Electoral Design and Voter Welfare from the U.S. Senate: Evidence from a Dynamic Selection Model[*]

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Abstract

Since 1914, the U.S. Senate has been elected and incumbent senators allowed to run for reelection without limit. This differs from several other elected offices in the U.S., which impose term limits on incumbents. Term limits may harm the electorate if tenure is beneficial or if they force high quality candidates to retire but may also benefit the electorate if they cause higher quality candidates to run. We investigate how changes in electoral design affect voter utility by specifying and structurally estimating a dynamic model of voter decisions. We find that tenure effects for the U.S. Senate are negative or small and that incumbents face weaker challengers than candidates running for open seats. Because of this, term limits can significantly increase voter welfare.

1 Introduction

In a variety of electoral situations, incumbents win substantially more than half of the time. This is sometimes referred to as an *incumbency advantage*. Authors such as Elhauge (1998) and Palmer and Simon (2006) have argued that this fact could reflect various barriers to entry for new candidates, and therefore might be a signal of electoral inefficiency. Many policies have been considered, at least in part, as a response to the possibility that incumbency confers an "unfair" advantage. Most prominent among these policies are term limits; others include matching funds for political candidates, mandated air time for television advertisements, and reforms to campaign finance laws, which are intended to make incumbency less advantageous.

To ascertain the potential costs and benefits of such programs, a natural counterfactual question is, how would electoral designs that eliminate or limit incumbents affect a voter's well-being? The purpose of this paper is to provide evidence on the welfare impact of different electoral designs, specifically term limits. To do this, we specify and structurally estimate a model of voter behavior for the U.S. Senate and analyze the impact of counterfactual electoral design. In the U.S. Senate, incumbents win almost 80 percent of the time. Unlike several other elected offices in the U.S., such as the U.S. presidency and several state senates, there are no term limits or other restrictions on incumbents running for reelection.[1]

We focus on several possible effects of eliminating an incumbent. Since becoming an incumbent requires having won, and winning candidates will tend to be of relatively high quality, eliminating incumbents will reduce quality by reducing the positive selection of good candidates. We call this a *selection effect*. The presence of a selection effect would imply that the incumbency advantage may not be due to any direct benefit of incumbency, but may rather simply be a consequence of the different distribution of quality for incumbents. Incumbency may also confer a direct electoral advantage. Many explanations have been posited along these lines, including

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[1] Individual states have attempted to pass term limit restrictions for senators from their state, but such changes were ruled unconstitutional by the Supreme Court (see *U.S. Term Limits, Inc. v. Thornton*, 514 U.S. 779).

pork-barrel spending, congressional relations, media coverage, incumbent visibility, and party attachment. We term these *tenure effects*, and our model is agnostic as to the sources of these effects. Last, we consider the possibility that eliminating an incumbent might change the *distribution of candidates*. For instance, Elhauge (1998) stresses that term limits may cause better quality candidates to run, thus improving the challenger quality distribution.

We believe that untangling the reasons behind the incumbency advantage is critical to understanding the counterfactual experiment. It is straightforward that we need to measure differences in candidate quality in elections with and without incumbents to evaluate whether term limits improve voter welfare by discouraging high quality candidates. However, evaluating the counterfactual also requires understanding whether the incumbency advantage stems from tenure effects or selection. As an example, consider one-term incumbents. To the extent that one-term incumbents win because of a beneficial tenure effect, that tenure effect will still accrue under a term limit; however, to the extent that some one-term incumbents come to office by beating five-term incumbents, and therefore sometimes have very favorable selection, term limits may limit the ability of that selection effect to ever occur. Thus, a key goal of this paper is to disentangle empirically the effects of selection, tenure and candidate quality distribution.

Moreover, data on electoral histories provide a natural way to disentangle our different effects because tenure effects are determined only by the tenure of the current candidate, while selection effects may depend on the electoral history of a seat. Two senators with the same tenure have different expected distributions of quality if they came to office by beating different types of incumbents, for instance ones who themselves had different tenure. The different quality distributions will then result in different reelection probabilities in subsequent elections. Thus, tenure and selection effects will be separately identified by differences in reelection probabilities based on the electoral history of a senate seat. Similarly, differences in candidate quality based on whether an incumbent is present in the election can also be distinguished by subsequent reelection probabilities.

We formulate a simple, stylized model of voter decisions for candidates that allows for the three above effects. In our model, the voters in each U.S. state are identical dynamically optimizing agents. They observe the permanent quality of two current candidates and then elect one of them. Permanent candidate quality is drawn from a fixed distribution which varies depending on whether the election is an open seat election or one where an incumbent is running. Once quality is drawn, the only change in the utility flow from a candidate over his career is his tenure effect. We allow the relationship between tenure and tenure effects to be of any shape, although we restrict the shape to be the same across candidates. An incumbent leaves the senate with an exogenous exit probability that depends on tenure. As such, we do not account for the selection bias that may result from senators choosing when to retire based on their electoral prospects.[2] Though simple, the model implies that tenure and the entire history of the seat following an open seat election (e.g., how many terms were served by each candidate who was later defeated by another candidate) will influence the probability of reelection, thus allowing for the above sources of identification.

We estimate our model using U.S. Senate data since 1914, the start of the elected senate. Our data contain the history of senatorial seats, recording how candidates came to office, how long they served in office and the reason they left office. Conditional on a given vector of structural parameters, the solution to the voter's dynamic choice problem implies a probability distribution over the possible electoral histories of a senatorial seat. We derive this distribution and use it to estimate the parameters of the model with the method of maximum likelihood. Using the estimated parameters, we then examine the welfare implications of counterfactual electoral design policies, by implementing the policies and solving optimal voter decisions given the policies. Because our model is a very simple representation of the electoral decision,

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[2] Kiewiet and Zeng (1993) find that age is the most important determinant of the retirement decision for House representatives, with scandals a distant second. Indicators of quality such as chairmanship of a committee, party leadership, or the victory margin in the previous election are not statistically significant. These findings support our choice of exogenous exit probabilities to the extent that they apply to the behavior of senators. Ansolabehere and Snyder Jr. (2004), using term limits as an instrumental variable, also find no evidence that candidates for statewide office (including the U.S. Senate) are strategic in their retirement decisions.

we also discuss the principal ways in which our model abstracts from reality and examine how potential variants of the model might affect our main conclusions.

2 Relationship to the existing literature

Starting in the 1970s, a vast literature has tried to quantify incumbency advantages.[3] Early studies regressed the winning probability on an incumbency dummy, generally finding a positive sign. These papers provide no evidence on the sources of the incumbency advantage and hence cannot be used to determine how electoral reforms would affect voter welfare.

A more closely related literature has tried to separate tenure and selection effects. The first method to attempt to separate tenure from selection effects defined the tenure effect as the difference between the vote share that a senator earned in his second and first elections. This measure became known as the *sophomore surge*.[4] Gelman and King (1990) pointed out that the sophomore surge approach also suffers from selection bias because a candidate who is elected would disproportionately have had a good draw in his first election, that may be idiosyncratic to the first election. They developed a reduced-form least squares method that helps mitigate this selection bias. Levitt and Wolfram (1997) apply a Heckman-style correction to the sophomore surge to further mitigate the Gelman and King (1990) selection bias.

Our paper builds on these earlier papers, in that our model and estimation explicitly control for the selection biases that these papers analyze. As in Gelman and King (1990), in our model, the winner of an election will likely have had a positive idiosyncratic shock in his first election, in the sense of facing a relatively weak competitor. Also, as in Levitt and Wolfram (1997), candidate quality density

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[3] Most studies use House election data, which contain a larger number of elections. They typically regress winning probabilities on a set of regressors. See the references in the surveys by Cover and Mayhew (1977), Fiorina (1989), and Mayhew (1974). For more recent studies, see also, Ansolabehere and Snyder Jr. (2004), Cox and Katz (1996), and Lee (2001), together with the other references cited in this section. There is also a literature studying the advantage in offices other than the House: recent studies include Ansolabehere and Snyder Jr. (2002), Gronke (2000) and Berry et al. (2000) (see also references therein).

[4] See Erikson (1971), Cover (1977), Gelman and King (1990) and references therein.

can differ based on whether the candidate is in an open seat election or not.

Another related literature has structurally estimated candidate career decisions to retire or face reelection. This literature attempts to predict reelection probabilities. Diermeier et al. (2005) estimate a model where candidate career decisions are endogenous but reelection probabilities are exogenous. In contrast, we treat retirement decisions as exogenous but endogenize election decisions, necessary to evaluate voter welfare.

Our paper differs from the above literatures in that we estimate a full dynamic model of voter behavior. This allows us to provide evidence on the relative magnitude of the selection, tenure and challenger quality effects, and more importantly, to analyze how these effects and electoral design ultimately affect voter welfare. In addition, our model is identified by the entire history of electoral outcomes since the open seat election in a manner that is consistent with the underlying model.[5] This allows us to identify our parameters of interest in an intuitive manner.

3   The Model

We propose a relatively simple model of voter behavior. Although parsimonious, to our knowledge, our model is the first to endogenize and estimate voter decisions in a rational dynamic model. In Section 6, we discuss the potential implications of more robust specifications.

We model voters in each senatorial seat as identical dynamically optimizing agents who value services from an elected official, in our case a senator. The valuation has two components: a senator-specific, permanent quality q and a tenure effect $\tau_m, m \geq 0$ common to all senators of tenure m. The quality q is an element of a compact set Q. Tenure is defined by the number of completed terms in office. Both q and m are observed by the voters. The utility flow for the voter in a given period is additive in these two components, i.e.,

$$u(q, m) = q + \tau_m. \tag{1}$$

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[5] In this way, our model relates to Samuelson (1987), who first recognized the importance of the entire history of a seat in evaluating incumbency advantage.

The voter values the expected sum of current and future utility flows, discounted by $\beta < 1$.

In each period, voters choose between two candidates in an election. There are two kinds of elections between which it is useful to distinguish. One is an *incumbent-challenger election*. This is an election where an incumbent runs against a challenger. The other type is called an *open seat election*, which takes place in situations where neither candidate is an incumbent. This happens when incumbents leave office for reasons other than losing an election. We assume that these reasons are exogenous and depend only on tenure.

The timing is as follows. At the beginning of the period, the incumbent either exits or runs for reelection. Denote the probability of exit at tenure m by δ_m. If he exits, two new candidates run for the seat. If he runs for reelection, a single challenger runs against the incumbent. Each candidate in an open seat election then draws his permanent quality q from an atomless distribution $F_o(q)$ with corresponding density $f_o(q)$. Correspondingly, each challenger in an incumbent-challenger election draw his permanent quality from an atomless distribution $F_c(q)$ with corresponding density $f_c(q)$.[6]

The tenure effects τ_m are tenure-specific constants known to the voter. The voter observes the qualities of the current candidates and then elects the candidate that maximizes expected discounted utility. The voter also knows the distributions F_o and F_c from which future candidates will draw their permanent qualities.

For an open seat election, the optimal choice of the voter is simple: choose the candidate with the higher q. The utility flows generated by the candidates are otherwise identical.

In an incumbent-challenger election the decision is more complicated. We express the problem recursively using a Bellman equation. Denote by q the quality of the incumbent and by q_c the quality of the challenger. The voter's decision can be expressed as a function of the incumbent senator's quality q and tenure m. Let $V(q, m)$ for $m > 1$ denote the expected discounted utility for the voter at the

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[6] We assume that F_o and F_c are atomless to ensure that the voter has strict preferences over candidates with probability one.

beginning of the period, before either exit occurs or new candidates appear. Let W denote the expected discounted utility from an open seat. Then,

$$V(q,m) = (1 - \delta_m) \int_Q \max \left\{ \begin{array}{l} q + \tau_m + \beta V(q, m+1), \\ q_c + \tau_0 + \beta V(q_c, 1) \end{array} \right\} f_c(q_c) dq_c + \delta_m W. \quad (2)$$

If the incumbent chooses to run again (which occurs with probability $1 - \delta_m$), the voter chooses between the incumbent and a challenger. The integral in the first term in (2) reflects the expected utility in this case, which involves integrating over q_c.

If the incumbent exits, creating an open seat election, the voter obtains W. Letting the two new candidates' qualities be defined by q and q_c,

$$W = \int_Q \int_Q \max \left\{ \begin{array}{l} q + \tau_0 + \beta V(q, 1), \\ q_c + \tau_0 + \beta V(q_c, 1) \end{array} \right\} f_o(q_c) f_o(q) dq_c dq. \quad (3)$$

The value of the open seat reflects the fact that two candidates are drawn and the higher q is retained.

Denote by $r(q, q_c, m)$ the optimal reelection rule of a voter when the incumbent has quality q and tenure m and the challenger has quality q_c; $r(q, q_c, m) = 1$ denotes reelecting the incumbent and $r(q, q_c, m) = 0$ denotes choosing the challenger. We now show that the solution to the decision problem can be characterized as a cutoff rule. As a result, the Bellman equation takes a simple form that is useful in computing the solution. We start by characterizing the decision rule.

Lemma 1 $r(q, q_c, m)$ *is weakly decreasing in* q_c.

The proof is in Appendix A.1. The lemma implies that the voter follows a cutoff rule: challengers are elected only if their quality exceeds a cutoff $\bar{q}(q, m)$. Note that voters do not simply choose the candidate with the higher q, or even the higher $q + \tau_m$, since the voter is forward-looking and considers future tenure effects and exit probabilities.

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The cutoff rule allows us to express the Bellman equation more concisely, as

$$V(q, m) = (1 - \delta_m) \max_{\bar{q}} \left(\begin{array}{c} F_c(\bar{q}) \left(q + \tau_m + \beta V(q, m+1) \right) \\ + \int_{\bar{q}}^{\infty} \left(x + \tau_0 + \beta V(x, 1) \right) df_c(x) dx \end{array} \right) \tag{4a}$$

$$+ \, \delta_m W. \tag{4b}$$

If the incumbent does not exit (the case given in (4a)), the expected return has two components: first, the payoff when the incumbent is retained, times the probability of retention $F_c(\bar{q})$; and second, the expected value of the challenger, conditional on his quality being above $\bar{q}$. The value with an incumbent exit is given in (4b).

4 Estimation

4.1 Overview

Our goal is to provide inference on the fundamental parameters of our model: the candidate permanent quality densities f_o and f_c, the tenure effects τ_m, the exit probabilities δ_m, and the discount factor β. Our data contain information on when and how each U.S. senator came to office and when and how he left office. These data allow us to understand, for instance, whether a senator came to office by winning an open election or by defeating an incumbent.[7]

We do not directly observe any component of quality. However, given a vector of fundamental parameters, the model generates a probability distribution over sequences of electoral outcomes. We use the method of maximum likelihood to find the parameter values that maximize the probability of seeing the observed electoral outcomes.

To understand how the model provides evidence on reelection probabilities that we observe in the data, it is useful to consider a special case. Suppose that tenure effects and exit probabilities are constant across tenure, i.e. $\tau_m = \bar{\tau}$ and $\delta_m = \bar{\delta}$.

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[7] Note that we use only data on election wins and not on vote shares. We made this decision in order to estimate parameters that are consistent with a well-specified model and because of the potential noisiness of vote shares.

In this case, the policy function satisfies $\bar{q}(q, m) = q$; the voter always chooses the candidate with the higher q because tenure does not affect current or future payoffs.

Suppose that candidate A won an open seat election in 1960 against candidate B and then defeated challenger C in 1966. After that election, we know that A's permanent quality q is distributed as the maximum of 3 $i.i.d.$ draws from F. Suppose instead that C had won in 1966. Then, we can infer instead that C's permanent quality is distributed as the maximum of 3 $i.i.d.$ draws from F. Thus, the probability of the incumbent winning in 1972 depends solely on the number of elections that have occurred since the last open election for that seat. As a result, the probability of reelection will be increasing in the number of terms since an open seat, and conditionally independent of tenure.

In general, the probability of reelection will depend on the entire history of wins and losses since an open seat election. Let us extend the electoral history of the previous paragraph to consider the 1972 election, and suppose that the challenger, D, wins in 1972. In the case where $\tau_1 = \tau_2 = \bar{\tau}$, our posterior on the permanent quality of D is independent of whether he beat A or C. However, consider the case where tenure effects depend on tenure, for example $\tau_1 < \tau_2$. For simplicity, assume that $\beta = 0$. If D defeated the two-term incumbent A in 1972, then D must have had a sufficiently high q to overcome his deficit in tenure effects $\tau_2 - \tau_1$. In contrast, we cannot make the same inference if D defeated the one-term incumbent C in 1972. Thus, our posterior density of the permanent quality of D is higher if he beat A than if he beat C.

Extending this example to 1978, D's probability of being reelected depends not only on his tenure (1 term) and the number of terms since an open seat election (3 terms), but also on whether he beat A or C. This example demonstrates why the entire history matters.

The example also suggests how our model can separately identify tenure effects from selection effects. Conditional on a candidate's tenure, the model will, for different parameter values, predict different probabilities of reelection given different histories since the last open seat election. By matching these predictions of the

model to the data, we can understand the relative importance of selection and tenure effects.

This discussion also illustrates the difficulty of using regressions to separate tenure effects from selection effects, as previous studies have attempted to do. To be consistent with the model, one cannot simply regress the probability of reelection on candidate tenure and simple statistics such as terms since an open seat or number of senators since an open seat. The regressors would instead have to include the entire history since the open seat election, which would imply thousands of regressors for our data set.

We now turn to the specifics of our data and our inference procedure.

4.2   Data and Institutional Background

We construct our data set using data on U.S. Senate elections from the *Roster of U.S. Congressional Office Holders* (ICPSR 7803). In the original data set each record refers to a senator seated in a given congress (a two-year period starting in odd-numbered years) and contains information about when and why the senator was seated and when and why he left congress. The ICPSR data set ends in 1998. We compiled more recent data in order to extend this data set up to the 2006 election.[8]

We use these data to construct records of histories from an open seat election to an exit. We refer to one such history as a *chain*. Each chain is a vector of zeros and ones, with dimension equal to the number of elections held between the open seat election and the exit of the last senator in the chain. We do not include the outcomes of open seat elections in the chain. The first element of the vector is equal to one if the winner of the open seat election wins his next election; that element is equal to zero if the challenger wins. The second element is equal to one if the winner of the second election wins the third election, and it is equal to zero if his challenger wins, etc.

The normal term of a senator is six years. Regular elections are held in November

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of even-numbered years, and senators take office in the January following their election. Each Senate seat belongs to one of three classes, based on the year in which its regular elections are held.

Senators can leave office at the end of their terms essentially for three reasons, losing a general election, losing a primary election or retiring. Our data contain instances where senators leave office *before* the end of a six-year term because of death, retirement, or moving to a different office or job. In this case, an election is held on or before the next even-numbered November. The election is called a *special* election unless that senatorial seat was scheduled to have an election at that time. The governor of the state often appoints an individual to serve as senator until someone is elected.

Every chain starts with an open seat. Open seat elections consist of all elections following the exit of a candidate because of death or retirement.[9] As a consequence, we treat all special elections as open seat elections even if one of the candidates briefly served as an unelected senator nominated by the governor. Our definition of an open seat election also implies that an election where the incumbent senator lost in the primary is not an open seat election. This is equivalent to treating the primary and general elections as a single election with two candidates.

We treat all elections, whether special or regular, as counting for one term. This simplification is imperfect because the time period in our model is one term, and so the voter is assumed to discount the future identically if there are four years between elections (due to a special election) or if there are six years between elections. Moreover, the interpretation of the tenure effects is that they depend on number of elections won rather than number of years served.

Senators have been elected by popular vote only since 1914, as initiated by U.S. Constitutional Amendment XVII. Before this change, senators were appointed by the state legislature. As we do not have a model of how the state legislature chose senators, we only consider data from elections held on or after 1914. Moreover, it is conceptually difficult to use chains that started before 1914 because we do not have

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[9] We observe cases where a senator loses an election and then retires between the election and the end of his term. We ignore the retirement decision in these cases.

a model for the density of permanent quality for an incumbent senator after 1914 unless every senator in his chain was elected and not appointed. Thus, our data set contains only chains that start on or after 1914.

The use of these Senate data avoids pitfalls present in other data sources. In particular, the U.S. House of Representatives contains many instances of redistricting and it is not clear how to treat elections following a redistricting, when two incumbents may run against each other.

Our data set contains 402 chains, with 613 different senators and 1395 elections. We observe an exit preceding each of these 402 chains. Out of the 402 exits, 72 required a special election to choose the next senator. Considering all elections besides open seat elections, the incumbent senator won 782 out of 993 times (79%). Of the 211 incumbent losses, 43 occurred during the primary, with the rest occurring during the general election.

Among the chains, 84 have dimension zero, which occurs when the winner of the open seat election exits without running for reelection. The chains contain at most 7 different senators and at most 16 elections. The longest tenure for a senator was Senator Strom Thurmond, who served from 1954 to 2002, winning 8 elections. Only 25 senators served more than 5 terms. To avoid estimating parameters with very few observations, we assume that $\tau_m = \tau_5$ and $\delta_m = \delta_5$ for all $m \geq 5$.

4.3   Inference and likelihood

As is well-known in the literature, it is difficult to estimate the discount factor of a dynamic discrete choice problem (see Rust (1987) and Magnac and Thesmar (2002)). We consider 4% to be a reasonable discount rate on an annual basis. Given that a regular term lasts six years, we set β equal to 0.96 to the power of six. In principle, we could jointly estimate all of the other parameters. However, since we treat the retirement probability as exogenous, we can obtain consistent estimates of the retirement probabilities δ_m without solving the voter's decision problem. Specifically, we estimate δ_m as the number of senators who retire with tenure m divided by the total number of senators that held office for at least m

terms.

We assume that the candidate quality distributions F_o and F_c are normal with means μ_o and μ_c and variances σ_o and σ_c, respectively.[10] Note that μ_o and μ_c are not separately identified given our data: a shift in both means would not change any observable prediction of the model. Thus, we normalize $\mu_c = 0$ and estimate μ_o. Similarly, we cannot separately identify σ_o from σ_c, because multiplying both standard deviations by the same factor has the same effect of changing the unit of measurement of the candidates' quality. Thus, we normalize $\sigma_c = 1$. Although σ_o is then identified from the data, we also normalize $\sigma_o = 1$ in the interest of parsimony.[11] Finally, adding a constant to τ_0 and the same constant to $\tau_1, ... \tau_5$ would yield the same predictions. Therefore, we set $\tau_0 = 0$.

We now discuss the estimation of the parameters. Consider first the contribution to the likelihood of chain d of dimension T. Denote the history of wins and losses prior to the tth election in the chain with the vector $h_t \equiv \langle d_1, ... d_{t-1} \rangle$.[12] Denote the posterior density over incumbent quality after history h_t as $g(\cdot | h_t)$, and the number of terms served by the incumbent holding office after history h_t as m_{h_t}. Define e_t as the random variable that indicates the outcome of the tth election in the chain, with the interpretation that $e_t = 1$ indicates the incumbent winning the election and $e_t = 0$ indicates the incumbent losing. We can then express the likelihood L of

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[10] Note that the support of the normal density is not compact, which is inconsistent with the assumption, made in Section 3, that the densities are drawn from a compact set Q. We made this assumption solely to facilitate the proof of Lemma 1. This proof can be extended to the normal density by considering truncations of the density to an interval $[-a, a]$, and letting a go to infinity. An example of this approach is contained in Mitchell (2000).

[11] We estimate a specification where we constrain $f_o = f_c$. For this specification, we set $\mu = 0$ and $\sigma = 1$, as these parameters are not identified.

[12] Recall from our definition of a chain that the first element, d_1, is the outcome of the incumbent-challenger election following the initial open seat election. Hence this vector does not contain the outcome of the open seat election, which has no informational content for our purposes.

chain d as:

$$L(d|\tau_1, ..., \tau_5) = \prod_{t=1}^{T} \Pr\left(e_t = d_t|h_t\right) \tag{5}$$

$$= \prod_{t=1}^{T} \int_x \left\{ \begin{array}{l} d_t \cdot F_c\left(\bar{q}(x, m_{h_t})\right) \\ +(1 - d_t) \cdot [1 - F_c\left(\bar{q}(x, m_{h_t})\right)] \end{array} \right\} dg(x|h_t)dx.$$

The expression (5) depends on the policy function $\bar{q}$, which in turn depends on the parameters. The expression also depends on the density of permanent quality for the incumbent at the start of period t, $g(x|h_t)$. We evaluate this density using Bayes' Law and the policy function $\bar{q}$. Let the prior density of the incumbent at time t (by the econometrician) be denoted p and decompose history h_t into two elements: the outcome of last period election d_{t-1} and the previous history h_{t-1}. Bayes' Law implies

$$\underset{\underset{\uparrow}{\text{Posterior density given } h_t}}{g(q|\langle d_{t-1}, h_{t-1}\rangle)} = \frac{\overset{\overset{\text{Prior density}}{\uparrow}}{p(q|h_{t-1})} \cdot \overset{\overset{\text{Probability of outcome } d_{t-1} \text{ given } q}{\uparrow}}{\Pr\left(d_{t-1}|\langle q, h_{t-1}\rangle\right)}}{\underset{\underset{\downarrow}{\text{Unconditional probability of outcome } d_{t-1}}}{\Pr\left(d_{t-1}|h_{t-1}\right)}}. \tag{6}$$

The prior density p is equal to f_o if the incumbent won an open seat election in the previous period, and f_c if the incumbent won against a previous incumbent. In all other cases, p is defined recursively as equal to $g(\cdot|h_{t-1})$.

We now show how this formula is applied to the different cases. First, consider the density of a one-term incumbent who won an open seat election in the previous period. In this case the prior density is f_o, and the conditional probability of winning the open seat given q is $F_o(q)$. For this case, (6) can be written as:

$$g\left(q|h_0\right) = \frac{f_o\left(q\right) \cdot F_o\left(q\right)}{\int_Q f_o\left(x\right) \cdot F_o\left(x\right) dx}. \tag{7}$$

Next, consider the cases with $t > 1$. We distinguish two cases, depending on whether the incumbent won or lost in the previous election. If $d_{t-1} = 1$, then the conditional probability of the election outcome in the previous period is equal to the probability that the challenger draws a permanent quality less than the threshold value

$\bar{q}(q, m_{h_{t-1}})$, hence:

$$g\left(q|h_t\right) = \frac{g\left(q|h_{t-1}\right) \cdot F_c\left(\bar{q}(q, m_{h_{t-1}})\right)}{\int_Q g\left(x|h_{t-1}\right) \cdot F_c\left(\bar{q}(x, m_{h_{t-1}})\right) dx}. \tag{8}$$

Finally, if $d_{t-1} = 0$, the incumbent was a challenger at $t-1$. This means that the prior density is f and that his permanent quality q is greater than the threshold $\bar{q}(\cdot)$ implied by the voters' decision rule, which is a function of the previous incumbent's quality and history. Since the previous incumbent quality is distributed according to $g(\cdot|h_{t-1})$, then equation (6) can be written as:

$$g\left(q|h_t\right) = \frac{f_c\left(q\right) \cdot \displaystyle\int\limits_{z:\bar{q}(z, m_{h_{t-1}})<x} g(z|h_{t-1})dz}{\int_Q f_c(q) \cdot \displaystyle\int\limits_{z:\bar{q}(z, m_{h_{t-1}})<x} g(z|h_{t-1})dzdx}. \tag{9}$$

In order to evaluate the log likelihood of our data set for a given parameter vector, we first compute the policy function using numerical dynamic programming. We then evaluate the likelihood for a chain using the computed policy function, together with (5) and (6), and sum the log of the likelihood for each chain. Details on the numerical procedure used in the estimation are in Appendix A.2.

5 Results

We first examine simple data on reelection probabilities, in order to understand what the data imply about the possible values of the parameters. We then turn to the structural estimation results. Last, we examine the implications of counterfactual electoral designs.

5.1 Evidence from Data

Our model implies that the history of a seat since an open seat election will affect the probability of reelection. We encapsulate the history of a seat at any election with two simple statistics: the number of terms since an open seat election and the number of terms that the incumbent had previously served. Table 1 provides a

Terms since last open seat election

Terms of tenure	1	2	3	4	≥ 5
1	.80 (.02) $N = 318$	.73 (.06) $N = 51$	.61 (.07) $N = 44$	.57 (.09) $N = 28$	.78 (.06) $N = 49$
2		.79 (.03) $N = 181$	.73 (.09) $N = 26$	.86 (.08) $N = 21$	.91 (.05) $N = 34$
3			.83 (.04) $N = 88$	1.00 (.00) $N = 12$	.75 (.07) $N = 36$
4				.82 (.06) $N = 44$	.78 (.10) $N = 18$
≥ 5					.91 (.04) $N = 43$

Table 1: Winning frequencies (standard deviations in parentheses) and number of observations N by tenure and terms since last open seat election.

grid that breaks down the probability of an incumbent winning based on these two factors.[13]

We first consider the diagonal of this table to understand what it implies about tenure effects. The diagonal provides the reelection probabilities for candidates who are initially elected to the Senate by winning an open seat election. The first element shows that winners of open seat elections who do not exit during their first term in office win 80% of the time in their next election. The second element shows that open seat winners who survive reelection and who do not exit during their first two terms in office have a conditional reelection probability of 73%. The conditional reelection probabilities with three or more terms are very similar to these two numbers.

We argue that the data from the diagonal show that tenure effects are *declining,* provided that there are no dynamic considerations and the candidate densities are

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[13] We exclude open seat elections from this table, as they provide no information in the context of our model.

the same for the two types of elections.[14] For a contradiction, assume that the tenure effects are zero, i.e., $\tau_m = 0 \ \forall m$, and $F_o = F_c$. With no dynamic considerations, identical candidate densities and zero tenure effects, in each election voters choose the candidate with the highest permanent quality. Therefore, the distribution of quality of an incumbent who initially won an open seat election and who served n terms is simply $max\{F_{o,1}, ..., F_{o,n+1}\}$. Thus, the expected quality is higher the more terms the incumbent has served, and the reelection probabilities should be increasing in the number of terms served, which we do not see in the data. If the tenure effects are increasing, rather than zero, this effect will be further exacerbated, showing that the tenure effects must be negative to explain this feature of the data.[15]

Next, we argue that tenure effects are *negative*. Since the effects are declining, it is sufficient to argue that $\tau_1 \leq 0$. One might hypothesize that $\tau_1 > 0$ is necessary to explain why the reelection probabilities from the diagonal are all significantly higher than 50%. However, there are two facets of the data that make this hypothesis unlikely.

First, in the absence of tenure effects, different densities, or dynamic considerations, selection alone implies that the incumbent will have a 67% chance of winning reelection,[16] a number reasonably close to the actual probability, and one that will be higher if candidates in an open seat election are of higher quality. Of course, this explanation is not nonparametric in that it might be driven by the density of candidate quality, which is assumed to be normal. Nonetheless, the point is that selection by itself will imply high reelection probabilities for incumbents.

Second, we obtain further evidence against positive tenure effects by examining the change in reelection probabilities along the first row of Table 1. If, in fact, τ_1 is positive, then we would expect that a senator who defeated an incumbent

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[14] There will be no dynamic considerations if either $\beta = 0$ or δ_m is constant across m. While we cannot construct a proof of our argument if there are dynamic considerations or if the two candidate densities are different, the same intuition will still apply.

[15] Note that a conventional "sophomore surge" analysis could not generate this result, as it either would not use any data beyond the $(1, 1)$ cell or would lump all of these elements together.

[16] We derive this figure by simulating the probability that the maximum of two draws from a normal density (the incumbent quality) is greater than a third draw (the challenger quality), since the decision rule in this case is simply to keep the higher quality candidate.

senator with one term of experience would, on average, have very high quality, as the electorate would have to endure a new senator instead of a senator with τ_1 for one period. When this incumbent-defeating senator gets to his first reelection campaign, he should then have a very high chance of reelection: not only is his expected quality very high by selection, but now the tenure effects work to his favor. This logic can be generalized to argue that reelection probabilities should be rapidly increasing along any given row of Table 1 if the tenure effects are positive. Yet, there is no pattern of rapid increase in the probability of reelection along any row. Indeed, for the above case (which has the most observations), the incumbent-defeating senators win reelection only 73% of the time, as compared to the 80% reelection probability for one-term incumbents who won an open seat election. The implication is that the selection was not all that favorable, and hence that τ_1 was not actually positive.

Finally, the decrease in reelection probabilities noted above also suggests that the open seat density is *different* from the incumbent-challenger density. The reason for this is that no matter what the tenure effects are, we would not expect to see *decreasing* reelection probabilities in any row, if the two densities are the same. The reason for this is that any difference in reelection probabilities between the candidates in a given row is due to selection, not tenure effects, since their tenures are the same. Moreover, the further down the row a candidate is, the more times he has been selected. This makes it very difficult to have selection generate the decreasing reelection rate when all candidates are drawn from the same density, regardless of the tenure effects.[17]

In contrast, different densities for candidates in open seat elections and challengers of incumbents can easily explain this decrease. In particular, if $\mu_o > 0$ then a challenger facing an incumbent starts from a lower quality density than the incumbent, and hence may, on average, have lower quality upon winning than the incumbent had upon winning his first election. We verified this hypothesis by simulating voter decisions with no tenure effects or dynamic considerations but with

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[17] While we cannot offer a formal nonparametric proof of this result, we were unable to find parameters for our model that resulted in decreasing probabilities of reelection along a row, when the two densities were the same.

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	N. obs.	Estimate
δ_1	611	0.1522 (0.015)
δ_2	369	0.2304 (0.022)
δ_3	208	0.2933 (0.032)
δ_4	110	0.3091 (0.044)
δ_5	79	0.3530 (0.054)

Table 2: Conditional exit probabilities by tenure (standard errors in parentheses)

positive μ_o.[18] Choosing $\mu_o = 1.0$ as an example, the winner of an open seat election would have a mean quality of 1.57 while a senator who defeated a one-term incumbent who won an open seat election would have a mean quality of only 1.34, indicating a lower reelection probability in the second case. Thus, a positive μ_o can explain the decrease in reelection probabilities between the first two elements of the first row of Table 1.

In summary, the statistics of the data reported in Table 1 suggest that tenure effects τ_m are negative for $m \geq 1$, and that the density of candidates is higher for open seat elections than for incumbent-challenger elections. It is important to note that the above discussion considered the effects of selection, tenure, and candidate density in isolation. We cannot consider all of these effects together using simple statistics. Moreover, with $\beta > 0$, decisions will vary in complicated ways based on the retirement probabilities. In order to precisely quantify the sources of the incumbency advantage, we turn to our structural model.

5.2   Base Structural Estimation Results

Table 2 shows the conditional exit probabilities used in the estimation of the other parameters. The reported values are the mean probabilities from the data, with the standard errors then computed by using the number of observations. Not surprisingly, these are precisely estimated and increasing in tenure.

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[18] Note that the decision rule in this case is still to keep the higher quality candidate.

Table 3 shows the main structural estimation results, with bootstrapped standard errors in parentheses. Model 1 refers to the case where all candidates are drawn from the same distribution; in Model 2, we allow for the possibility that open seat candidates draw from a distribution with a mean different from candidates challenging incumbents. Our principal results are those from Model 2. The units can be understood by noting that the standard deviation on the distribution of quality is one.

In Model 2, we find a *negative* and statistically significant tenure effect. The effect is small: for the most common cases — incumbents of one, two, or three years of tenure — the tenure effects are estimated to be less than two-thirds of one standard deviation of the quality of challengers. Thus, the results show that any advantage to incumbency is not inherent to the office, but rather the result of weaker candidates running as challengers against incumbents. Note also that the inference that tenure effects are negative or small is robust to the assumption of exogenous retirement. If senators were retiring because they were expecting a loss, then the senators who choose to run for reelection would have better selection than the unconditional average, implying that our tenure effects would be *upwardly* biased.

We also find that candidates running in an open seat election are superior to challengers who run against incumbents; as a way to evaluate the magnitude, consider that the average candidate in an open seat election would be in the 75th percentile of the quality distribution for challengers to an incumbent. Moreover, the difference $\mu_o - \mu_c$ is precisely estimated.

The significance of $\mu_o - \mu_c$ implies that Model 1, which assumes that there is no difference in challenger quality across the two elections, cannot fit the data as well as Model 2. This is substantiated by the likelihood ratio test based on the log likelihoods reported in Table 3, which rejects Model 1 ($\chi^2(1) = 42.22$, p-value $= .00$). Note that in Model 1, term limits can only lower the welfare of the electorate, limiting the use of Model 1 as a tool to analyze electoral design policies. Nonetheless, it is worth noting that Model 1 gives similar predictions to Model 2 in the sense

| | Model 1 | Model 2 |
	$(f_o = f_c)$	$(f_o \neq f_c)$
$ln\ L$	-527.740	-506.631
τ_1	-0.021 (0.219)	-0.666 (0.150)
τ_2	0.104 (0.217)	-0.707 (0.130)
τ_3	0.178 (0.251)	-0.631 (0.250)
τ_4	-0.736 (0.726)	-1.508 (0.517)
τ_5	0.333 (0.762)	-0.687 (0.525)
$\mu_o - \mu_c$	0	0.781 (0.088)

Table 3: Estimated parameters (standard errors in parentheses)

that the tenure effects are estimated to be very small or negative.

As the estimates reveal that the direct effect of tenure is negative, the incumbency advantage is due to a combination of selection and incumbents facing weaker challengers. We now ask how big is the incumbent's benefit from facing weaker challengers, by simulating the equilibrium predictions of the model with different parameter values. In the data, incumbents win 78.8% of the time, a figure that is similar to the estimated value of 79.6% for Model 2. However, if incumbents were faced with challengers with the same distribution of quality as in an open seat election, then the model predicts that they would win only 62.3% of the time. If there were no quality differences across candidates whatsoever, then an incumbent would always have a 50% probability of reelection. In this sense, roughly half of the incumbency advantage is due to lower quality challengers.

A useful measure of goodness of fit is the ability of the models to reproduce reelection probabilities. Table 4 provides the reelection probabilities as a function of tenure.

Model 2 is able to fit the reelection percentages by tenure very accurately, particularly for the first three rows, which contain the bulk of the data. It would be troubling to argue that tenure effects are small if the model underpredicts reelec-

Tenure	Data	Model 1 $(f_o = f_c)$	Model 2 $(f_o \neq f_c)$
1 ($N = 490$)	.757 (.019)	-0.032	-0.003
2 ($N = 262$)	.802 (.025)	0.000	+0.005
3 ($N = 136$)	.824 (.033)	-0.013	0.000
4 ($N = 62$)	.806 (.050)	-0.036	-0.022
≥ 5 ($N = 43$)	.907 (.044)	+0.015	+0.006
All ($N = 993$)	.788 (0.013)	-0.009	+0.008

Table 4: Goodness of fit: reelection frequencies by tenure; data (standard deviations in parentheses), and difference between models' predictions and data

tion probabilities and hence does not generate sufficient incumbency advantage in winning probabilities. Model 2, however, accurately predicts winning probabilities with negative tenure effects. Thus, the model is not throwing out tenure effects at the expense of generating a high winning percentage for incumbents; it generates them all through the selection effect and the different densities for incumbents and challengers. Model 1 does less well at fitting these moments, demonstrating the importance of allowing for different densities.

We further evaluate the goodness of fit of the estimated models by examining how well they match the conditional probabilities of reelection by terms served and terms since an open seat election given in Table 1. As noted in Section 5.1, these moments summarize much of the important identification of the model. Table 5 provides these probabilities for our two models, as well as indicating the difference between the data and the predictions of the models.

Model 2 is generally successful at matching these moments of the data. In all but seven cells, the predictions from Model 2 are within one standard deviation of the reelection probabilities from the data. In all but two cells, the predictions from Model 2 are within two standard deviations of the percentages from the data.

Terms since last open seat election

Terms of tenure	1	2	3	4	≥ 5
1	.67 .78 (−.13) (−.02)	.75 .70 (+.03) (−.03)	.81 .71 (+.19) (+.09)	.84 .73 (+.27) (+.16)	.86 .75 (+.08) (−.03)
2		.76 .82 (−.02) (+.04)	.80 .77 (+.07) (+.04)	.84 .77 (+.01) (−.09)	.88 .79 (−.03) (−.12)
3			.77 .84 (−.06) (+.01)	.82 .79 (−.19) (−.21)	.87 .80 (+.12) (+.05)
4		Model 1 Model 2		.73 .80 (−.09) (−.01)	.81 .75 (+.03) (−.03)
≥ 5					.92 .91 (+.02) (+.01)

Table 5: Goodness of fit: Models 1 and 2 predicted reelection frequencies by tenure and terms since open seat (difference between predictions of models and data in parentheses)

In contrast, Model 1 does much less well at matching these moments. In particular, Model 1 underpredicts by 13 percentage points the reelection probability for the case with the most observations, of an incumbent who won an open seat election seeking his first reelection (row 1, column 1), but overpredicts by 3 percentage points the reelection probability of a one-term incumbent who obtained office by defeating an open seat winner who had served one term (row 1, column 2). The reason for this relates to the discussion in Section 5.1: Model 1 has no way of explaining the drop in the probability of reelection between these two cells.

In comparison to our models, conventional "sophomore surge" analysis either looks only at the case where the number of terms since the last open seat election is one, or lumps together all one-term incumbents. By examining the reelection probability for candidates as a function of the entire history since an open seat election, our models generate results that are robust to different tenure effects and are substantiated in the data. Consistent with our results, the Levitt and Wolfram (1997) study of House incumbency advantage finds that a large fraction of the incumbency advantage is the result of the ability of incumbents to deter high quality challengers

Policy	Mean value of open seat	95 % conf. interval
No term limits	4.97	[4.39,5.45]
1-term limit	6.16	[5.30,7.03]
2-term limit	5.27	[4.54,5.97]
3-term limit	5.08	[4.40,5,64]

Table 6: The effect of term limits on the value of an open seat

from running against them. However, they also find evidence of substantial tenure effects, which we do not find. Whether this discrepancy is the result of different modeling assumptions, or evidence of different causes of incumbency advantage between the House and the Senate is an interesting topic for further research.

5.3 The Effect of Term Limits

We use our model to understand the impact of counterfactual electoral designs on voter welfare. We consider counterfactual worlds where different term limits are imposed on incumbents, and compute the value of an open seat W using equation (3) and our base parameter estimates. Table 6 reports the mean value for an open seat, as well as bootstrapped 95% confidence intervals for the mean value, both using the estimated Model 2.

We find that the highest welfare level accrues to the electoral system where there is a one-term limit. Under this system, expected welfare of an open seat rises from 4.97 to 6.16. Moreover, the entire 95% confidence interval of the counterfactual welfare, [5.30,7.03], lies above 4.97 and there is a statistically significant difference between welfare with a one-term limit and under the current system ($p = .00$).

To understand the magnitude of the average welfare gains from a one-term limit, we need to consider the welfare gains relative to a reference point. If senators were randomly picked from the distribution of challengers f_c every term, then the value of an open seat would be zero. Comparing zero to the welfare levels with and without term limits, our results imply that welfare would increase roughly 25% relative to the

Figure 1: Distribution of open seat values under alternative policy scenarios

difference in welfare between our current electoral system and one which randomly picks challengers to senate elections to serve as senators every term.

Two- and three-term limits also yield an improvement in welfare over the current electoral design. However, the welfare gains from these policies are much smaller than with a one-term limit, with a gain of .30 and .11 respectively, relative to 1.19 from the one-term limit.[19]

To evaluate the distributional consequences of electoral reform, we simulated the distribution of values of an open seat, also using the Model 2 estimated parameters. Figure 1 reports these values for the current electoral system as well as for the counterfactual worlds with one-term and two-term limits.[20] We find that one-term limits have a distribution of outcomes that is far better than the current system, while two-term limits have a distribution of outcomes that overlaps more closely with the current system. The three-term limit distribution of open seat values, omitted from the figure, is very close to that of the current electoral system.

Finally, to provide further evidence about the distribution of voter welfare, we computed the expected value of each of the current senatorial seats at the point immediately after the most recent election prior to Dec. 2006 (i.e., 2002, 2004 or 2006), conditioning on their history since the last open seat election. None of the current 100 senatorial seats has a value above 6.19, the value of an open seat under the 1-term limit; five seats have an expected value above the value with a 2-term limit; and 8 seats have an expected value above the value of the 3-term limit policy.

There are two reasons why we find that term limits improve voter welfare. First, tenure effects are estimated to be negative, implying that, on net, there is no reason

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[19] Statistically, welfare from the three-term limit is not significantly different than the base regime ($p = .15$) but welfare from the two-term limit is significantly different ($p = .00$), because of a substantial correlation in the welfare levels of different regimes across parameter values.

[20] More precisely, the figure displays the kernel smoothed density of the bootstrapped open seat values under each policy regime.

to avoid term limits to benefit from experience, but that rather the opposite is true. While the selection effect always implies that term limits are harmful, the substantial estimated difference in quality between candidates in an open-seat election and an incumbent/challenger election counters this effect. Moreover, the estimated magnitude of this effect is large enough that, in combination with the negative tenure effects, it is better to the voters if incumbents are forced not to run in order to attract higher quality candidates.

6   Discussion

Because our results derive from a relatively parsimonious specification, it is useful to understand what are the potential limitations of the model in explaining the welfare consequences of term limits. This also allows us to explore how alternate specifications might impact the results.

One the most stark assumptions in our model is that the density of candidate quality is exogenous. A more complete model might combine our model of endogenous voter decisions with a model of endogenous candidate quality, as in Diermeier et al. (2005). To the extent that term limits lower the reward from a senatorial career, they will adversely affect the distribution of senatorial candidates.[21] Even if term limits do not affect the attractiveness of a senatorial career, they may lower the quality of open-seat candidates given that the pool of open-seat candidates is finite and potentially small, and that regimes with term limits exhaust open-seat candidates more quickly than the current regime. These two factors suggest that our model provides an upper bound to the benefits of term limits. We believe that the upper bound is high enough to consider these policies as potentially beneficial.

A further reason to think our results might overstate the gains from term limits is that, by eliminating from the model the decisions politicians make, we eliminate political agency concerns. Smart and Sturm (2004) show that term limits lower

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[21] For example, Diermeier et al. (2005) find that term limits significantly decrease the value of a congressional seat. Consequently, it is less likely that skilled and older politicians choose to run for reelection.

the value of holding office in a model of political agency and therefore may make it harder to create appropriate incentives for incumbents. This cost of term limits is not incorporated into our model.

Our model of voter behavior differs from most of the political science literature in that it does not account for party, policy or other covariates that may correlate with the reelection probability. A natural way for party to affect decisions in the context of a rational dynamic model would be if candidates came from two distinct parties with distinct policies. The voters in a given state might favor candidates from one of the two parties also although care about our previous definition of candidate quality. In this case, quality would have both horizontal and vertical dimensions.

If the *favored group model* were the true data generating process, our estimation would tend to overestimate the open seat candidate density (since an open seat would always contain one favored candidate) and the tenure effects (since incumbents would typically be from the favored party). Moreover, with favored groups, there would be a similar reason to enact term limits to that of attracting higher quality candidates through more open seats: open seats always bring a new draw from the favored distribution, whereas incumbent/challenger elections typically only get a new draw from the unfavored distribution. However, while in our model the voter has no way to replicate the term limit environment (as open seats are exogenous), a patient voter could vote a marginal candidate from the preferred distribution out of office in order to get a new draw from the preferred distribution in the following period.

In principle, one could estimate the favored group model by specifying a state-specific random effect for each group. However, in prior work, we found that the party of the prior incumbent is not a positive predictor of the winner of an open seat election; see Gowrisankaran et al. (2004).[22] This suggests that party preferences are not persistent across chains and hence that we would likely not estimate a statistically or substantively significant state/party random effect.

The fact that candidate quality is permanent has an important impact. For

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[22] This paper also found that covariates such as House of Representatives experience also are not significant predictors of reelection.

instance, if quality for a given candidate was *i.i.d.* across time then there would be no selection effect benefiting experienced candidates; their high winning probabilities would have to be explained by positive tenure effects. Thus, by assuming that quality is permanent, we are favoring selection effects. Overstating selection effects makes the case for term limits weaker; in the limiting case with *i.i.d.* quality, the shortest possible term limits would always be optimal. Moreover, the model with *i.i.d.* quality would have difficulty explaining both the relatively flat relationship between winning probabilities and tenure that occur for open seat candidates (which suggests non-increasing tenure effects) and the increasing probability of winning with tenure overall.

In a model with a horizontal dimension to quality, candidates might also want to adjust their policy positions in order to match the preferences of their constituents. Allowing for endogenous choices of policy positions might be important, although it would significantly complicate the estimation of such a model. In addition, we assume that quality is not only permanent but known to voters. Including uncertainty about quality, and aversion to variance in quality, would add a trade-off between safe candidates and option value in unknown candidates that we do not consider.

It is also possible that there is important unobservable heterogeneity across seats and times. For instance, some places and times may be particularly prone to reelect incumbents. To address this, one could reestimate the model with two types of seats, as in Heckman and Singer ***ANDREA*. This model would also provide some heuristic evidence on the overall specification of the model, since allowing multiple types of voters might improve the fit in the event of a variety of misspecifications. However, Gowrisankaran et al. (2004) estimated a specification with multiple types of jurisdictions and found no significant evidence of multiple types of jurisdictions.

7   Conclusion

We analyze the causes of incumbency advantage for the U.S. Senate and their implication for electoral design by structurally estimating a dynamic model of voter behavior and evaluating the impact of counterfactual policies. Our results are iden-

tified by examining the impact of the entire history of election outcomes following an open election on the probability that an incumbent will win, conditioning on the tenure of the incumbent.

We find that the incumbency advantage is due to two effects. Incumbent senators are, on average, selected to be of high quality due to their past successes in winning elections. In addition, incumbent senators are able to deter high quality challengers. We find no evidence of other benefits intrinsic to incumbency: tenure appears to provide a small disadvantage in reelection. In large part because of the finding that incumbents deter high quality challengers, we find that imposing term limits can positively impact welfare, with a one-term limit causing a large and significantly positive effect.

Our results derive from a reasonably simple framework that, to our knowledge, is the first to directly estimate the impact of electoral design on voter welfare. Although our model abstracts from many important attributes of elections, we model voters as rational dynamically optimizing agents and endogenize and estimate voter behavior within this framework. We believe that an interesting direction for future work would be to specify richer optimizing models of voters and candidates, and combine these with other data besides the history of a seat.

A Appendix

A.1 Proof of Lemma 1

Proof. Denote by M the finite set of allowable tenures for an incumbent. We prove the lemma by first showing that $V(q, m)$ is increasing in the first argument, using standard recursive techniques (see Stokey et al. (1989)). Denote by C the metric space of all continuous functions $g : Q \times M \to \mathbb{R}$ that are weakly increasing in the first argument, where the metric is defined by the sup norm. Note that C is a complete metric space since these countinuous functions, on a compact domain,

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must be bounded. Define the mapping T for any function $g \in C$ by

$$T(g) = (1 - \delta_m) \int \max \left\{ \begin{array}{c} (q + \tau_m + \beta g(q, m+1)), \\ (q_c + \tau_0 + \beta g(q_c, 1)) \end{array} \right\} df(q_c)dq_c$$

$$+ \delta_m \int \int \max \left\{ \begin{array}{c} (q + \tau_0 + \beta g(q, 1)), \\ (q_c + \tau_0 + \beta g(q_c, 1)) \end{array} \right\} df(q)dqdf(q_c)dq_c$$

Notice that, whenever g is weakly increasing and continuous, so is $T(g)$, so T is an operator, $T : C \rightarrow C$. Notice that T meets Blackwell's sufficient conditions for a contraction: for any function $g' \geq g$, $T(g') \geq T(g)$, and for a constant c, $T(g + c) = T(g) + \beta c$, $0 < \beta < 1$. Hence, by the contraction mapping lemma, for all functions $V_0 \in C$, the sequence defined by $V_n = G(V_{n-1})$ converges to a function $V \in C$ that is the unique fixed point of the operator T. Since V is the fixed point, it is exactly the value function that solves the dynamic programming problem. Since $V \in C$, the value function V is weakly increasing in the first argument.

Note that q_c only shows up in two places in the choice of candidates (once in the current reward from choosing the challenger, once in the future value if the challenger is chosen), and if V is weakly increasing in the first argument, the total discounted reward from choosing the challenger is strictly increasing in q_c, while the discounted reward from choosing the incumbent is constant in q_c. As a result, $r(q, q_c, m)$ must be decreasing in q_c for any fixed q and m. ∎

A.2 Details on the numerical computation

The permanent quality distribution F is continuous, which implies that we need to approximate the value function in our computation. We choose a discrete grid approximation, and use 401 evenly spaced grid points between -6 and $+6$, in order to capture the tails of the standard normal density. We use linear interpolation in order to create a continuous policy function $\bar{q}$, necessary for an efficient search for the maximum likelihood parameters.

We find the parameter vector that maximizes the likelihood by using numerical search algorithms. We use two different algorithms: a routine that we developed

that combines the simplex method with random jumps and the method of simulated annealing by Goffe et al. (1992).

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