tech. Rep. 25-04, International Center for Public Policy, Andrew Young School of Policy Studies, Georgia State University.

Blattman, C., H. Larreguy, B. Marx, and O. Reid (2024): "Eat Widely, Vote Wisely: Lessons from a Campaign Against Vote Buying in Uganda," Working Paper 11247, CESifo.

Bliznakovski, J. (2024): "Clientelistic Linkage Mechanisms in Post-Communist Democracies 2009-2023. DALP Evidence," .

Bobonis, G. J., P. J. Gertler, M. Gonzalez-Navarro, and S. Nichter (2022): "Vulnerability and Clientelism," *American Economic Review*, 112, 3627–3659.

Bowles, J., H. Larreguy, and S. Liu (2020): "How Weakly Institutionalized Parties Monitor Brokers in Developing Democracies: Evidence from Postconflict Liberia," *American Journal of Political Science*, 64, 952–967.

Braconnier, C., J.-Y. Dormagen, and V. Pons (2017): "Voter Registration Costs and Disenfranchisement: Experimental Evidence from France," *American Political Science Review*, 111, 584–604.

Callen, M. and J. D. Long (2015): "Institutional Corruption and Election Fraud: Evidence from a Field Experiment in Afghanistan," *American Economic Review*, 105, 354–381.

Calonico, S., M. Cattaneo, and R. Titiunik (2014a): "Robust Nonparametric Confidence Intervals for Regression-Discontinuity Designs," *Econometrica*, 82, 2295–2326.

——— (2015): "Optimal Data-Driven Regression Discontinuity Plots," *Journal of the American Statistical Association*, 110, 1753–1769.

Calonico, S., M. D. Cattaneo, and R. Titiunik (2014b): "Robust Data-Driven Inference in the Regression-Discontinuity Design," *Stata Journal*, 115(513), 909–946.

Cantoni, E. and V. Pons (2021): "Strict Id Laws Don't Stop Voters: Evidence from a U.S. Nationwide Panel, 2008–2018," *Quarterly Journal of Economics*, 136, 2615–2660.

Cantoni, E., V. Pons, and J. Schäfer (2024): "Voting Rules, Turnout, and Economic Policies," *NBER Working Paper No. 32941.*

Card, D. and E. Moretti (2007): "Does Voting Technology Affect Election Outcomes? Touch-Screen Voting and the 2004 Presidential Election," *Review of Economics and Statistics*, 89(4), 660–671.

Debnath, S., M. Kapoor, and S. Ravi (2017): "The Impact of Electronic Voting Machines on Electoral Frauds, Democracy, and Development," *SSRN Electronic Journal*.

Desai, Z. and A. Lee (2021): "Technology and protest: the political effects of electronic voting in India," *Political Science Research and Methods*, 9, 398–413.

Duarte, R., F. Finan, H. Larreguy, and L. Schechter (2023): "Brokering Votes with Information Spread via Social Networks," *NBER Working Paper 26241*.

Enikolopov, R., V. Korovkin, M. Petrova, K. Sonin, and A. Zakharov (2013): "Field experiment estimate of electoral fraud in Russian parliamentary elections," *Proceedings of the National Academy of Sciences*, 110, 448–452.

Fajury, K. (2023): "Clientelism and Poverty: Voter Buying in Colombia," Unpublished manuscript.

Ferlenga, F. and B. G. Knight (2025): "Vote early and vote often? Detecting electoral fraud from the timing of 19th century elections," *Journal of Public Economics*, 243, 105317.

Finan, F. and L. Schechter (2012): "Vote-Buying and Reciprocity," *Econometrica*, 80, 863–881.

Fujiwara, T. (2015): "Voting Technology, Political Responsiveness, and Infant Health: Evidence From Brazil," *Econometrica*, 83, 423–464.

Gallup (2024): "No One Trusts Elections Less Than Bulgarians," `https://news.gallup.com/poll/652433/no-one-trusts-elections-less-bulgarians.aspx`, accessed: 2024-10-25.

Gans-Morse, J., S. Mazzuca, and S. Nichter (2014): "Varieties of Clientelism: Machine Politics during Elections," *American Journal of Political Science*, 58, 415–432.

Gonzalez, R. M. (2021): "Cell Phone Access and Election Fraud: Evidence from a Spatial Regression Discontinuity Design in Afghanistan," *American Economic Journal: Applied Economics*, 13, 1–51.

Hanmer, M. J., W.-H. Park, M. W. Traugott, R. G. Niemi, P. S. Herrnson, B. B. Bederson, and F. C. Conrad (2010): "Losing Fewer Votes: The Impact of Changing Voting Systems on Residual Votes," *Political Research Quarterly*, 63, 129–142.

Heckelman, J. C. (1995): "The Effect of the Secret Ballot on Voter Turnout Rates," *Public Choice*, 82, 107–124.

Herrnson, P. S., M. J. Hanmer, and R. G. Niemi (2012): "The Impact of Ballot Type on Voter Errors," *American Journal of Political Science*, 56, 716–730.

Hidalgo, F. D. (2012): "Renovating Democracy: The Political Consequences of Election Reforms in Post-War Brazil," Ph.d. dissertation, University of California, Berkeley, Berkeley, CA.

Hidalgo, F. D. and S. Nichter (2016): "Voter buying: Shaping the electorate through clientelism," *American Journal of Political Science*, 60, 436–455.

International IDEA (2024): "The Global State of Democracy 2024: Strengthening the Legitimacy of Elections in a Time of Radical Uncertainty," Report, accessed: 2025-04-25.

Kaplan, E. and H. Yuan (2020): "Early Voting Laws, Voter Turnout, and Partisan Vote Composition: Evidence from Ohio," *American Economic Journal: Applied Economics*, 12, 32–60.

Kraynova, M. and M. Rusinov (2021): "Election Fraud: Prevalence and Impact in Bulgaria," Tech. rep., Anti-Corruption Fund Bulgaria, accessed: May 2024.

Larreguy, H., J. Marshall, and P. Querubã N (2016): "Parties, Brokers, and Voter Mobilization: How Turnout Buying Depends Upon the Party's Capacity to Monitor Brokers," *American Political Science Review*, 110, 160–179.

McCrary, J. (2008): "Manipulation of the running variable in the regression discontinuity design: A density test," *Journal of Econometrics*, 142(2), 698–714.

Nichter, S. (2008): "Vote buying or turnout buying? Machine politics and the secret ballot," *American Political Science Review*, 102, 19–31.

Nickerson, D. W. (2015): "Do voter registration drives increase participation? For whom and when?" *Journal of Politics*, 77, 88–101.

Norris, P. (2014): *Why Electoral Integrity Matters*, New York: Cambridge University Press.

OSCE Office for Democratic Institutions and Human Rights (2021): "Republic of Bulgaria: Early Parliamentary Elections, 11 July 2021 — ODIHR Election Observation Mission Final Report," Tech. rep., OSCE/ODIHR, published July 2021; accessed 2025-08-06.

Schechter, L. and S. Vasudevan (2023): "Persuading voters to punish corrupt vote-buying candidates: Experimental evidence from a large-scale radio campaign in India," *Journal of Development Economics*, 160, 102976.

Schneider, R. (2020): "Free or fair elections? The introduction of electronic voting in Brazil," *Economía*, 21, 73–100.

Shue, K. and E. F. Luttmer (2009): "Who Misvotes? The Effect of Differential Cognition Costs on Election Outcomes," *American Economic Journal: Economic Policy*, 1, 229–257.

Stewart, C. I. (2011): "Voting Technologies," *Annual Review of Political Science*, 14, 353–378, first published online March 21, 2011.

Stokes, S. C. (2005): "Perverse Accountability: A Formal Model of Machine Politics with Evidence from Argentina," *American Political Science Review*, 99, 315–325.

Thompson, D., J. Wu, J. Yoder, and A. Hall (2020): "Universal vote-by-mail has no impact on partisan turnout or vote share," *Proceedings of the National Academy of Sciences*, 117, 14052–14056.

Vicente, P. C. (2014): "Is Vote Buying Effective? Evidence from a Field Experiment in West Africa," *The Economic Journal*, 124, F356–F387.

Villegas-Bauer, G. (2024): "The Effect of Split-Ticket Voting Cost on Effective Enfranchisement," *Electoral Studies*, 87, 102736.

The Electoral Effects of Voting Technology: Evidence from Bulgaria

Milena Djourelova and Teodora Tsankova

September 2025

Online Appendix

A Background

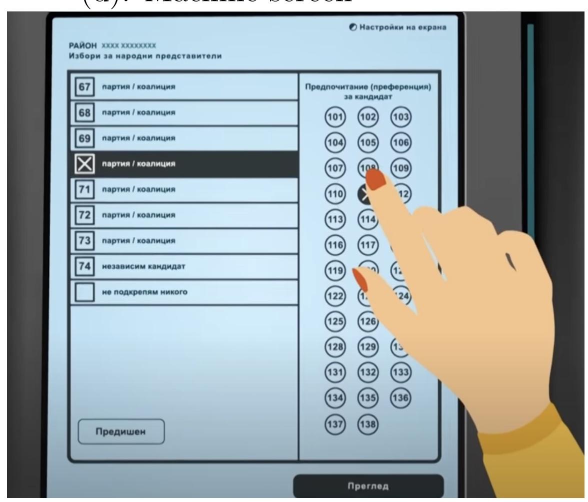
Figure A1: Logistics of paper-ballot versus machine voting

(a): Voting with paper ballot

(b): Voting with machine

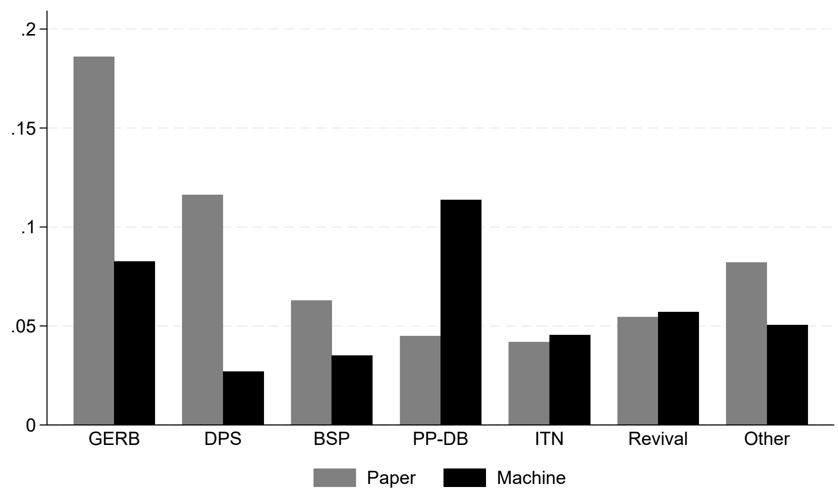
(c): Paper ballot

(d): Machine screen



Notes: The figure illustrates the logistics of paper-ballot and machine voting in Bulgarian general elections. Panels (a) and (b) depict the polling station setup for each type of voting technology, while panels (c) and (d) show the respective ballot formats.

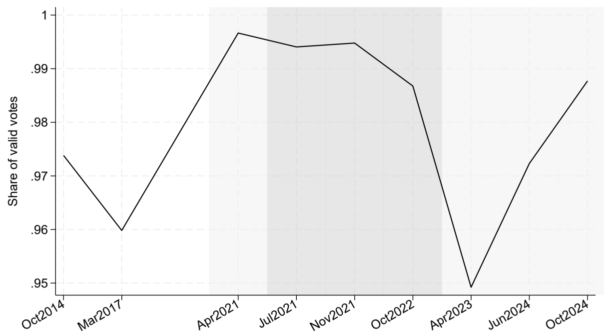
Figure A2: Machine take-up in mixed elections by party



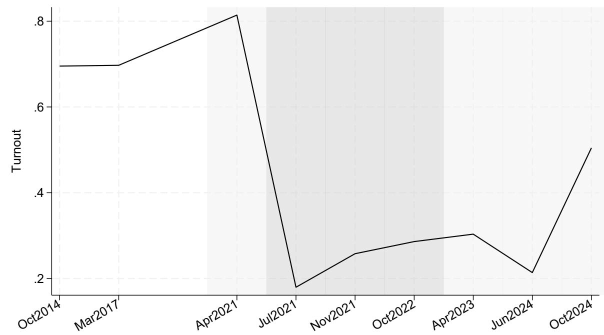
Notes: The figure plots party vote shares in mixed elections separately for votes cast with paper ballots (in gray) and machine votes (in black) in polling stations above the 300 ex-ante registered voters threshold.

Figure A3: Case study: Bukovlak

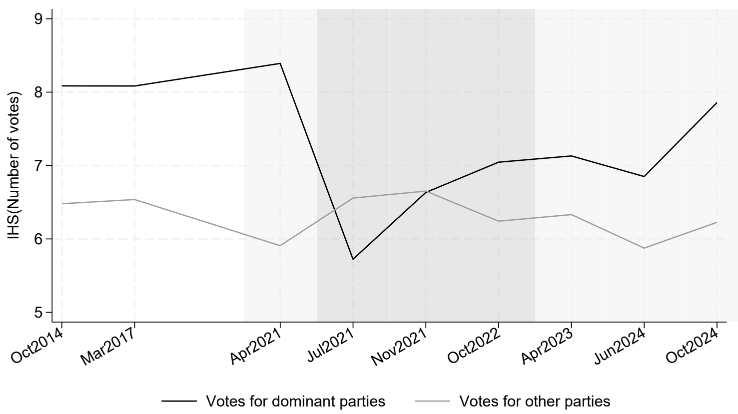
(a) Share of valid votes



(b) Turnout

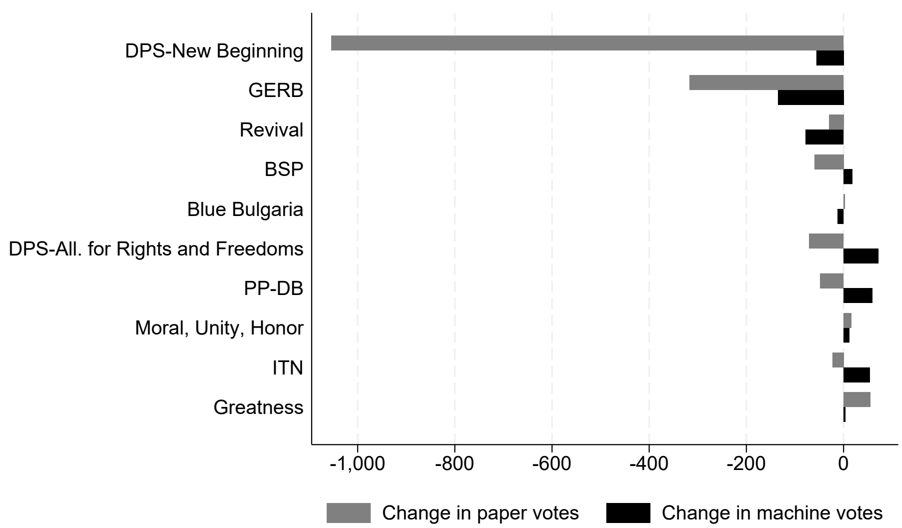


(c) Votes for baseline dominant parties versus other parties



Notes: Evolution of electoral outcomes in the village of Bukovlak.

Figure A4: Changes in the number of party votes in the October 2024 election recount



Notes: The figure plots the change in the number of party votes between the originally announced results after the October 2024 election and the recount per party by paper and machine. The figure includes the ten parties that received the highest overall number of votes according to the final election results.

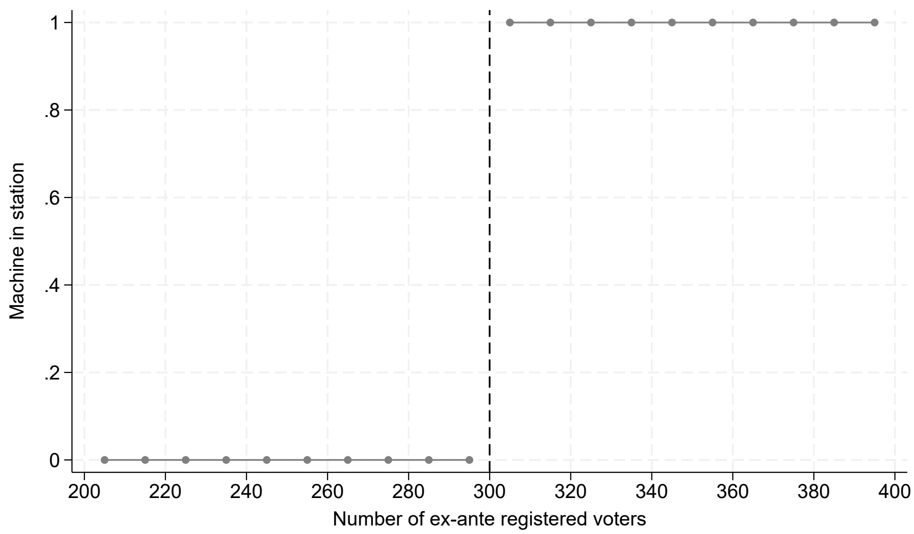
Table A1: Party stances on machine voting and allegations of electoral clientelism / fraud

Party	**Vote on Reintroducing Mixed System (2022)**	**Evidence of Electoral Clientelism**	**Evidence of Electoral Fraud**	**Sources**
DPS (Movement for Rights and Freedoms)	*Support*	*High* — Repeatedly linked to vote buying and voter coercion, especially in Roma and Turkish communities.	*Moderate* — Statistical anomalies flagged by ACF in DPS strongholds; no direct judicial findings.	OSCE/ODIHR 2017, 2019, 2021, 2023; ACF reports
GERB (Citizens for European Development of Bulgaria)	*Support*	*Moderate to High* — Reports of administrative pressure, public-sector coercion, and some vote buying.	*Moderate* — Statistical anomalies flagged by ACF in GERB municipalities; some court rulings.	OSCE/ODIHR 2017, 2021, 2023; ACF reports; court decisions
BSP (Bulgarian Socialist Party)	*Support*	*Moderate* — Some clientelism via municipal jobs and services.	*Low* — Few anomalies; limited official concern.	OSCE/ODIHR 2017, 2021
PP (We Continue the Change)	*Oppose* (supported machine-only voting)	*No official evidence* — Described as reformist and anti-clientelistic.	*No official evidence.*	OSCE/ODIHR 2022
DB (Democratic Bulgaria)	*Oppose* (supported machine-only voting)	*No official evidence* — Described as promoting electoral integrity.	*No official evidence.*	OSCE/ODIHR 2021, 2022
ITN (There Is Such a People)	*NA*	*No official evidence.*	*No official evidence.*	—
Revival	*Oppose* (supported machine-only voting)	*No official evidence.*	*No official evidence.*	—

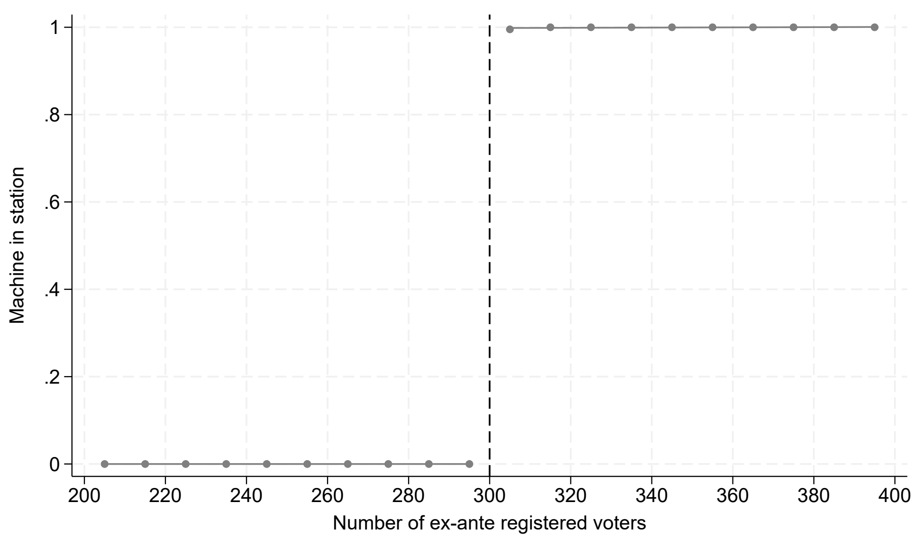
B RDD manipulation and placebo checks

Figure B1: Allocation of voting machines

(a): Machine elections



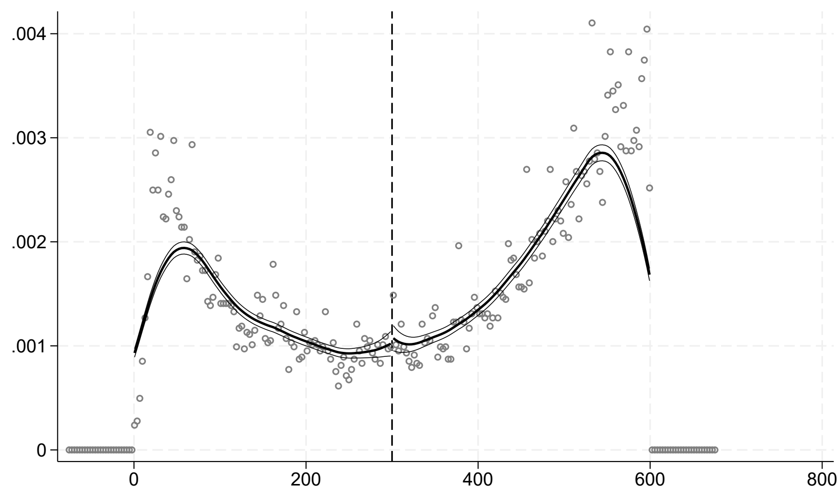
(b): Mixed elections



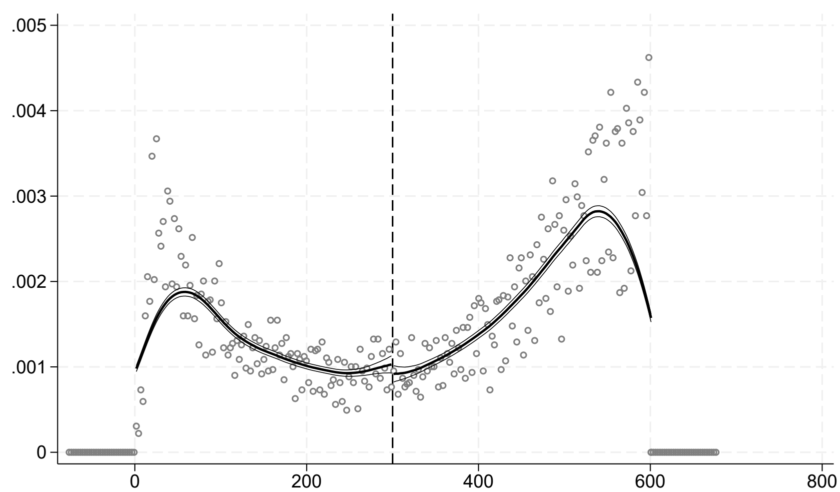
Notes: Binned scatter plot: Share of polling stations with (one or more) machine by bin of the number of ex-ante registered voters. The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold.

Figure B2: McCrary test for manipulation of the running variable

(a): Machine-only elections



(b): Mixed elections



Notes: McCrary test for discontinuity in the density of the running variable – number of ex-ante registered voters. The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. The sample in panel (a) consists of the three elections with machine-only voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold.

Table B1: Manipulation test: Number of registered voters at the end of election day

	(1) Machine elections	(2) Mixed elections
$\geq$ 300 ex-ante registered voters	-0.00462	-0.0224
	(0.0139)	(0.0143)
El. district $\times$ election FEs	Yes	Yes
Mean dep var	6.43	6.43
Effective observations left	895	1,139
Effective observations right	993	1,150
Bandwidth	57	53

Notes: Manipulation test for the number of registered voters. The table presents β coefficients estimated from Equation 1 for the machine (column 1) and mixed (column 2) elections. The dependent variable is the inverse hyperbolic sine (IHS) of the number of registered voters at the end of the election day, which is the sum of the number of voters in the lists handed to polling station officials and the number of voters added on the election day. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table B2: Placebo test: Baseline electoral outcomes prior to the introduction of machine voting

	Valid votes / turnout	
	(1) Oct2014	(2) Mar2017
$\geq$ 300 ex-ante registered voters	0.00595	0.00977*
	(0.00495)	(0.00579)
El. district $\times$ election FEs	Yes	Yes
Mean dep var	0.92	0.92
Effective observations left	382	410
Effective observations right	390	406
Bandwidth	72	75

	Turnout / registered voters	
	(1) Oct2014	(2) Mar2017
$\geq$ 300 ex-ante registered voters	-0.0131	0.00160
	(0.0168)	(0.0150)
El. district $\times$ election FEs	Yes	Yes
Mean dep var	0.54	0.56
Effective observations left	473	426
Effective observations right	485	426
Bandwidth	87	79

	IHS(Votes for most-voted party)	
	(1) Oct2014	(2) Mar2017
$\geq$ 300 ex-ante registered voters	-0.00852	0.0277
	(0.0560)	(0.0424)
El. district $\times$ election FEs	Yes	Yes
Mean dep var	4.88	4.97
Effective observations left	438	504
Effective observations right	448	538
Bandwidth	80	94

Notes: Placebo test for discontinuity in outcomes of interest at baseline. The table presents β coefficients estimated from Equation 1 for the baseline period prior to the introduction of machine voting. The dependent variables are the number of valid votes over turnout in the upper panel, turnout over the number of registered voters in the middle panel, and the IHS-transformed number of votes for the dominant party (i.e., the party obtaining most votes in the respective polling station) in the lower panel. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B3: Placebo test: Local elections 2023

	(1) Valid votes / turnout	(2) Turnout / registered voters
Machine voting	0.000532	0.0136
	(0.00571)	(0.0295)
El. district FEs	Yes	Yes
Mean dep var	0.93	0.48
Effective observations left	414	144
Effective observations right	488	211
Bandwidth	73	73

Notes: Placebo test for discontinuity in outcomes of interest during the first round of local elections conducted in October 2023, which takes places with paper ballots only. The table presents β coefficients estimated from Equation 1. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table B4: Placebo test: Socio-economic characteristics of polling station localities

(a): Machine elections

	(1) Log population	(2) Unemployment rate	(3) Share without secondary education	(4) Share minority population	(5) Share elderly population
$\geq$ 300 ex-ante registered voters	-0.214*	-0.0140	0.00640	0.0179	0.000983
	(0.114)	(0.0187)	(0.00989)	(0.0239)	(0.0102)
El. district $\times$ election FEs	Yes	Yes	Yes	Yes	Yes
Mean dep var	6.65	0.22	0.21	0.29	0.27
Effective observations left	1,832	1,559	2,088	2,187	1,909
Effective observations right	2,167	1,839	2,499	2,624	2,282
Bandwidth	115	101	129	135	120

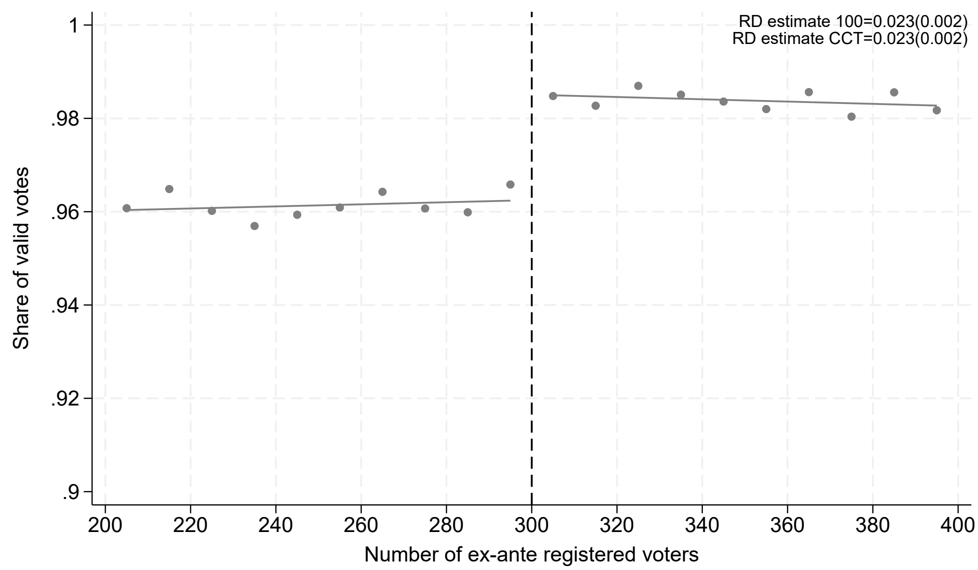
(b): Mixed elections

	(1) Log population	(2) Unemployment rate	(3) Share without secondary education	(4) Share minority population	(5) Share elderly population
$\geq$ 300 ex-ante registered voters	-0.185*	-0.0119	0.00984	0.0167	-0.00390
	(0.107)	(0.0176)	(0.00937)	(0.0227)	(0.00932)
El. district $\times$ election FEs	Yes	Yes	Yes	Yes	Yes
Mean dep var	6.71	0.22	0.21	0.28	0.27
Effective observations left	2,435	2,186	2,753	3,031	2,494
Effective observations right	2,892	2,568	3,312	3,671	2,972
Bandwidth	114	104	128	137	118

Notes: Placebo test for discontinuity in the socio-economic characteristics of polling station localities. The table presents β coefficients estimated from Equation 1. The dependent variables are from the 2011 census and are measured at the locality level. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors are clustered by locality. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

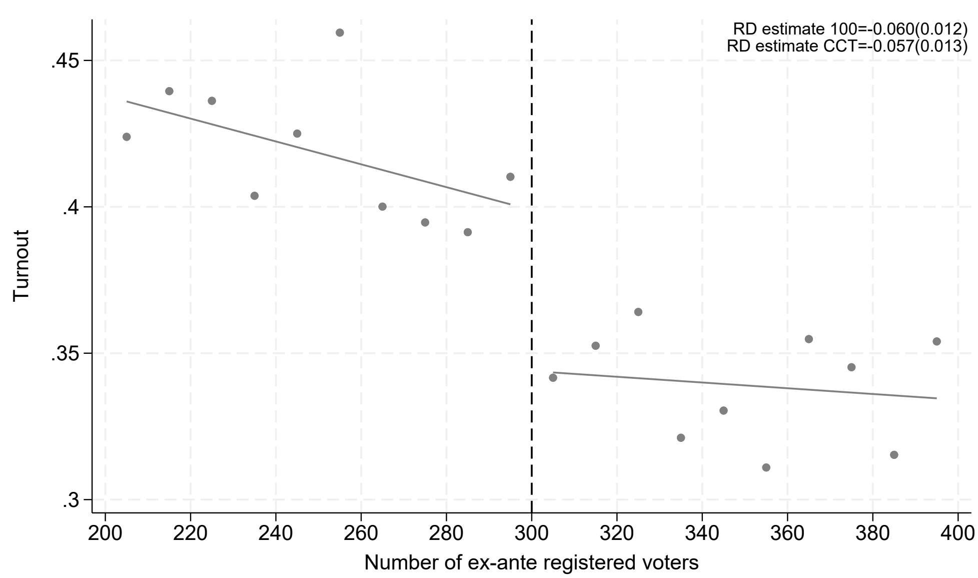
C Additional RDD results

Figure C1: Share valid votes: Presidential election



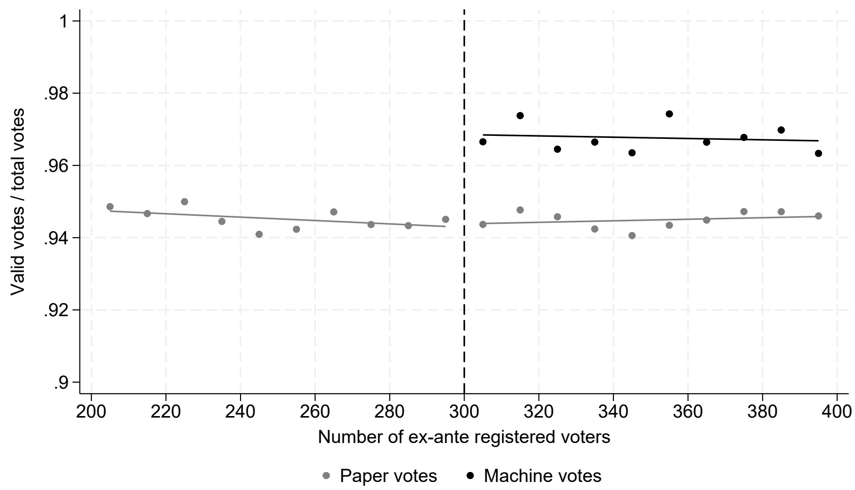
Notes: Binned scatter plot: Share of valid votes over turnout by bin of the number of ex-ante registered voters. The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. Sample: first and second round of the presidential election of November 2021.

Figure C2: Turnout: Presidential election



Notes: Binned scatter plot: Share of turnout over registered voters by bin of the number of ex-ante registered voters. The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. Sample: first and second round of the presidential election of November 2021.

Figure C3: Breakdown of valid votes in mixed elections



Notes: Binned scatter plot: Decomposition of the share of valid votes, by bin of the number of ex-ante registered voters. The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. The sample consists of the four elections with a choice of machine or paper voting in polling stations above the threshold.

Table C1: Share of valid votes: RDD estimates

(a): Machine elections

	Valid votes / turnout			
	(1) Jul2021	(2) Nov2021	(3) Oct2022	(4) Pooled
Machine voting	0.0354***	0.0386***	0.0365***	0.0372***
	(0.00359)	(0.00304)	(0.00301)	(0.00202)
El. district × election FEs	Yes	Yes	Yes	Yes
Mean dep var	0.98	0.97	0.96	0.97
Effective observations left	399	358	527	1,643
Effective observations right	472	410	601	1,935
Bandwidth	80	71	100	104

(b): Mixed elections

	Valid votes / turnout				
	(1) Apr2021	(2) Apr2023	(3) Jun2024	(4) Oct2024	(5) Pooled
Choice machine or paper	0.00232	0.0170***	-0.00249	0.00939**	0.00785***
	(0.00344)	(0.00473)	(0.00564)	(0.00383)	(0.00231)
El. district × election FEs	Yes	Yes	Yes	Yes	Yes
Mean dep var	0.96	0.95	0.94	0.95	0.95
Mean take-up	0.13	0.51	0.20	0.22	0.28
Effective observations left	435	572	321	419	2,532
Effective observations right	503	677	314	450	3,017
Bandwidth	84	109	60	79	118

Notes: RDD estimates for the effects of voting technology on the share of valid votes. The table presents β coefficients estimated from Equation 1. Panel (a) includes the three elections with machine voting in polling stations above the threshold, and Panel (b) includes the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors in pooled specifications are clustered by polling station. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

Table C2: Null votes: RDD estimates

(a): Machine elections

	Null votes / turnout			
	(1) Jul2021	(2) Nov2021	(3) Oct2022	(4) Pooled
Machine voting	-0.0309***	-0.0330***	-0.0328***	-0.0332***
	(0.00307)	(0.00272)	(0.00219)	(0.00166)
El. district × election FEs	Yes	Yes	Yes	Yes
Mean dep var	0.01	0.02	0.02	0.01
Effective observations left	425	315	440	1,625
Effective observations right	498	356	494	1,911
Bandwidth	84	62	85	103

(b): Mixed elections

	Null votes / turnout				
	(1) Apr2021	(2) Apr2023	(3) Jun2024	(4) Oct2024	(5) Pooled
Choice machine or paper	-0.000460	-0.0145***	0.00384	-0.0101***	-0.00689***
	(0.00316)	(0.00348)	(0.00534)	(0.00311)	(0.00202)
El. district × election FEs	Yes	Yes	Yes	Yes	Yes
Mean dep var	0.04	0.02	0.04	0.03	0.03
Mean take-up	0.13	0.51	0.21	0.22	0.28
Effective observations left	446	566	340	391	2,353
Effective observations right	516	671	346	420	2,791
Bandwidth	86	108	63	75	111

Notes: RDD estimates for the effects of voting technology on the share of null votes. The table presents β coefficients estimated from Equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors in pooled specifications are clustered by polling station. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C3: Blank votes: RDD estimates

(a): Machine elections

	Blank votes / turnout			
	(1) Jul2021	(2) Nov2021	(3) Oct2022	(4) Pooled
Machine voting	-0.00384***	-0.00504***	-0.00256	-0.00397***
	(0.00125)	(0.00127)	(0.00212)	(0.00110)
El. district × election FEs	Yes	Yes	Yes	Yes
Mean dep var	0.01	0.01	0.02	0.01
Effective observations left	544	630	689	1,820
Effective observations right	658	754	819	2,147
Bandwidth	105	120	128	114

(b): Mixed elections

	Blank votes / turnout				
	(1) Apr2021	(2) Apr2023	(3) Jun2024	(4) Oct2024	(5) Pooled
Choice machine or paper	-0.00137	-0.00239	-0.00161	0.00116	-0.000878
	(0.00113)	(0.00251)	(0.00223)	(0.00206)	(0.00126)
El. district × election FEs	Yes	Yes	Yes	Yes	Yes
Mean dep var	0.01	0.03	0.02	0.02	0.02
Mean take-up	0.14	0.52	0.22	0.24	0.28
Effective observations left	539	652	487	601	2,562
Effective observations right	638	783	541	710	3,046
Bandwidth	103	121	92	111	119

Notes: RDD estimates of the effects of voting technology on the share of blank votes. The table presents β coefficients estimated from Equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors in pooled specifications are clustered by polling station. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C4: Turnout: RDD estimates

(a): Machine elections

	Turnout / registered voters			
	(1) Jul2021	(2) Nov2021	(3) Oct2022	(4) Pooled
Machine voting	-0.0454***	-0.0777***	-0.0255*	-0.0493***
	(0.0173)	(0.0142)	(0.0146)	(0.0113)
El. district × election FEs	Yes	Yes	Yes	Yes
Mean dep var	0.44	0.40	0.40	0.41
Effective observations left	414	420	465	1,521
Effective observations right	486	499	510	1,776
Bandwidth	82	84	89	98

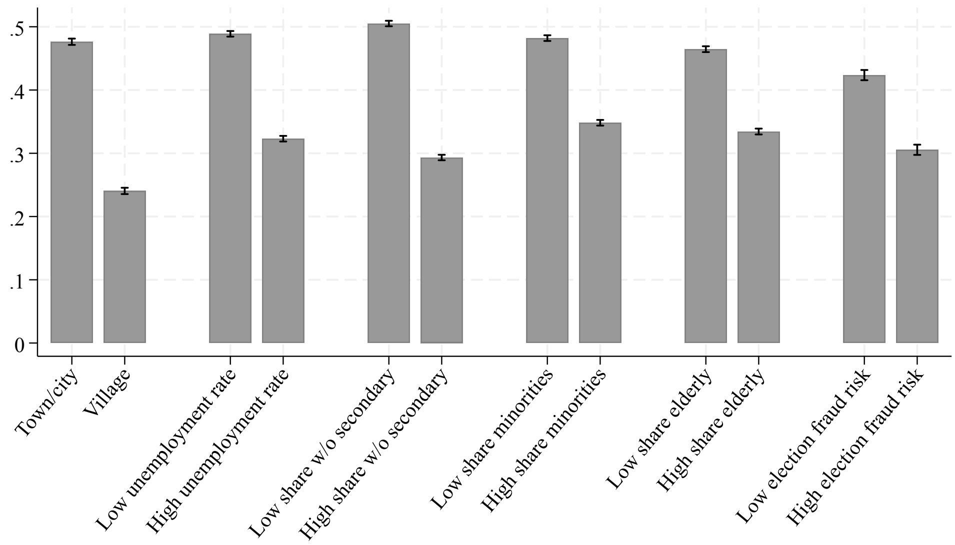
(b): Mixed elections

	Turnout / registered voters				
	(1) Apr2021	(2) Apr2023	(3) Jun2024	(4) Oct2024	(5) Pooled
Choice machine or paper	-0.0152	-0.0206	0.0261	-0.00807	-0.00537
	(0.0169)	(0.0132)	(0.0186)	(0.0155)	(0.0108)
El. district × election FEs	Yes	Yes	Yes	Yes	Yes
Mean dep var	0.52	0.41	0.39	0.42	0.43
Mean take-up	0.13	0.50	0.21	0.23	0.27
Effective observations left	435	471	392	476	1,863
Effective observations right	503	529	429	517	2,080
Bandwidth	85	89	75	90	88

Notes: RDD estimates of the effects of voting technology on turnout. The table presents β coefficients estimated from Equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors in pooled specifications are clustered by polling station. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

D Heterogeneous effects

Figure D1: Machine take-up by locality characteristics



Notes: Machine take-up in mixed elections by demographic and socio-economic characteristics of polling stations localities. The sample consists of the four mixed elections and is restricted to polling stations above the machine-assignment threshold. The samples for unemployment rate, share without secondary education, minority share, and share of elderly are divided at the median of the respective continuous distributions. High election fraud risk refers to localities where more than 10% of voters are assigned to polling stations flagged by the ACF.

D.1 Heterogeneity: Share of valid votes

Table D1: Effects on share of valid votes: By town/ village

	Valid votes / turnout	
	(1) Village	(2) Town/ City
Machine-only voting	0.0381***	0.0343***
	(0.00212)	(0.00842)
El. district × election FEs	Yes	Yes
Mean dep var	0.97	0.97
Effective observations left	1,309	72
Effective observations right	1,318	257
Bandwidth	89	84
p-value (1) = (2)		0.66

	Valid votes / turnout	
	(1) Village	(2) Town/ City
Choice machine or paper	0.00888***	-0.00634
	(0.00271)	(0.00527)
El. district × election FEs	Yes	Yes
Mean dep var	0.95	0.94
Effective observations left	1,896	83
Effective observations right	1,796	204
Bandwidth	94	63
p-value (1) = (2)		0.01

Notes: β coefficients estimated from Equation 1, reported separately for villages (Column 1) and towns or cities (Column 2). The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is the share of valid votes over turnout. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D2: Share of valid votes: Heterogeneity by unemployment rate

	Valid votes / turnout	
	(1) Below-median unemployment rate	(2) Above-median unemployment rate
Machine-only voting	0.0350***	0.0373***
	(0.00382)	(0.00224)
El. district × election FEs	Yes	Yes
Mean dep var	0.97	0.97
Effective observations left	587	1,136
Effective observations right	670	1,384
Bandwidth	105	112
p-value (1) = (2)		0.61

	Valid votes / turnout	
	(1) Below-median unemployment rate	(2) Above-median unemployment rate
Choice machine or paper	0.00624*	0.00983***
	(0.00376)	(0.00329)
El. district × election FEs	Yes	Yes
Mean dep var	0.95	0.95
Effective observations left	871	1,213
Effective observations right	990	1,380
Bandwidth	116	90
p-value (1) = (2)		0.47

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) unemployment rate. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D3: Share of valid votes: Heterogeneity by share without secondary education

	Valid votes / turnout	
	(1) Below-median share without secondary ed.	(2) Above-median share without secondary ed.
Machine-only voting	0.0276***	0.0366***
	(0.00434)	(0.00245)
El. district $\times$ election FEs	Yes	Yes
Mean dep var	0.97	0.97
Effective observations left	176	962
Effective observations right	262	1,036
Bandwidth	78	74
p-value (1) = (2)		0.07

	Valid votes / turnout	
	(1) Below-median share without secondary ed.	(2) Above-median share without secondary ed.
Choice machine or paper	0.00131	0.00920***
	(0.00427)	(0.00293)
El. district $\times$ election FEs	Yes	Yes
Mean dep var	0.95	0.95
Effective observations left	281	1,648
Effective observations right	432	1,717
Bandwidth	86	92
p-value (1) = (2)		0.13

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) shares of individuals without secondary education. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is the share of valid votes over turnout. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D4: Share of valid votes: Heterogeneity by share of ethnic minorities

	Valid votes / turnout	
	(1) Below-median minority share	(2) Above-median minority share
Machine-only voting	0.0308***	0.0396***
	(0.00249)	(0.00305)
El. district × election FEs	Yes	Yes
Mean dep var	0.97	0.97
Effective observations left	694	809
Effective observations right	737	1,004
Bandwidth	102	92
p-value (1) = (2)		0.03

	Valid votes / turnout	
	(1) Below-median minority share	(2) Above-median minority share
Choice machine or paper	0.00206	0.0113***
	(0.00270)	(0.00385)
El. district × election FEs	Yes	Yes
Mean dep var	0.95	0.95
Effective observations left	949	1,081
Effective observations right	967	1,324
Bandwidth	101	92
p-value (1) = (2)		0.05

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) share of ethnic minorities. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is the share of valid votes over turnout. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D5: Share of valid votes: Heterogeneity by share of individuals 65 and above

	Valid votes / turnout	
	(1) Below-median share elderly	(2) Above-median share elderly
Machine-only voting	0.0254***	0.0382***
	(0.00473)	(0.00232)
El. district × election FEs	Yes	Yes
Mean dep var	0.98	0.97
Effective observations left	135	1,255
Effective observations right	271	1,228
Bandwidth	68	93
p-value (1) = (2)		0.02

	Valid votes / turnout	
	(1) Below-median share elderly	(2) Above-median share elderly
Choice machine or paper	-0.00451	0.00913***
	(0.00479)	(0.00277)
El. district × election FEs	Yes	Yes
Mean dep var	0.95	0.95
Effective observations left	176	1,776
Effective observations right	341	1,662
Bandwidth	65	96
p-value (1) = (2)		0.01

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) shares of individuals aged 65 and above. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is the share of valid votes over turnout. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D6: Share of valid votes: Heterogeneity by baseline election fraud risk

	Valid votes / turnout	
	(1) Below-median election fraud risk	(2) Above-median election fraud risk
Machine-only voting	0.0377***	0.0191***
	(0.00216)	(0.00402)
El. district × election FEs	Yes	Yes
Mean dep var	0.97	0.97
Effective observations left	1,445	124
Effective observations right	1,710	128
Bandwidth	104	71
p-value (1) = (2)		0.00

	Valid votes / turnout	
	(1) Below-median election fraud risk	(2) Above-median election fraud risk
Choice machine or paper	0.00818***	0.00282
	(0.00245)	(0.00466)
El. district × election FEs	Yes	Yes
Mean dep var	0.97	0.97
Effective observations left	2,281	221
Effective observations right	2,715	245
Bandwidth	120	90
p-value (1) = (2)		0.31

Notes: β coefficients estimated from Equation 1, reported separately for localities with less than 10% of voters (Column 1) and more than 10% of voters (Column 2) assigned to ACF-flagged polling stations. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is the share of valid votes over turnout. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

D.2 Heterogeneity: Turnout

Table D7: Turnout: Heterogeneity by town/ village

	Turnout / registered voters	
	(1) Village	(2) Town/ City
Machine-only voting	-0.0480***	0.0209
	(0.0121)	(0.0341)
El. district × election FEs	Yes	Yes
Mean dep var	0.41	0.43
Effective observations left	1,223	69
Effective observations right	1,250	224
Bandwidth	84	79
p-value (1) = (2)		0.06

	Turnout / registered voters	
	(1) Village	(2) Town/ City
Choice machine or paper	-0.00459	0.0138
	(0.0113)	(0.0291)
El. district × election FEs	Yes	Yes
Mean dep var	0.43	0.42
Effective observations left	1,654	91
Effective observations right	1,577	341
Bandwidth	83	80
p-value (1) = (2)		0.56

Notes: β coefficients estimated from Equation 1, reported separately for villages (Column 1) and towns or cities (Column 2). The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is turnout over the number of registered voters. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D8: Turnout: Heterogeneity by unemployment rate

	Turnout / registered voters	
	(1) Below-median unemployment rate	(2) Above-median unemployment rate
Machine-only voting	-0.0300	-0.0562***
	(0.0208)	(0.0133)
El. district × election FEs	Yes	Yes
Mean dep var	0.42	0.41
Effective observations left	520	816
Effective observations right	582	975
Bandwidth	95	82
p-value (1) = (2)		0.29

	Turnout / registered voters	
	(1) Below-median unemployment rate	(2) Above-median unemployment rate
Choice machine or paper	0.0240	-0.0164
	(0.0207)	(0.0114)
El. district × election FEs	Yes	Yes
Mean dep var	0.43	0.43
Effective observations left	591	1,534
Effective observations right	639	1,878
Bandwidth	82	112
p-value (1) = (2)		0.09

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) unemployment rate. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is turnout over the number of registered voters. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D9: Turnout: Heterogeneity by share without secondary education

	Turnout / registered voters	
	(1) Below-median share without secondary ed.	(2) Above-median share without secondary ed.
Machine-only voting	0.0000497	-0.0512***
	(0.0184)	(0.0130)
El. district × election FEs	Yes	Yes
Mean dep var	0.46	0.40
Effective observations left	220	1,036
Effective observations right	358	1,136
Bandwidth	93	79
p-value (1) = (2)		0.02

	Turnout / registered voters	
	(1) Below-median share without secondary ed.	(2) Above-median share without secondary ed.
Choice machine or paper	0.0119	-0.00881
	(0.0199)	(0.0121)
El. district × election FEs	Yes	Yes
Mean dep var	0.45	0.43
Effective observations left	308	1,406
Effective observations right	513	1,458
Bandwidth	94	79
p-value (1) = (2)		0.38

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) shares of individuals without secondary education. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is turnout over the number of registered voters. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D10: Turnout: Heterogeneity by share of ethnic minorities

	Turnout / registered voters	
	(1) Below-median minority share	(2) Above-median minority share
Machine-only voting	-0.0561***	-0.0497***
	(0.0145)	(0.0165)
El. district × election FEs	Yes	Yes
Mean dep var	0.46	0.38
Effective observations left	662	690
Effective observations right	706	833
Bandwidth	97	78
p-value (1) = (2)		0.77

	Turnout / registered voters	
	(1) Below-median minority share	(2) Above-median minority share
Choice machine or paper	-0.00216	-0.00795
	(0.0144)	(0.0149)
El. district × election FEs	Yes	Yes
Mean dep var	0.47	0.41
Effective observations left	706	990
Effective observations right	694	1,196
Bandwidth	79	84
p-value (1) = (2)		0.78

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) share of ethnic minorities. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is turnout over the number of registered voters. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D11: Turnout: Heterogeneity by share of individuals 65 and above

	Turnout / registered voters	
	(1) Below-median share elderly	(2) Above-median share elderly
Machine-only voting	-0.0366	-0.0463***
	(0.0278)	(0.0126)
El. district × election FEs	Yes	Yes
Mean dep var	0.42	0.41
Effective observations left	203	1,142
Effective observations right	479	1,140
Bandwidth	96	85
p-value (1) = (2)		0.75

	Turnout / registered voters	
	(1) Below-median share elderly	(2) Above-median share elderly
Choice machine or paper	-0.0148	0.000100
	(0.0282)	(0.0117)
El. district × election FEs	Yes	Yes
Mean dep var	0.43	0.43
Effective observations left	261	1,419
Effective observations right	621	1,332
Bandwidth	93	79
p-value (1) = (2)		0.63

Notes: β coefficients estimated from Equation 1, reported separately for localities with below-median (Column 1) and above-median (Column 2) shares of individuals aged 65 and above. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is turnout over the number of registered voters. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

Table D12: Turnout: Heterogeneity by baseline election fraud risk

	Turnout / registered voters	
	(1) Below-median election fraud risk	(2) Above-median election fraud risk
Machine-only voting	-0.0417***	-0.117***
	(0.0117)	(0.0344)
El. district × election FEs	Yes	Yes
Mean dep var	0.42	0.41
Effective observations left	1,294	122
Effective observations right	1,510	118
Bandwidth	94	68
p-value (1) = (2)		0.04

	Turnout / registered voters	
	(1) Below-median election fraud risk	(2) Above-median election fraud risk
Choice machine or paper	0.00239	-0.0390
	(0.0113)	(0.0323)
El. district × election FEs	Yes	Yes
Mean dep var	0.41	0.40
Effective observations left	1,536	243
Effective observations right	1,728	277
Bandwidth	84	98
p-value (1) = (2)		0.23

Notes: β coefficients estimated from Equation 1, reported separately for localities with less than 10% of voters (Column 1) and more than 10% of voters (Column 2) assigned to ACF-flagged polling stations. The upper panel includes the three elections with machine voting in polling stations above the cutoff, and the lower panel includes the four elections with mixed voting in polling stations above the cutoff. The dependent variable is turnout over the number of registered voters. The bandwidth is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Robust standard clustered by polling station.

E Spillovers

Table E1: Share of valid votes: Municipality-level DiD

	Valid votes / turnout	
	(1)	(2)
Share voters in $\geq$ 300 stations $\times$ Machine election	0.0256***	0.0292***
	(0.00741)	(0.00753)
Share voters in $\geq$ 300 stations $\times$ Mixed election	-0.00382	-0.00181
	(0.00567)	(0.00577)
Municipality FEs	Yes	Yes
El. district $\times$ election FEs	Yes	Yes
Num. registered voters $\times$ election	Yes	Yes
Num. registered voters squared $\times$ election	No	Yes
Mean dep var	0.95	0.95
N	2376	2376

Notes: Municipality-level DiD estimates corresponding to Equation 2. The level of observation is municipality $\times$ election and the sample includes all elections since 2014. Robust standard clustered by municipality.

Table E2: Turnout: Municipality-level DiD

	Turnout / registered voters	
	(1)	(2)
Share voters in $\geq$ 300 stations $\times$ Machine election	-0.0495**	-0.0511**
	(0.0209)	(0.0217)
Share voters in $\geq$ 300 stations $\times$ Mixed election	-0.0180	-0.0107
	(0.0115)	(0.0127)
Municipality FEs	Yes	Yes
El. district $\times$ election FEs	Yes	Yes
Num. registered voters $\times$ election	Yes	Yes
Num. registered voters squared $\times$ election	No	Yes
Mean dep var	0.43	0.43
N	2376	2376

Notes: Municipality-level DiD estimates corresponding to Equation 2. The level of observation is municipality $\times$ election and the sample includes all elections since 2014. Robust standard clustered by municipality.

Table E3: Share valid votes: Spillovers to paper polling stations

	Valid votes / turnout	
	(1)	(2)
Leave-one-out share voters in ≥300 stations × Machine election	0.0011	0.0009
	(0.007)	(0.007)
Leave-one-out share voters in ≥300 stations × Mixed election	-0.0007	-0.0018
	(0.007)	(0.007)
Polling station FEs	Yes	Yes
El. district × election FEs	Yes	Yes
Num. registered voters × election	Yes	Yes
Num. registered voters squared × election	No	Yes
Observations	20,728	20,728
R^2	0.45	0.45
Mean dep. var.	0.94	0.94

Notes: Test for local spillovers of machine voting to paper polling stations. The leave-one-out share of voters in ≥ 300 polling stations is defined for the baseline election of March 2017, and is constructed as the leave-one-out municipality-level average. The regression sample is restricted to polling station below the machine-assignment threshold. The level of observation is polling station × election and the sample includes all elections since 2014. Robust standard clustered by municipality.

Table E4: Turnout: Spillovers to paper polling stations

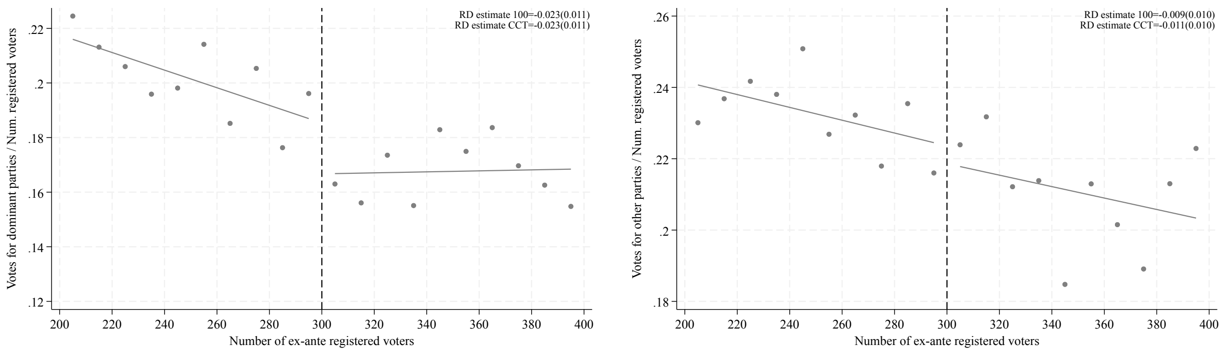
	Turnout / registered voters	
	(1)	(2)
Leave-one-out share voters in ≥300 stations × Machine election	-0.0049	0.0015
	(0.021)	(0.021)
Leave-one-out share voters in ≥300 stations × Mixed election	-0.0239	-0.0161
	(0.016)	(0.016)
Polling station FEs	Yes	Yes
El. district × election FEs	Yes	Yes
Num. registered voters × election	Yes	Yes
Num. registered voters squared × election	No	Yes
Observations	20,729	20,729
R^2	0.75	0.75
Mean dep. var.	0.59	0.59

Notes: Test for local spillovers of machine voting to paper polling stations. The leave-one-out share of voters in ≥ 300 polling stations is defined for the baseline election of March 2017, and is constructed as the leave-one-out municipality-level average. The regression sample is restricted to polling station below the machine-assignment threshold. The level of observation is polling station × election and the sample includes all elections since 2014. Robust standard clustered by municipality.

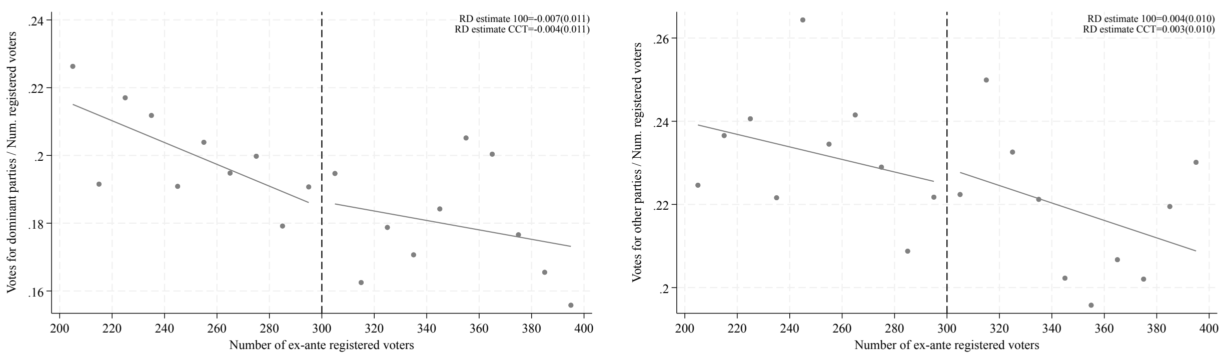
F Mechanism: Additional evidence

Figure F1: Votes for baseline dominant parties versus other parties: Outcomes expressed as shares of registered voters

(a): Machine elections (pooled)



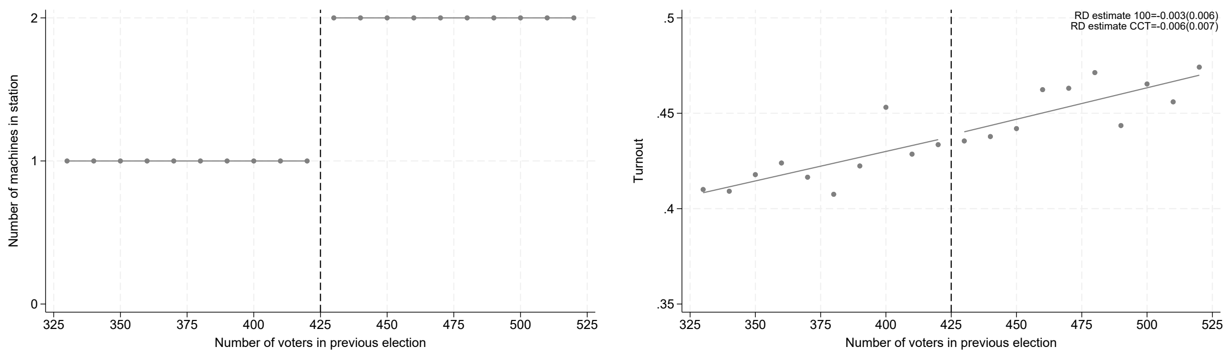
(b): Mixed elections (pooled)



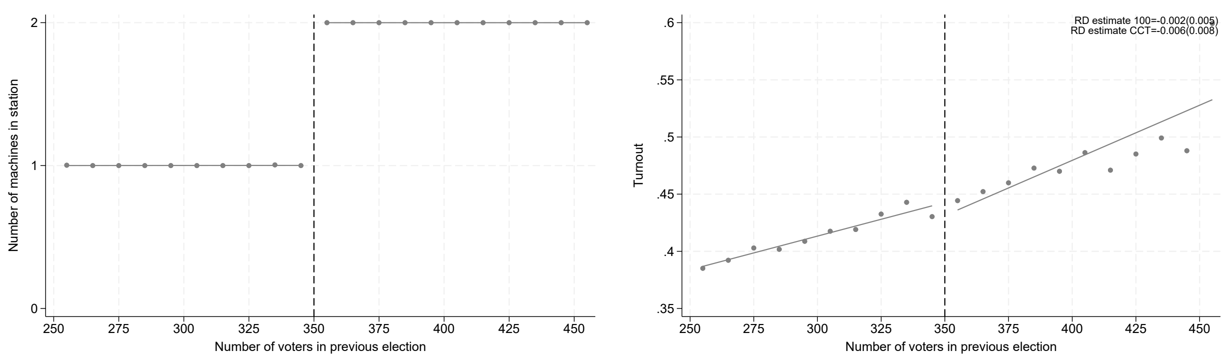
Notes: Binned scatter plot: The vertical line indicates the threshold that determines the allocation of voting machines across polling stations. The outcomes are expressed as shares of the number of registered voters. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold.

Figure F2: Number of machines and turnout: RDD estimates

(a): July 2021 election



(b): October 2022 election



Notes: Binned scatter plot: Number of machines in station and turnout by number of voters in the previous election. The vertical line indicates the threshold that determines the allocation of a second voting machine across polling stations. The sample is polling stations with at least one voting machine.

Table F1: Votes for baseline dominant parties versus other parties: Outcomes expressed as shares of registered voters

(a): Machine elections

	(1) Total valid votes / Num. registered voters	(2) Votes for dominant parties / Num. registered voters	(3) Votes for other parties Num. registered voters
Machine voting	-0.0333***	-0.0226**	-0.0111
	(0.0110)	(0.0107)	(0.00984)
El. district × election FEs	Yes	Yes	Yes
Mean dep var (levels)	0.40	0.18	0.22
Effective observations left	1,555	1,539	1,721
Effective observations right	1,824	1,828	2,048
Bandwidth	100	102	113
p-value (2) = (3)			0.43

(b): Mixed elections

	(1) Total valid votes / Num. registered voters	(2) Votes for dominant parties / Num. registered voters	(3) Votes for other parties Num. registered voters
Machine voting	-0.00198	-0.00429	0.00342
	(0.0104)	(0.0109)	(0.0102)
El. district × election FEs	Yes	Yes	Yes
Mean dep var (levels)	0.40	0.18	0.22
Effective observations left	1,882	2,223	2,059
Effective observations right	2,109	2,653	2,410
Bandwidth	89	110	102
p-value (2) = (3)			0.61

Notes: RDD estimates of the effects of voting technology on the number of votes for parties that are locally dominant at baseline, versus other parties. Outcomes expressed as shares of the number of registered voters. The table presents β coefficients estimated from Equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors clustered by polling station. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

Table F2: Votes for non-dominant parties: Established versus new parties

(a): Machine elections

	(1) IHS(Votes for non-dominant established parties)	(2) IHS(Votes for non-dominant new parties)
Machine voting	-0.0280	-0.0768
	(0.128)	(0.0759)
El. district × election FEs	Yes	Yes
Mean dep var (levels)	23.24	45.71
Effective observations left	1,675	1,288
Effective observations right	2,010	1,489
Bandwidth	111	86

(b): Mixed elections

	(1) IHS(Votes for non-dominant established parties)	(2) IHS(Votes for non-dominant new parties)
Choice machine or paper	0.00485	-0.109
	(0.110)	(0.0701)
El. district × election FEs	Yes	Yes
Mean dep var (levels)	23.39	46.47
Effective observations left	2,165	1,998
Effective observations right	2,563	2,306
Bandwidth	107	98

Notes: RDD estimates of the effects of voting technology on the number of votes for non-dominant parties: other established parties versus new parties. The table presents β coefficients estimated from Equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors clustered by polling station. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table F3: Votes for baseline dominant parties versus other parties: Consistent dominance definition

(a): Machine elections

	(1) IHS(Votes for dominant parties)	(2) IHS(Votes for other parties)
Machine voting	-0.190**	-0.0759
	(0.0918)	(0.0824)
El. district × election FEs	Yes	Yes
Mean dep var (levels)	55.99	71.35
Effective observations left	1,085	894
Effective observations right	1,293	1,058
Bandwidth	113	94
p-value (1) = (2)		0.36

(b): Mixed elections

	(1) IHS(Votes for dominant parties)	(2) IHS(Votes for other parties)
Choice machine or paper	-0.0710	-0.00484
	(0.0829)	(0.0753)
El. district × election FEs	Yes	Yes
Mean dep var (levels)	57.33	71.46
Effective observations left	1,414	1,201
Effective observations right	1,651	1,336
Bandwidth	110	93
p-value (1) = (2)		0.55

Notes: RDD estimates of the effects of voting technology on the number of votes for parties that were *consistently* locally dominant in both baseline elections, versus votes for other parties. The sample includes polling stations where the same party received the highest number of votes in both baseline elections. The table presents β coefficients estimated from Equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors clustered by polling station. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table F4: Votes for dominant parties versus other parties: Definition based on local incumbency

(a): Machine elections

	(1) IHS(Votes for parties affiliated with incumbent mayor)	(2) IHS(Votes for other parties)
Machine voting	-0.190**	-0.0917
	(0.0819)	(0.0676)
El. district × election FEs	Yes	Yes
Mean dep var (levels)	59.70	141.29
Effective observations left	1,576	1,107
Effective observations right	1,859	1,273
Bandwidth	116	83
p-value (1) = (2)		0.35

(b): Mixed elections

	(1) IHS(Votes for parties affiliated with incumbent mayor)	(2) IHS(Votes for other parties)
Choice machine or paper	-0.151*	0.0190
	(0.0823)	(0.0667)
El. district × election FEs	Yes	Yes
Mean dep var (levels)	65.31	131.51
Effective observations left	1,625	1,188
Effective observations right	1,791	1,266
Bandwidth	94	69
p-value (1) = (2)		0.11

Notes: RDD estimates of the effects of voting technology on the number of votes for parties aligned by the incumbent municipality mayor, versus other parties. The table presents β coefficients estimated from Equation 1. The sample in panel (a) consists of the three elections with machine voting in polling stations above the threshold. The sample in panel (b) consists of the four elections with a choice of machine or paper voting in polling stations above the threshold. The bandwidth in each regression is chosen using the MSE optimal procedure suggested by Calonico et al. (2014b). Standard errors clustered by polling station. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table F5: Votes for baseline dominant parties versus other parties: Municipality-level DiD

	IHS(Votes for dominant parties)	
	(1)	(2)
Share voters in $\geq$ 300 stations $\times$ Machine election	-0.301**	-0.254
	(0.151)	(0.156)
Share voters in $\geq$ 300 stations $\times$ Mixed election	-0.159	-0.119
	(0.179)	(0.185)
Municipality FEs	Yes	Yes
El. district $\times$ election FEs	Yes	Yes
Num. registered voters $\times$ election	Yes	Yes
Num. registered voters squared $\times$ election	No	Yes
Mean dep var	8.17	8.17
N	2376	2376

	IHS(Votes for other parties)	
	(1)	(2)
Share voters in $\geq$ 300 stations $\times$ Machine election	0.114	0.105
	(0.116)	(0.121)
Share voters in $\geq$ 300 stations $\times$ Mixed election	0.114	0.121
	(0.112)	(0.118)
Municipality FEs	Yes	Yes
El. district $\times$ election FEs	Yes	Yes
Num. registered voters $\times$ election	Yes	Yes
Num. registered voters squared $\times$ election	No	Yes
Mean dep var	8.40	8.40
N	2376	2376

Notes: Municipality-level DiD estimates corresponding to Equation 2. The level of observation is municipality $\times$ election and the sample includes all elections since 2014. “Dominant” parties are defined as those most-voted parties in a given municipality in either 2014 or 2017. “Other” parties are all other parties. Robust standard clustered by municipality.