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Trading old errors for new errors? The impact of electronic voting technology on party label votes in Brazil☆

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ABSTRACT

In the mid-1990s, Brazil introduced electronic voting technology that reduced residual ballots and consequently expanded *de facto* enfranchisement. We employ a regression discontinuity design similar to that of previous studies of the Brazilian electronic voting technology to show that electronic technology also caused a sharp rise in party label votes (*votos de legenda*) that can only be explained by voting error. We show that this error offsets a large portion of the gains in enfranchisement, highlighting the fact that even generally positive changes in voting procedures can have negative effects. Our results also suggest that party label votes should not be considered a measure of party strength in the Brazilian context.

In the closely-contested 2014 Brazilian general elections, the party of the runner-up presidential candidate did not field a single candidate for the national legislature in the states of Tocantins and Piauí, yet it still received 16,992 party label votes in those two states. Though this might seem a small number, it amounted to roughly a third of the record-high party label voting rate in the other 25 states where the party did field at least one legislative candidate. How is this possible?

The open list proportional representation system used in Brazil's legislative elections allows voters to cast a ballot for a specific candidate (i.e. nominal vote) or to cast a ballot for the entire party list, which is called the *voto de legenda*, or party label vote (henceforth PLV). In the 2014 general elections, just over 7% of the 115 million voters who turned out cast a PLV vote for the federal lower chamber. Scholars have typically interpreted PLVs as an indication of voters' ideological commitment to a party that renders individual candidates' names irrelevant.

In this paper, we present evidence that a large portion of party-label votes for all of Brazil's parties is the result of voter error induced by certain features of Brazil's electronic voting (henceforth EV) technology. We address, therefore, the broader literature on how the method in which votes are cast affects the ability of voters to express their opinion. We show that even with universal suffrage and effectively secret ballots, ballot design and voting technology can affect the results of elections.

The EV technology introduced in Brazil in the mid-1990s has been associated with several positive outcomes in the literature. By doing away with paper ballots, Brazil reduced the potential for fraud (be it at the time of voting, counting, or tallying votes) and mistakes, and is considered to have effectively enfranchised millions of voters. While there should be little doubt that EV technology has the potential to facilitate the voting process, especially among less educated voters, we argue that some heretofore unnoticed aspects of EV implementation have introduced a different form of error. The downside of the Brazilian voting system stems from two of its features: one the one hand, whereas with paper ballots the physical act of voting in the "majoritarian" elections (i.e. for president, governors, senators, and mayors) was very different from the act of voting in the proportional elections (i.e. for federal and state legislators, and city council members), with EV technology there are almost no differences at all; on the other hand, whereas with paper ballots the voter could choose the order in which she filled in the ballot, with the EV technology the voter can only proceed to the next vote after casting the previous ballot. In addition, the mandated order of voting is counterintuitive. The result is that a non-negligible share of voters mistakenly casts a PLV

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vote in the first election of the day, which is always a "down-ticket" election (i.e. federal representatives and/or city councilor), thinking they are voting in the presidential election (or mayoral, in the case of local elections).

We find evidence in support of several empirical implications of the hypothesis that voters are making such a mistake. This mistake artificially inflates the share of PLVs and therefore implies not only that analysts should reconsider the standard interpretation of what this type of vote means, but also that a significant portion of the reduction in invalid ballots which the literature attributes to EV technology is actually offset by a "new" type of voter error. These findings highlight the fact that the design of electronic ballots—-which are likely to become ubiquitous in the future— has potentially significant and sometimes unintended consequences for democracy.

Section 1 of the paper reviews the literature on the impacts of ballot design and technology on voting behavior, some of which has examined ballot changes in Brazil. We then provide background information on how votes are cast in Brazil. We subsequently present our "new error" hypothesis and its four empirical implications. Section 4 describes our research design, and is followed by two sections reporting our results. We then discuss how our results affect *de facto* enfranchisement and, in the final section, we summarize our findings and their policy implications.

1. Ballot design and voting technology

The study of voting technology and ballot design has experienced a rapid expansion in recent years, but has traditionally received much less attention than the study of electoral and party systems. The most comprehensive survey of ballot design *per se* was conducted by Reynolds and Steenbergen (2006), who found that countries with low literacy rates and new democracies tend to use more colors, symbols, and other elaborate features in paper ballots. The authors also show that these features can affect electoral results (at least marginally) in experimental settings, but found no—or limited—association between the use of these features and levels of democracy, number of parties, type of electoral system, and no impact on spoiled ballots. Candidate order on the ballot has been shown to matter for electoral results (Miller and Krosnick, 1998; Ho and Imai, 2008), as has the level of complexity of ballots (Niemi and Herrnson, 2003; Herrnson et al., 2012). These findings illustrate a broader consensus in the literature that relatively arcane ballot features can affect vote choice.

Ballot secrecy is also a key area of study. The literature on clientelism, for example, has examined how essential the possibility (real or perceived) of violating ballot secrecy is to the clientelistic exchange.[1] Recent work has further formalized conditions under which vote brokers can continue to operate under a secret ballot (Gingerich and Medina, 2013).

The effect of ballot design on *de facto* secrecy has also been given considerable attention in the literature. The introduction of Australian ballots, for instance, reduced the observability of the act of voting and has been associated with the weakening of patron-client relationships in the countryside and subsequent drop in land prices in Chile (Baland and Robinson, 2012).[2] In Brazil, the adoption of Australian ballots in the 1950s led to the election of more progressive candidates and to decreases in the level of control that political brokers exerted over voters (Gingerich, 2013).[3] This same change, however, was accompanied by a rise in spoiled ballots caused by the increased difficulty in casting a vote under the new system (Nicolau, 2015). Similar effects have been found in the transition to Australian ballots in the U.S. as well (Campbell et al., 1972) and are illustrative of the trade-offs involved in changing voting technology and ballot design. Even generally positive changes can be accompanied by less desirable outcomes.

The implications of the introduction of machine voting constitute an important sub-area within the literature on ballot effects. Ballot security and integrity are actively debated (Kohno et al., 2004); the mechanics of voting—and the errors likely to follow—have also garnered attention. Early studies on voter machines found that the new technology confused voters and actually led to greater roll-off (White, 1960; Mather, 1964).[4] Others have observed how flawed ballot design can lead to undervotes, such as in Florida's 13th district in the 2006 mid-term elections (Frisina et al., 2008), or how different types of machines lead to different rates of uncounted votes, with "punch card" technology faring quite poorly (Ansolabehere and Stewart, 2005). In terms of more positive outcomes, Nichols and Strizek (1995) examined voting technology introduced in the city of Columbus in 1992 that prevented voters from "forgetting" to cast a ballot in down-ticket races by employing "flashing red lights above each contest". The result was a significant reduction in voter roll-off (Nichols and Strizek, 1995).

The literature examining the shift from paper ballots to EV technology in Brazil has also found mostly positive effects stemming from the reduction of spoiled ballots and the enfranchisement of lower socio-economic status voters (Nicolau, 2002; Fujiwara, 2015; Hidalgo, 2014). These studies are discussed in more detail below, but we make the case that despite its many advantages, some less conspicuous features of electronic voting technology have, to a large extent, offset the gains in enfranchisement.[5]

2. Casting a ballot in Brazil

The argument put forth in this paper addresses the ways in which ballot structure and voting technology affect results, yet it is impossible to talk about the Brazilian ballot without some discussion of the electoral system.

Elections in Brazil have been held every two years since the early 1990s. Local elections (i.e. for mayors and city council members) are staggered with the general election (i.e. for the presidency, governorships, senate, federal lower chamber, and state assemblies). Since its first experience with electoral democracy, in 1945, Brazil has employed majoritarian systems to elect presidents, governors, mayors, and senators, and proportional representation (PR) to elect members of unicameral municipal and state-level legislatures, and the lower chamber of Congress.[6] Some of the finer points of the PR system used in Brazil have changed over time, but it has always featured relatively high district magnitude and

[1] For a comprehensive review of this literature, see Stokes (2007).

[2] The "Australian ballot" (Katz, 1997), by which voters mark their preferred choice on a pre-printed ballot that includes the names of all candidates (or parties), was created in the XIX century, and spread to become the most common type of ballot around the world (Reynolds and Steenbergen, 2006).

[3] The ballot had been officially secret in Brazil since 1932.

[4] Roll-off is the tendency of voters to not cast a vote in less important "down-ticket" elections.

[5] It should be stressed, from the outset, that we by no means advocate a return to a paper ballot system, as we believe that small changes in the way votes are cast could alleviate pernicious effects, and contribute to consolidating the enfranchisement gains of the new technology.

[6] The 1988 Constitution introduced runoffs between the two candidates receiving the most votes (for president, governor, and mayors of municipalities with more than 200,000 voters) whenever the first place winner does not obtain 50% of the votes in the first round. Until 1986, parties could field several candidates for senator in each state and the winning party was determined by pooling the votes of all their candidates.

employed an open list system that allows voters the choice of voting for a specific candidate (i.e. nominal vote), or simply casting a vote for a party (i.e. *legenda* vote).[7] Regardless of how the voter chooses to cast her vote for legislative elections, it is always used to determine the total tally for the party's list.[8] If the voter casts a nominal vote, the same vote is also used to rank candidates within the list.

While the essence of the electoral system has remained essentially the same, ballot structure has twice undergone considerable changes. Ballots were originally distributed by parties to voters who then simply placed them in envelopes and deposited them in the ballot box. The first major change occurred in the mid-1950s, with the introduction of the Australian ballot; the second in the mid-1990s, with the adoption of EV technology (Nicolau, 2015).

During the four decades of the Australian ballot, elections for all public offices were typically included on the same single-sheet official paper ballot. Voting for a candidate in majoritarian elections almost always implied ticking a box.[9] Given the much larger number of candidates contesting the proportional elections, providing a printed ballot with all candidates names was impractical.[10] Therefore, voting for a candidate in these elections implied writing-in the candidate's name, nickname, or number, while voting for a party required writing-in the party's name, acronym, or number. As a partial exception, between 1986 and 1990 the ballots included boxes with pre-printed party names that could be ticked to cast a PLV in proportional elections, but voters could also write-in the candidates' name or number. In all elections, voters had the option of leaving the ballot blank, or casting a *nulo* vote by making any markings beyond writing in names, numbers, and acronyms. Null and blank votes, as a consequence, included both intentional protest and unintentional voting error.

EV technology was first introduced in Brazil during the 1996 local elections. This transformed the voting process into an act of punching buttons on a machine the size of a first generation desktop computer with a small built-in screen and a keypad reminiscent of a large calculator or touch-tone phone.[11] Since then, voters simply enter the number of their preferred candidates (or parties). They are then shown a picture of the candidate (or logo of the party if casting a PLV vote) and can "confirm" or "cancel" (in which case they start again). If they type and confirm a wrong number, the voter will have cast a null vote. In order to cast a blank ballot, the voter can press the "branco" key and confirm. The voter can only proceed to the next ballot once she has cast an actual vote (blank, null, or valid) in the preceding one.

Although no change was made to the electoral system, the introduction of EV technology alone has produced non-trivial changes in voting results. By doing away with the steps of interpreting the sometimes unclear intention of voters and tallying the votes locally, the change is likely to have reduced electoral fraud, though quantitative analysis has not yet clearly determined this. One change that is widely acknowledged is the sharp reduction in null and blank votes. This was first noted by Nicolau (2002), and rigorous statistical analysis has shown this reduction to be particularly prevalent in poorer areas with lower levels of education (Fujiwara, 2015; Hidalgo, 2014). These results suggest that the adoption of EV technology enfranchised a significant share of the poorest and less educated voters who had difficulties expressing their preferences with paper ballots. In fact, this change has been linked to an increase in representation of left-leaning parties, greater pro-poor spending, and better health outcomes by Fujiwara (2015).

3. Party label votes and the "new" voting error

Prior to the introduction of EV technology, voters had to write-in the names or numbers of candidates or parties in legislative elections. With widespread illiteracy and very low education levels, this was a large hurdle for many voters to clear. It is not surprising that parties and candidates often campaigned using the numbers assigned by the electoral authority or adopted mnemonic nicknames as a way to get ahead. Although voting was challenging for the average voter, voting for the party list was in fact easier than voting for a specific candidate. This is because each party was (and still is) identified by a two-digit number,[12] whereas candidates for the lower chamber of Congress are identified by four-digit numbers and for the state or municipal legislative candidates the numbers are five digits long. Party acronyms are typically between two and five letters long, while candidate names, even when simplified to official nicknames, are generally longer than that.

The strong incentives for personalism inherent in the open list system (Carey and Shugart, 1995) meant that most politicians campaigned for themselves (as opposed to for their parties), and the practice of casting a PLV was always relatively rare. Since the start of the current democratic period in the mid-1980s, the PT (Worker's Party)—the main left-wing party in the country—has typically obtained the largest share of PLVs among all parties. This was particularly true in the party's early years, when its electoral strength was still quite limited (Samuels, 1999; Nicolau, 2006). For this reason, the literature first associated PLVs with left-wing parties (Mainwaring, 1992), but as it became clear that not all left-wing parties sought and obtained large shares of PLV (Carneiro and Schmitt, 1995) this interpretation evolved to consider PLVs as a by-product of strategic choices determined by the lack of resources (Samuels, 1997). In either case, the standard interpretation of the PLV was, and still is, that it represents an intentional choice by voters driven by some level of political sophistication and commitment to the party.

In 2014, for the first time, the PT's share of PLV for the federal lower chamber was surpassed by that of another party (The Party of

[7] The origins of the PLV lay in rules for counting votes as stipulated in the Electoral Code of 1950 (Law n. 1164 of July 24, 1950). Article 55 of this law, determined that if a (then party-provided) ballot contained only the party name, it would be counted as a vote for that party. It also determined that if there was conflicting information between candidate and party names, the party name would prevail.

[8] Currently, and in most of the elections in the recent past, parties were permitted to run joint lists. Voters, however are only able to cast ballots for specific parties. If a voter casts a PLV for a party in a joint list, such a vote really benefits the list and not necessarily the party.

[9] As Nicolau (2015) observes, in the 1982 election no boxes were provided and voters were required to write in the name of the candidates in majoritarian elections. In the online Supplemental materials we provide images of several variants of the paper ballots.

[10] Parties can run their own lists or coalesce with other parties to present joint lists. Lists are allowed to field at least the same number of candidates as there are seats. With multiple parties contesting each district, the are often hundreds of candidates to choose from.

[11] In particular, the voting machines keypad resembles the typical public phone that was then widely used by poorer voters.

[12] At the end of the military dictatorship, and prior to the 1982 election, six parties were registered with the electoral authority. Following Law 6996/1982, the authority assigned single digit numbers from 1 to 6 to these parties, with legislative candidates being identified by three digit numbers starting with the party digit. With further liberalization of political competition, a large number of new parties were formed, ten of which were granted registration in August of 1985. The electoral authority subsequentially added a leading "1" to the numbers of the original parties, and distributed two-digit numbers to the new entrants by lottery. The numbering system has remained in place to this day, with new parties being assigned two-digit numbers, and old numbers being recycled if a party becomes defunct.

the Brazilian Social Democracy, or PSDB).[13] This result has strengthened an alternative, albeit similar, interpretation, suggesting that PLVs represent a type of coattail effect generated by strong up-ticket candidates (Nicolau, 2006). Voters, in this scenario, make up their minds for the up-ticket candidates and intentionally decide to cast a ballot for any down-ticket candidate supported by their main choice. If they cannot decide on a candidate, they simply vote for the party.

Our argument, in contrast, is that a large portion of PLV under the EV voting system is simply error.[14] We agree that less educated voters should find EV technology easier to use than the old paper ballot. EV also offers voters a chance to confirm their choice, something that should also reduce voting errors. However, EV blurs the distinction between majoritarian and proportional elections and imposes a specific order of voting which makes it easier (relative to paper ballots) for voters to get confused with which election they are actually casting a vote in.

These features of the voting system have gone mostly unnoticed, except for an untested conjecture by Kinzo (2004), who noted that EV technology “forced” voters to make a decision in down-ticket elections before they could proceed to the up-ticket elections. Forcing voters to cast ballots in a specified order is relevant in the Brazilian context for two reasons: First, the order of voting, which places the “most important” votes at the end, is counter-intuitive. The idea of an “up-ticket” option suggests that important votes are typically on the “top” of a ballot, or that these should be voted on first. It is not surprising, therefore, that voters would think their first vote is for the up-ticket candidate. Second, and crucially, if voters enter the number of their up-ticket choice in the first vote presented to them, the system will identify it as a vote given to the party's list in the first legislative election of the day. This happens because up-ticket candidates use the two-digit party code that voters would type to cast a PLV.[15] Granted, the voting machine will show the voter the logo of the party instead of the picture of a candidate, but this may be too nuanced for some voters to realize.

While voting was arguably more onerous with paper ballots, it was almost impossible to confuse the two votes. Voters could recognize the main vote of the day, and make their choice by ticking one box among a relatively short list of boxes followed by a clearly recognizable number and name. Voting in the less important, and much harder to understand proportional contests,[16] in contrast, required writing-in a name, number, or acronym. With EV technology, voters might think they are casting a vote for president in the first vote of the day and not realize their mistake. Those who do make this mistake will end up unintentionally casting a PLV for their presidential candidate's party.

Consequently, if this type of miscast ballot is in fact driving PLV, we expect to find the introduction of EV technology to be associated with a sharp increase in PLVs. This is the main empirical hypothesis tested in the paper (Hypothesis 1).

Our “new error” hypothesis generates additional testable empirical implications. We expect that parties that field competitive up-ticket candidates will see a pronounced increase in PLVs under EV technology, whereas other parties will not (Hypothesis 2). This hypothesis should manifest itself slightly differently in local and general elections. In local elections, parties—even major ones—do not field mayoral candidates in *all* municipalities. In this context, we expect parties to obtain higher shares of PLV in municipalities employing EV technology than in paper ballot municipalities *in which they field mayoral candidates*. We expect no difference between PLV in EV technology municipalities and paper ballot municipalities in which they do not field mayoral candidates. In the general election, there is no variation across municipalities: some parties field presidential candidates while others do not. In this setting, we expect PLV to increase in EV relative to paper ballot municipalities only for parties that fielded presidential candidates.

Another observable implication of our hypothesis allows us to further test whether PLVs in EV technology are intentional votes or not. If our “new error” hypothesis is true, we expect the prevalence of PLVs to be positively associated with levels of development under paper ballots, but negatively associated with EV technology (Hypothesis 3). The rationale, here, is that unintentional PLVs are produced by a misunderstanding of how the ballot works, which is likely to be more widespread in less developed areas of the country. Intentional PLVs, in contrast, require some level of sophistication by voters, who have to understand what a party is and that different politicians from the same party are—to some extent—interchangeable.

A final implication of the “new error” is that if voters mistakenly think the first vote in EV technology is a vote for president, then they should also mistakenly think the last vote is not for president. For this reason, voters who cast PLVs by mistake in the first vote are likely to cast null or blank ballots for president. We would expect therefore, with EV technology, the share of PLVs in the first election of the day (i.e. federal lower chamber) to be positively associated with invalid votes in the last vote of the day (i.e. president). With paper ballots, on the other hand, we expect a weak negative association because PLVs indicate stronger partisanship, which should be correlated with higher interest in politics and with less propensity to cast an invalid vote for president (Hypothesis 4).

4. Design of the RD study

Simple frequencies suggest our main empirical hypothesis is plausible. The overall share of PLVs spiked considerably with the introduction of EV technology, but of particular interest is the way in which this spike occurred. In the 1996 local elections, 16.7% of those who voted in city council elections in municipalities with EV cast PLV, while the corresponding number in municipalities using paper ballots was just 1.2%. In the next local election (2000), all municipalities used EV technology and PLV rose to 12% of turnout.

For general elections, the EV roll-out began in 1998. In the previous election (1994), which used only paper ballots, the share of PLVs for the federal lower chamber (the first vote of the day) was 5%. In 1998, 16.6% of the votes in municipalities with EV were PLVs, while this figure was only 3.7% in municipalities with paper ballots. In 2002, when all municipalities used EV technology, PLV was 9.1% of total turnout.

While these summary statistics are quite compelling, the

[13] For the state assemblies, the PT still held both an absolute and relative advantage in PLVs.

[14] We do not claim that *all* votes cast for the parties are error, a point to which we return later in the paper.

[15] For example, the PT's presidential candidate runs with the party's official number, which is 13. All of the party's candidates for the lower chamber of Congress have four-digit numbers that begin with 13, and, in order to cast a PLV for the party in that election, the voter should simply type 13.

[16] Evidence that voters have more difficulty recalling their vote for the lower house than for president supports our qualification of the proportional contests. In the post-electoral wave of the 2014 Brazilian Electoral Panel Survey (BEPS), taken a few days after the election, only 60% of respondents who claimed to have voted could name their choice for the Camara de Deputados. This includes 15% who claimed to have cast an invalid vote. This stands in sharp contrast with the presidential election, in which 97% of the sample that turned out could recall their choice. (Ames et al., 2015). These results do not seem atypical. In the Brazilian Electoral Study (ESEB) in 2002, for instance, only 67% of respondents who voted could remember their choice for Deputado Federal, whereas almost all respondents recalled their presidential choice.

phased-in adoption of EV technology in Brazil's 1996 local elections and 1998 general elections allows us to employ a standard regression discontinuity (henceforth RD) design to formally examine whether the use of electronic ballots is associated with increases in PLVs. As such, our approach mirrors previous work that analyzed the effects of EV technology on spoiled ballots in the elections of 1998 (Fujiwara, 2015; Hidalgo, 2014).

RD is a suitable approach to infer the effects of an intervention (treatment) that used an arbitrarily set cutpoint on an observed ordinal scale (the forcing variable) to determine which units (municipalities) are assigned to the treatment (EV technology) and control (paper ballot) conditions. The expectation is that units that fall just above or just below the cutpoint should be similar in most respects, except for the fact that some were treated while others were not. As long as underlying characteristics vary continuously with the forcing variables, any observed discontinuity in the outcome of interest will be attributable to the treatment itself.

In the elections in which EV technology and paper ballots were employed simultaneously, the electoral authority (TSE) used an arbitrary cutpoint in the number of registered voters to determine which municipalities would receive EV technology. In each election, there were a few municipalities under the threshold that for idiosyncratic or systematic reasons, explained below, used EV technology. Except for these few cases, compliance with the rule determining which municipalities were to implement EV was perfect.

For the 1996 local elections, the threshold for implementation of EV technology was 200,000 registered voters, but all state capitals (regardless of size) as well as the town of Brusque also used EV technology.[17] None of the non-complying municipalities fall close to the cutpoint, so we eliminated these from the sample and estimated a sharp RD.

For the 1998 general elections the, threshold for EV technology implementation was 40,050 voters, as of 1996. Once again, compliance was perfect above the threshold, but all municipalities in four states (Amapá, Roraima, Rio de Janeiro and Alagoas) were included, regardless of size, as well as seven other municipalities that petitioned to be included in the EV rollout program (Fujiwara, 2015). We excluded all municipalities from these four states, as well as the seven outlying ones, and employed a sharp RD design. In the Supplemental materials we report results from matching estimators that rely on the non-compliers, which are almost identical to the RD estimates.

If we take the position that the RD design simulates an experiment with random assignment, then it is important that the control and treatment groups be as similar as possible on observable and non-observable confounding variables. This would lead us to compare only municipalities in the narrowest possible band around the cutpoint, as only in such a narrow band is the "as-if random assignment to treatment" assumption plausible (Dunning, 2012, p.127). However, the prevailing approach in the literature is to assume the continuity of potential outcomes at the cutpoint, and focus on estimating the difference between the two potential outcome functions as one approaches the cutpoint from above and below (Bueno et al., 2014). This approach requires data-driven driven procedures to choose the bandwidths that yields the best tradeoff between bias and efficiency of the estimator of the differences in the limits of the potential outcome functions. The most commonly employed procedure is Imbens and Kalyanaraman's (2011) optimal bandwidth procedure (IK), though other bandwidth selectors exist, such as Calonico et al.'s (2014) method (CCT), and the cross-validation (CV) method by Ludwig and Miller (2007).[18]

As the preferred choice of bandwidth varies across research traditions, we follow Bueno and Tuñón's (2015) suggestion to report results from many bandwidths. This is made possible by focusing on graphical representations of RD estimates in the main body of the paper. We present three different estimates for all bands: our preferred difference-of-means estimates (Dunning, 2012, p.128), local linear regression (Imbens and Lemieux, 2008; Gelman and Imbens, 2014), and a (third-order) polynomial local linear estimate. In the Supplemental information we present results for additional specifications in table format.

We operationalized the RD local linear estimator in a single regression, allowing for intercept shifts and slope shifts on the forcing variable. The local linear model we effectively estimate is:

$$PLV\,Share = \beta_0 + \beta_1 Ballot + \beta_2 Electorate + \beta_3 Ballot \times Electorate + \varepsilon$$

where *PLV Share* is the share of PLV relative to turnout, *Electorate* is the difference between the size of the electorate at the time of deciding EV rollout and the cutpoint used to define EV technology municipalities (i.e. the forcing variable). *Ballot* is a dichotomous indicator that takes on the value of 1 if EV technology was used. In this specification, β_1 is the estimate of the causal effect of the implementation of EV technology on the share of PLVs.[19] The polynomial estimate departs from the above specification simply by the inclusion of $Electorate^2$, $Electorate^3$, and interactions thereof with the forcing variable. For the difference-in-means estimator, we rely on standard errors provided by *t*-test allowing for different variances above and below the cutpoint (Dunning, 2012, p.194).[20]

As exhaustively shown by Hidalgo (2014) and Fujiwara (2015), and discussed by Dunning (2012), the way in which EV was implemented in both elections generated very plausible as-if-random setups. The cutpoint was determined after the forcing variable was measured, and a number of pre-treatment covariates, as well as the density of the forcing variable, are also smooth around the cutpoint. In the Supplemental materials, we report standard graphs of covariates by forcing variable as well as the density of the forcing variable at the cutpoint of implementation of EV technology (Imbens and Lemieux, 2008; McCrary, 2008).

5. Electronic voting and party label votes

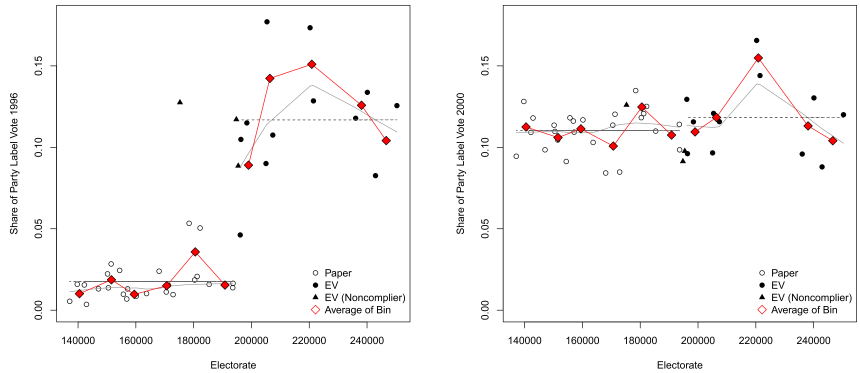
In this section, we report results of the RD analysis of the effects of EV technology on PLVs in the 1996 and 1998 elections. We examine Hypotheses 1 and 2 for each of these elections separately, and turn to Hypotheses 3 and 4 in the subsequent section. Throughout the text, we measure PLV relative to turnout (not relative to valid votes, as in most studies of PLV) in order to facilitate comparisons with the effects of EV technology on spoiled ballots.

[17] Brusque, a midsize municipality, was included because it was the city that pioneered experiments with electronic voting machines, having been in use in one form or another since 1989.

[18] Bandwidth selector algorithms are somewhat sensitive to the scale, especially when the forcing and outcome variables are in different orders of magnitude. For this reason, we divided the forcing variable (originally measured in voters) by 1000 prior to applying these algorithms.

[19] This operationalization is equivalent to what is obtained by estimating separate regressions on either side of the threshold and subtracting the predicted values at the threshold from each other, with the advantage that it allows for a direct comparison of the slopes on either side. Understanding whether the slopes are similar around the threshold is convenient because it gives us a rough assessment of the bias in the simplest difference of means estimator (Dunning, 2012, p.158).

[20] This is algebraically identical to computing differences in means by regression with robust standard errors (Samii and Aronow, 2011).



(a) Party Label Votes 1996 (b) Party Label Votes 2000 (Placebo)

Fig. 1. Regression discontinuity and placebo test for 1996 elections.

5.1. RDD results for the 1996 local elections

Our main result for this election is presented graphically in Fig. 1. Here we report the share of PLV for municipal councilors around the cutpoint for introduction of EV technology, in the 1996 and 2000 local elections. Recall that both EV and paper ballots were used in 1996, but only EV technology was used in 2000, so the latter is, in effect, a placebo test.

The graph reports PLV rates for all municipalities within a band of $h = 80$ k voters[21] around the cutpoint, as well as average values for municipalities in six equally sized bins (diamonds). The horizontal lines are averages on either size of the cutpoint, such that the differences between these lines correspond to the differences of means estimator suggested by Dunning (2012). The lighter irregular line is a lowess regression fit to data on either side of the cutpoint.

The figure excludes the states in which all municipalities used EV technology. The horizontal lines are averages on either size of the cutpoint, such that the differences between these lines correspond to the differences of means estimator suggested by Dunning (2012). The lighter irregular line is a lowess regression fit to data on either side of the cutpoint.

The differences in PLV at the cutpoint are very conspicuous regardless of the approach used, suggesting a sharp increase in PLV. There is hardly any overlap between the two groups in 1996. The few non-compliers (triangles) further strengthen our results, as they perform as the other EV technology municipalities even though they are “more similar” to the paper ballot municipalities.

The subsequent local elections, held in 2000, serve as a placebo test. Because all municipalities used EV technology in that year, we expect to see no difference in shares of PLV across the two groups defined by the roll-out in 1996. If some factor other than the use of EV technology affected the 1996 result, it is likely to have also affected results in 2000. The data show, in fact, that the share of PLV in both groups converged to the levels observed in the EV group in 1996.

5.1.1. Estimates of EV effects

Formal results are depicted in Fig. 2. Estimates of RD effects are stable across a wide range of possible bandwidths, and also across method of estimation, consistently yielding effects in the vicinity of 0.10. This increase of 10 percentage points in PLV is statistically significant, even when the sample is severely restricted in the most narrow bands, and is not particularly sensitive to choice of method. It corroborates what was seen in the raw data, and nearly triples the share of PLV relative to baseline values.

The figure also shows that standard bandwidth selectors lead to relatively wide bands for analysis. In fact, the figure only includes one of these selectors because the other two yield even wider bands. This is partially a function of the fact that data are relatively sparse at the cutpoint for the 1996 elections. Nonetheless, we also observe this pattern of relatively wide “optimal” bands in the 1998 election (in which the density of cases around the cutpoint was much larger).

Figure reports difference-in-means, local linear, and polynomial RD estimates of the effects of EV technology on PLVs for different bandwidths. Size of the sample and absolute distance to cutpoint are shown on the horizontal axis. 95% confidence intervals around the difference-in-means estimates are also reported. Vertical dashed line represents the smallest bandwidth among common bandwidth selection methods.

5.1.2. Parties with up-ticket candidates

In order to evaluate the hypothesis that the effect of EV technology is more pronounced for parties that fielded up-ticket candidates (Hypothesis 2), we pooled electoral results for the 10 parties that most frequently fielded mayoral candidates in the 19

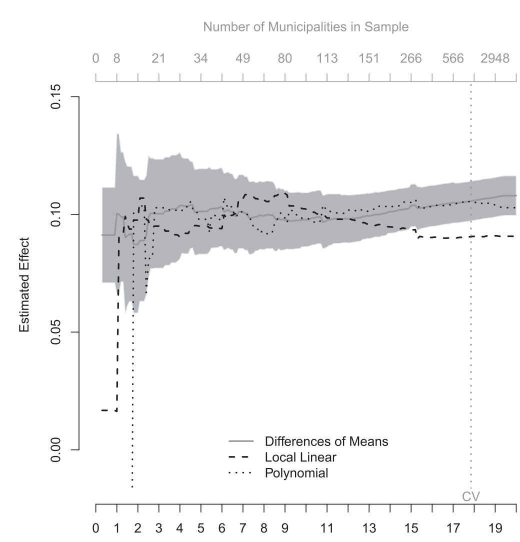


Fig. 2. Rd estimates for multiple bandwidths (1996 elections).

[21] All bands in this paper are defined based on registered voters.

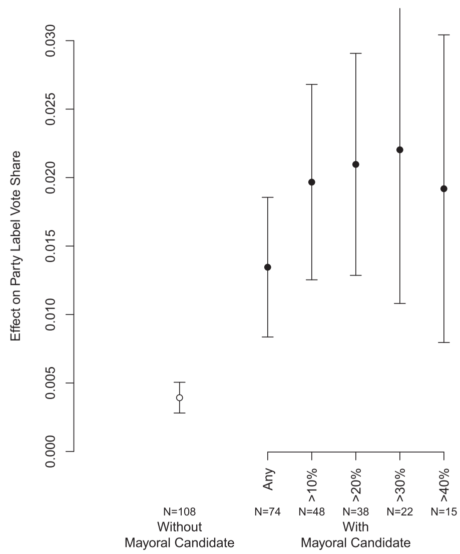


Fig. 3. Heterogenous EV effects on party label vote shares, 1996

municipalities that comprise a narrow band around the cutpoint ($h \pm 25$k).[22]

PLVs for parties that did not field a mayoral candidate averaged 0.04% in paper ballot municipalities and 0.44% in EV technology municipalities—a statistically significant increase of 0.39 percentage points (p-value <0.001), which we did not expect. However, in municipalities where these same parties did field a candidate, the EV technology effect relative to paper ballots was about three times larger (1.35 percentage points, p-value <0.001).

Not all mayoral candidates are equally competitive. If we change the comparison criteria from having simply fielded a candidate to requiring that candidates obtain a higher vote share, an interesting picture emerges. As Fig. 3 shows, the EV effect on PLV increases to 2.1 percentage points when parties field mayoral candidates that receive at least 20% of the vote, something that happened in 38 instances in our sample. The EV effect is even more pronounced if we further increase the threshold.

Estimates were obtained by pooling all parties that contested elections in any municipality in the narrowest band. We compare parties that did not field a mayoral candidate with parties that fielded candidates of different levels of "competitiveness". N corresponds to the number of party/municipalities observations in each category. Estimates are differences-in-means with 95% confidence intervals.

The existence of an EV technology effect on vote share even for parties that did not field mayoral candidates suggests that our hypothesis does not account for all of the ways in which EV might have led to more party votes. It is possible, for instance, that part of the increase was not just error, but that the new technology simply made it easier to cast an intentional party ballot. However, the data are clearly compatible with the larger portion of this effect (at least two-thirds of it) being a "new error".

In sum, in the 1996 election there is a clear discontinuity in PLV at the cutpoint for implementation of EV. This discontinuity was not observed in the subsequent election when only EV was used. It is stronger for parties that fielded competitive mayoral candidates in EV technology municipalities; these parties were therefore more likely to benefit from the new error.

5.2. RDD results for 1998

Results for 1998 are presented graphically in Fig. 4, for a band of $h = 10$k voters. We are able to work with much narrower bands than used in the 1996 elections because the density of municipalities at the cutpoint for EV implementation in this election was considerably higher.

Results are presented for the elections of representatives to the federal lower chamber, which was the first ballot cast in the 1998 election.[23] The discontinuity in PLV at the threshold of EV implementation is, again, very clear. Fig. 4(b) is presented in the same scale as Fig. 1(a), above, clearly demonstrating how similar the levels of PLV using paper ballots and EV technology were in the 1996 and 1998 elections.

Only five of the non-complying municipalities (represented by triangles) fall in the band of analysis, and their behavior is compatible with our interpretation of the causal effects. Four of these cases yielded much higher PLV than similar municipalities using paper ballot, and a fifth non-complier would have been the second highest municipality with PLV among paper ballot municipalities. Granted, these non-compliers selected into the treatment, so we should not base inferences on these comparisons.

The placebo tests reinforce the idea that the shift observed in 1998 was due to EV technology. These tests examine PLV levels in the 1998 RD sample in years in which all municipalities used the same voting method. In 1994, when only paper ballots were used (Fig. 4(a)), the rates of PLV were identical across all municipalities and very similar to what was observed in the municipalities that used paper ballots in 1998. In 2002 (Fig. 4(c)), all municipalities used EV technology, and the levels of PLVs were similar to those observed in the EV technology group in 1998. In fact, PLV voting in 1998 was slightly *lower* in the group of municipalities that had used EV technology in the previous election, though this difference is relatively small.

5.2.1. Estimates of EV effects

Fig. 5 reports the three different RD estimates for several bandwidths. Once again, results are in the vicinity of 0.10, stable across different bandwidths and similar across methods of estimation. Difference-in-means estimates are always statistically significant, regardless of the bandwidth used, and indicate more than a doubling in the share of PLV from a baseline of just under 4%. Estimates also do not vary much at different standard bandwidth selectors, the three of which are relatively large, and shown in Fig. 5.

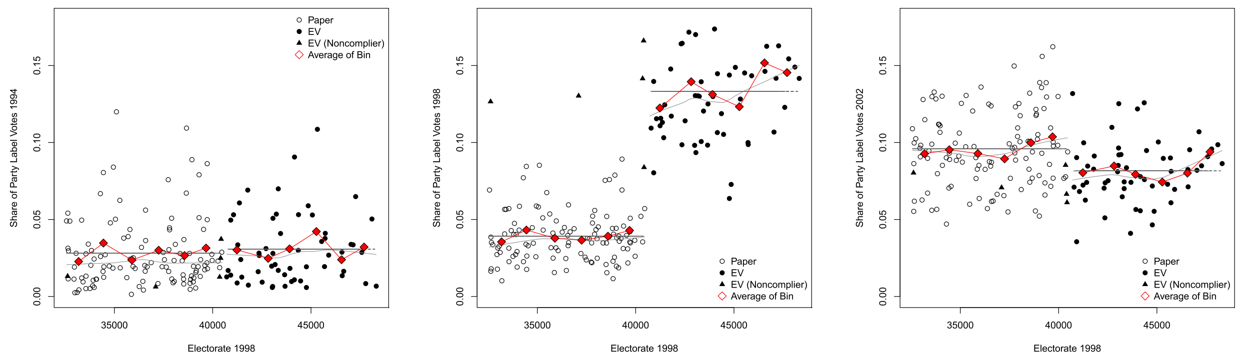
Figure reports difference-in-means, local linear, and polynomial RD estimates of the effects of EV technology on PLVs for different bandwidths. Size of the sample and absolute distance to cutpoint are shown on the horizontal axis. 95% confidence intervals around the difference-in-means estimates are also reported. Vertical dotted line represents the bandwidth chosen by common selection methods.

5.2.2. Parties with up-ticket candidates

In order to evaluate our hypothesis that the new error disproportionately benefited parties with strong up-ticket candidates (Hypothesis 2), we pooled results from the main parties contesting

[22] The parties included in this analysis are the PMDB, PFL, PSDB, PPB, PDT, PTB, PL, PSB, PT, and PSD. The full names of these parties are immaterial to the analysis, and are provided in the Supplemental information.

[23] An analysis for the state assembly, the second vote in 1998, yields similar results and is reported in the Supplemental information.



(a) Party Label Votes 1994 (Placebo) (b) Party Label Votes 1998 (c) Party Label Votes 2002 (Placebo)

Fig. 4. Regression discontinuity and placebo tests for 1998 lower chamber elections.

legislative elections in the 99 municipalities in a narrow band around the cutpoint ($h = \pm 4k$).[24]

We performed an exercise similar to the one carried out for the local elections, and report estimated difference-in-means RD effects on PLV in different subsets of our sample, depending on whether the party had an up-ticket candidate or not—and how competitive the candidate was in the municipality. Unlike in the local elections, in this case the same parties consistently either fielded an up-ticket candidate or not in all municipalities in the sample.

As reported in Fig. 6, we see an increase in PLV even for parties that did not field presidential candidates. However, the increase in PLV for the parties that did field presidential candidates (PSDB, PT and PPS) is larger, and increases markedly if we look only at municipalities in which the presidential candidates were particularly competitive. In municipalities in which the presidential candidates obtained as little as 20% of the vote, the RD estimate of the effect of EV technology is more than triple what it is for parties without presidential candidates. This is notable given that the two main candidates for president met this threshold in more than 75% of the municipalities in the sample. These results are compatible with voters intending to cast a vote for president and mistakenly registering a PLV.

Figure shows the estimates of the effect of EV technology on PLV for different subsets of the data (parties with and without a presidential candidate, and for presidential candidates with different levels of "competitiveness"). The N refers to the number of party/municipality observations in each group. Results are shown for the narrowest band of analysis ($h = \pm 4k$) and correspond to difference-in-means estimates with 95% confidence intervals.

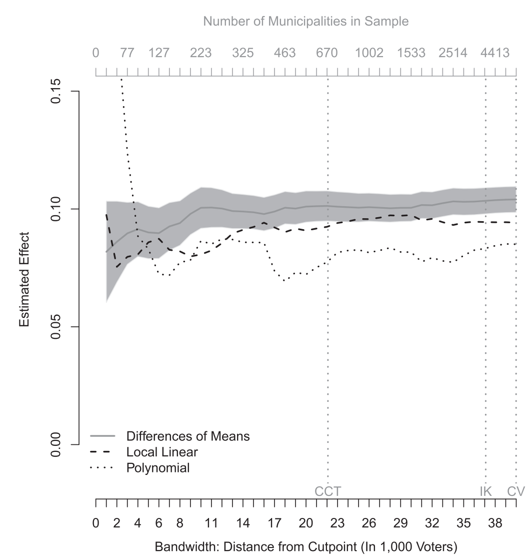


Fig. 5. Rd estimates for multiple bandwiths (1998 elections).

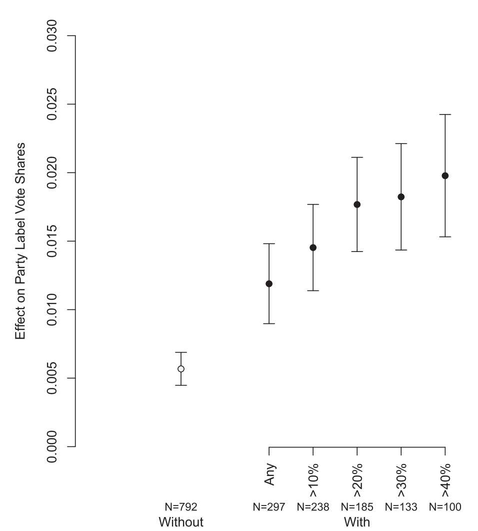


Fig. 6. Heterogenous EV effects on party label vote shares, 1998

6. Are PLVs really the product of error?

The results show that EV technology is associated with a substantial increase in PLVs. We interpret this increase as the product of error, but it is logically possible—though we argue unlikely—that voters intended to cast PLV votes under paper ballots but were unable to so due to the complexity involved. This alternative is unlikely for multiple reasons. First, one would be hard pressed to imagine large swathes of the electorate wanting to cast a PLV and not being able to. If voters wanted to cast a straight ticket ballot, the PLV would not be the most natural way to do it. Considering that

[24] The parties included in this analysis are the same 10 parties included in the analysis of results of the local elections, plus the PPS, which fielded a competitive presidential election in 1998.

Table 1
Party label votes over time: 1986–2014.

	Ballot type	PLV share	Correlations between PLV share and	
			HDI-M (hypothesis 3)	Invalid pres. vote (hypothesis 4)
1986	Paper (write-in with boxes)	8.58	†	†
1990	Paper (write-in with boxes)	10.32	†	†
1994	Paper (write-in only)	4.96	0.44	−0.34
1998	**Paper (write-in only)**	**3.67**	**0.20**	**−0.19**
1998	**Electronic**	**16.56**	**−0.35**	**0.53**
2002	Electronic	9.12	−0.67	0.67
2006	Electronic	8.77	−0.61	0.61
2010	Electronic	8.13	−0.62	0.60
2014	Electronic	7.05	−0.57	0.43

PLV figures are for the first vote of the day (federal lower chamber). † Indicates correlation coefficient cannot be computed because municipal-level data are not available. Figures for 1998 are shown separately for EV technology and paper ballots. The two correlation columns refer to the linear correlation coefficient between the shares of PLVs observed in each municipality and the the Human Development Index of the municipality (test of Hypothesis 3) and share of invalid votes in the presidential election (test of Hypothesis 4). In all years, p-values <0.001 for both sets of correlation coefficients.

politicians campaign for themselves in open list systems, it would be much more intuitive to cast a nominal vote for a legislative candidate aligned with an up-ticket candidate than to vote for the party label. In addition casting a PLV under the paper ballot system was relatively easier than with EV technology. If anything, intentional PLVs should have been more prevalent with paper ballots.

Fortunately, the patterns in which PLVs are observed allow us to discriminate between our "new error" hypothesis and this alternative interpretation of the previous results. An intentional PLV requires some level of sophistication, so if PLVs are intentional, the association between the level of development of the municipality (as measured by the HDI-M) should be positive both with paper ballots and EV technology. As stated in Hypothesis 3, if our new error hypothesis is correct we should have observed a positive correlation with paper ballots and a negative one with EV technology.

The data in the second-to-last column in Table 1 support Hypothesis 3. Formerly, PLVs in paper ballot systems were more prevalent in developed municipalities. But since the introduction of EV technology, PLVs have come disproportionally from the least developed areas of the country. In this respect, the contrast between the two technologies is very stark.

In 1994, the earliest election for which municipal level data are available, the average PLV share in municipalities with HDI-M above the median of the country was more than double the less developed half. This same pattern was observed in the paper ballot municipalities in 1998, with the linear correlation between HDI-M and share of PLV being 0.24 and 0.20 respectively (in both cases p-value <0.01). In contrast, for municipalities that employed EV technology in 1998 the association between HDI-M and PLV was sharply reversed to −0.35 (p-value<0.01), indicating that voters in less developed municipalities tended to cast more PLVs. This association remained strongly negative through the 2014 election.[25]

Data presented in the last column of Table 1 supports Hypothesis 4. The correlation between the shares of PLV in the first vote of the day and invalid votes for president (the last vote of the day) was negative in 1994 and in the paper ballot municipalities in 1998. These observations are compatible with the idea that with paper ballots, PLVs represented a more engaged type of vote. Therefore, in places were more voters cast PLVs there were also likely to be clearer preferences in the presidential vote. Crucially, for our argument, this pattern was sharply reversed with the introduction of EV technology. This reversal indicates that EV produced a sharp break in voter behavior, and the strong positive association can only be understood as another consequence of the new type of voting error: where voters fail to grasp that the first vote is not for president, they also fail to understand that the last vote is for president.

Table 1 also summarizes PLV patterns in elections since 1986. It reinforces the more general idea that PLV shares have always been strongly influenced by the type of ballot used, which, in itself, is additional evidence that PLVs do not only reflect intentional behavior by voters. In the 1986 and 1990 elections, the ballots provided boxes with party names that could be ticked by voters who wanted to cast a PLV but in 1994 these boxes were removed, making it much harder to cast a such as vote. Not surprisingly, this was the year in which the share of PLVs was lowest – much lower, in fact, than in the preceding two elections. The share of PLVs increased considerably when EV technology was introduced, but has been declining ever since, even though there was no change in ballot structure.

The data presented in Table 1 suggest that error *probably* continued to be a strong determinant of PLV after its introduction. Observed PLV shares are the product of a combination of error and intentionality. The fact that the correlations between PLV rates and levels of development and invalid votes for president have remained roughly stable since the introduction of EV technology suggests that PLVs should not be attributed to voter sophistication in any year after 1998. At the same time, there are contextual reason—not examined in this paper—to suspect that intentional party-label voting has declined. For instance, not only has there been considerable disenchantment by the traditional supporters of the PT—the party that received the most PLVs through the 1980s and 1990s—but the party has also been making less of a push for PLVs because it now constantly fields joint party lists with smaller parties in exchange for support for its up-ticket candidates.[26] In this context, PLVs cast for the PT would end up helping to elect non-PT candidates, so the party has little incentive to cultivate this type of vote. Similarly, the PSDB, the other main presidential contender, has never campaigned for PLVs, suggesting that its increase in such votes might have been accidental. Given this evidence, we argue—but cannot prove through systematic analysis—that intentional PLVs have declined over time and what remains of PLVs continues to be mostly unintentional, as it was the case in 1998.

[25] Analysis of local election data reveals essentially the same patterns, with minor caveats, and results are included in the Supplemental materials.

[26] The fact that it does not make sense to cultivate a PLV if a party routinely joins electoral lists with other parties was previously noted by Samuels (1997).

Table 2
Comparison of enfranchisement and "new error" effects.

		Local elec. (1996)			General elec. (1998)		
		DiM	LL	Poly.	DiM	LL	Poly.
Invalid Votes (Enfranchisement)	Baseline	18.60	18.78	18.15	33.40	33.52	33.54
	RD Effect	−7.60	−8.13	−7.36	−23.80	−23.88	−25.81
	(SE)	1.50	2.18	2.82	1.21	2.05	2.84
	P-value	0.02	0.20	2.17	<0.01	<0.01	<0.01
Party-Label Votes (New Error)	Baseline	2.6	3.0	2.9	4.0	4.0	4.0
	RD Effect	9.60	8.90	8.25	9.10	8.19	8.39
	(SE)	1.28	1.72	2.00	0.56	0.73	1.01
	P-value	0.02	0.01	0.12	<0.01	<0.01	<0.01
	Lower Bound	6.80	6.30	5.84	4.75	4.28	4.38
N			190			99	

Columns report difference-in-means, local linear and polynomial RD estimates of the effect of EV technology on Invalid Votes and Party Label Votes in the 1996 and 1998 elections. The computation of the "Lower Bound" effects on PLVs are explained in the text.

7. The "new error" and *de facto* enfranchisement

Important previous work on the introduction of EV technology in Brazil identified a substantial reduction in the share of invalid votes in proportional elections, which has been interpreted as a significant *de facto* enfranchisement of voters. Our results, however, suggest that such enfranchisement was at least partially offset by the "new error."

The first rows in Table 2 report our RD estimates for the reduction in the shares of invalid votes (blank or null votes relative to turnout) for narrow bandwidths in the 1996 and 1998 elections, using the three different estimation methods discussed earlier. We report the baseline levels observed in the municipalities included in the RD sample, as well as the effects of the introduction of EV technology. Figures are expressed in percentages and results are compatible with those reported by Hidalgo (2014) and Fujiwara (2015): they indicate a sharp reduction in invalid votes, which was especially pronounced in the 1998 election.

The table also presents RD estimates of the increase in PLVs. These are, in practice, upper bound estimates of the percentage of votes lost to the new error, and would be accurate if the new error accounted for all of the increase in PLV that we document. In addition, we present back-of-the-envelope lower bound estimates of the effects of the new error. These were calculated by netting out the effects for parties without mayoral and presidential candidates, which cannot be caused by the error we describe. We netted these effects by taking the ratio between the increase in PLV for parties without up-ticket candidates in each election and the increase for those with any up-ticket candidate (presented in Figs. 3 and 6, above). We then applied these to the upper bound estimate.[27] Results suggest that the new error offsets between one-third and one-half of the enfranchisement gains in the local elections, and between 20% and 38% of the gains in the general elections.

It is still possible that EV brought about the pro-poor policy changes that Fujiwara (2015) identified. Even if part of the change in voting patters that occurred after the introduction of EV was due to the new error, the fact remains that these changes did indeed take place. If our analysis is correct, however, the policy changes that followed the introduction of EV were caused not only by enfranchisement of the poor, but also by the fact that the new error happens to benefit parties that introduced pro-poor policy changes. In this instance, chance would have played a large role in determining a "positive" policy outcome.

8. Conclusion

The sharp discontinuities observed in our analysis of the 1996 and 1998 elections showed that EV technology did have a strong effect on PLV (Hypothesis 1). Additional analysis corroborated the idea that parties that fielded competitive up-ticket candidates saw a much greater increase in PLV than those that did not (Hypothesis 2). Small increases in PLV for parties that did not field competitive up-ticket candidates lead us to conclude that the new error explains most (but not all) of the increase in PLV under EV. Evidence also demonstrates that PLVs went from being much more prevalent in higher-development areas at the time of paper ballots to being much more prevalent in lower-development areas with EV technology (Hypothesis 3). Finally, PLVs went from being negatively associated with invalid votes to being positively associated with them in the main election of the day (Hypothesis 4). We therefore interpret most of the increase in PLV as error.[28]

The consequences of our findings are substantively relevant: if we discount the new error from the enfranchisement effects found in previous studies, the net enfranchisement gains of EV technology, while still positive, are considerably smaller than previously thought.

It is possible that voters who mistakenly cast a PLV for the party of their preferred up-ticket candidate would have voted for a legislative candidate of that same party. In this case, the overall distribution of seats might have been similar if voters had been able to cast an intentional vote, even if the identity of the seat holders had been affected. However, if we consider that split ticket voting is the norm,[29] then even the partisan balance in legislative bodies is likely affected by this error.

The more general implications of our findings relate to the unintended consequences of voting methods. The fact that the type of technology used in Brazil requires voters to cast votes in a specified order is not a particularly salient issue. This is most likely simply the consequence of other design choices that were made with noble intentions. However obscure it might be, the design of the

[27] These are very conservative estimates of the new error, as increases in PLV for these parties could be caused by various types of error. The share of effects attributable to error would be much larger if we used the ratio we found for parties with competitive candidates.

[28] We have shown this for lower chamber elections and municipal councils, but in the Supplemental materials we show that it also holds for state assembly votes.

[29] If not for anything else, because of the simple fact that more than a dozen parties typically contest legislative elections while far fewer contest up-ticket ones.

electronic ballot used in Brazil has substantially important effects, some of which are deleterious to enfranchisement and democracy. These effects, moreover, can go unnoticed for years.

The relatively high complexity of the Brazilian electoral and party systems makes these obscure ballot design choices even more relevant. Brazilian voters operate in an environment in which a large number of parties contest elections, in which an open-list electoral system allows each party to field multiple candidates, and in which voters sometimes cast independent votes for up to five different offices at the same time. Simplifying any of these dimensions might reduce the incidence of error. But even in the absence such structural changes, the type of error we document here could be mitigated by inverting the order of voting or by requiring a different code for PLVs than the one use when casting votes for candidates in up-ticket elections.

A more widespread adoption of electronic voting machines has been hampered by fears of voting irregularities. This said, we believe electronic voting methods (be they machines in physical polling places or via web-based electronic voting) are here to stay, and will only be more widely adopted and standardized in the near future. Our findings serve as a reminder that when it comes to the design of electronic voting systems, even apparently inconsequential design decisions must be carefully considered.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.electstud.2016.04.001.

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