`eforensics` Analysis of the 2024 President Election in Pennsylvania*

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I use the `eforensics` model (Mebane 2023) to analyze precinct data from the 2024 election for president in Pennsylvania. The election occurred in a state considered a battleground state for the overall president election. The competitiveness of the race was enhanced by decreases in Democrats' relative advantage: Democrats came into the election "with their weakest voter registration advantage compared with Republicans in recent decades. The party's raw registration numbers began to rise after Biden dropped out in late July, and [in September 2024] that trend is continuing. But simultaneously, the number of Republicans has increased even more quickly" (Walker and Meyer 2024).

In addition to extensive and intensive preelection campaigning and mobilization that contributed to electors' attending to one another hence behaving strategically, the election process experienced disruptions. On election day bomb threats directed at dozens of precincts caused delays (Chang 2024; Swan, Otterbein, Sakellariadis and Gedeon 2024), there were ballot printing errors and tabulator failures (WJAC Staff 2024; Dodd, Reyes and King 2024) and problems and partisan tactics caused thousands of mail ballots to be rejected or challenged (Sneed 2024; Wang 2024; ACLU Pennsylvania 2025). At several precincts the delays prompted voting hours to be extended after the originally scheduled poll closing time, for example until 10 p.m. (Chang 2024). Such problems made it more difficult to vote and, if asymmetric in their partisan impacts, are likely to have produced lost votes. For example at least thirteen precincts were reported to have had bomb threats in heavily Democratic Philadelphia, and at ten of these precincts "between 6:43 p.m. and 6:55 p.m. on Tuesday [...] Police said all of the locations were searched by K-9 units" (Chang 2024).

I have precinct data for the state from a public interest group (McGregor 2025). Table 1 reports statewide totals from my data for votes cast and for electors. The totals shown for Trump and Harris in the table match the values reported at official sites such as Commonwealth of Pennsylvania (2025). The "Total Votes Cast" in the table includes 74,010 votes beyond those cast for Trump or Harris. Commonwealth of Pennsylvania

Table 1: Pennsylvania 2024 President Election Vote Totals

Party	Votes
Trump	3,543,308
Harris	3,423,042
Electors	9,175,518
Total Votes Cast	7,040,360

Note: statewide vote totals by party. $n = 9189$ precincts.

(2025) reports 67,856 votes were cast for two third-party candidates (Oliver and Stein); I lack precinct votes counts for separate third-party or write-in candidates, but perhaps the data include votes for candidates besides the two third-party candidates.

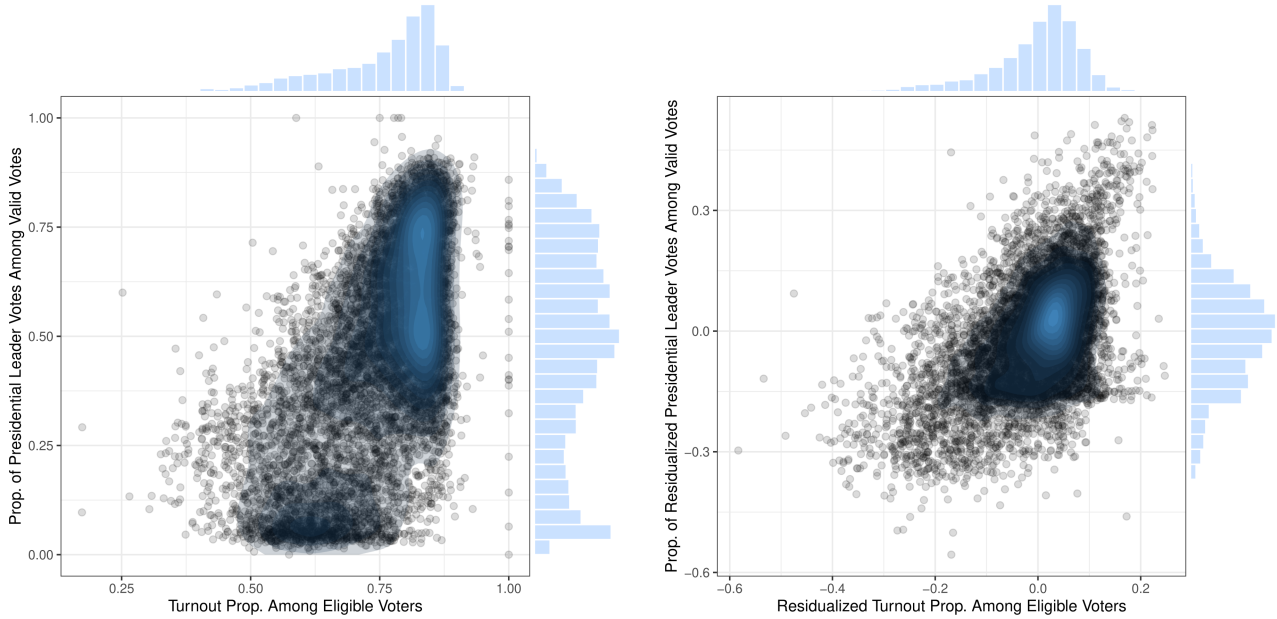
For `eforensics`-plots and subsequent `eforensics` model estimation the leader (the candidate who benefits from any `eforensics`-fraudulent votes) is the candidate with the most votes. The number of votes cast, V_i, is the variable[1] used to produce "Total Votes Cast" in Table 1. The `eforensics`-plots for precinct turnout and leader vote choice proportions reveal strong multimodality in vote choice proportions in the original data (Figure 1(a)): the most obvious multimodality relates to diversity among precincts in vote choice.[2] A set of precincts that have turnout of 1.0 is apparent at the right edge of the plots: these arise because for 24 precincts original observed values have $N_i < V_i$, and for these I impute $N_i := V_i$.[3] The multimodality in vote choice proportions is reduced but not eliminated when county and imputation-status fixed effects are removed (Figure 1(b)), so while county-specific variation is a reason for the multimodality in Figure 1(a) it is not the only reason. The residualized data are not very clumpy (efficiency .9969), but the joint distribution of the residualized data is not all that close to elliptical.

[1]The variable is called `total_votes`.

[2]For `eforensics` plots and estimation 32 precincts are omitted because their vote counts are zero.

[3]The precinct (observed N_i, V_i) triples observed with $N_i < V_i$ for each precinct i are Allegheny 11760 (474, 485), Berks 392 (933, 1168), Berks 830 (1126, 1421), Centre 150 (776, 905), Centre 263 (0, 821), Centre 268 (0, 1111), Delaware 2790 (0, 732), Elk 110 (328, 767), Lehigh 490 (708, 2258), Luzerne 157 (329, 1166), Montgomery 1130 (619, 985), Montgomery 1700 (255, 1029), Northampton 760 (164, 715), Northumberland 865 (29, 367), Susquehanna 160 (405, 934), Venango 720 (76, 211), Wayne 235 (535, 938), Westmoreland 820 (225, 626), Westmoreland 2850 (0, 754), Wyoming 300 (261, 407), York 415 (1130, 2456), Philadelphia 2nd Congressional (0, 678), Philadelphia 3rd Congressional (0, 1789), Philadelphia 5th Congressional (0, 16).

Figure 1: `eforensics`-plots: Pennsylvania 2024 President



(a) original data (b) county-status-residualized data

Note: scatterplots, 2D empirical densities and marginal histograms for turnout and leader vote proportions. $n = 9157$ precincts. For `eforensics` estimates see Tables 2 and 3. Entropy: residualized observed (b), 8.02; Normal simulation, 9.08; efficiency, .9969.

The `eforensics` estimates reported in Table 2 are for a model specification that includes county fixed effects for turnout and vote choice as well as turnout and vote choice fixed effects for elector-imputation status (i.e., is $N_i := V_i$?). With these fixed effects the data being analyzed are effectively those shown in Figure 1(b). Diagnostics signal that the mixture probabilities feature MCMC posterior multimodality, e.g., $D(\pi_2) = 0$ is significant and $M(\pi_2) = .110$ is large. Diagnostics that suggest there are lost votes are expected given the previously mentioned election-day problems, although perhaps other factors also prompted asymmetric counterfactual declines in turnout. Of $n = 9157$ precincts in the analysis 1820 have `eforensics`-frauds, of which nine are extreme frauds. The statewide total across precincts of `eforensics`-fraudulent votes, $F_w = 225440.2$ $[207757.1, 252978.1]$, exceeds the statewide gap of 120266 votes between Trump and Harris.

Considering the example of German elections (see Mebane 2025, Section 8.1), the fact

Table 2: Pennsylvania 2024 President `eforensics` Estimates, County Fixed Effects

Type	Parameter	Covariate	Mean	lo[a]	up[b]
mixture probabilities	π_1	No Fraud	.733	.677	.800
	π_2	Incremental Fraud	.265	.199	.322
	π_3	Extreme Fraud	.00169	.000436	.00303
turnout	γ_1	imputed electors	.995	−.384	2.14
vote choice	β_1	imputed electors	−.261	−.412	.0413
incremental frauds	ρ_{M0}	(Intercept)	−.0837	−.347	.338
	ρ_{S0}	(Intercept)	−.732	−.817	−.623
extreme frauds	δ_{M0}	(Intercept)	−.318	−1.00	.242
	δ_{S0}	(Intercept)	−.675	−1.26	−.153

MCMC posterior multimodality diagnostics:
dip test p-values $D(\pi_1) = 0$; $D(\pi_2) = 0$; $D(\pi_3) = .929$.[c]
means difference $M(\pi_1) = .110$; $M(\pi_2) = .110$; $M(\pi_3) = .00157$.[d]

units `eforensics`-fraudulent: (1811 incremental, 9 extreme, 7337 not fraudulent)
manufactured votes $F_t = 111917.4\ [84106.6, 136932.4]$[e]
  incremental manufactured $F_t = 111088.4\ [83441.8, 135732.8]$[e]
  extreme manufactured $F_t = 829.1\ [546.7, 1502.1]$[e]
total `eforensics`-fraudulent votes $F_w = 225440.2\ [207757.1, 252978.1]$[e]
  incremental total $F_w = 223652.3\ [205683.8, 251653.7]$[e]
  extreme total $F_w = 1787.8\ [1248.0, 2201.5]$[e]

Note: selected `eforensics` model parameter estimates (posterior means and credible intervals). County fixed effects for turnout and vote choice are not shown. $n = 9157$ precinct units. Electors, votes cast and votes for the leader: $\sum_{i=1}^{n} N_i = 9173772$; $\sum_{i=1}^{n} V_i = 7040360$; $\sum_{i=1}^{n} W_i = 3543308$. [a] 95% HPD lower bound. [b] 95% HPD upper bound. [c] dip test for unimodality null hypothesis over all MCMC chains. [d] difference between largest and smallest chain-specific posterior means. [e] posterior mean [99.5% credible interval].

that the intercept for the incremental manufactured frauds magnitudes lacks a definite sign—$\rho_{M0} = -.0837$ $(-.347, .338)$—inductively suggests that the incremental manufactured votes, $F_t = 111088.4\ [83441.8, 135732.8]$, very likely are produced from malevolent distortions of electors' intentions. The frauds magnitudes intercept for the incremental stolen votes is negative, with incremental stolen votes having a posterior mean of $F_w - F_t = 223652.3 - 111088.4 = 112563.9$. Again drawing on German elections, with a negative frauds magnitudes intercept the incremental stolen votes can be interpreted as ambiguous, likely being unknown admixtures of malevolent distortions and electors'

strategic behaviors. Subtracting these stolen votes from $F_w = 225440.2$ leaves $225440.2 - 112563.9 = 112876.3$ `eforensics`-fraudulent votes that likely stem from malevolent distortions, here including the incremental manufactured votes with the extreme `eforensics`-fraudulent votes that very likely stem from malevolent distortions. This reduced total 112876.3 is smaller than winning margin of 120266 votes.

When an `eforensics` model specification produces diagnostics that signal there is MCMC posterior multimodality in mixture probabilities, my usual practice is to expand the use of geographic fixed effects, if possible (Mebane 2025, Section 5.3). With this election such an approach produces the estimates reported in Table 3, which come from a model specification that includes county fixed effects for turnout, vote choice and frauds magnitudes, along with turnout and vote choice fixed effects for elector-imputation status. Diagnostics for these estimates still signal that the mixture probabilities feature MCMC posterior multimodality, e.g., $D(\pi_2) = 0$ is significant and $M(\pi_2) = .0283$ is large. Slightly fewer precincts have `eforensics`-frauds than with the model of Table 2: now of $n = 9157$ precincts in the analysis 1804 have `eforensics`-frauds, of which eight are extreme frauds. The total of `eforensics`-fraudulent votes, $F_w = 210392.4$ $[190749.6, 236940.0]$, has a posterior mean that is slightly smaller than the $F_w = 225440.2$ $[207757.1, 252978.1]$ reported in Table 2, but the 99.5% credible intervals overlap. The total number of `eforensics`-fraudulent votes estimated using the model of Table 3 still exceeds the difference of 120266 votes between Trump and Harris.

The model specification for Table 3 does not much change the estimated numbers of precincts that have `eforensics`-frauds nor of `eforensics`-fraudulent votes, but the specification supports more specific diagnostics for the frauds magnitudes. Given the fixed effects, frauds magnitudes coefficients are estimated for every county, which facilitates sharper comparisons with the examples from German elections, for which the `eforensics` models include *Wahlkreis* fixed effects.

The active `eforensics`-frauds magnitudes shown in Figure 2 suggest it is a close

Table 3: Pennsylvania 2024 President `eforensics` Estimates, County Fixed Effects 2

Type	Parameter	Covariate	Mean	lo[a]	up[b]
mixture probabilities	π_1	No Fraud	.732	.708	.752
	π_2	Incremental Fraud	.267	.246	.290
	π_3	Extreme Fraud	.00192	.000893	.00296
turnout	γ_1	imputed electors	1.27	1.15	1.53
vote choice	β_1	imputed electors	$-.105$	$-.264$	.161

MCMC posterior multimodality diagnostics:
dip test p-values $D(\pi_1) = 0$; $D(\pi_2) = 0$; $D(\pi_3) = .577$.[c]
means difference $M(\pi_1) = .0285$; $M(\pi_2) = .0283$; $M(\pi_3) = .000716$.[d]

units `eforensics`-fraudulent: (1796 incremental, 8 extreme, 7353 not fraudulent)

manufactured votes	$F_t = 88600.0\ [78425.9, 99282.4]$[e]
incremental manufactured	$F_t = 88115.0\ [78126.0, 98838.0]$[e]
extreme manufactured	$F_t = 484.9\ [227.1, 704.5]$[e]
total `eforensics`-fraudulent votes	$F_w = 210392.4\ [190749.6, 236940.0]$[e]
incremental total	$F_w = 209118.0\ [189963.6, 235675.2]$[e]
extreme total	$F_w = 1274.4\ [711.6, 1837.1]$[e]

Note: selected `eforensics` model parameter estimates (posterior means and credible intervals). County fixed effects for turnout, vote choice and `eforensics`-frauds magnitudes are not shown (see Figure 2 for active frauds magnitudes fixed effects). $n = 9157$ precinct units. Electors, votes cast and votes for the leader: $\sum_{i=1}^{n} N_i = 9173772$; $\sum_{i=1}^{n} V_i = 7040360$; $\sum_{i=1}^{n} W_i = 3543308$. [a] 95% HPD lower bound. [b] 95% HPD upper bound. [c] dip test for unimodality null hypothesis over all MCMC chains. [d] difference between largest and smallest chain-specific posterior means. [e] posterior mean [99.5% credible interval].

call—or perhaps more precisely a highly focused call—to say whether the `eforensics` estimates reported in Table 3 mean the election was decided or nearly decided by malevolent distortions of electors' intentions. For the German elections discussed in Mebane (2025, Section 8.1), a frequent pattern is that there are active incremental frauds magnitudes for all or almost all *Wahlkreise*, but these active incremental frauds magnitudes are all negative. Because no one believes German federal elections feature election frauds but everyone believes they feature widespread elector strategic behaviors, this pattern motivates the inductive generalization that when all active incremental frauds magnitudes are negative, it is ambiguous whether the reason for estimated `eforensics`-fraudulent votes is malevolent distortions of electors' intentions or electors' strategic behaviors. In Figures

2(a,b) every county is shown having active incremental frauds magnitudes (county names are associated with the x-axis numbers in Table 4), which matches a key feature of the German election examples. But in Figures 2(a,b) the signal that `eforensics`-fraudulent votes stem from malevolent distortions depends mainly on Philadelphia.

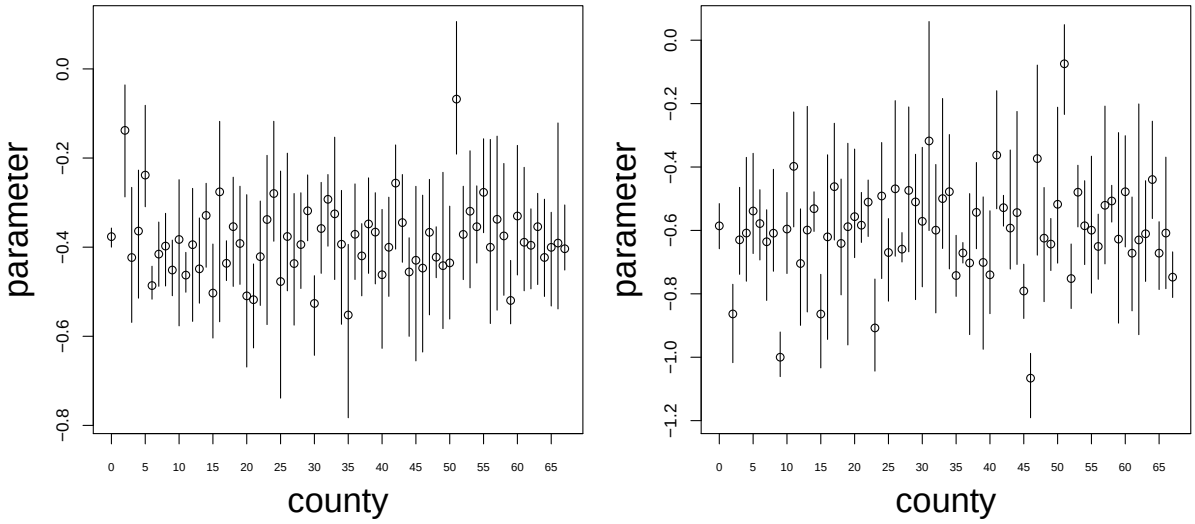
Considering the incremental stolen votes first, in Figure 2(b) the posterior mean of the active stolen votes frauds manitudes coefficient is negative for every county, and only for two counties does the 95% HPD interval include positive values. The exceptional counties are Philadelphia and Huntingdon. Even though a direct induction from the German elections might suggest concluding from these two exceedences that all of the incremental stolen votes should be interpreted as arising from malevolent distortions, a more nuanced view is that there is a signal that likely the incremental stolen votes at least in part come from malevolent distortions in Philadelphia and Huntingdon, but generally—including in these two counties—the incremental stolen votes are unknown admixtures of malevolent distortions and electors' strategic behaviors. I think the more nuanced interpretation is the most reasonable one, given Pennsylvania's status as a key battleground into which extensive and intensive campaigning and mobilization efforts were directed, which means many electors' were aware of what other electors' planned to do in the election. Maybe most or almost all of the incremental stolen votes are false positives prompted by electors' strategic behaviors.

The active incremental manufactured frauds magnitudes (Figure 2(a)) are similar in that the only county that has a nonnegative frauds magnitude coefficient is Philadelphia. For all counties the frauds magnitude coefficients have negative posterior means. A nuanced interpretation that matches that for stolen incremental votes is probably most appropriate. Maybe most or almost all of the incremental manufactured votes are false positives prompted by electors' strategic behaviors.

Figure 2: Pennsylvania 2024 President: `eforensics`-frauds Magnitudes Fixed Effect Parameters

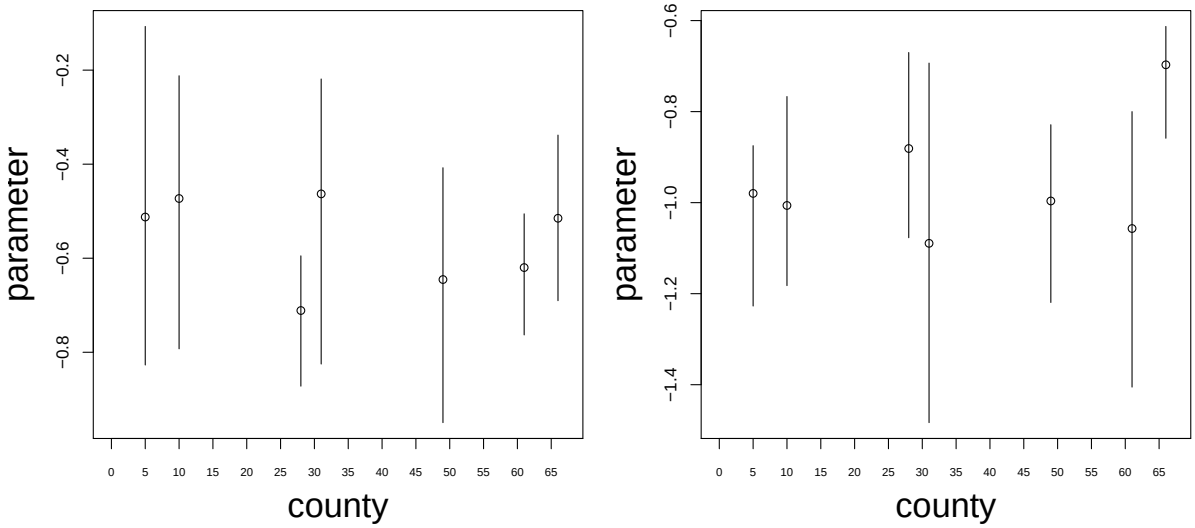
(a) incremental manufactured: ρ_{Mj}

(b) incremental stolen: ρ_{Sj}



(c) extreme manufactured: δ_{Mj}

(d) extreme stolen: δ_{Sj}



Note: active fixed effects parameters (posterior means and 95% HPD intervals) for frauds magnitudes parameters (ρ_{Mj}, ρ_{Sj}, δ_{Mj}, δ_{Sj}) in the `eforensics` model reported in Table 3. For names of the county for each place on the x-axis, see Table 4.

Table 4: Pennsylvania 2024 President Election: Counties with Active `eforensics`-frauds

0	Adams	18	Clinton	35	Lackawanna	52	Pike
2	Allegheny	19	Columbia	36	Lancaster	53	Potter
3	Armstrong	20	Crawford	37	Lawrence	54	Schuylkill
4	Beaver	21	Cumberland	38	Lebanon	55	Snyder
5	Bedford	22	Dauphin	39	Lehigh	56	Somerset
6	Berks	23	Delaware	40	Luzerne	57	Sullivan
7	Blair	24	Elk	41	Lycoming	58	Susquehanna
8	Bradford	25	Erie	42	McKean	59	Tioga
9	Bucks	26	Fayette	43	Mercer	60	Union
10	Butler	27	Forest	44	Mifflin	61	Venango
11	Cambria	28	Franklin	45	Monroe	62	Warren
12	Cameron	29	Fulton	46	Montgomery	63	Washington
13	Carbon	30	Greene	47	Montour	64	Wayne
14	Centre	31	Huntingdon	48	Northampton	65	Westmoreland
15	Chester	32	Indiana	49	Northumberland	66	Wyoming
16	Clarion	33	Jefferson	50	Perry	67	York
17	Clearfield	34	Juniata	51	Philadelphia		

Note: counties with incremental frauds, numbered to match the x-axis in Figure 2(a,b). Extreme frauds (Figure 2(c,d)) are in Bedford, Butler, Franklin, Huntingdon, Northumberland, Venango and Wyoming counties.

Whether any malevolent distortions that the incremental `eforensics`-fraudulent votes may reflect include intimidations or other actions that accompany all the bomb threats is unclear, because the primary effect I expect such threats to produce is lost votes. A caveat is that because of a limitation of the displays in Figure 2[4] the credible intervals for more counties may be nonnegative.

The model specification that includes county fixed effects for turnout, vote choice and frauds magnitudes conveys much the same impression as does the specification that includes fixed effects only for turnout and vote choice (Table 2), except the fuller specification supports a more nuanced reading of the election. The estimates from the

[4]The caveat is that for all fixed effects except any displayed in position zero, which corresponds to the intercept, I simply add the posterior mean of the intercept to the fixed effects' coefficient and to the limits of its 95% HPD interval, without adjusting for how these intervals should change to represent the full variation of the combined fixed effects. So pending implementation of such corrected credible intervals, the displays in Figure 2 should be viewed merely as informally illustrative.

fuller specification clarify that it is not simple to distinguish the part of the `eforensics`-fraudulent votes that stems from malevolent distortions of electors' intentions from the part that may be triggered by electors' strategic behaviors. Guidance from the key example of German federal elections is complicated by the fact that for incremental manufactured or stolen votes estimates of several active frauds magnitudes are close to being nonnegative, and the coefficient for one important county has an indeterminate sign.

Probably the appropriate approach is not as simple as omitting all of the incremental stolen votes and declaring the rest to reflect only malevolent distortions. Probably some of the posterior mean of $F_t = 88115.0$ incremental manufactured votes and some of the posterior mean of $F_w - F_t = 209118.0 - 88115.0 = 121003$ incremental stolen votes stem from malevolent distortions: details from the `eforensics` estimates show that 28 Huntingdon precincts have incremental frauds[5] with a posterior mean total among them of $F_t = 1020.9$ manufactured and $F_w - F_t = 2384.7 - 1020.9 = 1363.8$ stolen votes out of a total of $\sum N_i = 15060$ electors, $\sum V_i = 12716$ votes cast and $\sum W_i = 10361$ leader votes, and 118 Philadelphia precincts have incremental frauds with posterior mean totals among them of $F_t = 8296.8$ manufactured and $F_w - F_t = 22736.6 - 8296.8 = 14439.8$ stolen votes out of a total of $\sum N_i = 67691$ electors, $\sum V_i = 53297$ votes cast and $\sum W_i = 31210$ leader votes; perhaps only some of these should be considered to stem from malevolent distortions. Then if all the the extreme `eforensics`-fraudulent votes are treated as due to malevolent distortions, the `eforensics`-fraudulent votes from malevolent distortions in the election have a posterior mean of $F_w = 1274.4$ plus some share of the $8296.8 + 1363.8 + 14439.8 = 24100.4$ incremental manufactured votes in Philadelphia and incremental stolen votes in Huntingdon and Philadelphia. Including all of the latter would give a posterior mean statewide of 25374.8 `eforensics`-fraudulent votes deemed to stem from malevolent distortions of electors' intentions. That's a not negligible proportion of the difference of 120266 votes between Trump and Harris.

[5]One Huntingdon precinct, Huntingdon: 270, has extreme frauds with $F_{ti} = 53.9$ $[19.6, 83.3]$, $F_{wi} = 118.1$ $[51.1, 170.7]$, $N_i = 446$, $V_i = 395$ and $W_i = 338$.

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