Jon Mellon has been working on this problem and is worth citing.

"MMM" is alliterative but I think it would be clearer to use more familiar words like composition, etc.

The Margin and Mix Method:

A Zero-Loss Approach to Decomposing Electoral and Compositional Shifts

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Abstract

Accurately analyzing the impact of demographic changes within and across groups between elections is challenging with existing methods, which often fail to account for total vote shifts. I introduce the Margin and Mix Method (MMM), a novel approach that resolves this issue by precisely accounting for both within-group and cross-group compositional changes. Using simulated data, I show MMM not only produces accurate and interpretable results but also provides a framework to standardize the sequencing of the calculation to ensure consistency in analysis. Finally, I apply this method to the 2016 and 2020 U.S. elections, showing how previous approaches introduce errors involving millions of votes, while MMM provides a zero-loss, precise model for understanding electoral change.

Did these errors lead to incorrect conclusions? If you can show that, your case will be harder to dismiss.

Introduction

There are plenty of academic citations — Gelman, Bartels, McCarty, Sides et al. — so I wouldn't lead with non-academic citations.

Recent debates on U.S. demographic trends have focused on the influence of racial composition and class-based voting patterns on election outcomes (Klein, 2024b). Some argue that demographic trends favor the Democratic Party (Klein, 2024a), while others emphasize the need for Democrats to focus on winning working-class, white voters (Judis and Teixeira, 2023). These debates reflect both public curiosity (Fessenden et al., 2020; Kolko and Monkovic, 2020) and a deeper academic interest in understanding vote share shifts across elections (Zingher, 2019; Hill et al., 2021). However, existing approaches to studying this question often fail to adequately account for the complexities of electoral composition, particularly when considering both shifts within groups and changes across groups. Recent work by Marble et al. (2024) argues that correctly accounting for votes requires knowing the group's size and its turnout rate as well as the rate at which the group voted for each candidate. The authors provide an exciting new tool for translating voter survey data, like ANES, into estimations of support for parties by racial groups.

Yet, in their work, as well as in other academic studies, authors fail to correctly account for the impact of the change in composition across groups. For example, in Marble et al. (2024), the authors use what I call a derivative-based approach. They seek to understand the shifting support of Mitt Romney and Donald Trump from the 2012 to the 2016 election. To do so, they first shift the margin of victory for Trump within white voters, fixing the racial composition of the electorate at 2016 levels. They next check the impact of the changing racial composition by fixing the margins within groups at 2016 levels. They stop their analysis here, but following the same logic, fixing the racial composition and the margins within group and simply shifting the total number of votes and summing across the three shifts shows that their method does not accurately capture the total sum of the change in the electorate. Indeed, their approach generates a misspecification of votes of nearly 4.2 million for Trump and 1.2 million for Biden.

I take this to be the core statement of your logic, but from this alone, I don't see your key move. Can you be clearer about the core intuition?

Don't go easy on us on my account - you might want to explain if you see us making the same error or a different one.

Currently, there are two main approaches widely used in the literature to study compositional effects: the derivative-based approach and the regression-based approach as in Hill et al. (2021). I argue that neither approach adequately captures the complex dynamics of the 'state space' of electoral change, which refers to how the relationship between demographic variables and time shifts between elections. While both the derivative-based approach (e.g., (Marble et al., 2024)) and regression-based methods (e.g., (Hill et al., 2021)) have contributed to understanding vote shifts, they inadequately model how changes in group composition influence outcomes across elections.

because it XXXX — don't miss an opportunity to reinforce your core intuition.

To address this gap, I propose the Margin and Mix Method (MMM), a zero-loss, non-linear solution that better models the dynamic changes across subgroups. By extending the insights of previous authors, MMM offers a novel solution that fully captures dynamic shifts across both time and subgroups, providing a more precise understanding of electoral outcomes. I contrast the MMM approach with the derivative-based method, demonstrating its failure to accurately account for the composition shifts it ~~is~~ used to study.

The paper proceeds as follows. First, I review existing literature and mathematical approaches, with a focus on the derivative-based method. I then introduce MMM, which more accurately captures compositional shifts compared to the derivative-based approach. After introducing the MMM approach, I provide an illustrative example to demonstrate the non-linear nature of the state space. I then present a simplified example using rounded data from the 2016 and 2020 U.S. elections to explain the methodology. I demonstrate that in this simple case, the MMM approach leaves no votes incorrectly explained, highlighting the zero-loss nature of the method. From there, I apply the methodology to more detailed estimates of the two elections and compare the results to previous attempts to solve the problem to show how this new methodology improves our understanding of election outcomes. I conclude by demonstrating how hypothetical compositional shifts could have altered the ~~outcome of the~~ 2020 election, underscoring the robustness of the MMM approach. I show how, even with fixed vote totals, the derivative-based approach fails to correctly capture vote changes, whereas the MMM approach does so without error.

How do your substantive conclusions differ from prior work?

Theory

Is this a "Theory" or more like "Background"?

Electoral outcomes are shaped not only by individual vote choices but also by the composition of the electorate across demographic and identity groups. While there is significant research which focuses on individual-level voter behavior, understanding how group-level dynamics shift over time is essential for explaining election outcomes. Individuals belong to specific groups and it is the composition of the electorate across groups that ultimately determines who wins and loses (Axelrod, 1972). This is particularly relevant to the study of political science since in large elections, candidates must rely on appeals to broad groups rather than tailoring only to individuals. While social media has increased the ability of candidates to engage in micro-targeting of their appeals (Hersh and Schaffner, 2013), electoral success relies on a candidate's ability to build coalitions of voters. In an era of increasing polarization, building electoral coalitions based on identity and group membership has become a key strategy for candidates seeking broad-based support (Lemi, 2021). This underscores the need for political scientists to focus on group dynamics, particularly as voter persuasion declines and turnout-based strategies gain importance (Hill, 2017).

Also Hersh 2015

But see Sylvia Kim's Political Behavior article

Recent scholarship has increasingly recognized the importance of these compositional effects in shaping election outcomes. A variety of approaches have been developed to disentangle how shifts within and across groups impact overall vote shares. Hill et al. (2021) use a regression-based approach to attribute changes in vote share to either composition or conversion, while Zingher (2019) focus on estimating how changes in group size affect party support based on underlying group dynamics. However, as Engelhardt (2019) points out, distributional shifts across groups within the electorate and attitudinal shifts within groups can mask each other, making interpretations of coefficients from regressions difficult and obscuring the true drivers of electoral change. There are also several analyses that rely on simple extrapolation to estimate the effect of shifting compositions. Fraga et al. (2021) look at how different compositions and turnouts across racial groups harmed Clinton in the 2016 election by using 2012 turnout rates and estimating a new vote share. Carmines et al. (2016) argue that shifts between political coalitions and changes in turnout affect vote share. While these studies contribute to our understanding of compositional effects, they fail to fully capture the dynamic interactions between group shifts and electoral outcomes.

Articles are singular regardless of the number of authors

Building on this work, the most extensive attempt to propose a clear methodology to segment compositional effects from rate effects is provided by Marble et al. (2024). They argue that the difference in votes a group contributes to the election outcome

I think it will be helpful very early to fix ideas by defining these terms, perhaps using notation.

can be captured by:

$$\begin{aligned}\text{Diff Net}_{t,t-1}(x) = {} & [\text{Vote Share}_t(x, \text{Republican}) - \text{Vote Share}_t(x, \text{Democrat})] \\ & \text{x Turnout}_t(x) \text{ x Group Size}_t(x) \\ & - [\text{Vote Share}_{t-1}(x, \text{Republican}) - \text{Vote Share}_{t-1}(x, \text{Democrat})] \\ & \text{x Turnout}_{t-1}(x) \text{ x Group Size}_{t-1}(x)\end{aligned} \tag{1}$$

Define all notation — t, x Clarify that this is in raw votes.

Where Turnout$_t(x)$ x Group Size$_t(x)$ can be thought of as the compositional component. Using this equation, they calculate for each group a different-turnout, group size and vote choice component to describe how each individual voting group contributed to the change in total vote share in the two elections for a party. To calculate the compositional effect and the vote share effect separately, they then first hold composition fixed from the 2012 election and calculate the impact of the shifted vote share from 2012 to 2016 and then hold vote share fixed at the 2012 election and shift composition to the 2016 election. The joint sum of these totals is the implied effect of a group on the election outcome. Building on this work, Fraga et al. (2023) examine the shift within Latino voters, conducting an analysis of this subgroup, but applying a similar methodology. They find that demographic shifts within the Latino group is a driver for their increased support of Trump in 2020 compared to 2016.

> why not stick with the older term?

However, this derivative based method has two key drawbacks. First, it conflates composition and volume. Composition (hereafter called mix) can be thought of as the proportion of the total electorate comprised by each group; i.e. 60 percent white, 40 percent non-white. Whereas volume is the total size of the electorate. Importantly, the calculation in Marble et al. (2024) allows for changes in group size and turnout rate, but does not capture how group sizes do not change equally for all groups. This means that we cannot identify what component of the change is related to a simple increase in the size of the electorate that would have no effect on the share of votes a candidate receives - only the total - and what component of the change is a shift across groups that might have an impact on the outcome. Second, having already calculated

> In theory or just in how they implement it? This seems to be key, so can you provide an example?

three hyphens = m-dash in Latex

the effect of the shift in vote share within a group, by calculating their composition effects using the previous elections rate, their method does not take into account the sequential nature of the problem, which will misstate the total effects of composition. Importantly, the bias of their estimate can be both substantial and even yield the wrong sign when a candidate goes from winning (losing) a group to losing (winning) that group.

Here, too, help readers understand the underlying intuition

of "a candidate", "candidate x," etc

I propose an alternative specification of the formula for calculating the difference between vote shares. I begin by defining $z(t)$ as the total number of votes a group gives to a party of candidate. I am interested in describing how that group's contribution to the candidate's vote total compares to their contribution in the prior period and I want to show how that contribution is broken into rate, composition (or mix) and volume. Given that those are the three bins I would like to explain, then $z(t)$ must be defined as a function of those three bins:

define "t" as time or an election.

$$z(t) = f(t)g(t)h(t) \tag{2}$$

why f(t), g(t), and h(t) — could more informative letters/notation help?

Where $f(t)$ is the rate at which a group votes for the candidate, $g(t)$ is the proportion of the electorate that the group comprises and $h(t)$ is the total number of voters in the election. Given that equation 2 is a composite function, we can apply the derivative multiplication rule to find the derivative:

$$z'(t) = f'(t)g(t)h(t) + f(t)g'(t)h(t) + f(t)g(t)h'(t) \tag{3}$$

And indeed this derivative suggests using a formula exactly identical to the one proposed by Marble et al. (2024), whereby the first part of the expression is the impact of the change in rate, the second part the impact of the change in mix, and the third part the impact of the change in volume. However, this formula is misleading. As defined, $z(t)$ is a fundamentally non-linear equation in a four dimensional state-space.

Is their error ignoring the non-linearity or the volume — or is it that the non-linearity means that the volume is relevant?

Therefore, the slope is not constant and as Δt grows, this formula will less accurately capture $\Delta z(t)$. In the simple example comparing two elections, $\Delta t = 1$, which even in a function as simple as x^2 can yield large differences between the calculated value of $z(t_2)$ based on the derivative and the true value of $z(t_2)$.

State very clearly – the derivative is the instantaneous slope, different than our interest here.

Instead, to calculate the impact of rate, mix, and volume separately, I propose employing a sequential gradient ascent ~~method~~ to explore the state-space:

$$\begin{aligned}\Delta z(t) =& [f(t_2) - f(t_1)]g(t_1)h(t_1) \\ &+ f(t_2)[g(t_2) - g(t_1)]h(t_1) \\ &+ f(t_2)g(t_2)[h(t_2) - h(t_1)]\end{aligned} \tag{4}$$

While initially counter intuitive, the proof that this is equal to $z(t_2) - z(t_1)$ is trivial and is presented in the Appendix. There are two noteworthy constraints to this approach. First, turnout, a fundamentally important feature of election results, affects both $g(t)$ and $h(t)$, as does population growth. To see this for $g(t)$, consider that both the percentage of the total voters that a group comprises is a function of both the proportion of the population comprised of the that group and the turnout rate of that group as in equation 1. For $h(t)$, a similar challenge exists- an increase in the total number of potential voters in a group (population size) and the total number of realized voters (turnout) both affect the final total size of the voting population.

Need to clarify / re-write this sentence

m-dash

While a decomposition of the formula into the component parts of turnout and population change is achievable, I argue it is not necessary for the purposes of this paper for two main reasons. First, across the simple case of two time periods only four years apart, underlying changes in the racial composition of the potential electorate are unlikely to be meaningful, at least compared to the impact of turnout. Second, turnout changes are only interesting insofar as they are differential. If all groups increase turnout at the same rate (thus preserving the relative group sizes), then there are no compositional (or mix) affects. With this specification, any changes that are

Do Marble et al. make the same assumption?

universal (overall population growth, increased turnout across all groups) are captured in volume, while any changes that are differential are captured in mix. → Wouldn't this be Marble et al.'s argument?

A second crucial caveat is that this sequence is not unique. The gradient ascent can be calculated by moving any order-combination of rate, mix, and volume. There are two key arguments for why this proposed ordering is the most justifiable. First, by moving rate first, the rate calculation exactly matches all previous work that has been done on the impact of shifts in rates- which is to say, calculating the impact of shifts in rates on the first period's volumes. Second, by moving volume third, the impact of mix is also calculated on the first period's volumes. This ensures that the final calculation, volume, reflects only a perfectly proportional shift from the previous period. In essence, this order rearranges all of the components of the calculation according to the levels observed in the first period, and only after rearranging those components, does volume move last, leaving it as a simple stretching or shrinking of the newly specified outcome.

But is this ultimately a subjective choice? Or does one sequence dominate?

Also, is it true that sequence matters only in the non-linear case? If so, be very clear about that.

The Method

Non-Linearity, An Illustration

→ I didn't expect this — clarify, then, how your approaches differ.

Linear estimation is the most commonly used econometric tool in evaluating relationships between data within political science. As a result, any argument for moving away from a linear model needs careful justification. While the derivative-based approach of Marble et al. (2024) is also non-linear, Figure 1 provides a clear illustration of why this particular problem requires a non-linear approach. Consider Figure 1a. In this figure, I present an electorate divided into 8 equal parts. On the left hand side, the politician of interest receives 3 votes from each of 4 of those parts of the electorate, and 0 from the remaining four parts in the first election. This yields 12 total votes for the politician. The right-hand side displays the results of a second election. In this second election they won 32.4 votes. This shift in the total votes for the politician comes from three sources: rate (the extent to which a group supports the politician), mix (the relative mix of groups that both support and do not support the politician) and volume (the total number of voters).

? How can they win a fraction of votes?

For this figure, the changes are as follows. Since the first election, the politician has increased their total support within the groups that they had previously received votes from to the tune of 50%, yielding 4.5 votes from each of those groups instead of 3. Importantly, this change is without any change in the underlying size of the electorate- this comes from vote switching, not from turnout or population dynamics. Additionally, the politician manages to capture an equal number of votes in a 5th, previously apathetic group of voters, yielding a 25% increased share over the previous set of 4 groups. Finally, the electorate grows, either through immigration, through an increase in turnout, or simply from population growth. This change in the population is equal to 44% in this example. While these numbers reflect changes of significant magnitude far and beyond what would ever be expected to happen in a real election, they provide clear examples of the impacts of the shift.

I mean, Ireland w/ FF and Canada w/ the Liberals shows we can see dramatic ΔS.

I would either use an example with integers or explain that the fact that you can't get integers is an example of the problem!

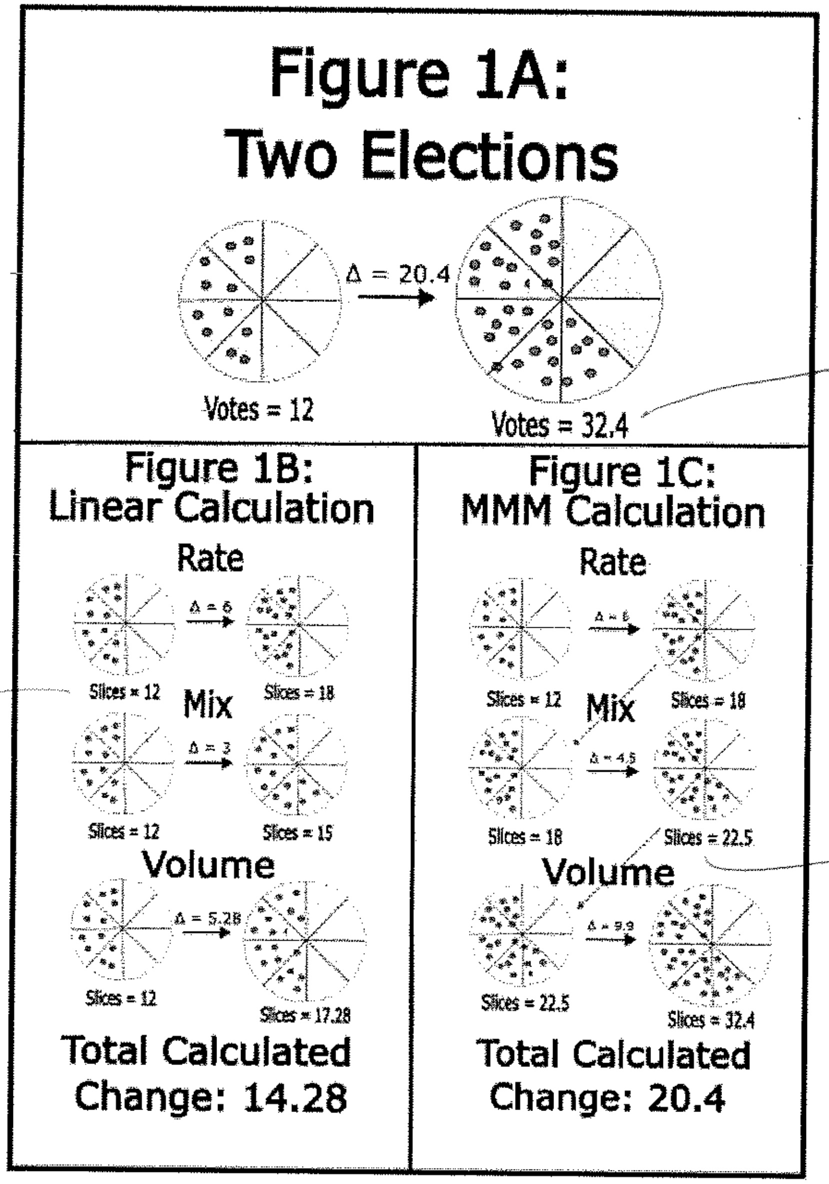

Figure 1: An Illustration of why the MMM is necessary.

How is a fractional number of votes possible? Can you make a whole number?

what are slices? Why introduce new vocabulary?

why introduce the new term "slices"?

This might be easier to understand as a barplot with Δ's heights.

Now consider Figure 1b. In this figure, I utilize the derivative-based approach. I first calculate the impact of the 50% change in rate, then the impact of the 25% change in the mix and finally, the impact of the 44% change in total volume. As can be seen, the sum of these changes is 14.28. Since our total difference is 20.4, this approach leaves just over 30% of the vote in the unspecified error term, a value greater than any of the calculated component parts. However, in Figure 1c, I apply the method I propose in this paper, where the impact is calculated sequentially. Here, I show that while the impact of rate is identical in both methods (a shift of 6 total votes), mix is

→ Too rhetorical — "its simplifying assumptions lead to incorrect answers"

underestimated in Figure 1b by 50% and the impact of volume is underestimated by just over 53%. Even in this simple example, I have shown that if we truly want to understand the impact of population dynamics and turnout, which plays into both mix and volume, the derivative-based approach and the linear regression approach simply will not suffice. Nevertheless, this artificial example bears little resemblance to the real world, so in the next section I will examine the impact of this approach with data much closer to a real world example.

Simple Case

redundant word choice

In this section, I will introduce a basic example of the MMM ~~math~~ introduced in the previous sections. Table 1 shows a simple comparison of data from the 2016 and 2020 US presidential elections. The data is based on the blocs package introduced by Marble et al. (2024), with racial groups collapsed to the simple case of white and non-white. For illustrative purposes, I have introduced rounding to the closest 500,000^{ths} place. Table 1 shows a result favoring Clinton in the 2016 election by 8 million votes, with margin and margin rate calculated from the perspective of the democratic candidate.[1] Comparably, Biden performed significantly better in 2020, winning by 17 million votes, for a change in Non-White margin of 4 million votes and a change in White margin of 5 million votes. This is equivalent to a 7.5% decline in margin within the Non-White voting block and an improvement of 6.6% in margin within the White community. There was also a 3.6% shift towards non-white voters and away from white voters. Total votes in the system increased by 26 million, which explains why Biden improved his margin of victory in both groups.

Somewhere, you should state that survey data has biases but that you are setting them aside

Clarify — is this accurate? What method are you using?

Table 2 demonstrates the importance of shifting away from the calculation introduced in previous work. While none of the other papers mentioned in this study calculated the impact of volume, I have produced the logical calculation that would follow from the derivative-based approach discussed above. By leaving volume unspec-

[1] As best as I can tell, I have replicated the process used by Marble et al. (2024) in creating this data. The difference in their reported votes from reality seems to be related to their estimation of voter support for candidates based on the ANES.

→ Clarify the method used

Table 1: Comparing Two Elections

Election	Group	Candidate 1	Candidate 2	Total	Margin	Margin Rate (%)	Mix (%)
1st Election (2016)	Non-White	29.5	7.5	37.0	22.0	59.5	28.7
	White	39.0	53.0	92.0	−14.0	−15.2	71.3
	Total	68.5	60.5	129.0	8.0	6.2	100.0
2nd Election (2020)	Non-White	38.0	12.0	50.0	26.0	52.0	32.3
	White	48.0	57.0	105.0	−9.0	−8.6	67.7
	Total	86.0	69.0	155.0	17.0	11.0	100.0
Comparing the Two Elections	Non-White	8.5	4.5	13.0	4.0	−7.5	3.6
	White	9.0	4.0	13.0	5.0	6.6	−3.6
	Total	17.5	8.5	26.0	9.0	4.8	0.0

Note: Votes are reported in millions. Candidate 1 refers to Clinton (2016) and Biden (2020); Candidate 2 refers to Trump.

Important; you need to clarify here

ified, previous work in essence shifted any unexplained votes to an error term that was comprised not just of volume, but ~~to~~ of (?) incorrectly calculated effects of mix. The upper third of Table 2 shows that using the derivative-based approach leaves a Mean Absolute Error (MAE) of just over 1.4 million votes misattributed. However, the MMM approach correctly specifies the proper placement of the votes into their appropriate categories, leaving a MAE of 0 votes, precisely explaining the change within the system. While a large portion of the mispecification indeed does belong in the previously undefined category of volume, in the final third of the table I show that the benefit that Biden received from the change in the racial composition of the electorate is understated by 650,000 votes using the derivative method. The MMM approach also has the appealing property of explaining rate in the exact same way as the derivative-based approach, leaving our interpretation of previous work that calculated the impact of rate unchanged.

Table 2: Concept Demonstration

Method	Group	Rate	Mix	Volume	Calc Mar Chng	Var to Act	Variance %
Derivative Calculation	Non-White	−2.76	2.74	4.43	4.42	0.42	10.4
	White	6.11	0.70	−2.82	3.99	−1.01	−20.1
	Total	3.35	3.44	1.61	8.41	−0.59	−6.5
MMM Calculation	Non-White	−2.76	2.40	4.36	4.00	0.00	0.0
	White	6.11	0.40	−1.51	5.00	0.00	0.0
	Total	3.35	2.79	2.85	9.00	0.00	0.0
Comparing the Two Approaches	Non-White		0.34	0.07	0.42		
	White		0.31	−1.31	−1.01		
	Total		0.65	−1.24	−0.59		

Note: All numbers are in millions. Variance percentages are shown with one decimal place.

is "accounted for" more accurate?

In summary, the MMM approach has the desirable property of leaving every vote in the system precisely specified, delivering a zero-loss summary of the changes in the system, and this result is robust to further partitions of the underlying data[2]. The MMM approach also has the appealing property of explaining rate in an identical fashion to previous work. In future work, I intend to examine the robustness of the MMM approach to subpartions of the data.

On Overfitting

This could just be a footnote

While zero-error terms in regression models often raise concerns about overfitting (Wooldridge, 2010), the MMM approach is not subject to these risks. As it is not a regression or estimation technique, but rather an accounting framework, zero-error reflects the accurate decomposition of shifts rather than problematic estimation.

Real Data

If this is Markle et al. just cite them

In this section I apply the MMM approach to the fully specified data available in the blocs package. I again show data from the 2016 and 2020 US presidential elections, but this time with the data split into 5 racial categories (as defined in the blocs package). The blocs package estimates a percentage of votes of the total from a given racial group. While the blocs package allows for an error band around this estimation, I have taken the mean estimates and multiplied them by the total votes from the two US presidential elections. An important note ~~about the~~ MMM approach is that, as a zero-loss calculation, there is no MAE in the calculation, but if the underlying data has a confidence interval (as it would if it is itself an estimation), then the MMM approach can be used to estimate the bins for any specified estimate taken from the underlying data. *have*

Cite US Atlas of Elections, or a better source

Unlike in the simple example in the previous section, I have utilized no rounding in the individual categories, but have rounding the total votes in the system to the nearest millionth place. As can be seen by comparing these vote totals to those actually reported in the election (Wikipedia, 2024), the blocs package estimations, which are

[2]See Appendix for the robustness of the method to partitions

based upon ANES exit surveys (Marble et al., 2024), strongly overestimate support for Biden. Nevertheless, these estimates are the best available for racial group support for presidential candidates and these issues are not relevant for the purposes of this paper. Table 3 shows the racial categories and their estimated vote totals for both presidential elections. Again, margin and margin rate are calculated from the perspective of the democratic candidate.

→ Be super clear about what tables are what methods and consider reformatting the tables to make

Table 3: Comparing Two Elections, Real Data from Marble et al. (2024)

Election	Group	Candidate 1	Candidate 2	Total	Margin	Margin Rate (%)	Mix (%)
1st Election (2016)	Black	13.25	0.89	14.14	12.36	87.40	10.96
	Hispanic	9.87	3.17	13.03	6.70	51.40	10.10
	Other	5.84	3.16	8.99	2.68	29.80	6.97
	White	39.17	52.78	91.95	−13.61	−14.80	71.28
	NA	0.49	0.39	0.88	0.10	10.80	0.68
	Total	68.61	60.39	129.00	8.22	6.38	100.00
2nd Election (2020)	Black	15.42	1.47	16.89	13.95	82.60	10.89
	Hispanic	13.21	4.47	17.68	8.73	49.40	11.41
	Other	8.64	5.16	13.80	3.48	25.20	8.90
	White	47.95	57.21	105.16	−9.25	−8.80	67.84
	NA	0.80	0.67	1.47	0.13	8.60	0.95
	Total	86.02	68.98	155.00	17.03	10.99	100.00
Comparing the Two Elections	Black	2.17	0.58	2.75	1.59	−4.80	−0.07
	Hispanic	3.34	1.31	4.65	2.03	−2.00	1.30
	Other	2.80	2.01	4.81	0.80	−4.60	1.93
	White	8.78	4.43	13.21	4.35	6.00	−3.44
	NA	0.31	0.28	0.59	0.03	−2.20	0.27
	Total	17.40	8.60	26.00	8.81	4.61	0.00

Note: Votes are reported in millions. Candidate 1 refers to Clinton (2016) and Biden (2020); Candidate 2 refers to Trump.

Table 4 compares the results of the derivative-based approach to the MMM approach. I show that, again, the calculations are identical with respect to rate, but that they differ both in respect to mix and volume. The total MAE of the derivative-based approach in this specification is 1.2 million, versus the MAE of 0 for the MMM approach. This comparison allows for an opportunity to highlight another appealing property of MMM over the derivative-based approach. Appendix Table A3 shows the same calculation from the perspective of the Republican candidate (in both cases, Trump). A careful comparison between Table A3 and Table 4 shows that while each vote gained (lost) for Biden compared to Clinton from a rate perspective is a vote lost (gained) for Trump, this one-to-one trade off ~~completely~~ collapses when calculating the impact of mix and of volume under the derivative-based approach. The total MAE

I thought they didn't account for volume?

when the impact of the three bins is calculated from the perspective of Trump is 4.2 million. Comparatively, in all three bins using the MMM approach, a vote gained or lost by a candidate in either party is perfectly offset by a vote gained or lost by the candidate of the opposing party.

If a table is worth including, take the time to walk the reader through it.

Table 4: Concept Demonstration, Real Data from Marble et al. (2024)

Method	Group	Rate	Mix	Volume	Calc Mar Chng	Var to Act	Variance %
Derivative Calculation	Black	−0.68	−0.08	2.49	1.74	0.15	9.3
	Hispanic	−0.26	0.86	1.35	1.95	−0.08	−4.0
	Other	−0.41	0.74	0.54	0.87	0.07	8.9
	White	5.52	0.66	−2.74	3.43	−0.92	−21.2
	NA	−0.02	0.04	0.02	0.04	0.01	17.6
	Total	4.14	2.22	1.66	8.03	−0.78	−8.9
MMM Calculation	Black	−0.68	−0.07	2.34	1.59	0.00	0.0
	Hispanic	−0.26	0.83	1.46	2.03	0.00	0.0
	Other	−0.41	0.63	0.58	0.80	0.00	0.0
	White	5.52	0.39	−1.55	4.35	0.00	0.0
	NA	−0.02	0.03	0.02	0.03	0.00	0.0
	Total	4.14	1.81	2.86	8.81	0.00	0.0
Comparing the Two Approaches	Black		0.00	0.15	0.15		
	Hispanic		0.03	−0.11	−0.08		
	Other		0.11	−0.04	0.07		
	White		0.27	−1.19	−0.92		
	NA		0.01	0.00	0.01		
	Total		0.42	−1.20	−0.78		

Note: Votes are reported in millions. Variance percentages are shown with one decimal place.

Talk about specific numbers from the table and their meanings.

In summary, the MMM approach is more consistent then the derivative-based approach, correctly specifying the appropriate bins of vote changes, leaving an MAE of 0 when applied to real-world data. In addition, it has the appealing property of highlighting the zero-sum nature of elections- any vote won by one party, is a vote lost for the opposition.

Simulating Impact of Hypothetical Shifts

Maybe this belongs in an appendix? Or can you streamline?

In this section, I highlight the importance in understanding and correctly specifying the roles of rate and mix within elections. To do so, I will examine hypothetical scenarios that would have led to Trump winning the popular vote for the 2020 presidential election and compare those to the actual results implied by the blocs package. I will do so only for rate and for mix, since any shift in volume would be equivalent to applying

Again, just call it Marble et al.

using an eigenvector to achieve a linear transformation of the data, perfectly preserving the underlying relationships. To begin, Table 5 shows how rates would have had to have shifted in order to guarantee a win for Trump in 2020 without any mix shifts. To achieve this effect, I multiplied Biden's margin rate within each group by a factor of .9, preserving the relative rates at which each group voted for Biden, but reducing his vote totals. As can be seen, this shift is sufficient to shift just over 17.2 million votes to Trump versus the actual reported result. And what do we learn from this?

Table 5: Hypothetical Data, Only Rate Changes

Election	Group	Candidate 1	Candidate 2	Total	Gross Margin	Margin Rate (%)	Mix (%)
1st Election (2020)	Black	15.42	1.47	16.89	13.95	82.60	10.89
	Hispanic	13.21	4.47	17.68	8.73	49.40	11.41
	Other	8.64	5.16	13.80	3.48	25.20	8.90
	White	47.95	57.21	105.16	−9.25	−8.80	67.84
	NA	0.80	0.67	1.47	0.13	8.60	0.95
	Total	86.02	68.98	155.00	17.03	10.99	100.00
2nd Election (2020)	Black	13.88	3.01	16.89	10.86	64.34	10.89
	Hispanic	11.89	5.79	17.68	6.09	34.46	11.41
	Other	7.78	6.03	13.80	1.75	12.68	8.90
	White	43.16	62.00	105.16	−18.84	−17.92	67.84
	NA	0.72	0.75	1.47	−0.03	−2.26	0.95
	Total	77.41	77.59	155.00	−0.17	−0.11	100.00
Comparing the Two Elections	Black	−1.54	1.54		−3.08	−18.26	0.00
	Hispanic	−1.32	1.32		−2.64	−14.94	0.00
	Other	−0.86	0.86		−1.73	−12.52	0.00
	White	−4.80	4.80		−9.59	−9.12	0.00
	NA	−0.08	0.08		−0.16	−10.86	0.00
	Total	−8.60	8.60		−17.20	−11.10	0.00

Note: Votes are reported in millions. Variance percentages are shown with one decimal place.

Conversely, Table 6 demonstrates how mix would have had to shift, without any changes in the underlying rates within groups, ~~in order~~ to deliver a Trump popular vote win. In this specification, to achieve the desired result, I had to multiply the size of each of the non-white voting blocs by a factor of .44, essentially reducing them by more than half. This leads to a shift in the mix of the electorate from just under 68% white to nearly 86% white, an enormous shift. The impossibility of this shift highlights the importance that Republicans will need to place on changing rates within minority groups in future elections, especially as demographic changes continue to accelerate in the future. → Well, if they want to win the popular vote.

I have not produced a table comparing the MMM approach and the derivative-based approach for either Table 5 or Table 6, as either specification produces identical

Table 6: Hypothetical Data, Only Mix Changes

Election	Group	Candidate 1	Candidate 2	Total	Gross Margin	Margin Rate (%)	Mix (%)
1st Election (2020)	Black	15.42	1.47	16.89	13.95	82.60	10.89
	Hispanic	13.21	4.47	17.68	8.73	49.40	11.41
	Other	8.64	5.16	13.80	3.48	25.20	8.90
	White	47.95	57.21	105.16	−9.25	−8.80	67.84
	NA	0.80	0.67	1.47	0.13	8.60	0.95
	Total	86.02	68.98	155.00	17.03	10.99	100.00
2nd Election (2020)	Black	6.78	0.65	7.43	6.14	82.60	4.79
	Hispanic	5.81	1.97	7.78	3.84	49.40	5.02
	Other	3.80	2.27	6.07	1.53	25.20	3.92
	White	60.68	72.39	133.07	−11.71	−8.80	85.85
	NA	0.35	0.30	0.65	0.06	8.60	0.42
	Total	77.43	77.57	155.00	−0.14	−0.09	100.00
Comparing the Two Elections	Black	−8.63	−0.82	−9.46	−7.81	0.00	−6.10
	Hispanic	−7.40	−2.50	−9.90	−4.89	0.00	−6.39
	Other	−4.84	−2.89	−7.73	−1.95	0.00	−4.99
	White	12.73	15.18	27.91	−2.46	0.00	18.01
	NA	−0.45	−0.38	−0.83	−0.07	0.00	−0.53
	Total	−8.59	8.59	0.00	−17.18	−11.08	0.00

Note: Votes are reported in millions. Variance percentages are shown with one decimal place.

results. However, in Table 7 and 8 I utilize similar hypothetical data to highlight the shortcomings of the derivative-based approach. In Table 7, as in Table 5 and Table 6, I shift 2020 data ~~in order~~ to turn a Biden victory into a narrow Trump win. To do so, I multiply the rate each group voted for Biden by a factor of .93 and the racial composition of all non-white groups by a factor of .8. This is still a strong mix shift towards white-voters, but the size of this shift is unimportant. More important is that in this specification, there is no volume at play in the system. Therefore, this is the closest possible comparison to what previous work has attempted to explain, without assuming the calculation that prior authors would have used to account for volume. Table 7 presents the resulting shift in votes, with the value at the bottom of column 3 highlighing that the total votes in the system has remained identical. In this synthetic example, the only two possible buckets for explaining votes are rate within groups and mix between them.

be consistent with capitalization

Table 8 highlights that while both the derivative-based approach and the MMM approach correctly specify that 0 votes were contributed to either candidate due to volume changes, the derivative-based approach has an MAE of 1.7 million votes. By comparing this total to the MMM approach, it is clear all of these unidetified votes come from a misspecification of the impact of mix, in almost all cases by hundreds of

Table 7: Hypothetical Data, Both Rate and Mix

Election	Group	Candidate 1	Candidate 2	Total	Gross Margin	Trad Mar (%)	Trad Mix (%)
1st Election (2020)	Black	15.42	1.47	16.89	13.95	82.60	10.89
	Hispanic	13.21	4.47	17.68	8.73	49.40	11.41
	Other	8.64	5.16	13.80	3.48	25.20	8.90
	White	47.95	57.21	105.16	−9.25	−8.80	67.84
	NA	0.80	0.67	1.47	0.13	8.60	0.95
	Total	86.02	68.98	155.00	17.03	10.99	100.00
2nd Election (2020)	Black	11.47	2.04	13.51	9.43	69.82	8.72
	Hispanic	9.83	4.32	14.14	5.51	38.94	9.12
	Other	6.43	4.61	11.04	1.81	16.44	7.12
	White	48.82	66.30	115.13	−17.48	−15.18	74.28
	NA	0.60	0.58	1.18	0.01	1.00	0.76
	Total	77.14	77.86	155.00	−0.71	−0.46	100.00
Comparing the Two Elections	Black	−3.95	0.57	−3.38	−4.52	−12.78	−2.18
	Hispanic	−3.38	−0.16	−3.54	−3.23	−10.46	−2.28
	Other	−2.21	−0.55	−2.76	−1.66	−8.76	−1.78
	White	0.87	9.10	9.97	−8.23	−6.38	6.43
	NA	−0.20	−0.09	−0.29	−0.11	−7.60	−0.19
	Total	−8.87	8.87	0.00	−17.75	−11.45	0.00

Note: Votes are reported in millions. Variance percentages are shown with one decimal place.

thousands of votes.

In summary, this section has shown that changes in both rate and mix can be used to engender different outcomes in elections. Crucially, it has also shown that even when volume is not at issue, the derivative-based approach fails to correctly specify the votes explained in the system. The unspoken assumption of previous work that any unexplained variance belonged in the volume category (or in unexplainable error), is therefore insufficient.

This is great but you should have been this clear earlier about how the Marble et al. approach assumes this.

Table 8: Hypothetical Data, Both Rate and Mix

Method	Group	Rate	Mix	Volume	Calc Mar Chng	Var to Act	Variance %
Derivative Calculation	Black	−2.16	−2.79	0	−4.95	−0.43	9.6
	Hispanic	−1.85	−1.75	0	−3.60	−0.37	11.5
	Other	−1.21	−0.70	0	−1.91	−0.24	14.5
	White	−6.71	−0.88	0	−7.59	0.64	−7.7
	NA	−0.11	−0.03	0	−0.14	−0.02	19.5
	Total	−12.04	−6.13	0	−18.18	−0.43	2.4
MMM Calculation	Black	−2.16	−2.36	0	−4.52	0.00	0.0
	Hispanic	−1.85	−1.38	0	−3.23	0.00	0.0
	Other	−1.21	−0.45	0	−1.66	0.00	0.0
	White	−6.71	−1.51	0	−8.23	0.00	0.0
	NA	−0.11	0.00	0	−0.11	0.00	0.0
	Total	−12.04	−5.71	0	−17.75	0.00	0.0
Comparing the Two Approaches	Black		−0.43	0	−0.43		
	Hispanic		−0.37	0	−0.37		
	Other		−0.24	0	−0.24		
	White		0.64	0	0.64		
	NA		−0.02	0	−0.02		
	Total		−0.43	0	−0.43		

Note: Votes are reported in millions. Variance percentages are shown with one decimal place.

Conclusion

—> Need to flesh this out

As demographic shifts reshape the U.S. voting landscape, understanding how these changes between groups affect election outcomes is crucial for both scholars and policymakers. Previous methods for explaining these shifts have often introduced significant errors, oftentimes amounting to millions of votes. The Margin and Mix Method (MMM), as defined in this paper, eliminates such errors, providing a zero-loss approach that precisely specifies how changes in rate, mix, and volume influence election outcomes. Importantly, the MMM approach is broadly applicable, extending beyond U.S. elections. It can be used in any context where subdividing an electorate or population into distinct groups— whether based on ethnicity, geography, age, education, or income— helps explain outcomes. The method is also valuable for analyzing other time-series cross-sectional data where participation changes, as it accurately accounts for shifts in group composition over time.

Future work will explore the robustness of the MMM approach in two key areas. First, I will investigate its ability to account for nested subgroups, demonstrating how shifts within smaller partitions contribute to broader electoral changes, as explored by

Fraga et al. (2023). Second, I will extend the analysis across multiple time periods to capture long-term trends, showing how the MMM approach can reveal the evolving dynamics of group shifts over time. These studies will further validate MMM as a tool for analyzing both historical shifts in political support and provide a basis for extending our understanding of electorate dynamics for predicting future electoral outcomes.

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Appendix

Proof of Equation 4

$$
\begin{aligned}
\Delta z(t) &= z(t_2) - z(t_1) \\
z(t_2) - z(t_1) &= f(t_2)g(t_2)h(t_2) - f(t_1)g(t_1)h(t_1) \\
&= f(t_2)[g(t_1)h(t_1) - g(t_1)h(t_1) + g(t_2)h(t_1) - g(t_2)h(t_1) + g(t_2)h(t_2)]- \\
&f(t_1)g(t_1)h(t_1) \\
&= f(t_2)g(t_1)h(t_1) - f(t_1)g(t_1)h(t_1) + f(t_2)g(t_2)h(t_1)- \\
&f(t_2)g(t_1)h(t_1) + f(t_2)g(t_2)h(t_2) - f(t_2)g(t_2)h(t_1) \\
&= [f(t_2) - f(t_1)]g(t_1)h(t_1)+ \\
&f(t_2)[g(t_2) - g(t_1)]h(t_1)+ \\
&f(t_2)g(t_2)[h(t_2) - h(t_1)]
\end{aligned}
$$

Q.E.D.

To demonstrate the robustness of the method, I present Appendix Tables 1 and 2. Table A1 splits votes out from the Non-White category into Black and All Others, leaving the White category untouched. Table A2 shows that both the derivative-based approach as well as the MMM approach correctly leave the specification of the impact of rate, mix, and volume to white voters (the unchanged category) unchanged from Table 2. This highlights the robustness to irrelevant alternatives of the MMM approach, showing how it behaves comparably to the derivative-based approach.

Table A1: Comparing Two Elections, Robustness to Irrelevant Alternatives

Election	Group	Candidate 1	Candidate 2	Total	Margin	Margin Rate (%)	Mix (%)
1st Election (2016)	Black	13.25	0.90	14.15	12.35	87.3	11.0
	All Others	16.25	6.60	22.85	9.65	42.2	17.7
	White	39.00	53.00	92.00	−14.00	−15.2	71.3
	Total	68.50	60.50	129.00	8.00	6.2	100.0
2nd Election (2020)	Black	15.40	1.50	16.90	13.90	82.2	10.9
	All Others	22.60	10.50	33.10	12.10	36.6	21.4
	White	48.00	57.00	105.00	−9.00	−8.6	67.7
	Total	86.00	69.00	155.00	17.00	11.0	100.0
Comparing the Two Elections	Black	2.15	0.60	2.75	1.55	−5.0	−0.1
	All Others	6.35	3.90	10.25	2.45	−5.7	3.6
	White	9.00	4.00	13.00	5.00	6.6	−3.6
	Total	17.50	8.50	26.00	9.00	4.8	0.0

Note: Votes are reported in millions. Candidate 1 refers to Clinton (2016) and Biden (2020); Candidate 2 refers to Trump.

Table A2: Concept Demonstration, Robustness to Irrelevant Alternatives

Method	Group	Rate	Mix	Volume	Calc Mar Chng	Var to Act	Variance %
Derivative Calculation	Black	−0.71	−0.07	2.49	1.70	0.15	9.9
	All Others	−1.30	1.98	1.94	2.63	0.18	7.4
	White	6.11	0.70	−2.82	3.99	−1.01	−20.1
	Total	4.11	2.61	1.61	8.33	−0.67	−7.4
MMM Calculation	Black	−0.71	−0.07	2.33	1.55	0.00	0.0
	All Others	−1.30	1.72	2.03	2.45	0.00	0.0
	White	6.11	0.40	−1.51	5.00	0.00	0.0
	Total	4.11	2.04	2.85	9.00	0.00	0.0
Comparing the Two Approaches	Black		0.00	0.16	0.15		
	All Others		0.27	−0.08	0.18		
	White		0.31	−1.31	−1.01		
	Total		0.57	−1.24	−0.67		

Note: Votes are reported in millions. Variance percentages are shown with one decimal place.

Table A3: Concept Demonstration for Trump, Real Data from Marble et al. (2024)

Method	Group	Rate	Mix	Volume	Calc Mar Chng	Var to Act	Variance %
Derivative Calculation	Black	0.68	0.04	−0.82	−0.11	1.48	−93.1
	Hispanic	0.26	−0.40	−0.45	−0.59	1.44	−71.0
	Other	0.41	−0.35	−0.18	−0.11	0.69	−85.8
	White	−5.52	−0.31	0.91	−4.92	−0.56	12.9
	NA	0.02	−0.02	−0.01	0.00	0.03	−86.4
	Total	−4.14	−1.04	−0.55	−5.73	3.07	−34.9
MMM Calculation	Black	0.68	0.07	−2.34	−1.59	0.00	0.0
	Hispanic	0.26	−0.83	−1.46	−2.03	0.00	0.0
	Other	0.41	−0.63	−0.58	−0.80	0.00	0.0
	White	−5.52	−0.39	1.55	−4.35	0.00	0.0
	NA	0.02	−0.03	−0.02	−0.03	0.00	0.0
	Total	−4.14	−1.81	−2.86	−8.81	0.00	0.0
Comparing the Two Approaches	Black		−0.04	1.52	1.48		
	Hispanic		0.43	1.02	1.44		
	Other		0.28	0.40	0.69		
	White		0.08	−0.65	−0.56		
	NA		0.01	0.01	0.03		
	Total		0.77	2.31	3.07		

Note: Votes are reported in millions. Variance percentages are shown with one decimal place.