First Look and Opportunities for Research

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Security Concerns in Approval Voting Systems

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Abstract

Approval voting is an electoral system in which voters may cast a vote for as many candidates as they approve of for a given office. This single-winner system awards victory to the candidate that is approved by the greatest number of voters. Compared to other methods, such as instant-runoff voting (IRV) and plurality voting, approval voting has a number of benefits that make it an extremely attractive alternative to the electoral schemes in wide use today[i].

Although aspects of this system have been used in historical contexts[ii] and within academic, cooperate, and political[iii] organizations, it's relatively recent formalization and entrenched preceding voting methods have prevented approval voting from seeing widespread use in public elections. However, in 2018 Fargo became the first US city to adopt approval voting[iv]. With a similar push for reform in St. Louis[v] and an upswell in public and academic interest, approval voting may very well see increased use in the US.

Due to its recent rise to prominence, publications on election security concerns specific to approval voting has been sparse to non-existent. In a field of study as young as approval voting, there is often much low hanging fruit that will seem obvious in retrospect but is difficult to predict now. With the lack of work on this subject publicly available, early implementors of approval voting systems are working largely in the dark. In the worst-case scenario, serious vulnerabilities may be overlooked, elections invalidated, and public faith shaken. Lack of shared knowledge will, at the very least, mean that a huge amount of time is spent doing redundant work.

In this paper I provide a brief overview of approval voting, examine the use case for approval voting in US political elections today, compare several implementations of approval voting ballots, consider potential problems and vulnerabilities in these implementations, and highlight some opportunities for future research.

Index

Introduction to Approval Voting

Approval voting is an electoral system for choosing a single winner from two or more candidates. In this system, voters either “approve” or “disapprove” of every candidate, and the candidate with the most “approves” is the winner. It’s a relatively simple system that allows voters to express support for multiple candidates, rather than simple choosing their one favorite, as in the case of plurality voting, or with more complicated ranking and scoring systems as in the cases of ranked choice systems and range or score voting. To those familiar with the plurality system that the majority of United States political elections use today, it can be most easily summarized as “vote for any” rather than the current “vote for one”.

Approval voting has a wide range of advantages compared to other voting systems and, along with ranked choice voting, approval voting has recently become more publicly visible thanks to a variety of activists, good government advocates, and legal reform effort.

The advantages of approval voting have been covered in much depth elsewhere[vi], so I will just briefly describe a few of the most significant advantages approval voting has over plurality voting:

I. Picks the candidate approved of by the most voters.

II. Is more expressive and more fully captures voter preferences.

III. Voting for your favorite candidate is never strategically unwise, therefor minor candidates aren’t “wasted”, thus avoiding spoiler effects[vii].

IV. Avoids complexity added by other voting systems (ranked choice systems in particular), keeping both voting and aggregating result simpler and clearer.

V. It is constitutional, has been used in the United States before[viii], and can be run on every voting system currently in use in the United States.

Here, it is helpful to lay out what we want from a given voting method. There is some debate about what precise criteria define a good voting method, but the continuum below describes Smiths voting system classification.

Worst Voting System — Best Voting System

Expressiveness

The ability for voters to express their preferences

Worst Voting System

No expression, suppression of vote

Best Voting System

Full expression, voter's complete preferences are expressed

Simplicity

Level at which voter preferences are expressed incorrectly, either by the voter or during aggregation of votes

Worst Voting System

Impossibly difficult for voters, no votes are correctly recorded

Best Voting System

Pure efficiency, every preference is correctly and effortlessly recorded

Practicality

Are votes precinct-countable? Can voting system be run on existing infrastructure? Is the voting system politically feasible and sustainable?

Worst Voting System

Completely impractical, politically impossible or logistically prohibitive

Best Voting System

Absolutely practical, runs on existing infrastructure, politically stable

Honesty

The level at which voters express their true preferences and resist strategic voting. Specific properties include;

Participation: An honest vote is strategically better than abstention

Favorite-Safe: It is never strategically advantageous for a non-favorite rather than a favorite

Monotonicity: Increasing the vote for a candidate will not lessen her chance to win and decreasing the vote will not improve her chance to win

Worst Voting System

Completely dishonest, no one will express their true preferences

Best Voting System

Completely honest, every voter will express their true preferences

Manipulability

Level to which voters' preferences can be distorted

Worst Voting System

Completely insecure, every vote can be manipulated

Best Voting System

Absolutely secure, no votes can be manipulated

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Scenarios Under Consideration

Before we begin to discuss potential security concerns, it's important to explicitly lay out what scenarios and conditions we'll be considering, and which topics and concerns are outside the scope of this paper.
In this paper, we are concerned specifically with an approval voting system standing in place of a plurality voting system in the United States. We are only considering single-winner races with at least two candidates; while there are versions of approval voting designed to handle multi-winner contests, they will not be considered here. We are also not concerned with methods or techniques used to defeat election security (e.g. we won't focus on how a malicious actor has gained access to paper ballots, only what they can do with them). We also will not cover methods of breaching election security which are equally of concern to plurality voting systems.
Fargo, North Dakota passed a ballot initiative which instated approval voting in 2018, with Saint Louis voting on a similar initiative in the coming months[ix]. In just a few months, Fargo will become the first US city to use approval voting in a major political election. The scenario that this paper will consider is one similar to the one faced by Fargo: a mid-sized city transitioning from plurality to approval voting for the first time, with a limited budget, an approaching deadline, and a relative lack of precedent.

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Converting Plurality Voting Machines

One major advantage of approval voting is that every voting machine currently operating in the United States can be tweaked to handle approval voting[x]. New machines would be ideal, since modification of existing machines opens opportunities for hacking or, more likely, errors to occur. Still, many municipalities face financial constraints, and so many would opt for conversion rather than purchasing new equipment.

Jan Kok developed a theorem[xi] for converting existing machines to single digit range voting that generalizes to approval voting, and I summarize his method below. It computes the total number of votes, and the N totals for each of the N candidates, and it prevents the voter from entering (or at least refuses to count) an illegal "overvote".

Approval Voting Definition

I. As your vote in an N-candidate election you provide either a 1 (representing approval) or a 0 (representing disapproval)

II. The candidate with the highest average score is elected

Example: 4 voters and 4 candidates:

voter#1: (0, 1, 1, 1)

voter#2: (1, 1, 0, 1)

voter#3: (0, 0, 0, 1)

voter#4: (1, 1, 0, 1)

Resulting average scores:

(2/4=0.5, 3/4=0.75, 1/4=0.25, 4/4=1)

(Candidate 4 Wins)

Plurality Voting Machine Definition

It computes the total number of votes, and the N totals for each of the N candidates, and it prevents the voter from entering (or at least refuses to count) an illegal "overvote."

Error detection

Plurality machines that detect overvotes would detect illegal range votes.

Plurality machines that detect undervotes would detect "unintentional blank" votes.

Kok's Theorem

Any plurality voting machine can be used to perform a single-digit range voting election (with "X" no-opinion scores allowed, or forbidden, either is ok) if it is capable of handling multiple plurality races.

Smith's Evaluation

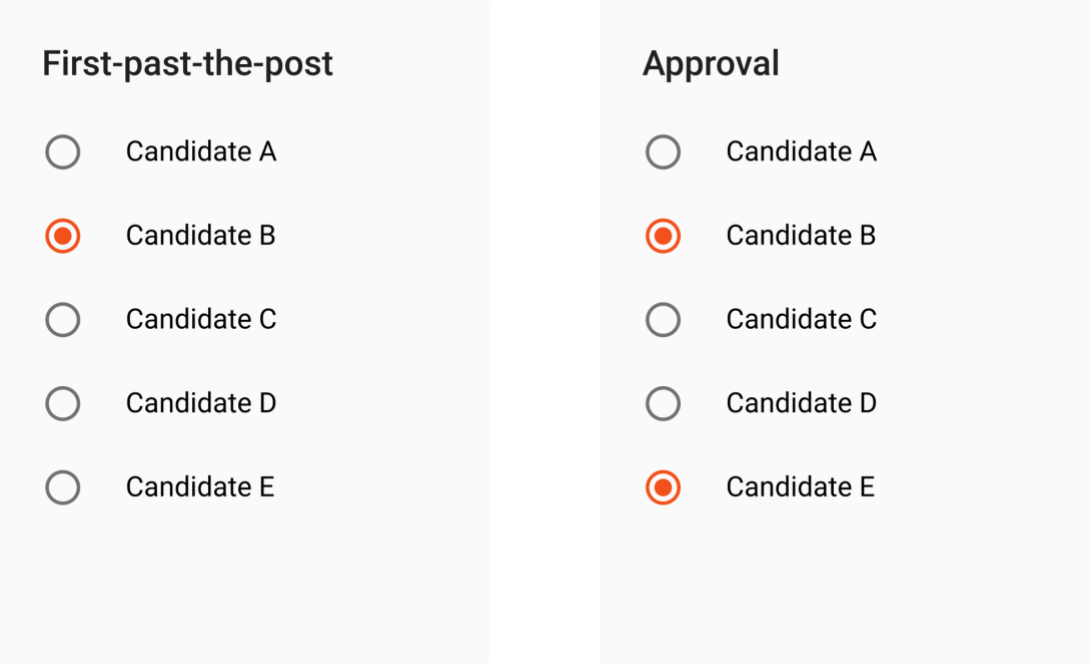
Below is a summary of an evaluation of Kok's theorem by Smith on currently used voting machines:

Optical Scan	*Butterfly Punch Card Ballots*	*D.R.E. Machines*	*Pen and Paper Ballots*
No issues reported	Functional, but inconvenient due to increasing the number of cards required	No issues reported	No Kok transformation required

Approval Voting Ballots

Another small perk of approval voting is that the ballots currently being used and proposed will be very familiar to plurality voters as, on first glance, the two look very similar.

figure 1

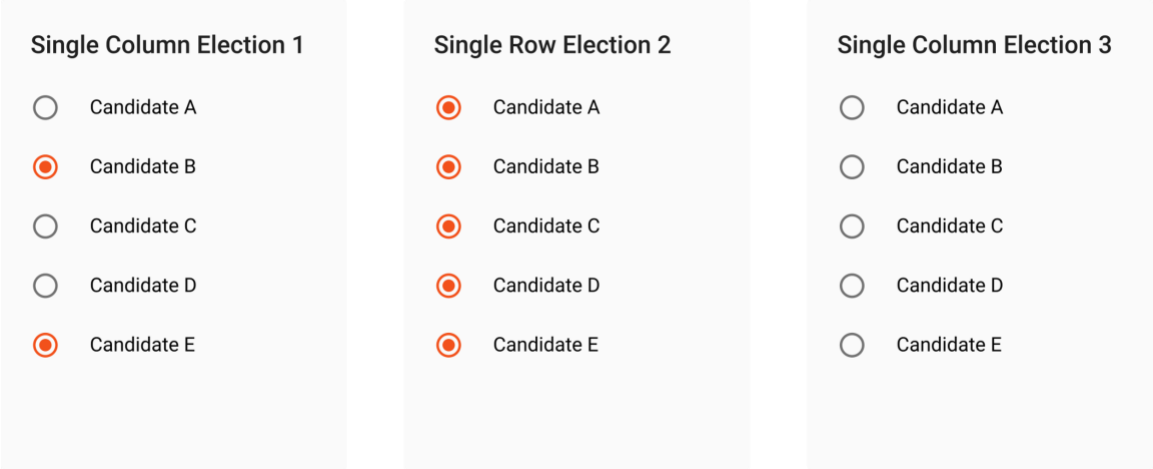


A plurality ballot example on the left and a typical approval ballot on the left. Note that orange items represent voter actions.

The key distinction between the two is not the ballot itself, but how voters are intended to interact with the ballots. On the plurality ballot a voter may “vote for one” whereas the approval ballot allows the voter to “vote for any”. This subtle distinction may confuse voters in an area that has recently transitioned to approval voting and may cause significant undervote. This would potentially damage third party candidates and diminish the amount of expression available to the votes but, because approval voting is favorite-safe, monotonic, and incentivizes participation, approval will never preform any worse than plurality.

However, this relative safety is a feature that plurality does not share. In a “choose your favorite only” vote, an under vote is either considered an abstention or it can, in some rare cases, invalidate your ballot. Even more interestingly, the standard approval voting ballot protects you from over voting even more. In plurality, if you were to vote for more than a single candidate, your ballot would be disqualified as an overvote and your vote would not count. Not only does the approval ballot protect you from accidental overvoting but, in the standard approval voting ballot represented in figure 1, it is *impossible* to invalidate you ballot by either under or overvoting.

figure 2



Three examples of valid standard approval voting ballots. Note that on a plurality ballot, ballots one and two would be disqualified while ballot three would have expressed no preference, which in plurality voting is equivalent to not having voted.

Some approval voting advocates see this as a feature rather than a bug, pointing out that even if voters mistakenly cast a vote for their least favorite candidate, as long as the voter has voted for at least their favorite then they are strategically no worse off than they would have been with an invalid plurality ballot. They also say that, all else being equal, fewer invalidated ballots mean that more voters have been able to express their preferences. Another viewpoint thinks of this as a problem, but a small one that will in all likelihood have negligible real-world impact.

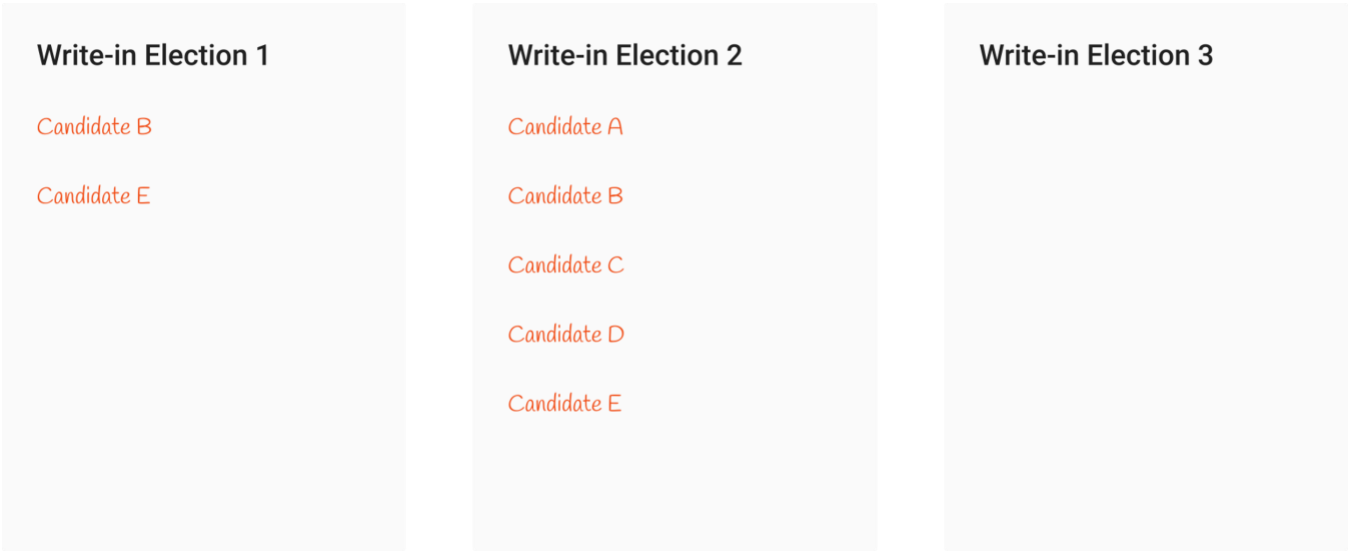
Still others think of this as a problem of compelled speech – meaning that abstention on any given candidate in this system is equivalent to disapproval. They have provided several tweaks that address this issue, the most salient of which being a trinary system, rather than binary, in which a voter votes for a given candidate using values of either 1, 0, or *. Here, * represents an abstention and is not included in the candidates average score. Another way to conceptualize this (and, indeed, all of approval voting) is as a special case of range voting. Standard approve/disapprove approval voting can be thought of as a range vote where the possible scores are 1 and 2, for approve and disapprove respectively.

Approval voting with abstention can be thought of as a range vote with the possible scores of 1, 2, and 3 which represent approve, disapprove, and abstain. This formulation does make disapproves explicit down votes, and it also potentially opens the door to disqualified ballots by under voting. However, this doesn't appear likely to be adopted by local governments, and currently – to my knowledge – is not under serious consideration in the US. Therefore, we won't consider it in our analysis.

Alternative Ballot Designs

There are several other approval ballot designs that have gotten some traction within the reform movement. They each come with their own pros and cons, which we'll discuss briefly here.

Write-in Only Ballot



Three examples of valid write-in only approval ballots. Note election 1, 2, and 3 are theoretically equivalent to their corresponding elections in figure 2.

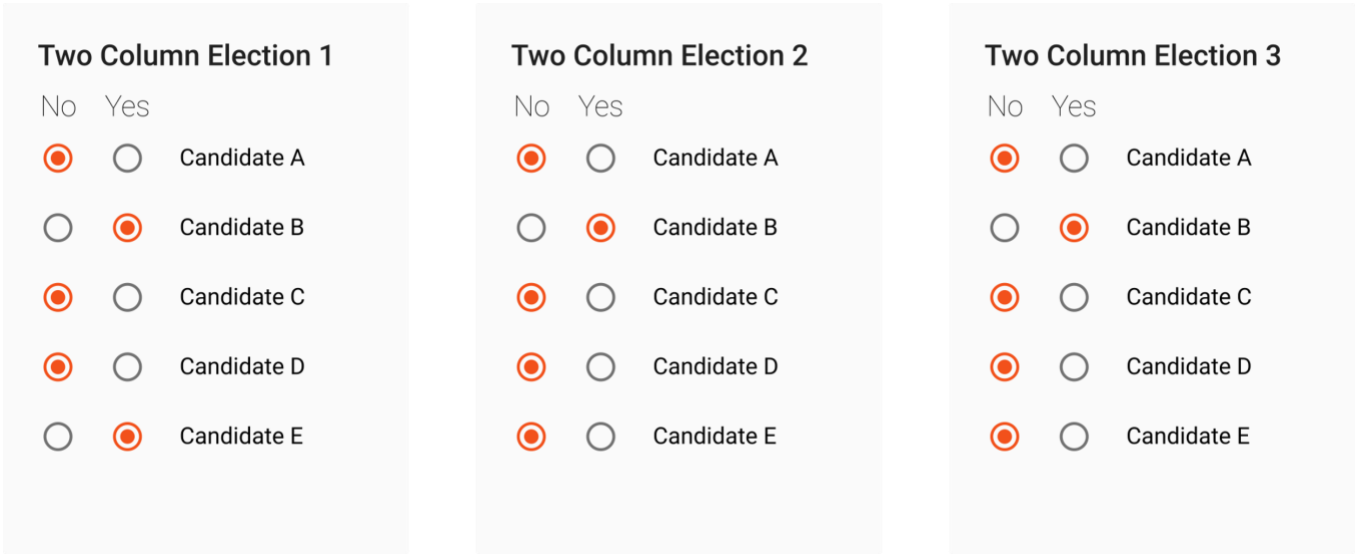
The write-in ballot is an elegant, if somewhat unwieldy solution. Here again, it is impossible for a ballot to be disqualified for under or over voting – all three are perfectly valid. It also may reduce ambiguity – just write down your preferences. However, it had some serious downsides: it is time consuming to tally, it requires a very high level of knowledge from voters, and it would likely require entirely new voting machines in many cases.

Written Yes/No Ballot

Three examples of written yes/no ballots. Note election 1, 2, and 3 are theoretically equivalent to their corresponding elections in figure 2.

The written Yes/No ballot comes in several variations, some using “approve” and “disapprove” or “Y” and “N” or some sort of iconographic marking like ✓ and $\boldsymbol{x}$. This hybrid method has some of the advantage of the other designs (e.g. explicitness about the requirement for a mark, clear presentation of the candidates), however it inherits their disadvantages as well. It is novel and may be confusing to new users, it will also likely require some infrastructure upgrades, and tallying may well be more arduous and error prone. It is also easily invalidated, as a single blank text box (without introduction trinary approval voting) will result in an undervote that will invalidate the ballot.

Two Column Bubble Ballot



Three examples of written two column bubble ballots.

The two-column bubble ballot simultaneously has the most benefits and the biggest problems. This design again forces voters to make their disapprovals explicit and opens up the door for ballots being disqualified for under voting. On the one hand, this design is close to familiar, but yet different enough that voters may take notice and be more likely to alter their behavior to conform to the ballot design. It also can, in some ways, prevent erroneous voting as you have to make an explicit binary choice for each candidate. However, it also suffers from a whole host of issues including disqualification by under voting (leaving a row blank), disqualification for overvoting (filling both bubbles on a given row), and human interaction design difficulties in the placement of the yes and no columns.

While each of these designs have their own set of advantages and disadvantages, they are mostly academic projects at this point, with the standard single column bubble ballot being the most recognized, the most well regarded, and the most likely to see real world implementation.

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Primary security concerns

After reviewing the most widely available and authoritative sources on approval voting, within the constraints laid out in this paper, I've developed with the following list of potential areas of concern:

Technical Concerns

Kok transformation & equipment transition as a potential vulnerability:

I. Intentional manipulation: deb_disapproves vs jan_disapproves, inverting counts, counting additionally for inputs which might be hard to detect etc.

II. Unintentional implementation errors: basically, the above but through ignorance not malice

III. Vulnerability of hardware: New hardware in transit, old hardware being opened up/moved in order to do updates provides opportunity for physical breaches

Impervious to Invalidation

I. May allow certain types of fraud and hacks to go undetected: e.g. insignificant district by district overcounts for a candidate that become significant because of electoral maps and aggregation, undercounting may have the same problem

II. If physical access to the ballots are gained, modifying the originals wouldn't invalidate them: may be able to force a recount by loudly breaching a system, recount with modified ballots would become the official count

III. Use difficulty of invalidation as part of a public faith attack: muddy the waters, make the count seem suspect and murky, and loudly breach systems in order to erode the trust in the election - may be able to get election bogged down in lawsuits, trigger a recount, invalidate election or, at the very least, weaken the perceived integrity of the election system as a whole

New avenues for coercion, corruption, and human frailty

I. Low strategic cost of approving of non-favorite candidates might lower the threshold for public manipulation, misinformation campaigns, and outright bribery

II. Potentially low visibility of fraud (doesn't invalidate ballot, voter still voted for favorite) might incentivize corrupt actor to manipulate counts subtly – pole workers, election officials, etc.

III. Finally, the new approval system may be poorly implemented, voter confusion could be high, and there could be dramatic (and negative) impacts on public faith in elections, on the results of the election itself via high numbers of erroneous ballots.

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Conclusion, Discussion, and Opportunities for Future Research

I come away from this paper feeling relatively optimistic about the level of security concerns that exist uniquely in approval voting systems. I did not find any glaring or critical security vulnerabilities that would lead me to recommend against using approval voting, nor did approval balloting options seem to present design difficulties that were insurmountable (or indeed significantly more difficult that the ones that we currently face for plurality ballots). An important caveat, however, is that this was merely a first look. I took a survey of the field and documented my impressions from a 30,000ft point of view. There may well be critical issues that this paper did not address. To that end, I believe that the following are promising areas for additional study and research:

Strategic and Game Theoretic Vulnerabilities

Largely unaddressed by this paper is the possibility of manipulating strategic or game theory design issues that may be present in approval voting. A major concern would be some route to "rigging the game", either by candidates, voters, or third parties.

Corruption and Bad Faith Actors

Briefly addressed above, without more large scale and real-world examples to draw data from, it's still unclear how actors may behave under approval voting systems. In particular, I think that a comparative study of voters and electors susceptibility and proclivity towards bribery and graft under different voting schemes (IRV, Approval, Range, and Plurality) would be a very worthwhile area of further study.

Best Practice Ballot Design

Another area that could use more research is on ballot designs for approval voting. Specifically, experimental studies comparing different approaches to ballot designs would be extremely useful, particularly if those results could then be compiled into a best practices guide for implementors in the real world.

Hacking

A broad area for future research that tends toward the practical. Specific research topics may include cryptographic approaches, breaches on real-world systems, and best practice system designs for preventing & detecting these types of attacks.

Practical Effect of Approval Voting

Less of a security specific concern, and more of a political & social question; how would a world in which approval voting replaces plurality voting be different? Would the ultimate outcome improve or damage our political system and social welfare? Do we like those outcomes?

Sources, additional resources & reading material can be found below. Please feel free to reach out to me at logan-grote@uiowa.edu if you have any questions or comments.

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