Statistical Science
2011, Vol. 26, No. 4, 479–501
DOI: 10.1214/08-STS263
© Institute of Mathematical Statistics, 2011

Analysis of the 2004 Venezuela Referendum: The Official Results Versus the Petition Signatures

Gustavo Delfino and Guillermo Salas

Abstract. On August 15th, 2004, Venezuelans had the opportunity to vote in a Presidential Recall Referendum to decide whether or not President Hugo Chávez should be removed from office. The process was largely computerized using a touch-screen system. In general the ballots were not manually counted. The significance of the high linear correlation (0.99) between the number of requesting signatures for the recall petition and the number of opposition votes in computerized centers is analyzed. The same-day audit was found to be not only ineffective but a source of suspicion. Official results were compared with the 1998 presidential election and other electoral events and distortions were found.

Key words and phrases: Referendum, election, voting machines, touch screen, ballot, correlation, uncertainty, audit.

1. INTRODUCTION

A referendum to recall President Hugo Chávez was carried out in Venezuela on August 15, 2004. The president was not recalled since the official "no" votes (votes in favor of the president) exceeded the official "sí" votes (votes in favor of removing the president from his post). The Organization of American States (OAS) and the Carter Center observed the proceedings and carried out some analyses of the voting data. They concluded that no tampering was apparent and that official results were accurate [3].

In this manuscript, we carry out a more in-depth analysis of both the voting data and the data that arose from two audits carried out after the recall referendum. We focus on the association between the proportion of voters who had signed a petition to carry out the referendum and the actual proportion of "sí" votes recorded at each voting center and compare what was observed relative to what might have been expected under some reasonable assumptions about voter behavior. We also highlight the differences between what was observed and what might have been expected relative to the type of voting center (manual or computerized) and note that official results obtained from computerized voting centers were surprising.

We conclude that results from our analysis of the voting and auditing data suggest that official results may not be as accurate as the OAS/Carter Center report suggest. The objective of this article is to argue that a second look at the results of the Presidential Recall Referendum of 2004 in Venezuela might be justified.

2. THE ELECTORAL PROCESS IN VENEZUELA

Electoral events in Venezuela are organized by the "Consejo Nacional Electoral"[1] (CNE). On December 6, 1998 the current president won the elections with 3,673,685 (57.79%) votes versus 2,863,619 (42.21%) votes for his adversaries. The total number of voters in the electoral registry (REP) at that time was 11,001,913.

In 1999 a new constitution was enacted which allows citizens to request a recall referendum (RR) to decide whether the president should continue in office. This

Gustavo Delfino is Professor, School of Mechanical Engineering, Universidad Central de Venezuela, Venezuela (e-mail: gdelfino@umich.edu). Guillermo Salas is Former Professor, Physics Department, Universidad Simón Bolívar, Venezuela (e-mail: guillermosalasd@gmail.com).

[1]Before the new constitution it was known as the "Consejo Supremo Electoral" (CSE); see http://www.cne.gov.ve.

referendum can only be activated after half of the period for which the president has been elected has transpired. In order to activate the referendum, a petition signed by at least 20% of the voters registered in the REP has to be submitted to the CNE. It is also possible to request a consultative nonbinding referendum with the signatures of 10% of the voters registered in the REP.

On January 3, 2000 a new CNE was appointed but it failed to organize elections as scheduled. Therefore, on June 5 of 2000, yet another CNE was appointed. On July 30, 2000 the president was reelected for a 6-year period with 3,757,773 (59.76%) votes versus 2,530,805 (40.24%) for his adversaries. The REP had 11,701,521 registered voters at that time.

In 2002 signatures were collected requesting a consultative referendum which was activated in the middle of a general national strike. The Supreme Court disabled the CNE, therefore this consultative referendum never took place. Citizens then collected signatures again, this time for a recall referendum. This was the legal instrument which the government and the opposition represented by the *Coordinadora Democrática* agreed to use, with the OAS and the Carter Center acting as guarantors [1]. This agreement ended the strike.

In 2003, the National Assembly was unable to agree on a new CNE, so the Supreme Court appointed a new temporary CNE on August 26, 2003, even though this procedure was not contemplated in the constitution. The new CNE rejected the signatures of the petition for a referendum saying that they had been collected before half of the presidential period had transpired.

On November 28, 2003 signatures were collected once again, this time under the supervision of the CNE. On May 28, 2004, a significant fraction of the signatures had to be reverified by the CNE. Enough signatures were valid so, on August 15, 2004 the Presidential Recall Referendum finally took place.

3. VOTE COLLECTION STRUCTURE

Venezuela is politically organized into states, counties (municipalities) and townships (parishes). Each county has one or more voting centers. There can be several voting tables (voting stations) per center, and each one has one or more electoral notebooks. In computerized centers, one voting machine is assigned to each electoral notebook. One ballot box is assigned to each table. Therefore, the ballots from multiple machines may be combined in a single ballot box. See Figure 1 for the detailed layout of the system.

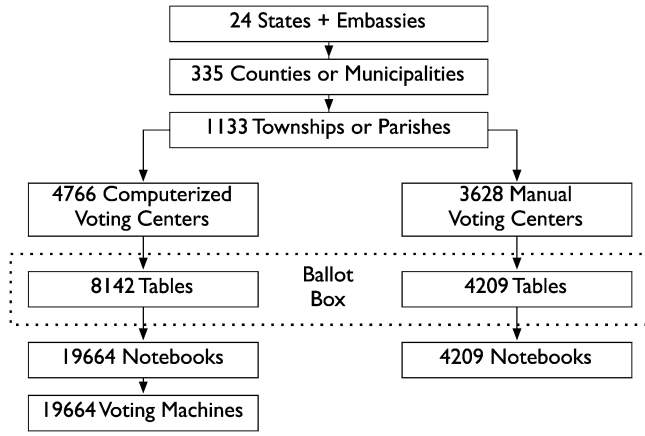


FIG. 1. *Venezuelan vote collection structure.*

Each voting center has a unique identifying code which makes it possible to compare electoral results on a center by center basis.

Although the number of manual centers is large, the number of people registered in those centers is much smaller than those registered in computerized centers. These distributions are shown in the histograms of Figure 2.

4. THE VOTING PROCEDURE

There were only two ways to vote[2]: sí (yes) or no. In order for the president to step down, the number of sí votes had to be greater than 3,757,773 and greater than the number of no votes.

Touch-screen voting machines were used for the first time in Venezuela for the Referendum. These machines also gave the voter a paper ballot to be deposited in a box. The boxes were never opened except for some of those selected for auditing. The results were sent electronically from the voting machines to the CNE servers using TCP/IP connections over telephone lines, after which the voting machines printed out the results, as well as a duplicate set of all the paper ballots in a continuous uncut format. The voting centers also had a continuous satellite TCP/IP connection which was to be used only by fingerprint machines which were supposed to prevent anyone from voting twice, even in different voting centers.

In order to give the citizens confidence in the results, two audits were made. The first one was done on the same day as the Referendum (hot audit). The second one was carried out three days later (cold audit).

[2]In manual voting centers it was also possible to cast a null vote.

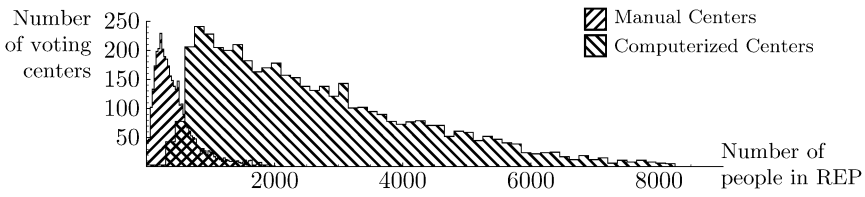


FIG. 2. *Histogram of the size of the manual and the computerized centers.*

The official results were 3,989,008 (40,64%) sí votes versus 5,800,629 (59,10%) no votes, with 14,037,900 registered voters in the REP. A large fraction of the votes (87.1%) were cast at computerized voting centers.

The whole electoral process and the audits were supervised and endorsed by the OAS and the Carter Center. They found no evidence of alterations or tampering in the results in their final report.

5. THE SIGNATURES

5.1 Introduction

In order to activate the Referendum, on November 28, 2003, signatures and fingerprints were collected in a four-day event organized by the CNE, with witnesses from all political parties. Special forms, with serial numbers were supplied by the CNE to all political parties. There were 2,676 signature collection centers (SCCs), all of them in Venezuela. No signature collection was allowed outside Venezuela.

There were two kinds of forms: types A and B. Type A forms were used in the SCCs. Type B forms were also assigned to SCCs, but they were meant to be used for house to house signature-collecting (under pro-government witness supervision). There were 618,800 type A forms and 98,286 type B forms. Each form had a maximum capacity of 10 signatures.

The number of signatures required to activate the Referendum was 20% of the REP used to elect the president, that is, $0.2 \times 11{,}701{,}521 = 2{,}340{,}305$ signatures. The law required the publication in a newspaper of a list of ID numbers of all the people who signed the petition.

The CNE divided the signatures into three categories: valid, invalid and questionable. An important number of questionable signatures had to be collected again in order to reach the required minimum number of signatures.

Opposition groups claimed to have submitted 3,467,051 signatures to the CNE. Within the CNE, 19,842 signatures were lost.[3] An additional indeterminate number of signatures were lost before reaching the CNE.

It is reasonable to assume that most of those who signed requesting the Referendum intended to vote sí in favor of the recall.[4] However, it is also possible that some signers voted no. This might have been the case for government supporters who signed the petition because they believed they could use the referendum to help solve the high level of political confrontation in the country. There were also signers who changed their political preferences between the time of the signature collection and the vote.

In the following sections, the official results of the referendum will be compared with the signatures collected. This will reveal some important facts about these results.

5.2 Si Vote Uncertainty With Regard to Signatures

Let k be the relative number of sí votes, as defined in equation (1):

$$k = \frac{\text{sí votes}}{\text{signatures}}. \tag{1}$$

Also, let s be the relative number of signatures in a voting center, as defined in equation (2):

$$\begin{aligned} s &= \frac{\text{signatures}}{\text{sí votes} + \text{no votes} + \text{null votes}} \\ &= \frac{\text{signatures}}{\text{total votes}}. \end{aligned} \tag{2}$$

For each value of s, there is a maximum possible k which is just $1/s$ as shown in equation (3):

$$\begin{aligned} k_{\max} &= \frac{\max(\text{sí votes})}{\text{signatures}} = \frac{\text{total votes}}{\text{signatures}} \\ &= \frac{\text{total votes}}{s \cdot \text{total votes}} = \frac{1}{s}. \end{aligned} \tag{3}$$

[3] See http://buscador.eluniversal.com/2004/05/09/apo_art_09152D.shtml

[4] The OAS and the Carter Certer concur with this statement. See [2], Section 5, second paragraph.

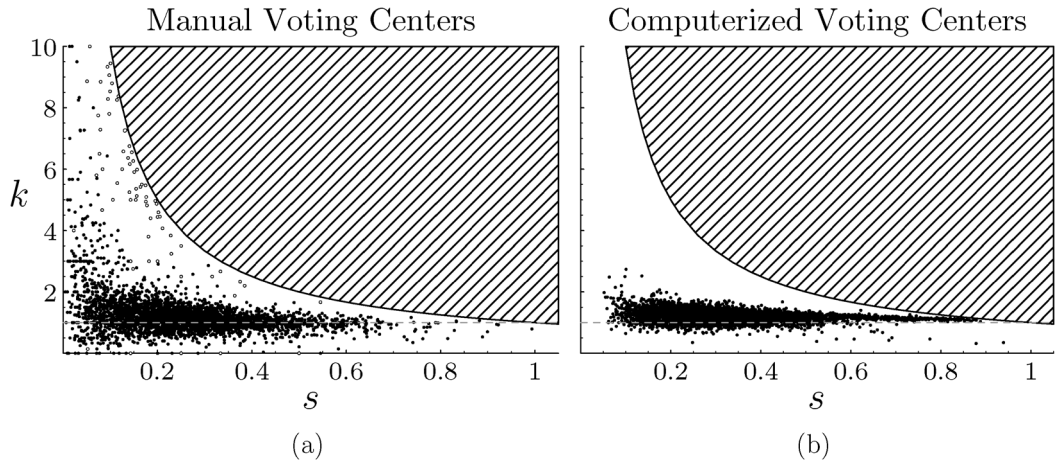


FIG. 3. *Relationship between k and s for computerized and manual centers. The shadowed area contains the mathematically impossible values of k. The maximum k value is* $1/s$. *The hollow dots represent voting centers located in consular offices.*

In voting centers with a large value of s, we expected a value of k around 1. This is because each signature has a high probability of resulting in a sí vote, and at the same time $k_{\max}$ gets close to 1.

For example, in a voting center with 1,000 total votes and 900 signatures, the number of expected sí votes is between 900 and 1,000. Here $s = 900/1{,}000 = 0.9$ and $k_{\max} = 1/0.9 = 1.1\bar{1}$. Therefore, the uncertainty in the value of k is very small, as it should be between[5] 1 and $1.1\bar{1}$.

The situation is completely different in voting centers with a small value of s. Notice that there is an essential singularity in k at $s = 0$ as shown in equation (4):

$$k = \frac{\text{sí votes/total votes}}{s}. \tag{4}$$

This singularity can produce very high values of k in the neighborhood of $s = 0$. Hence, the level of uncertainty in k becomes very large.

For example, in a voting center with 1,000 total votes and 2 signatures, the number of expected sí votes is between 2 and 1,000. Here $s = 2/1{,}000 = 0.002$ and $k_{\max} = 1/0.002 = 500$. Therefore, the uncertainty in the value of k is extremely large, as it should be between 1 and 500.

The reasons for the uncertainty in k just discussed are purely mathematical. In practical terms, high values of k in centers with a small s were due to the following facts:

- There were only 2,676 SCCs compared to 8,394 voting centers. Therefore, voters living far from a SCC could not sign the petition, even if they wanted to. This was the case in mostly rural areas.
- There were many people who did not sign the petition because of their fear of retribution from the government. On the other hand, voting was secret.
- There were sí votes from people who could not sign because they were not in the REP or were outside the country at the time of signature collection.
- Some SCCs ran out of forms. Not everyone was able to go to a more distant SCC to sign.
- An undetermined number of signatures were lost.
- There were sí votes from people who just didn't bother to sign the petition.

Notice that all these issues with the signatures did not affect all voting centers equally. Centers with a small value of s are more likely to have been affected by these issues than centers with a high value of s.

A plot of k versus s is shown in Figure 3. Notice that when s is not large, *all* the computerized centers are very far away from $k_{\max}$, clearly contradicting the expected nonlinear behavior with respect to s. On the other hand, the manual center results are effectively distributed in the allowed range regardless of the relative number of signatures.

In summary:

> It is expected that k's from voting centers with a small value of s will be much more variable than those with large values of s.

[5]The value of k could be lower than 1 if, for any reason, the number of votes was low (e.g., high abstention).

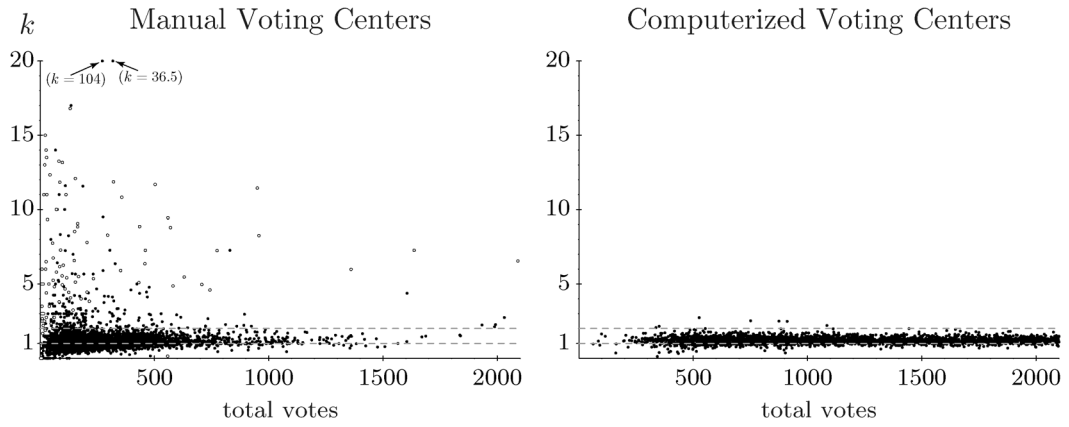


FIG. 4. *Relationship between k and total number of votes for computerized and manual centers in the same size range. The hollow dots represent voting centers located in consular offices.*

5.2.1 *Behavior of k with regard to the size and characteristics of the voting centers.*. Although the manual centers tend to have fewer voters than the computerized centers, this does not seem to be the only reason for the different behavior in k. This can be seen in Figure 4.

There were many small computerized voting centers in rural areas. Many used mobile phone lines to connect the voting machines to the CNE servers to transmit the results because of the lack of regular phone lines in these remote areas.

There were 586 townships which included both manual and computerized voting centers. These mixed townships had 5,449 voting centers (2,538 manuals and 2,911 computerized). Notice in Figure 5 (top) that the behavior of k in these mixed townships, is very different for manual and computerized centers. Appendix B shows an example of such a mixed township.

Another interesting comparison is related to hamlets ("caseríos"). A total of 2,162 voting centers in hamlets were identified[6] (1,852 manual and 310 computerized).

Due to the reasons mentioned in Section 5.2, many hamlets must have been far away from a SCC. For this reason voting centers located in hamlets should include large values of k. In Figure 5 (bottom) it can be seen that these large values are found only in manual voting centers.

Furthermore, Figure 5 shows that the behavior of the k values in computerized voting centers in hamlets looks more like that of the rest of the computerized centers than the behavior of the 1,852 manual centers located in the rest of the hamlets.

5.3 Correlations Between Si Votes and Requesting Signatures

Let $r_{sí}$ be the correlation of sí votes with respect to the number of signatures.

The Carter Center and the OAS said the following in one of their reports [2]:

> A very high correlation between the number of signers and the number of sí votes per center in the universe of automated voting machines has been found—a correlation coefficient of 0.988. This means that in voting centers where a high signer turnout was obtained, a high sí vote also was obtained.[7]

What this report does not mention is that for manual voting centers, the correlation is 0.607, a much lower value. This difference can be visualized in Figure 6. Notice that a straight line from the origin to each of the points has a slope of k. The high correlation value for computerized centers translates into similar k values (or slopes) for most centers.

In this case, the high correlation in computerized voting centers also implies that in voting centers where a low signer turnout was obtained, a low sí vote was also obtained. This can be seen in the origin of Figure 6(b). Hence, when the number of signatures tends to zero, the number of sí votes also tends to zero. But, as observed in Figure 6(a), manual centers do not exhibit the same behavior.

[6]The official list of voting centers was searched for the word "CASERIO" in the address field. These produced the list of 2,162 voting centers.

[7]This correlation value was reproduced with a difference of just 0.001 which is negligible.

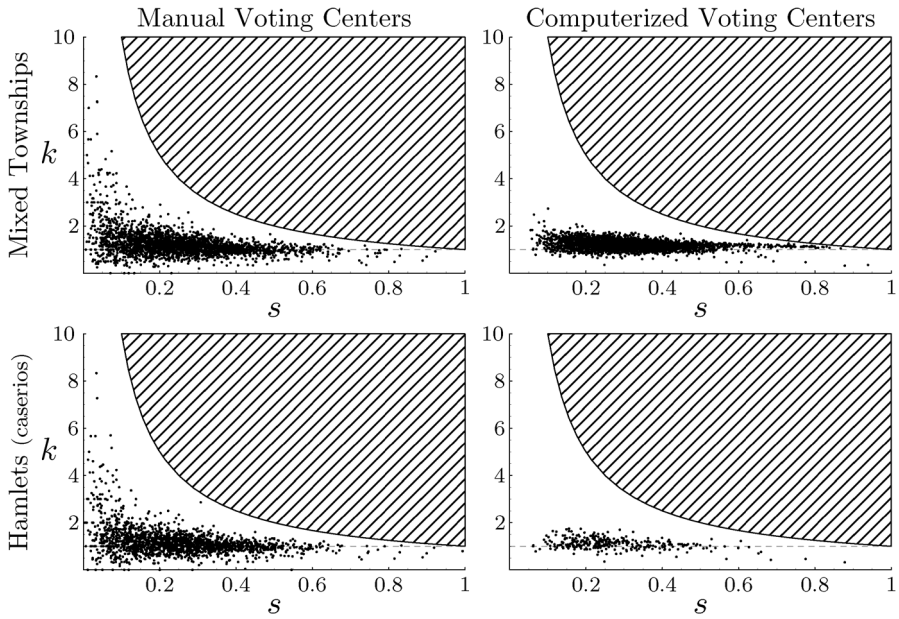


FIG. 5. *Relationship between k and s for computerized* (*right*) *and manual centers* (*left*) *for mixed townships* (*top*) *and hamlets* (*bottom*).

The behavior found in computerized centers seems unexpected because the relationship between signatures and sí votes should not be linear, especially when the number of signatures is small. As explained in Section 5.2, you could expect a large number of sí votes if there were a large number of signatures, but as the number of signatures per center decreases, the level of uncertainty in the number of sí votes with respect to the number of signatures increases.

In Table 1 the correlations are calculated for centers where signers were a minority ($s \leq 0.5$) and a majority ($s > 0.5$). Notice that as expected, the correlation for manual centers is much higher when there are many signatures (0.947) than when there are fewer signatures

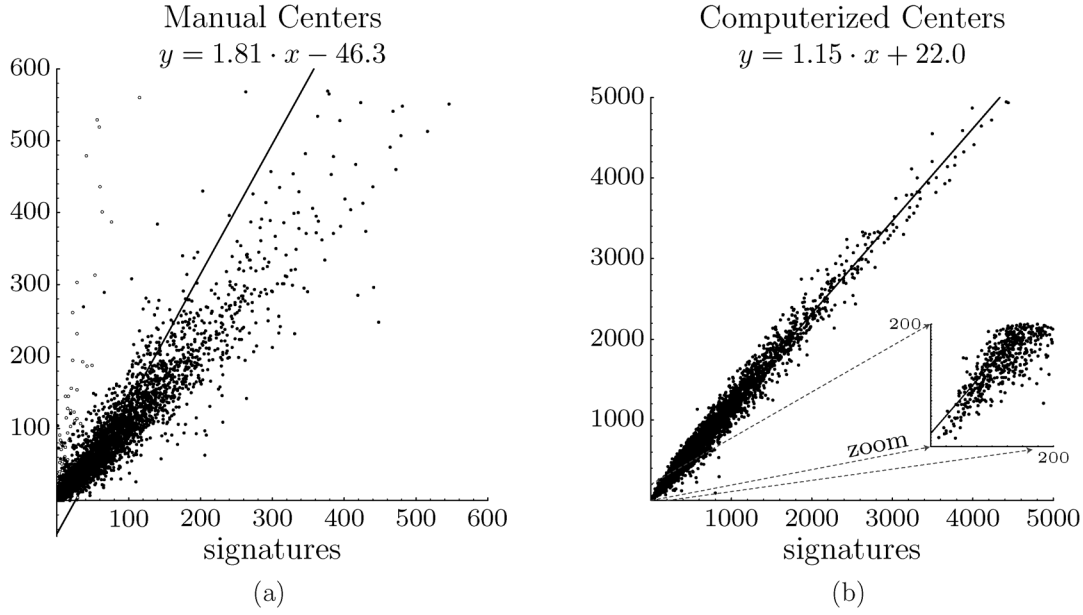


FIG. 6. *Manual centers have a correlation of* 0.607 *with respect to the signatures while computerized centers have a correlation of* 0.989. *A correlation of* 1 *would look like a straight line.*

TABLE 1
Correlations of sí votes with respect to the relative number of signatures s per center, for manual and computerized voting centers

	$s \le 0.5$		$s > 0.5$		All	
	$r_{sí}$	#	$r_{sí}$	#	$r_{sí}$	#
Manual	0.613	3,375	**0.947**	221	0.607	3,596
Computerized	0.983	3,943	0.994	645	0.989	4,588
Both	0.953	7,318	0.996	866	0.973	8,184

(0.613). This is the expected behavior because when you have many signatures the uncertainty of k is small, and the number of sí votes is equal to $k \times$ signatures so the uncertainty in the absolute number of sí votes is also small.

In the case of the 645 computerized voting centers where $s > 0.5$ the correlation was 0.994 which is very high. It stands out that in the computerized voting centers where signers were a minority, the correlation is still very high at 0.983. Furthermore, there is not a single computerized voting center with many more sí votes than signatures as seen in Figure 6(b). In other words, for some reason, computerized centers do not seem to show the expected nonlinear relationship between signatures and sí votes.

5.4 Correlation Plot

In order to further investigate the change of uncertainty as the relative number of signatures varies, a technique similar to a moving average is used. The difference is that instead of calculating an average, a correlation is calculated. A window size of 150 voting centers was used. This is the same number of centers that were audited.

In order to do this, the first step is to sort the voting centers, computerized and manual, according to their s value. Then $r_{sí}$ is calculated for centers in positions 1 to 150. Subsequently $r_{sí}$ is calculated for centers in positions 2 to 151, and so on. The result is shown in Figure 7.

For manual centers, there are large variations in the correlation in the left side of Figure 7. This is the result of outliers coming in and out of the 150 centers calculation window. As the outliers are real official data, they should not be dropped. Instead, logarithms can be used for both the number of votes and signatures. This way the effect of the outlier is taken into account in a better way. The result of using this technique is shown in Figure 8.

Regardless of whether correlations are calculated on a linear scale (Figure 7) or on a logarithmic scale (Figure 8), the important fact to point out is that the reduction in correlation as s decreases is large for manual centers, whereas it is negligible for computerized centers.

6. THE HYPOTHESIS

What has been presented thus far should be enough to cast a serious shadow of doubt regarding the official results in the computerized centers. Based on this, it is natural to consider the following hypothesis[8]:

HYPOTHESIS. *In computerized centers, official results were forced to follow a linear relationship with respect to the number of signatures.*

If this hypothesis were true, because of the reasons explained in Section 5.2, the results would be distorted

[8]The mechanics of how votes could have been altered, and by whom is not studied here. However, the fact that the machines established a TCP/IP connection to the CNE, disconnected and only then printed the results, opens many security holes. These issues are beyond the scope of this article.

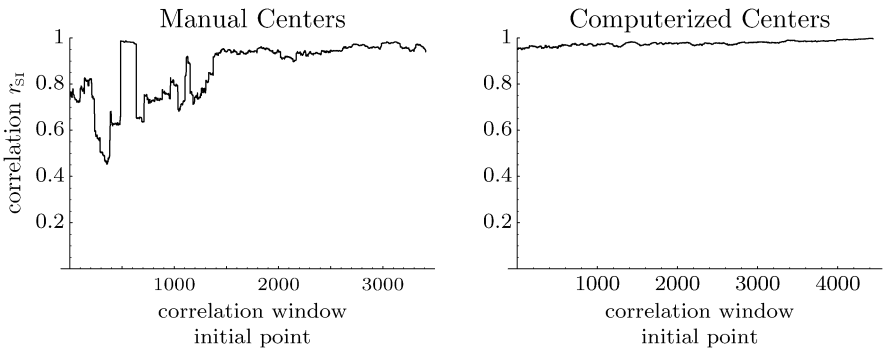


FIG. 7. *Correlations plot using a window of* 150 *voting centers.*

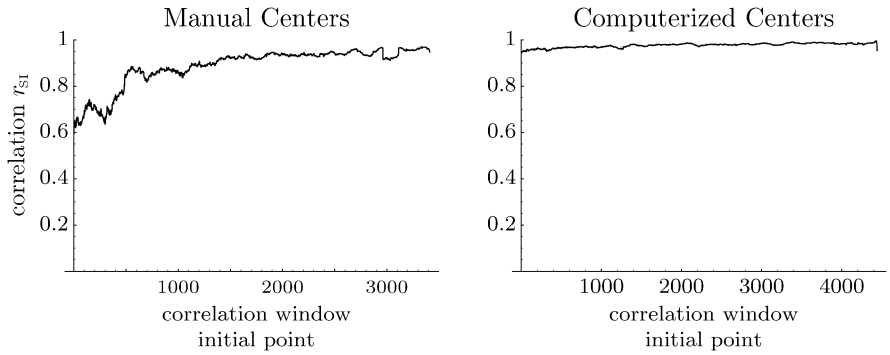


FIG. 8. *Correlations plot (logarithmic scale) using a* 150 *voting centers window.*

with respect to reality, especially in voting centers with a small s value.

In places where the signatures did not correctly capture the political intention of the people, two things would happen:

1. The number of sí votes, according to the official CNE results, would tend to be much lower than the number of real sí votes.
2. The official results of those computerized voting centers would be a poor representation of the political intentions in the area.

In the next section the results of the referendum will be compared to those of the 1998 presidential election in order to find out if these distortions are indeed present.

7. 1998 ELECTION COMPARISON

Despite the fact that more than 5 years separate the 1998 presidential election and the Referendum, and that the Referendum was not an election, there are reasons that make the comparison of both events interesting:

- In both cases the future of the presidency was at stake.
- In Venezuela, since 1958 a new president had been elected every 5 years. Immediate reelection was prohibited by the 1961 constitution. Between the 1998 election and the 2004 Referendum, 5 years and 8 months had gone by. On the other hand, the president had repeatedly claimed that he would stay in office at least until the year 2021.
- Both events were open for all Venezuelan citizens in the electoral registry.
- Both cases involved a very polarized electorate. In 1998 the top two candidates obtained 96.17% of the valid votes. The other 3.83% of the votes went to candidates who were also politically opposed to the winning candidate.
- There were 8,431 voting centers in 1998 and 8,394 voting centers for the Referendum. The events had 8,328 voting centers in common.
- Comparing the 1998 election and the Referendum results gives an estimate of whether the popularity of the president increased or decreased in the vicinity of each voting center.

Additionally, the 1998 electoral results are used for comparison because at that time, the CNE was not under the influence of the current government.

7.1 Correlations Between % of Opposition Votes in 1998 and in RR

By comparing the electoral results (percentage of opposition) on a township by township basis, it was detected that some of them had a high correlation with respect to previous results while others had a very low correlation. The townships with higher opposition results with respect to 1998 tend to have a higher correlation than the others. This correlation will be called r_{1998}, and the percentage of opposition difference will be called $\Delta\%^{\mathrm{RR}}_{1998}$ as defined in equation (5):

$$\Delta\%^{\mathrm{RR}}_{1998} = (\%\ \text{Opposition in RR}) - (\%\ \text{Opposition in 1998}). \tag{5}$$

In order to illustrate this, the results of two townships are plotted in Figure 9. In the *"Olegario Villalobos"* township, the correlation with respect to the signatures and the 1998 percentage of opposition is large at $r_{\mathrm{sí}} = 0.988$ and $r_{1998} = 0.984$ respectively. Additionally, notice that the average s is 0.639, so signers were the majority in this township. Therefore, the signatures are likely to have captured the political intentions of voters here.

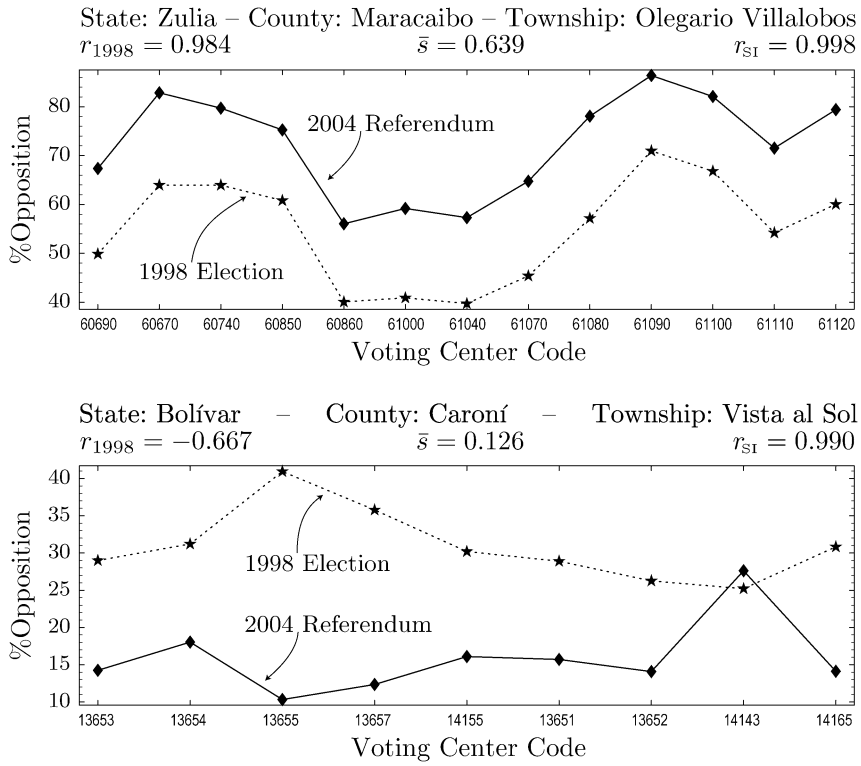


FIG. 9. *Two sample townships. All the centers shown are computerized voting centers.*

In the case of the *"Vista al Sol"* township, the average s is very low. Therefore, the uncertainty in the number of sí votes with respect to the signatures could be large, as was shown in Section 5.2. In other words, the signatures are not likely to have captured the political intentions of the township accurately. This uncertainty is just not seen in the official results, as the correlation of sí votes with respect to the signatures is 0.990. Furthermore, the referendum results seem very distorted with respect to the 1998 election, with a negative correlation of -0.667. In this township, the center with the most opposition in 1998 ended up being the most pro-government, and vice versa.[9]

The two townships shown in Figure 9 behave consistently with the hypothesis. *"Olegario Villalobos"* was able to increase its percentage of opposition because many signatures were collected, whereas *"Vista al Sol"* could not increase its percentage of opposition because only a few signatures were collected. If this repeats itself in the rest of the country, then r_{1998} would be large when $\Delta\%^{\mathrm{RR}}_{1998}$ is large, and r_{1998} would be small when $\Delta\%^{\mathrm{RR}}_{1998}$ is small. In an untouched process, these two variables should be independent.

In Figure 10, it is shown that, indeed in all of the country there is a strong relationship between $\Delta\%^{\mathrm{RR}}_{1998}$ and r_{1998} for computerized centers at the township, county and state levels. This relationship is much weaker—almost inexistant—for manual voting centers. This finding is consistent with the hypothesis.

8. VARIABILITY IN VALUES OF k AND THE CORRELATION BETWEEN PERCENTAGE OF OPPOSITION AND VALUES OF s, FOR VARIOUS ELECTORAL EVENTS

In Section 5.2, it was stated that as the value of s decreases, the variability in k is expected to increase. According to equation (4) this variability must also be present in the relation between s and the percentage of opposition. Therefore, as s becomes small, it should correlate poorly with the percentage of opposition. For this reason, when s is small, it should not determine the percentage of opposition. On the other hand, when s becomes large, it should correlate better with the percentage of opposition.

[9]This center returned to being the one with the most opposition 77 days later in the state governors election.

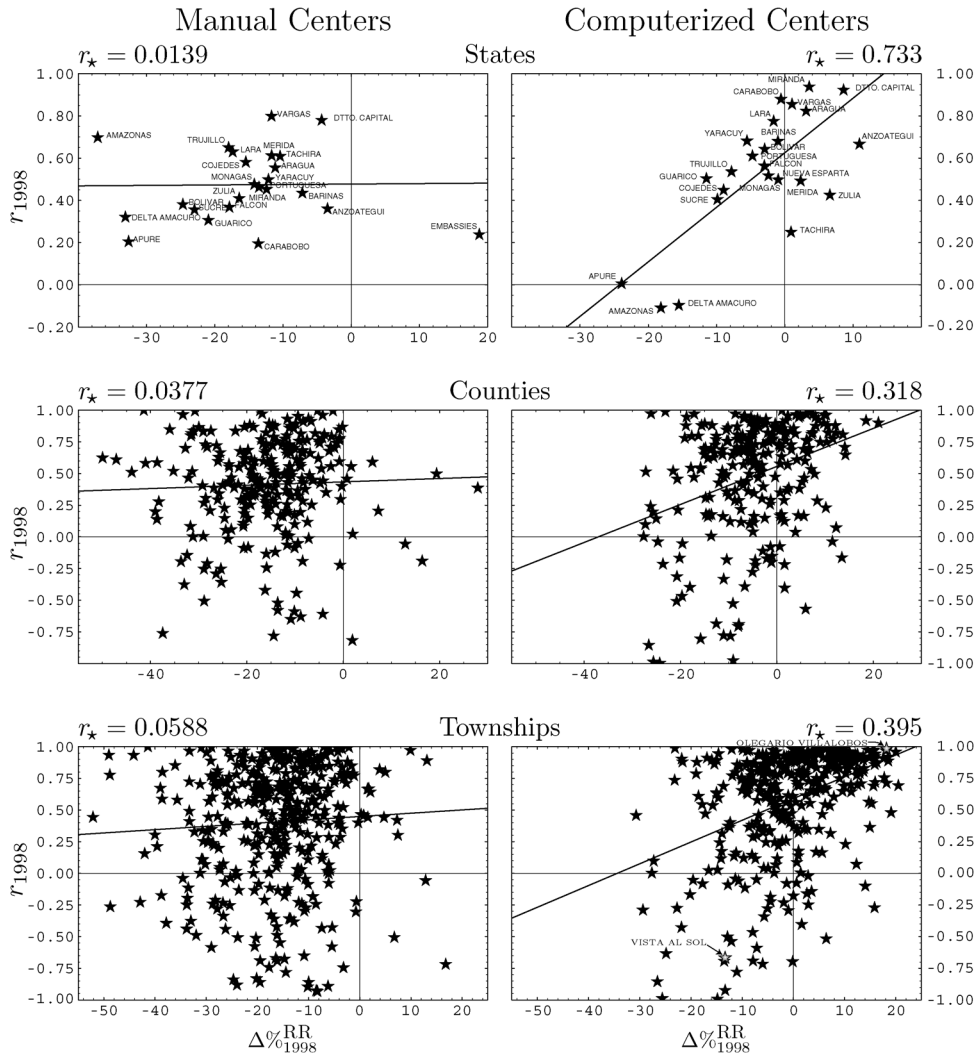


FIG. 10. *Relationship between r_{1998} and $\Delta\%^{\mathrm{RR}}_{1998}$ at the state, county and township levels for manual and computerized voting centers. The correlation between $\Delta\%^{\mathrm{RR}}_{1998}$ and r_{1998} is shown as $r_\star$. Assuming that $\Delta\%^{\mathrm{RR}}_{1998}$ and r_{1998} are independent, the probability of seeing those $r_\star$ values is calculated in Appendix D.*

Let r_s be the correlation of the percentage of opposition and s, and let $\tilde{s}$ be the median of all the values of s for computerized centers. For the subset of computerized centers with $s \le \tilde{s}$ this correlation will be called $r_{s,s\le\tilde{s}}$, and for the remaining centers where $s > \tilde{s}$ the correlation will be called $r_{s,s>\tilde{s}}$.

The value of $r_{s,s\le\tilde{s}}$ should be smaller than $r_{s,s>\tilde{s}}$. These properties just defined are calculated for various electoral events in Table 2.

The exit poll shown in Table 2 was made under the supervision of Penn, Schoen and Berland Associates.

The State Governors election took place just 77 days after the Referendum. By counting votes for and against the pro-government candidate, a percentage of opposition was calculated. During this election, the same voting machines were used, but there was an important difference: the paper ballots were manually counted for a randomly selected voting machine in each and every voting center. The results for the correlation r_s for this election are shown in Table 2.

From Table 2 it is clear that only the Referendum official results fail to exhibit a positive correlation difference. Also notice in Figure 11 that for the Referendum official results, there is not a single voting center with a small s and large percentage of opposition. The fact that only in the official Referendum results $r_{s,s\le\tilde{s}}$ is not smaller than $r_{s,s>\tilde{s}}$ is consistent with the hypothesis.

TABLE 2
Correlation r_s for computerized centers with s above and below $\tilde{s}$, for different electoral events

Date	Event	$r_{s,s\le\tilde{s}}$	$r_{s,s>\tilde{s}}$	$r_{s,s>\tilde{s}} - r_{s,s\le\tilde{s}}$
Dec 6, 1998	Presidential election	0.439	0.685	0.246
Jul 30, 2000	Presidential election	0.607	0.802	0.195
Aug 15, 2004	Referendum official results	**0.845**	**0.830**	**−0.015**
Aug 15, 2004	Exit polls	0.325	0.739	0.414
Oct 31, 2004	States Governors election	0.475	0.707	0.232

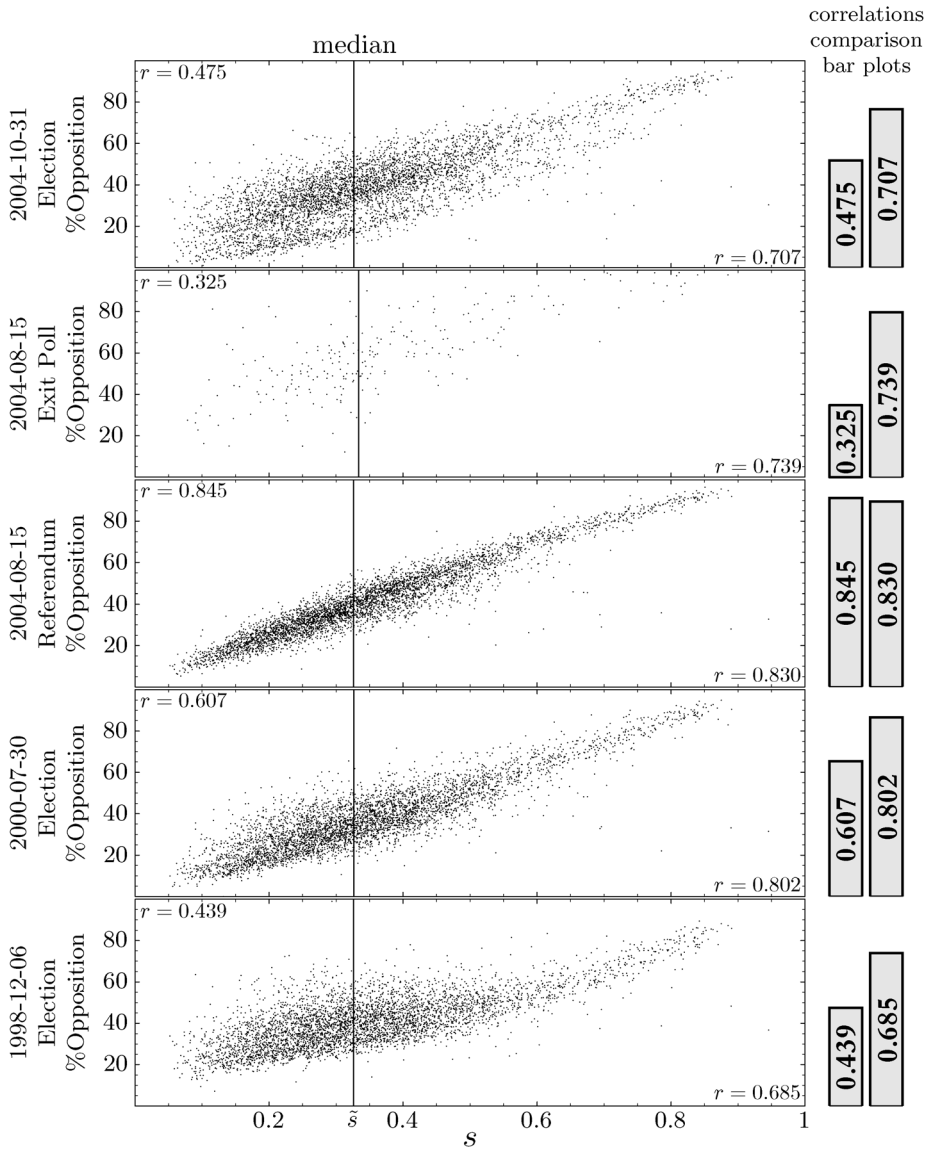


FIG. 11. *Correlation between percentage of opposition and s for the lower two ($s \le \tilde{s}$) and upper two quartiles ($s > \tilde{s}$) for computerized centers. The correlation for the lower two quartiles is expected to be smaller than the correlation in the upper two quartiles. This expected difference is not seen in the Referendum official results.*

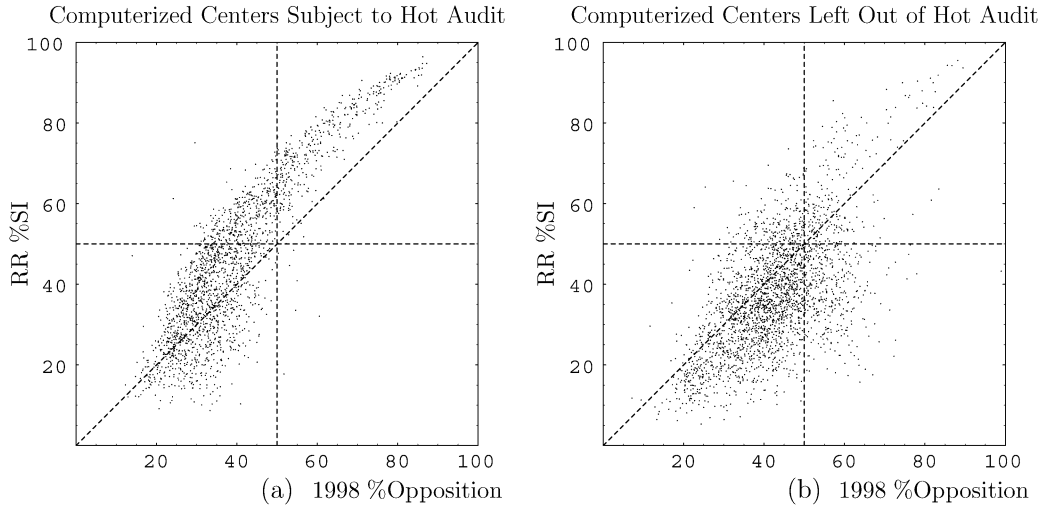


FIG. 12. *Centers inside* (a) *and outside* (b) *of the* 20 *counties to where the hot-audit drawing was restricted.*

9. HOT AUDIT

In general, the paper ballots from the computerized centers were not manually counted. The CNE assured the Venezuelan citizens that the voting machines had to accurately reflect the voters intention, because a sample of 192 machines (1% of them) would be randomly selected and audited the same day of the referendum. This is indeed a valid way of eliminating suspicion, as long as the selection is a truly random sample of *all* the voting machines.

The day of the referendum, the CNE informed the public that because of logistical reasons, the sample would be taken from a restricted universe of 20 counties located in urban areas, leaving out of the audit more than 300 counties. With this decision, confidence in the results was adversely affected to say the least.

The computerized voting centers inside and outside of the 20 counties, to which the hot-audit universe was reduced, are shown in Figure 12. It is clear that these 20 counties are not representative of all the computerized voting centers. See Appendix E for further details on this subject.

Furthermore, out of 192 centers selected for hot audit, only 26 were actually audited in the presence of witnesses representing the opposition and the international observers. The following excerpt from the Carter Center Comprehensive Report [4] is very illustrative:

> Auditors, table members, and military personnel were not properly informed that the audit would occur nor were they clear about the procedure to be followed. The instructions themselves did not clearly call for a separate tally of the Yes and No votes, and in some centers, the auditors only counted the total number of voters. (...)
> Nevertheless, Carter Center observers were able to witness six auditing processes. In only one of the six auditing sites observed by The Carter Center did the paper ballot receipt counting actually occur. In this place, the auditing was conducted by the *mesa* president, and the recount of the ballots produced exactly the same result as the *acta* printed by the voting machine. In the rest of the sites observed, the auditor appointed by the CNE did not allow the opening of the ballot box, explaining his/her instructions did not include the counting of the Yes and No ballots from multiple machines.
> There were also complaints of military denying access to voting centers where audits were being conducted. Carter Center observers could not confirm this claim. (...)
> The CNE provided The Carter Center with copies of the audit reports of 25 centers. It was clear from the forms that the audit was not carried out in many places because the fields in the form were left empty, there were no signatures of pro-government or opposition witnesses, etc. The forms were poorly filled out, clearly showing inadequate training. The instructions issued by the CNE to the auditors were either incomplete or unclear. This is a direct consequence of issuing the audit regulation three

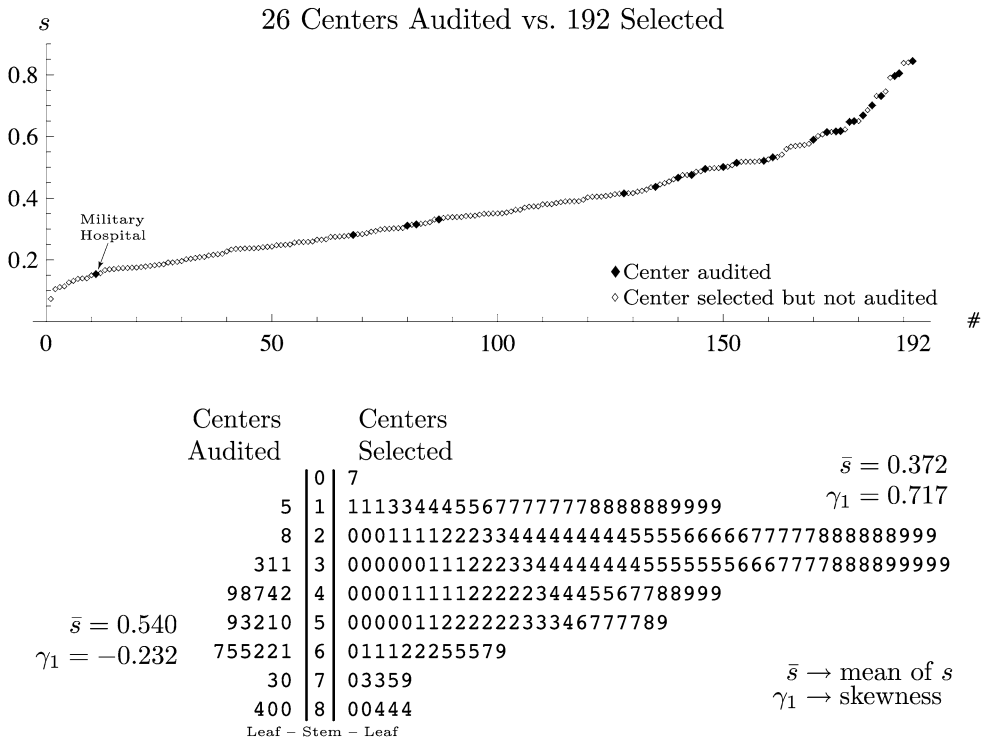


FIG. 13. *Comparison between the s value of the* 192 *selected centers and the* 26 *audited centers. TOP: The selected centers are ordered according to the value of s and plotted. BOTTOM: Back-to-back stem-and-leaf plot showing the same values of s as in the top figure. To obtain s values, multiply stem by* 0.1 *and leaves by* 0.01.

> days before the election. The final result was that the CNE squandered a crucial opportunity to build confidence and trust in the electoral system and outcome of the recall referendum.

Auditing only 26 centers out of 192 selected centers, is basically a cancellation of the auditing process. But, is there anything special about these 26 centers? If this drastic reduction in audit size was because it was "poorly executed," and poor execution is independent of the value of s, then the value of s of these 26 centers would behave as a random sample within the s value of the 192 selected centers.

From Figure 13, it is clear that the 26 centers that were actually audited seem to have a much higher value of s than the 192 centers from where they come from. The average s for the 192 selected centers is $\bar{s}_{\text{selected}} = 0.372$ while for the audited ones it is $\bar{s}_{\text{audited}} = 0.540$. Additionally, the distribution of the 192 selected centers is positively skewed while the distribution of the 26 audited centers is negatively skewed.

Can this be just a coincidence? A Monte Carlo simulation was done, selecting 26 random centers out of the 192 selected for auditing. The result of this simulation is that the probability of having a $\bar{s}_{\text{audited}} = 0.540$ is 1 in 50 million; and this does not take into account the difference in skewness.

This result is consistent with the hypothesis, because centers with a small value of s are the ones most susceptible to distortions.

Thus, it has been shown that the audited centers are not representative of neither the universe of all computerized centers, nor the restricted universe used to select them.

The audited centers are not representative of the universe of computerized voting centers (see Figure 14) because:

1. In the audited centers, the sí vote won by 63.47% to 40.91%.
2. $\Delta\%^{\text{RR}}_{1998}$ is very different.
3. The value of s is much larger.

Additionally, the townships, counties and states where centers were audited are not representative of the other townships, counties and states. They are not representative with regard to their $\Delta\%^{\text{RR}}_{1998}$ and the correlation with respect to the 1998 election r_{1998}. This can be seen in Figure 15.

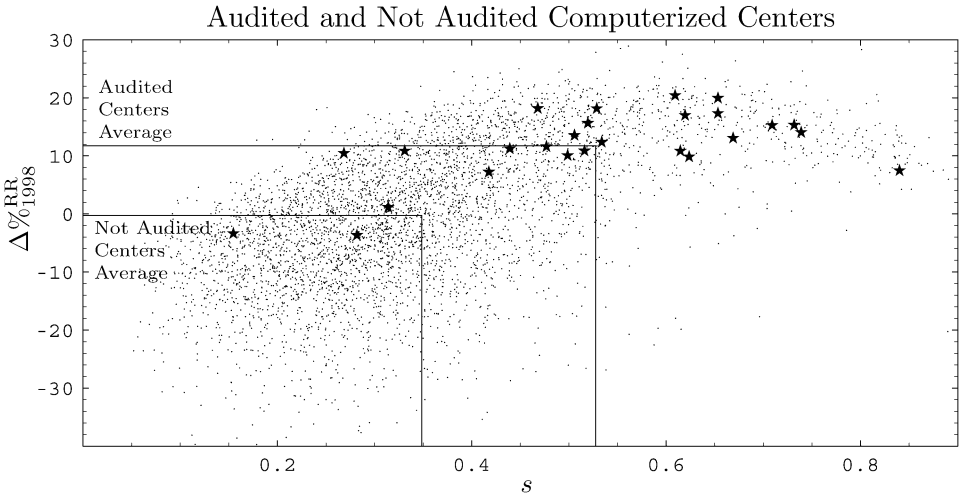


FIG. 14. *In this figure, the* 26 *computerized audited centers are compared with the universe of computerized centers. The average* s *and* $\Delta\%^{RR}_{1998}$ *are indicated with lines.*

10. COLD AUDIT

Given the fact that the hot audit failed to serve its purpose, another audit was made three (3) days after the referendum. This audit cannot validate the official results mainly because of two reasons:

- The audited entity itself cannot select the centers to be audited. According to the OAS/Carter report [3] "The sample was generated by CNE staff" on its own computer using its own software.
- The control mechanisms that had been implemented to certify that the samples were unaltered were not used.

The draw to select the centers to be audited was broadcast live on the official television station, but the results were not shown. Usually, the whole idea of transmitting a draw on TV, is to let the public know the results as they are being generated.

When the ballot boxes were closed and sealed, and the electoral centers closed, the seal was signed by witnesses. The boxes were then taken into custody of the military.

The following excerpt from the OAS/Carter Center report [3] explains the mechanism used to certify that the boxes were unaltered:

> Each box was physically checked to see whether:
>
> 1. The material used to seal the box was intact or whether there were signs that it had been taken off and then replaced.
> 2. There were cracks or holes through which votes might have been extracted or inserted.
>
> If a box was defective in regard to sealing, cracks, or holes, all the boxes of that polling station were excluded from the audit and a note to that effect recorded in the minutes.

However, the witnesses who had signed the boxes were not called to certify the authenticity of the box.

When this audit was questioned, the Carter Center and OAS response was that:

> Furthermore, the correlation between the signers and the sí votes is almost identical in the universe and in the sample. The difference between the correlations is less than 1 percent:

	Correlation coefficient
Universe	0.988
Sample	0.989

This certainly can be used to argue that the boxes opened were representative of the official results, but does not indicate anything in regard to validating the official results.

Interestingly, the draws for the hot and cold audit included 16 common centers. These 16 centers were successfully cold-audited, but none of them were allowed to be hot-audited.

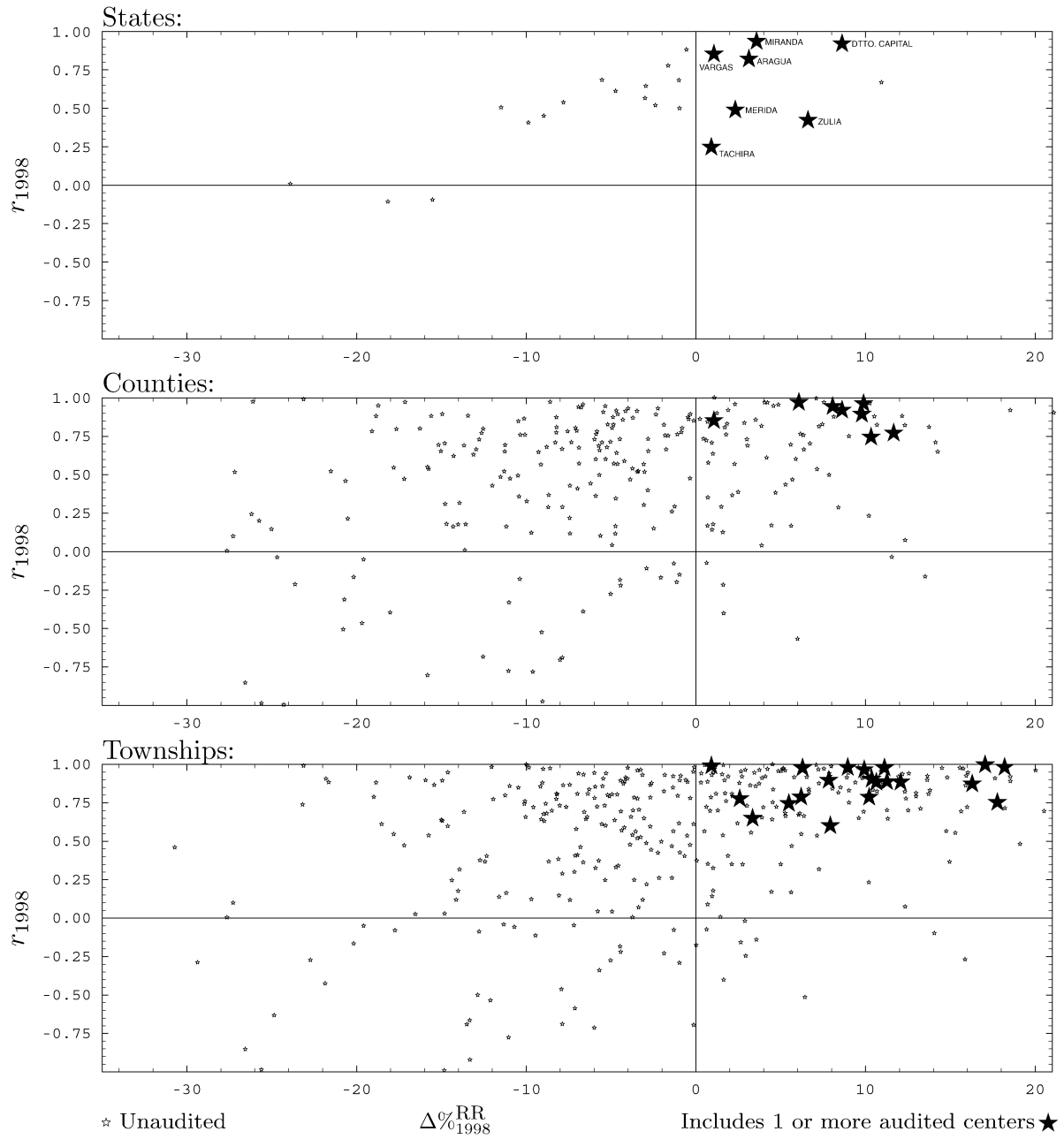


FIG. 15. *Townships, counties and states where the* 26 *audited centers are located. The vertical axis is the correlation with respect to the percentage of opposition in* 1998 (r_{1998}). *The horizontal axis is the difference in percentage of opposition with respect to* 1998 ($\Delta\%^{RR}_{1998}$).

11. CONCLUSIONS

We have explored the voting data arising from the RR carried out in 2004 and also the results of two audits conducted after the RR took place. We have identified several issues associated with the results obtained from voting centers using touch-screen voting machines. In particular:

1. The official sí results in computerized centers seem to behave in an excessively linear fashion relative to the number of signatures in support of the RR in each voting center (see Section 5).
2. The official sí results in computerized centers are surprising given the results of the 1998 elections in those same centers (see Section 7).
3. The percentage of votes for the opposition seem to be too highly correlated with s, the relative number of signatures in a voting center, in particular in those centers where s was small (see Section 8).

When combined with the facts that in general, paper ballots were not counted and that voting machines were connected to a central CNE server *before* voting results could be printed, these observations suggest that the official results obtained from computerized voting centers deserve a closer look.

In principle, two audits—a hot audit carried out immediately following the referendum and a cold audit carried out three days later—should have helped resolve any questions arising about the voting and vote counting processes. However, an analysis of the data that resulted from the two audits reveals that the audits were not conducted as had originally been announced and thus could not alleviate doubts about the official results nor could they be used to certify the accuracy of results. In particular, we argue that:

1. The computerized centers in the 20 counties to which the hot audit was restricted by the CNE were not representative of the universe of computerized voting centers (Figure 12).
2. The hot-audited centers were not representative of the rest of the computerized centers (Figure 14).
3. Townships, counties and states where computerized centers were hot-audited were not a representative sample of townships, counties and states in Venezuela (Figure 15).
4. The probability that the centers that were hot-audited do not appear to be a random sample of all computerized voting centers seems to be high and thus it is difficult to believe that the unexpected sample of audited centers was due to chance alone. Note that centers that were actually audited were drawn from a subsample of all centers with a high proportion of signatures (Figure 13).
5. Audits were suspended in centers with low s, where the linearity in the official results is most questionable.

While none of this constitutes proof of tampering, we believe that our analyses of some of the data collected in association with the recall referendum cast some doubt about the accuracy of the official results. If in fact it is reasonable to assume that:

- A person who signed the form requesting a referendum was likely to vote sí.
- A person who did not sign the form is not necessarily likely to vote no, then the very high correlation between the proportion of signers and the proportion of sí votes at a center should be viewed with suspicion rather than as a confirmation that official results are believable, as the OAS/Carter Center report claim. Indeed, an excerpt from the report states that:

> "There is a *high correlation between the number of YES votes per voting center and the number of signers of the presidential recall request per voting center*; the places where more signatures were collected also are the places where more YES votes were cast. There is no anomaly in the characteristics of the YES votes when compared to the presumed intention of the signers to recall the president."

We argue exactly the opposite and have provided persuasive arguments to support our position.

APPENDIX A: DATA PROCESSING METHODOLOGY

Official Referendum results were downloaded from the CNE website: http://www.cne.gob.ve/referendum_presidencial2004/.

The download was automated using a custom-made Perl script. All the data was stored on a MySQL database. Calculations were made using *Mathematica 5.2* which was connected to MySQL using the DatabaseLink package. Electoral results from the 1998 presidential election were obtained on an original CNE CD-ROM, and the data was converted from Microsoft Access to MySQL. The REP from July 2004 was also converted from MS Access to MySQL. The CNE signature data was obtained on a CD from Súmate, and is the same version given to the OAS and the Carter Center. This data was supplied in a single text file.

By matching people's identification numbers (cédula number) from the signatures and REP data, it was possible to find the number of signatures per voting center.

In order to classify voting centers into manual and computerized, the following sources of information were used:

- Súmate's list of computerized and manual voting centers.
- On the CNE website, computerized centers show results down to the voting machine level, whereas manual voting centers show results down to the voting table level.

The list of computerized and manual centers obtained using the aforementioned sources was compared on a township by township basis with the CNE infrastructure document [5].

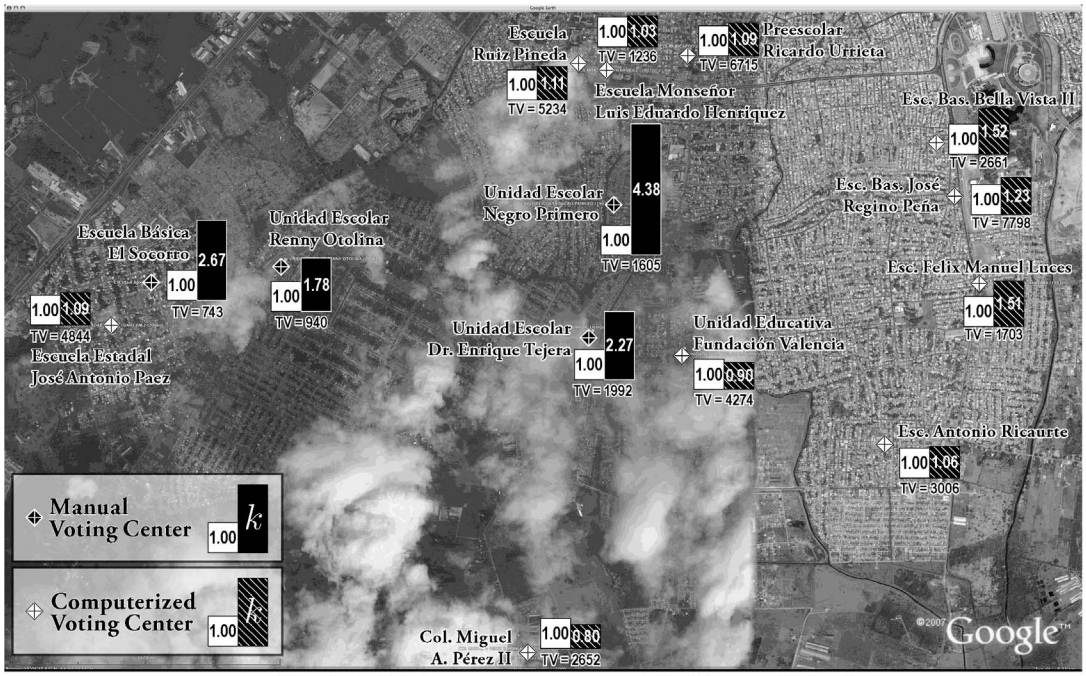


FIG. 16. *Partial aerial view of Miguel Peña township* (*taken from the* Google Earth™ *mapping service*). *Manual versus computerized voting centers are compared in regards to their k value and total number of votes* (*TV*). *The image is centered at Latitude* $10°7'32.66''N$ *and Longitude* $68°1'22.48''W$.

The list of centers effectively audited on the day of the Referendum was obtained from a document given by the *Coordinadora Democrática* to the Carter Center and OAS. A copy of this document and the data needed to reproduce this study can be found at: http://esdata.info/2004.

The coordinates of the voting centers shown in Appendix B were provided by "Delta Electoral."

The simulation was done using a deck of cards shuffling algorithm. The random number generator used by this algorithm was the "Wolfram rule 30 cellular automaton generator for integers," which is provided by *Mathematica*.

APPENDIX B: A MIXED TOWNSHIP EXAMPLE

Miguel Peña is a township in Valencia County, in the state of Carabobo. It is one of the townships with higher population in the country. It had 32 voting centers, 28 computerized and 4 manual.

In Figure 16, a partial aerial view of this township is shown. In it, notice that manual and computerized voting centers are in the same urban neighborhood. Despite this, the values of k are much higher for the manual centers than for the surrounding computerized centers, regardless of the total number of votes.

In Figure 17 notice that in this township, the lowest k value of the 4 manual centers is greater than the maximum k value of the 28 computerized voting centers.

APPENDIX C: ADDITIONAL NONLINEARITY PLOTS

According to the exit polls made under the supervision of Penn, Schoen and Berland Associates, the opposition won the Referendum by a wide margin. By changing the numerator of equation (4) from percentage of sí votes to percentage of sí from exit polls, a value of $k_{\text{exit polls}}$ can be calculated. The result, for computerized centers only, is plotted on Figure 18.

Similarly, k_{1998} can be calculated by using the percentage of opposition in the 1998 presidential election in the numerator of equation (4). The result, for computerized centers only, is shown on Figure 19.

APPENDIX D: MONTE CARLO SIMULATIONS FOR CORRELATION BETWEEN $\Delta\%^{\text{RR}}_{1998}$ AND r_{1998}.

Assuming that $\Delta\%^{\text{RR}}_{1998}$ and r_{1998} are independent, regardless of being calculated at state, county or township level, then the correlation between them $r_\star$ must be casual. In order to find the probability that the observed $r_\star$ is casual, it is possible to reorder the values

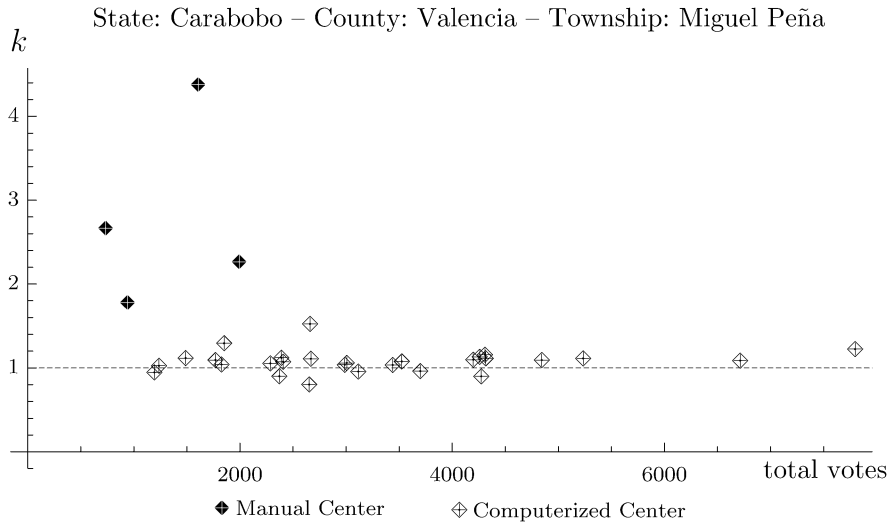


FIG. 17. *Behavior of k versus total votes in all of Miguel Peña's voting centers. Manual and computerized centers are shown.*

of r_{1998} with respect to $\Delta\%^{\mathrm{RR}}_{1998}$. This reordering was made 100,000 times and the correlation was calculated each time. In all cases, the resulting distribution was found to be normal. The estimated probabilities for manual and computerized centers at state, county or township level are shown in Figure 20.

APPENDIX E: DIFFERENCES IN CHARACTERISTICS, OFFICIAL RESULTS AND REP VARIATION OF THE 20 COUNTIES SUBJECT TO HOT-AUDIT DRAWING IN COMPARISON TO THE OTHER COUNTIES

When the CNE decided to restrict the audit to 20 urban counties, it created two groups of computerized centers:

- 2,040 computerized centers inside the 20 counties and therefore subject to be selected in the draw. Variables referring to these centers will use a 20 as a subindex ($\bullet_{20}$).
- 2,553 computerized centers not subject to hot audit at all. Variables referring to these centers will use a $\varnothing$ as a subindex ($\bullet_{\varnothing}$).

In Figure 12 it is shown that the behavior in computerized centers in the 20 counties is very different from that of the rest of the country.

E.1 Differences in Characteristics

When the CNE set up the signature collection event, it established the number of signature collection cen-

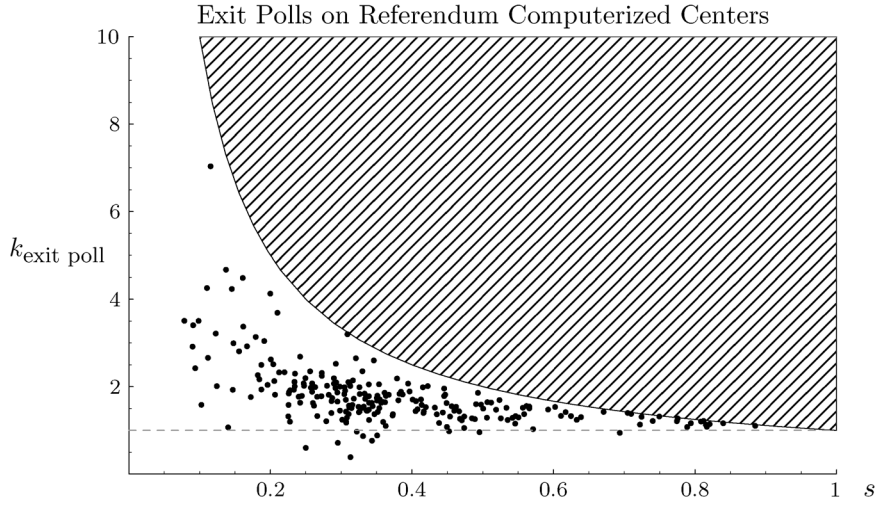


FIG. 18. *Exit polls at computerized centers.*

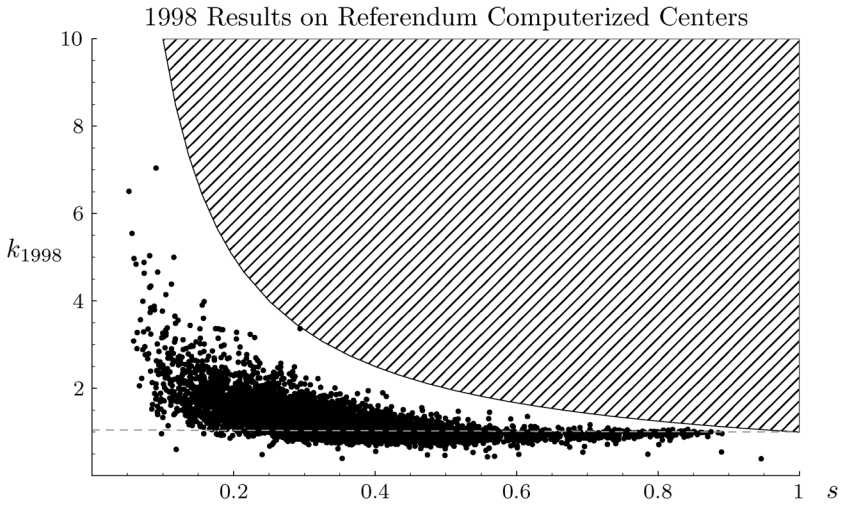


FIG. 19. 1998 *presidential election at computerized centers.*

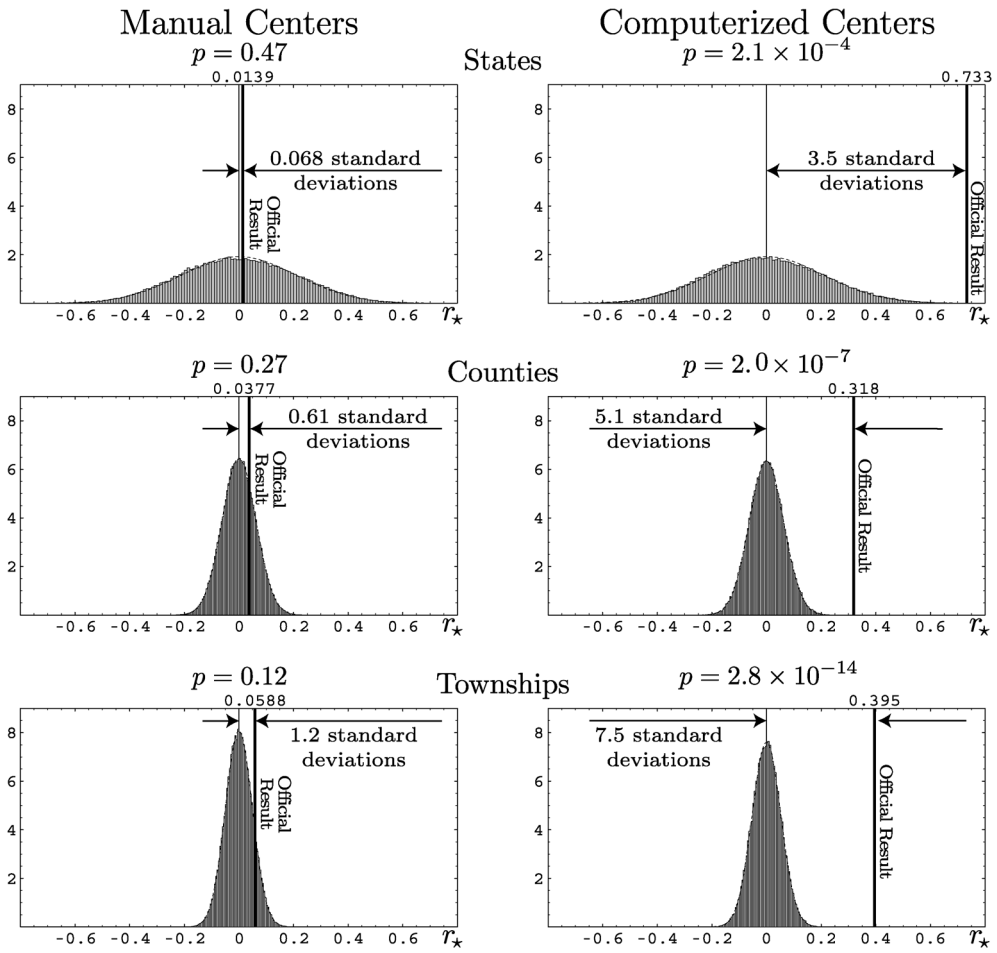


FIG. 20. *Comparison of official results correlation* $r_\star$ *versus expected value distribution found after* 100,000 *simulations for manual and computerized centers at state, county or township level. The simulation results follow a normal distribution, which is shown as a dotted line. The probability of the official* $r_\star$ *happening by chance is indicated as* p.

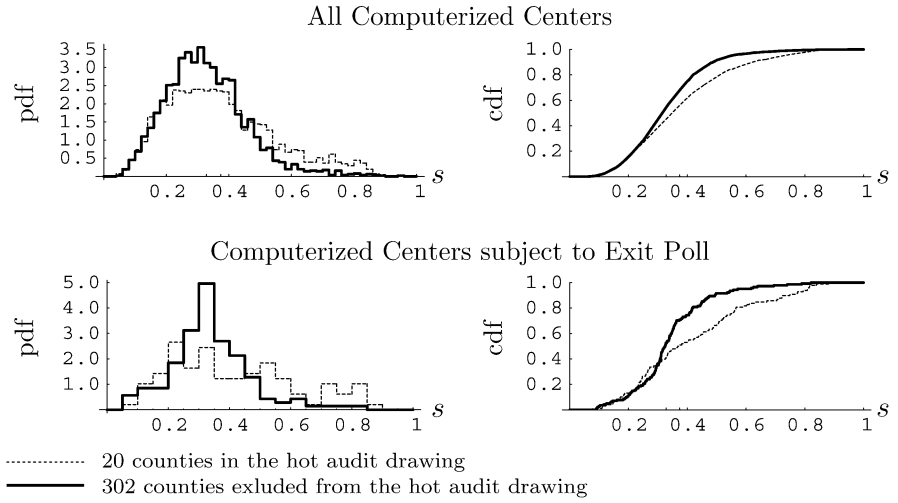


FIG. 21. *Comparison of s probability density function (pdf) and cumulative density function (cmf) for computerized centers inside the* 20 *counties of the hot audit and in the* 302 *excluded counties.*

ters (SCC) directly in proportion to the number of people in the electoral registry (REP) for each county. A lot of people live in urban counties, therefore, a lot of SCCs were assigned to these counties. Thus, access from where the people lived to where they had to sign was much easier in these 20 counties. On the other hand, voting centers are more numerous and better distributed throughout the national territory.

For example, a county like Chacao in the Miranda state has 27 km^2 of area and 11 SCCs. In Chacao there were 24 voting centers, all of them computerized. On the other hand, the much larger Macanao Península in Margarita Island has an area of 330.7 km^2 and only had 3 SCCs. There were 8 voting centers in Macanao, all of them computerized.

In Figure 21, it can clearly be seen that the 20 counties have higher s values which is consistent with the ideas just explained.

There were many computerized centers in rural areas where it was much more difficult to sign than to vote. When the audit universe was restricted to 20 *urban* counties, all computerized centers in rural areas, the ones with a higher uncertainty in k, were excluded from the hot-audit drawing universe.

E.2 Differences in Results

When the value of s decreases, in general, it is expected that the k values should increase, after all, $k_{max} = 1/s$. Hence, a larger k is expected in rural counties than in the 20 counties of the hot audit where signing was less troublesome. However, in the official results, exactly the opposite occurred, as shown in Figure 22.

Considering that for the official referendum results $\bar{k}_{20}$ is the average of 2,040 voting centers and $\bar{k}_{\varnothing}$ is the average of the remaining 2,553 voting centers, how likely is it that just by chance, $\bar{k}_{20}$ be larger than $\bar{k}_{\varnothing}$ by 3.4%? What could be expected is that $\bar{k}_{20}$ would be smaller than $\bar{k}_{\varnothing}$. Contrary to official results, in the exit polls and in the 1998 election $\bar{k}_{20}$ is significantly less than $\bar{k}_{\varnothing}$, as shown in Figure 22.

As seen in Figure 23, the distribution of k values among the 2,040 auditable centers is quite different from that of the 2,553 nonauditable centers. The k values in the 2,040 auditable centers tend to be larger than in the other 2,553 nonauditable centers. The portion of centers with k smaller or near to 1, is much smaller in the 2,040 auditable centers than in the other 2,553. That is contrary to what happened in the 1998 election and in the exit poll. Additionally, note that the k pdf seems to be much more symmetric than that in the 1998 results or the exit polls.

How likely is it that k_{20} cmf be below $k_{\varnothing}$ cmf with such a large difference ($D = 0.233$)? Being conservative and assuming that both k_{20} and $k_{\varnothing}$ distributions came from the same continuous distribution, the probability can be estimated using the Kolmogorov–Smirnov Test for two samples. This probability was found to be in the order of 2.6×10^{-54}. For the reasons previously exposed, the distribution of $k_{\varnothing}$ should be greater—not equal—than that of k_{20}. Hence, the actual probability should be much smaller.

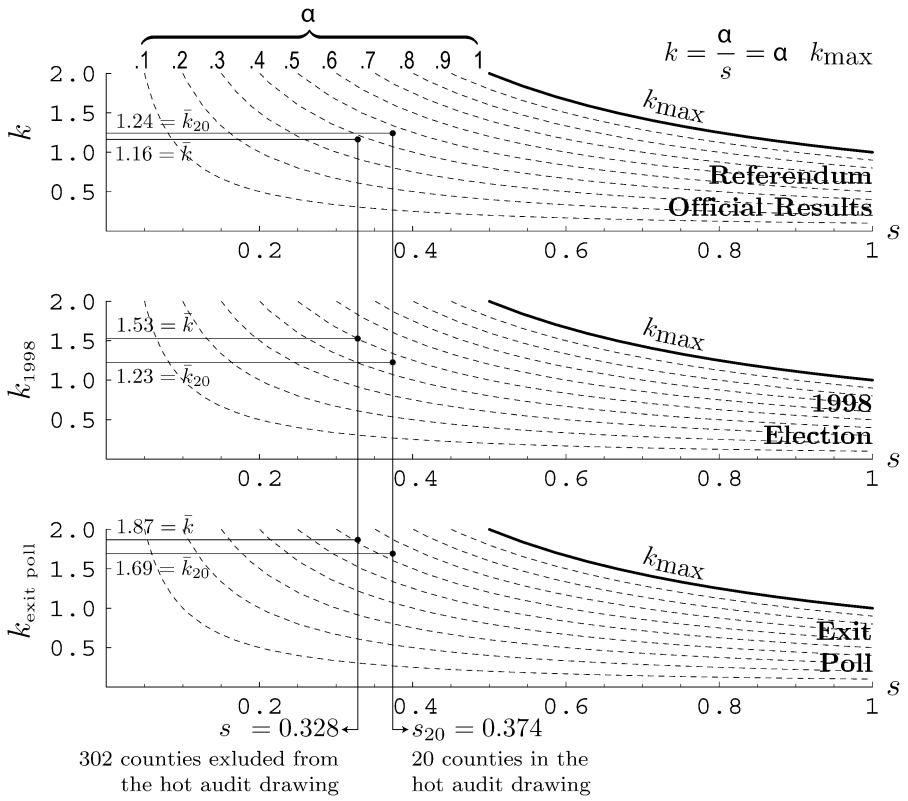


FIG. 22. *Comparison of average k and s values for the computerized centers inside and outside the* 20 *counties to which the hot-audit universe was restricted. These* $\bar{k}$ *and* $\bar{s}$ *values are shown for the official referendum results, for the* 1998 *presidential election and for the referendum exit polls.*

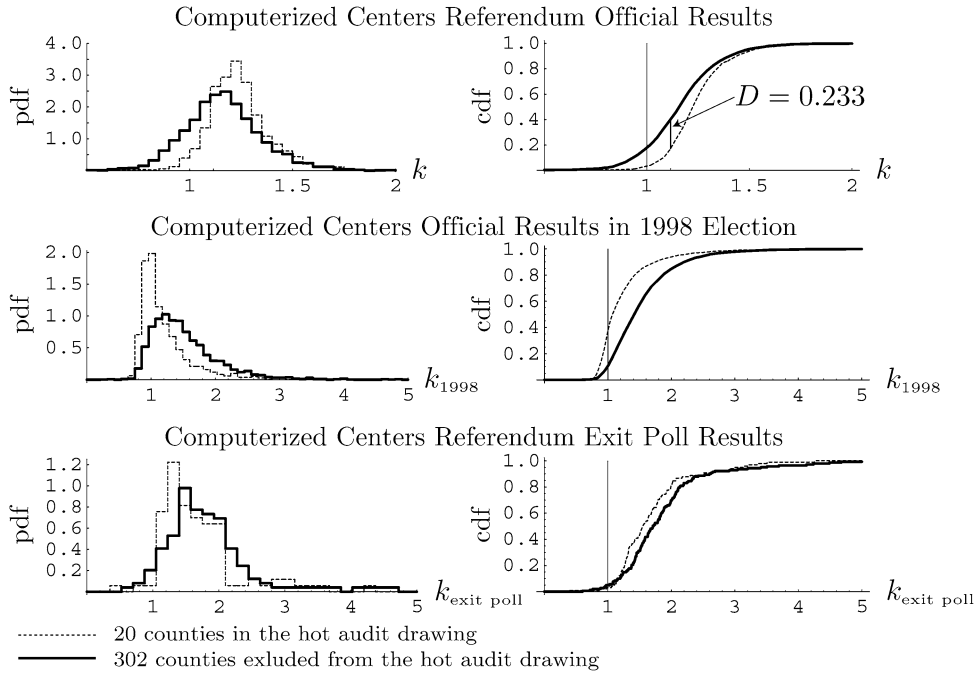


FIG. 23. *Comparison of k probability density function (pdf) and cumulative density function (cmf) for computerized centers inside the* 20 *counties of the hot audit and in the* 302 *excluded counties. The maximum cmf difference (Supremum) for the official results is shown as D.*

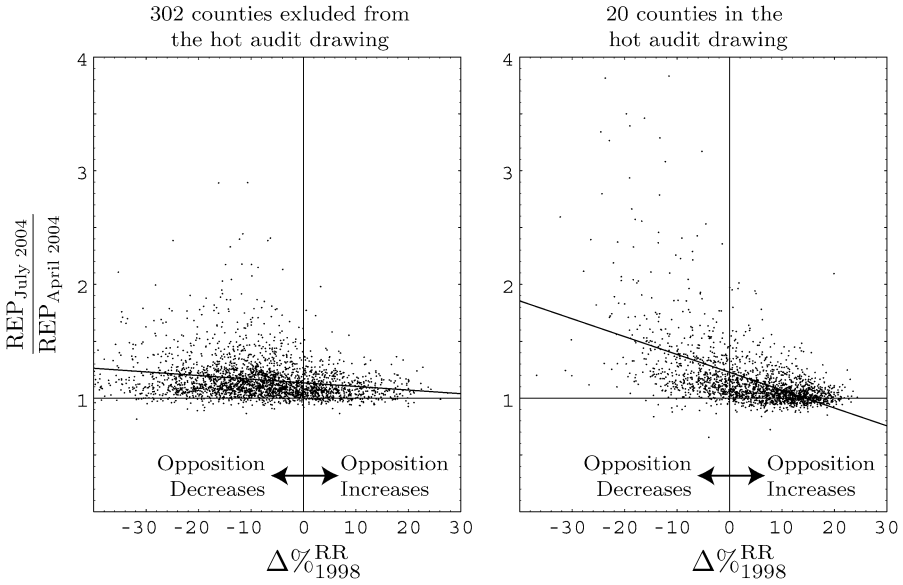


FIG. 24. *REP variation versus* $\Delta\%^{\text{RR}}_{1998}$ *in computerized centers inside and outside the* 20 *counties of the hot-audit drawing. A least-square line is included in both cases.*

E.3 Electoral Registry (REP) Differences

Between April and July 2004, 1,842,959 (14.9%) voters were added to the REP. In the computerized centers the number of registered voters went from 10,849,321 to 12,390,159. In Figure 24 it is shown how differently these increments were distributed in the computerized centers. Furthermore, in Figure 25, it can be seen that the 192 centers selected to be hot audited exclude an area where the government has important gains without a big increase in the REP.

ACKNOWLEDGMENT

The authors would like to thank all the people who contributed and supported this effort. Countless hours of volunteer work helped make this paper a reality.

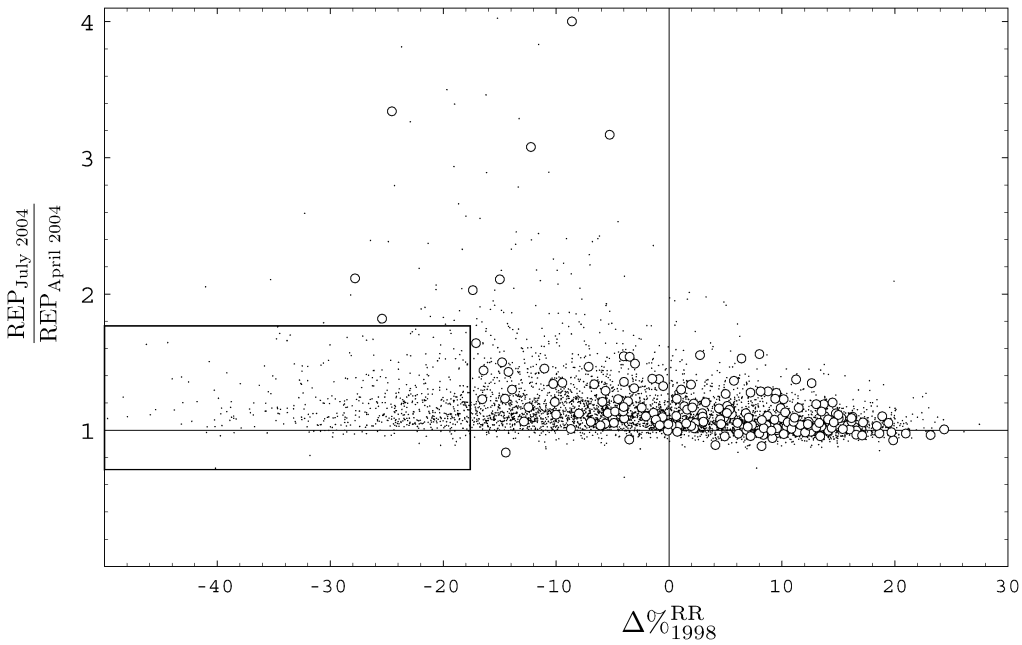


FIG. 25. *REP variation versus* $\Delta\%^{\text{RR}}_{1998}$ *in all computerized centers indicating the* 192 *selected for hot-auditing. None of the* 192 *selected centers were in the rectangle area.*

REFERENCES

[1] THE CARTER CENTER and THE OAS (May 23 of 2003). Agreement of the forum for negotiation and agreement in Venezuela. Available at http://web.archive.org/web/20060826224121/http://www.cartercenter.org/doc1338.htm and http://www.oas.org/OASpage/eng/Venezuela/Acuerdo052303.htm.

[2] THE CARTER CENTER and THE OAS (November 16 of 2004). Report on an analysis of the representativeness of the second audit sample, and the correlation between petition signers and the yes vote in the Aug. 15, 2004 presidential recall referendum in Venezuela. Available at http://www.cartercenter.org/documents/1834.pdf.

[3] THE CARTER CENTER and THE OAS (26 of August 2004). Audit of the results of the presidential recall referendum in Venezuela. Available at http://www.cartercenter.org/documents/1820.pdf and http://www.oas.org/documents/Venezuela/Referendo-OEA-CCarter.pdf.

[4] THE CARTER CENTER (February 25 of 2005). Observing the Venezuela presidential recall referendum: Comprehensive report. Available at http://www.cartercenter.org/documents/2020.pdf.

[5] CONSEJO NACIONAL ELECTORAL (August 13 of 2004). Infraestructura electoral referendo revocatorio presidencial 15 de Agosto 2004. Available at http://www.cne.gov.ve/estadisticas/infraestructura2004_02.pdf.