

Dynamic Policy Sabotage*

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Abstract

A common feature of democratic politics is that the opposition may sabotage the implementation of policies put forth by the incumbent party. This paper presents a theoretical analysis of the opposition's optimal use of sabotage and of how the prospect of sabotage conditions the incumbent's agenda. We show that, when a proposed policy enjoys moderate public support, the incumbent will attempt to pass it as early as possible, and the opposition will exert increasing effort to sabotage it as the next election approaches. In contrast, the incumbent delays the passage of highly popular policies until near the end of her term, and these are not subject to sabotage. Finally, the threat of sabotage persuades the incumbent to abandon unpopular proposals. In extensions, we show how our results compare under different electoral institutions, and how legislative obstruction can be used as an alternative or complement to sabotage.

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1 Introduction

The passage of the Affordable Care Act (ACA) was initially viewed as a political triumph for the Obama administration. The implementation of the act, however, faced many difficulties and proved to be politically damaging for the Democrats.¹ Public discontent with the ACA helped the Republicans retake the House and the Senate in subsequent elections; and it may even have contributed to Clinton’s defeat in the 2016 election (Kogan and Wood 2019). While some of the failings of the ACA were self-inflicted by the Obama administration, its problems were exacerbated by the persistent subversive efforts of the Republican party. For example, Republican officials in several states used consumer protection laws to impose onerous licensing and certification requirements on “navigators”—enrollment counselors who help individuals apply for insurance (Ollove, 2013). They also succeeded in restricting federal funding of the risk corridors program—essentially a safety net for participating insurers—which led to many insurers leaving the market (Norris, 2019).

Policy reforms commonly arouse opposition during their passage through the legislature as well as during their implementation. Sometimes, the opportunity or the political will to put up a challenge at the legislative stage is limited. This would be the case when the incumbent has a legislative majority, or when the identity of the winners and losers from the policy is unclear *ex ante*.² This leaves sabotage as the only resort for the policy’s opponents, be they the opposition party or other powerful vested interests, such as unions.³ The leader of the militant coal miner strike in the U.K. in 1984, Arthur Scargill, famously said that “a fight back against this Government’s policies will inevitably take place outside rather than inside Parliament” (Routledge, 1983).

Despite its importance, the phenomenon of policy sabotage has not been widely studied, either theoretically or empirically. This paper provides a formal theoretical account of it. In our model, an incumbent faces reelection at a future date and decides when, if ever, to enact a policy experiment with uncertain outcomes, the success of which will be judged

¹One well-publicized debacle was the launch of the enrollment website. In addition, many were forced off their existing health plans, despite promises by President Obama to the contrary. The average premium also increased 24 percent after the ACA went into effect (Clason, Kopp and McIntire 2020).

²Uncertainty about the distributional effects of a policy can mean that a policy is favored by the majority *ex ante* but opposed by many *ex post* (Fernandez and Rodrik, 1991). This uncertainty is often a salient feature of structural economic reforms (Przeworski, 1991). Stephan Haggard even suggests that “the most difficult political challenges come out not initially, but somewhat later in a [reform] program...” (Williamson, 1994, pg. 474).

³Interestingly, the most ardent opposition of structural reforms often comes from the bureaucracy itself (Przeworski, 1991, pg. 160).

by voters. If the policy is enacted, the opposition can make a costly effort to sabotage its implementation. Sabotage lowers the policy’s odds of succeeding whether it is sound or not, and hence obfuscates the voters’ inference regarding the true quality of the policy. For the sake of clarity, in our main model (Section 4) we rule out legislative obstruction, so that the opposition can *only* thwart the incumbent through sabotage, but this restriction is relaxed in Section 5. Throughout the analysis, our goal is to characterize the opponent’s optimal use of sabotage, and how the prospect of sabotage influences the incumbent’s incentive to enact the policy.

A novel aspect of our approach is that we treat the incumbent’s term explicitly as a finite, continuous period of time during which decisions can be made. This allows us to shed light on the political dynamics *within* an electoral cycle. For example, our model speaks to the so-called “honeymoon hypothesis”—the popular wisdom that politicians tend to enact new policies immediately after election (McCarty, 1997; Frensdreis, Tatalovich and Schaff, 2001; Grossback, Peterson and Stimson, 2005). The conventional explanation is that politicians enjoy the greatest political capital, and therefore have the strongest impetus to enact policies, in the beginning of their term. While some examples fit the hypothesis⁴, there is also anecdotal evidence to the contrary, of governments that drag their feet in enacting a policy even when there is popular demand for it (Rodrik, 1996).⁵ Our analysis reconciles these observations by showing that incumbents will seek to implement moderately popular policies early in their term, consistent with the hypothesis, but delay enacting highly popular policies.

In the model, uncertainty about the policy takes two forms: there is uncertainty about whether the policy is destined to ever succeed *and* how long it will take for a successful policy to yield demonstrable results. Economic reforms, for instance, fit these assumptions closely: it takes time for the society to adjust and so even a sound reform may appear like a failure early on.⁶ A consequence of these assumptions is that the voter’s confidence in the policy continuously deteriorates in the absence of a proven success. Thus, the model also naturally accommodates the phenomenon of “reform fatigue,” whereby popular support for a policy reform quickly wanes in the absence of observable results (Bruno, 1993; Lora, Panizza and Quispe-Agnoli, 2003; Tommasi and Velasco, 1996).

⁴For example, economic liberalization in post-communist Poland and New Zealand in the 1980s (Williamson, 1994).

⁵Some instances of this are economic reforms in Australia by the Hawke government, in Spain by Gonzalez’s Socialist government, and in Colombia by the Barco government (Williamson, 1994).

⁶In describing post-communist economic reforms, Adam Przeworski noted that “structural transformations of the economy are a plunge into opaque waters: the people do not know where the bottom is and how long they will have to hold their breath.” (Przeworski, 1991, pg 168).

We assume that once the policy is enacted, the incumbent is committed to it, and the next election becomes an implicit referendum on the policy. Thus, the incumbent wants to see it succeed, while the opposition wants to see it fail.⁷ The voters' confidence in the policy at the time of the election depends on three factors: its initial popularity, how long the policy has taken to produce an observable success, and the extent of policy sabotage by the opposition. Policy sabotage cannot render successful policies unsuccessful, but it can delay the realization of an observable success.

The first result of our analysis is a characterization of the incumbent's optimal strategy. The incumbent never enacts an unpopular policy. When the policy is moderately popular, the incumbent enacts the policy *immediately*. This is because the incumbent's reelection in this case hinges on the policy producing a demonstrable success. Since the realization of a success may be delayed, the incumbent must enact the policy as early as possible to maximize its chances of success. On the other hand, if the policy is highly popular, then the incumbent has an incentive to delay enacting it. Doing so ensures the voters' confidence in the reform remains high even if a success is not observed, and forces them to reelect the incumbent to see it through. These results are robust to the presence or absence of sabotage, but the threat of sabotage deters the incumbent from enacting some moderately popular policies.

In deciding whether to sabotage, the opposition faces the following trade-off. Sabotage delays the arrival of a policy success, but it can also backfire since it may cause voters to attribute a lack of success to sabotage—that is, it may divert blame away from the incumbent. We show that the optimal use of sabotage depends on the popularity of the policy. In particular, popular policies that are enacted late in the term are not sabotaged. The reason is that, if public confidence in the reform remains high even in the absence of a success, there is no value in preventing a success. However, the opposition does sabotage moderately popular policies, as in this case the incumbent needs a proven success to survive. In this case, we also find that the intensity of sabotage increases over time as the next election draws near.⁸

In Section 5, we present a variant of our model that allows the opposition to obstruct the policy in the legislature, in addition to (or as an alternative to) engaging in ex post sabotage. This extension of our model serves as a unifying framework for thinking about both types of obstructionist tactics, and is rich in implications. In particular, we find that if the policy is

⁷The opponent may dislike the reform in itself or simply want to ensure its failure in order to gain a political advantage. The model accommodates either interpretation.

⁸Though not directly related to our setting, empirical studies on legislative obstruction suggest that dilatory tactics such as the filibuster are indeed used more frequently near the end of a Congressional session (Binder, Lawrence and Smith, 2002; Wawro and Schickler, 2007).

moderately popular, the incumbent will attempt to pass it early on, but give up on it after a certain point. The opposition will make only a moderate effort to block it in the legislature, but if it does pass, he will then exert serious effort to sabotage it. On the other hand, if the policy is very popular, then the incumbent will most want to pass it towards the end of her term. The opposition has the strongest incentive to block such late attempts, but paradoxically, these are the only attempts that will *not* be followed by sabotage if successful. Naturally, because our results concern the timing of decisions within a term, they depend on the institutional details of the electoral system. In our main model, the election date is fixed and known—a good approximation of politics in the U.S. and other presidential systems. On the other hand, in many parliamentary democracies, there are various ways an election may be triggered before the end of the incumbent’s term, so the election calendar is uncertain. In Section 6, we explore policy sabotage in this alternative setting.⁹ We show that in this case, the incumbent never has an incentive to delay policy experiment—in other words, the honeymoon effect always prevails, unlike in the benchmark setting. The opposition, as before, sabotages only if the policy is moderately popular, but the intensity of sabotage is now *decreasing* over time.

Literature

By and large, the scholarly literature has focused on the obstruction of policies during the legislative process (for example, Cox and McCubbins 2007; Binder, Lawrence and Smith 2002; Woon and Anderson 2012; Wawro and Schickler 2007; Krehbiel 1998). Recent work by Fong and Krehbiel (2018) and Patty (2016) provide theoretical rationales for dilatory tactics as a form of legislative obstruction. The former focuses on how the threat of delay alters the composition of bills to be proposed by the agenda setter; the latter suggests obstruction allows legislators to signal their ideology or competence.

The only theoretical analysis of policy sabotage that we are aware of is a contemporaneous paper by Hirsch and Kastellec (2019). In their model, the incumbent is non-strategic and the opponent decides whether to sabotage the policy, which serves as a signal of the incumbent’s ability. As in our paper, sabotage potentially diverts blame from the incumbent and is useful only when the incumbent is “somewhat unpopular.” However, their model is static in nature

⁹Specifically, we allow the incumbent to call an election at any time, as well as the possibility of elections being triggered by exogenous events (e.g., votes of no confidence).

and therefore cannot speak to the timing of the incumbent’s decision to enact policies nor the dynamics of policy sabotage.

Our model predicts that the incumbent sometimes has an incentive to delay enacting a policy. This is reminiscent of the observation in the political business cycles literature that incumbents sometimes pursue policies with short-term benefit (but possibly long term costs) near the end of the electoral cycle (Nordhaus, 1975; Drazen, 2000). There are also several studies that sought to explain the delaying of reforms, such as macro-economic stabilizations, as resulting from a war of attrition between political factions who want to avoid taking on the burden of the reform (Alesina and Drazen, 1989; Drazen and Grilli, 1993; Orphanides, 1996; Martinelli and Escorza, 2007).

Finally, from a technical perspective, our model is related to the literature on experimentation with “good news” exponential bandits (e.g., Keller, Rady and Cripps 2005; Keller and Rady 2010). Within this literature, Hwang (2018) studies policy experimentation with potential political turnover, and explores the welfare impact of the frequency of elections. Bowen et al. (2016) studies policy experimentation by an incumbent who has career concerns. They find that the politician decreases the intensity of reform effort over time in the absence of success. The focus of these papers is on the strategic incentive to exert effort to accelerate the implementation of a policy. In contrast, we focus on policy sabotage, which retards the implementation of the policy.

2 The Model

There are two players, an incumbent I and an opponent (e.g., an opposition party) O . Time $t \in [0, T]$ is continuous and there is no discounting.¹⁰ The incumbent is in office starting at $t = 0$, and at $t = T$ the next election takes place, at which point voters choose whether to reelect the incumbent.

The incumbent can choose to enact a proposed policy at any time $t \in [0, T]$ during her term. This action is assumed to be irreversible: once the policy is enacted, the incumbent is committed to it.¹¹ Furthermore, we assume that the policy will be continued beyond the next election if the incumbent is reelected and terminated otherwise. As a result, the election

¹⁰The results would not change qualitatively if we introduced time discounting.

¹¹As Przeworski (1991, pg. 169) noted, there are political costs associated with giving up on a reform. People lose trust in the government if reforms are seen as having failed.

becomes an implicit referendum on the policy: any inference voters make about the policy itself will affect the incumbent’s odds of reelection.¹²

There is uncertainty about whether the policy will ultimately succeed and, if so, how long it will take for a success to materialize. Specifically, under the status quo, voters obtain a flow payoff θ , normalized to zero. If the policy is enacted, then voters receive a baseline flow payoff $\theta - \alpha$. Substantively, α represents the cost of financing or administering the policy.¹³ If the policy is *good*, it generates publicly observed *successes* at a Poisson rate¹⁴ $\lambda > 0$, and voters obtain a lump-sum payoff of 1 from each success. If the policy is *bad*, it never succeeds. The ex ante probability that the policy is successful is $p \in (0, 1)$, which we will refer to as the *popularity* of the policy. To make the problem non-trivial, we assume $\lambda > \alpha > 0$, which implies that a good policy is beneficial to welfare, while a bad one is detrimental.¹⁵

It is worth noting that the assumption that the payoff from a good policy comes in “lumps” is mostly for ease of exposition. Our results would hold qualitatively under the following alternative payoff structure, which we will refer to as the *delayed completion* case: the net flow payoff to voters is $-\alpha$ if the reform has not yet succeeded; once the reform succeeds, the net flow payoff increases to $\lambda - \alpha$ permanently, and no further successes are possible. A good reform’s time to success is exponentially distributed with rate λ , while a bad reform never succeeds. This case has a natural interpretation: for instance, if the policy in question involves the building of infrastructure, its success means that the project has been completed and can be used by the public, whereas a lack of success denotes a (potentially endless) delay in completion.

The incumbent is office-motivated: she obtains a payoff 1 from winning the election at time T and 0 from losing. Given our assumption that the election is an implicit referendum on the policy, the incumbent is reelected if voters have sufficient confidence in the policy at the time of the election. Specifically, if we let μ_t be the voters’ (posterior) belief at time t that the policy is good, it is optimal for voters to reelect the incumbent iff $\lambda\mu_T \geq \alpha$.¹⁶ If the

¹²An alternative set of assumptions yielding the same results is that the policy can be abandoned by the incumbent, or taken up by the opponent himself after time T , but the likelihood of the policy being *good*, as defined below, is related to the incumbent’s valence. If so, an unsuccessful policy would reflect negatively on the incumbent herself, even if renounced. Framed this way, the incumbent’s behavior would be driven by *career concerns* (Holmström, 1999).

¹³Alternatively, it could be an adjustment cost if we think of the policy as a structural reform.

¹⁴This means that, over a period of length ϵ , the policy has an approximate probability $\lambda\epsilon$ of succeeding. See Billingsley (2008) for details.

¹⁵Specifically, the net flow payoff from the policy is $\lambda\mu - \alpha$, from the point of view of an agent who believes the policy is good with probability μ .

¹⁶For simplicity, we assume voters reelect the incumbent if they are indifferent, that is, if $\lambda\mu_T = \alpha$.

incumbent does not enact the policy (status quo), her reelection probability is assumed to be $\frac{1}{2}$.¹⁷

The opponent can sabotage the policy once it is enacted. Formally, the opponent exerts effort $s(t) \in [0, \lambda)$ at each instant t at a flow cost $c(s(t))$.¹⁸ $s(t)$, which we will also refer to as the intensity of sabotage, is publicly observed by voters, and it affects the incumbent's policy as follows: under a given intensity of sabotage s , the success rate of a good policy is reduced to $\lambda - s$. Naturally, a bad policy never succeeds, regardless of the opponent's action. Intuitively, sabotage should be understood as partially obstructing the implementation of the policy, for instance by challenging it in the courts, pressuring local politicians not to cooperate with the new policy, organizing protests or strikes, etc. Such actions are costly to the opponent and readily observed by voters.

The opponent's cost of effort is assumed to have the following standard properties: c is twice continuously differentiable, with $c(0) = c'(0) = 0$, $c''(s) > 0$ for $s \in [0, \lambda)$ and $c(s) \rightarrow +\infty$ as $s \rightarrow \lambda$. In other words, effort to sabotage becomes more costly at an increasing rate, and fully sabotaging the policy for any length of time is prohibitively expensive.¹⁹ The opponent's goal is to defeat the incumbent, obtaining a payoff of 1 if the incumbent loses her reelection bid and 0 otherwise.

The solution concept we use is Perfect Bayesian Equilibrium. The proofs are relegated to the Appendix.

3 Benchmark: No Sabotage

As a benchmark, we first consider the case where the incumbent can enact and implement the policy unopposed.

The voters' posterior belief μ_t can be calculated using Bayes' rule, as follows. If the policy has not been enacted, $\mu_t = p$, as no information is generated. If the policy has succeeded, $\mu_t = 1$: voters become certain that the policy is good. If the policy was enacted at time

¹⁷The results are qualitatively similar if, conditional on no reform being undertaken, the incumbent has a probability $q \in (0, 1)$ of being reelected. One justification is that absent a "signature" policy, the incumbent will be evaluated along other dimensions (e.g., valence) which we can take to be exogenous and probabilistic.

¹⁸Note that we allow the opponent's effort to vary over time.

¹⁹To fix ideas, the reader may consider the case $c(s) = \frac{c}{2}s^2$ for $s \in [0, \lambda]$, where c is large enough that $s = \lambda$ is never optimal.

$t_0 \leq t$, and has not yet succeeded, then

$$\mu_t = \frac{pe^{-\lambda(t-t_0)}}{pe^{-\lambda(t-t_0)} + 1 - p}. \quad (1)$$

This expression is strictly decreasing in t : voters become more pessimistic about the policy the longer it fails to succeed. Thus, our model naturally incorporates the idea of "reform fatigue", which is common in the literature.²⁰

The following Proposition summarizes the incumbent's equilibrium strategy.

Proposition 1. *There are thresholds \underline{p} , \bar{p} such that:*

1. *If $p \geq \bar{p}$, it is optimal for the incumbent to enact the policy at any time $t \in [t^*(p), T]$, where $t^*(p)$ satisfies*

$$\mu_T = \frac{pe^{-\lambda(T-t^*(p))}}{pe^{-\lambda(T-t^*(p))} + 1 - p} = \frac{\alpha}{\lambda},$$

and she is always reelected.

2. *If $\underline{p} \leq p < \bar{p}$, the incumbent enacts the policy at time $t = 0$, and she is only reelected if the policy succeeds.*
3. *If $p < \underline{p}$, the incumbent never enacts the policy.*

Moreover, $\bar{p} = \frac{\alpha}{\lambda}$ and $\underline{p}(1 - e^{-\lambda T}) = \frac{1}{2}$.

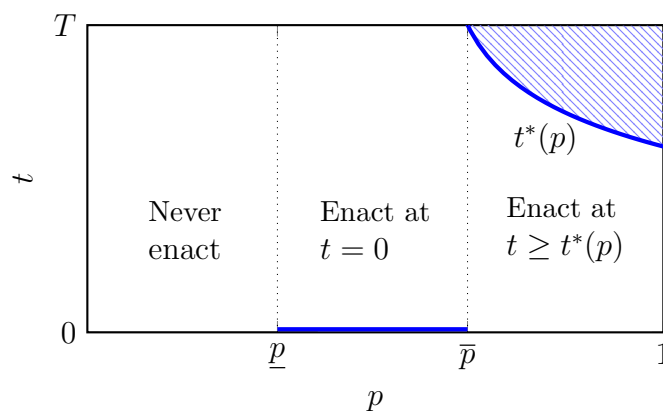


Figure 1: Incumbent's equilibrium strategy

²⁰See Bruno (1993); Lora, Panizza and Quispe-Agnoli (2003); Tommasi and Velasco (1996).

As illustrated in Figure 1, the optimal time for the incumbent to enact the policy is non-monotonic in the policy’s initial popularity p . Assuming that $\underline{p} < \bar{p}$, there are three distinct regions. When the reform is very popular *ex ante* ($p > \bar{p}$), the incumbent is willing to enact the policy at any time $t \geq t^*(p)$, where $t^*(p)$ is decreasing in p .²¹ In this case, the incumbent can get reelected on the basis of voters’ optimistic prior beliefs about the policy, instead of a demonstrable success; she has no incentive to enact the policy early, as this would only create an opportunity for reform fatigue to set in. Our model thus rationalizes the somewhat puzzling observation that policymakers sometimes drag their feet in adopting policy or reform that are highly promising (Rodrik, 1996).

When the policy is moderately popular, that is, $p \in (\underline{p}, \bar{p})$, the incumbent enacts the policy at $t = 0$, a result that corresponds to the so-called honeymoon effect (McCarty, 1997; Frensdreis, Tatalovich and Schaff, 2001; Grossback, Peterson and Stimson, 2005). In this case, the policy must prove its worth in order for the incumbent to be reelected. Since the incumbent is optimistic enough about the policy, she commits to it—and gives it the best possible chance of success by starting early. Finally, for $p < \underline{p}$, the incumbent has no incentive to enact the policy at any time, as she is too pessimistic about its odds of ever succeeding.

In terms of social welfare, the incumbent’s behavior is potentially inefficient in both directions. When $p > \bar{p}$, voters would prefer the policy to be enacted at time $t = 0$, but the incumbent delays it until $t^*(p)$. For $p < \bar{p}$, both the voters and the incumbent prefer to enact the policy at $t = 0$ if at all, but their thresholds may differ: The incumbent may be too cautious or too adventurous compared to the public, depending on the parameters of the model.²²

4 Equilibrium with Policy Sabotage

We now introduce the main scenario of interest, in which an opponent may sabotage the implementation of the policy. Recall that the intensity of sabotage is publicly observed. Thus, while sabotage delays success, voters react rationally to sabotage by being *less* pessimistic about the policy in the absence of a success. In other words, the public (correctly) attributes some of the blame for the policy’s current failure to the opponent. It is therefore not

²¹If we perturb the model to give the incumbent a small incentive to learn about the quality of the reform (e.g., due to social welfare concerns), she would have a strict incentive enact the policy at exactly $t^*(p)$.

²²For instance, if we generalize the incumbent’s probability of winning with no reform to an arbitrary q , high values of q make the incumbent too cautious, as reelection is almost assured even without any attempt at reform, while low values of q drive the incumbent to take too many risks, a form of gambling for resurrection.

straightforward whether sabotage will help the opponent or, rather, play into the hands of the incumbent.

Formally, the voters' posterior belief at time t given that the policy was enacted at $t_0 \leq t$; no success has been observed thus far; and the opponent follows sabotage strategy s , is

$$\mu_t = \frac{pe^{-\int_{t_0}^T (\lambda - s(t)) dt}}{pe^{-\int_{t_0}^T (\lambda - s(t)) dt} + 1 - p}. \quad (2)$$

Comparing this to Equation 1, it can be seen that μ_t is higher in the face of sabotage, i.e., voters update less negatively after a lack of success when the policy was sabotaged.

Proposition 2 below characterizes the equilibrium. Substantively, it explains how the opponent's decision to sabotage depends on the policy's initial popularity; how the intensity of sabotage varies over time; and how the threat of sabotage influences the incumbent's decision whether to enact the policy in the first place.

Proposition 2. *Let \bar{p} , \underline{p} and $t^*(p)$ be as defined in Proposition 1. There is a set $P \subsetneq [\underline{p}, \bar{p}]$ such that:*

1. *If $p \geq \bar{p}$, it is optimal for the incumbent to enact the policy at any time $t \in [t^*(p), T]$; the opponent does not obstruct on the equilibrium path, and the incumbent is reelected regardless of whether a success has been observed.*
2. *If $p \in P$, it is optimal for the incumbent to enact the policy at $t = 0$, and the opponent exerts effort to sabotage at a positive and increasing rate, i.e., $s(t) > 0$ for all $t \in [0, T]$ and $s(t)$ is strictly increasing in t . The incumbent is reelected iff there is a success.*
3. *If $p < \bar{p}$ and $p \notin P$, the incumbent does not enact the policy.*

The first insight of Proposition 2 is that the threat of sabotage does not affect the incumbent's incentive to enact the policy when it is either unpopular ($p < \underline{p}$) or very popular ($p > \bar{p}$). In particular, when the policy is very popular, the opponent has no reason to sabotage it since the incumbent can maintain sufficiently high public confidence even in the absence of a demonstrable success.

However, sabotage may deter the incumbent from enacting moderately popular policies (i.e., $\underline{p} < p < \bar{p}$), though the timing of the policy, conditional on the incumbent's decision to

enact, is unaffected by the prospect of sabotage.²³ Here, the lack of a demonstrable success will result in the incumbent's removal from office. Thus, the opponent has an incentive to sabotage the policy. Anticipating this, the incumbent may choose not to pursue the policy at all. Interestingly, the incumbent's net incentive to enact the policy in this case is not necessarily monotonic in the policy's popularity. The reason is that, while a more popular policy is more likely to succeed if left to its own devices, it also gives the opponent a greater incentive to engage in sabotage. Whether more popular policies are more likely to be enacted then depends on which effect dominates.

The proposition also shows that, when the opponent sabotages, he begins immediately upon the enactment of the policy and increases his effort as the next election approaches. The reason is as follows: the opponent's gain from preventing a success immediately before the election is large, as this amounts to the difference between certain defeat and certain victory. In contrast, preventing a success earlier in the incumbent's term may or may not end up mattering in the long run—after all, if the reform is fundamentally sound, it may still succeed later. This argument suggests that the opponent would prefer to fully postpone his efforts to sabotage until close to the end of the term; however, this is prohibitively costly given the increasing marginal cost of effort. The opponent therefore spreads out his effort over time, while increasing it close to the election.

It is worth noting that our model treats the incumbent and opponent asymmetrically after the policy is enacted: the opponent can modulate the intensity of sabotage over time, whereas the incumbent has no further strategic actions at her disposal. This modeling choice is not essential to the results. Indeed, our model can be extended to allow the incumbent to choose a time-varying level of effort e_t which accelerates the implementation of the policy, at a cost. Under such assumptions, the incumbent's effort will increase close to the election, just like the opposition's effort to sabotage. The logic is similar: a success right before the election is the difference between certain defeat and certain victory. In contrast, the stakes are lower earlier on, because even in the absence of an early success the incumbent has some probability of succeeding and securing reelection later.

²³Namely, only a strict subset of the policies with popularity $p \in [\underline{p}, \bar{p}]$ are enacted under the threat of sabotage.

5 Legislative Obstruction

Our model assumes that the incumbent is able to enact the policy whenever she pleases, and the opponent is only able to sabotage its implementation *ex post*. This is a reasonable assumption if the reform can be set in motion by means of an executive order, or if the incumbent has a legislative majority.

Often, the opponent has a chance to block the policy at the legislative stage—that is, before the policy is passed—in addition to possibly sabotaging it after it passes. The natural question that arises then is how the opponent should deploy both tactics. Specifically, how does the possibility of sabotage affect the opponent’s incentive to block the policy in the legislature? And how does the optimal combination of legislative opposition and sabotage depend on the popularity of the policy being opposed? Our model can be extended to answer these questions, and in so doing, provide a unified framework for thinking about legislative obstruction and sabotage.

We extend our model as follows. Suppose that at each instant $t \in [0, T]$ the incumbent chooses whether or not to *campaign* to pass the policy (bill) through the legislature. While the incumbent campaigns, the bill is passed at a Poisson rate $\tilde{\lambda} - b(t)$ at each instant t , where $\tilde{\lambda}$ is the baseline rate at which the bill passes and $b(t)$ is the level of effort made by the opponent to block its passage.²⁴ Legislative obstruction, too, is costly: the opponent pays a flow cost $\tilde{c}(b_t)$ for it, satisfying the same assumptions as c in Section 4.²⁵ In a nutshell, what we have added to the model is a degree of uncertainty—which the opponent can influence—about when the policy will be enacted.

For simplicity, we assume that the rate at which the bill passes is independent of its type—that is, the legislature is not able to discern whether the policy will be a success.²⁶ If the bill eventually passes at a time $t' \geq t$, the continuation game is exactly the same as would have been obtained in Section 4 assuming the incumbent chose to enact the policy at time t' .

Proposition 3 below characterizes the equilibrium of the game in the legislative stage (as the equilibrium conditional on the bill passing is as described in Section 4). To help state the result, we make two clarifications about notation. First, as in Proposition 1, \bar{p} denotes the threshold on the policy’s popularity above which the incumbent can ensure reelection (by delaying enactment), and $t^*(p)$ denotes the earliest time at which passing a popular policy

²⁴Naturally, the model in Section 4 is a special case of this setting in which $\tilde{\lambda}$ is infinite.

²⁵That is, \tilde{c} is C^2 , $\tilde{c}(0) = \tilde{c}'(0) = 0$, $\tilde{c}''(b) > 0$ for $b \in [0, \tilde{\lambda})$ and $\tilde{c}(b) \rightarrow +\infty$ as $b \rightarrow \tilde{\lambda}$.

²⁶This assumption guarantees that no learning about the reform happens at the legislative stage.

guarantees reelection. Second, we let $t_*(p)$ denote the time such that, if the bill passes at time $t_*(p)$, the probability of observing a success—taking the equilibrium level of sabotage into account—would equal $\frac{1}{2}$.²⁷

Proposition 3. *The equilibrium strategies at the legislative stage are as follows.*

- (i) *If $p \leq \bar{p}$, the incumbent campaigns to pass the bill through the legislature during the period $[0, t_*(p)]$.²⁸ The opponent's effort to block the bill $b(t)$ is single-peaked over $[0, t_*(p)]$.*
- (ii) *If $p > \bar{p}$, the incumbent campaigns to pass the bill during $t \in [0, \tilde{t}_*] \cup [t^*(p), T]$ for some $\tilde{t}_* < t_*(p)$. The opponent's effort to block the bill $b(t)$ is single-peaked over $[0, \tilde{t}_*]$ and increasing over $[t^*(p), T]$. Moreover, if obstruction is not too costly,²⁹ the opponent's effort to block the bill later in the term is greater than earlier in the term i.e., for all $t \in [t^*(p), T]$ and $t' \in [0, \tilde{t}_*]$, $b(t) > b(t')$.*

Proposition 3 shows firstly that the incumbent will try to pass the bill early if the proposed policy is moderately popular (i.e., $p \leq \bar{p}$). The underlying logic mirrors our previous results: since a moderately popular policy must succeed to get the incumbent reelected, the incumbent's gain from passing it decreases over time. More specifically, after time $t_*(p)$, the incumbent's baseline reelection probability is higher than if the policy is enacted, so she abandons it altogether.

Figure 2 illustrates the Proposition for the case of a highly popular policy ($p > \bar{p}$). Interestingly, in this case the incumbent's incentive to pass the bill is non-monotonic: she will campaign early on, but if the bill does not pass quickly, she will then put the bill on hiatus until time $t^*(p)$. Of course, the incumbent now has an incentive to campaign after $t^*(p)$, as passing a popular bill late guarantees victory. For $t < t^*(p)$ the same logic applies as in the case $p \leq \bar{p}$, except that now, the probability of reelection conditional on *not* passing the bill by time $t^*(p)$ is no longer $\frac{1}{2}$; it is higher because the incumbent will have a chance to win by passing the bill later on (during $[t^*(p), T]$). Hence the cutoff for early attempts to pass the bill, \tilde{t}_* , is reached strictly earlier than the analogous cutoff when the policy is moderately popular, $t_*(p)$.

When the incumbent campaigns for the bill after $t^*(p)$, the opponent's incentive to block it is increasing in t . The reason is similar to the logic of increasing sabotage discussed in

²⁷To be precise, we present the results of Proposition 3 under the assumption that this time is smaller than $t^*(p)$. If not, the same results hold if we define $t_*(p) = t^*(p)$.

²⁸Note that, for low enough p , the incumbent will not attempt to pass the bill; this simply means $t_*(p) \leq 0$.

²⁹Formally, there is $\eta > 0$ such that this statement holds for any \tilde{c} such that $\tilde{c}((\tilde{c}')^{-1}(1)) < \eta$.

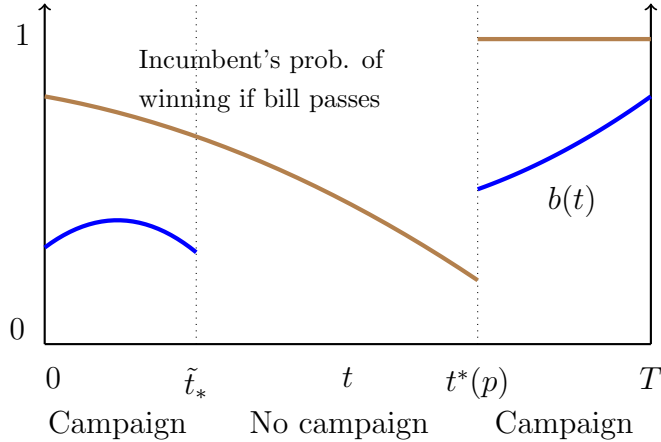


Figure 2: Equilibrium in the legislative stage for $p > \bar{p}$

Section 4: successfully blocking the passage of the bill close to the end of the term—and hence preventing a sure win for the incumbent—has a greater impact on the election. On the other hand, the opponent’s incentive to block early attempts to pass the bill (during the period $[0, t_*(p)]$) may be non-monotonic. The reason is that, over the course of this period, the passage of the bill becomes better for the opponent—as a policy enacted later has a lower chance of succeeding—but the opponent’s payoff from successfully blocking the bill also increases. In general, the path of effort depends on the interplay between these two forces.

Our results indicate that there is a complex relationship between the popularity of a policy and the intensity and type of opposition it faces. For instance, if a popular policy passes at a time $t > t^*(p)$, then the opponent would not attempt to sabotage it. Thus, to an outside observer, it would appear that the opponent tried hard to block the policy at the legislative stage, but forwent any opportunity to sabotage it after its passage. On the other hand, if a policy passes early on, we would observe that the opponent did not try very hard to block the bill, but then severely sabotaged its implementation afterward.³⁰ In particular, then, it is neither the case that more popular policies are opposed more strongly at every stage, nor the reverse.

³⁰These observations leverage our results on obstruction from Section 4, where we show that popular late reforms are not obstructed, but unpopular early reforms are.

6 Uncertain Timing of Elections

Our results so far rely implicitly on the assumption that the date of the election, T , is commonly known to all players. This assumption is a good fit for democracies with separation of powers, but may not describe other types of democracies such as parliamentary systems, where new elections may be called by the incumbent, or triggered by a vote of no confidence engineered by the opposing party.

In this section, we modify the model in Section 2 to allow for these possibilities. The results shed lights on the implications of alternative electoral institutions. Formally, we assume instead of an election at a known date T that the next election arrives at a Poisson rate $\delta(\mu) > 0$. $\delta(\mu)$ is assumed to be a decreasing function of μ , the voters' posterior belief about the incumbent's policy. This assumption is motivated by two empirical regularities about parliamentary systems: breakdowns of the ruling coalition are inherently unpredictable, but they are less likely to occur when the incumbent is popular. We also allow the incumbent to call for a new election at any time t .

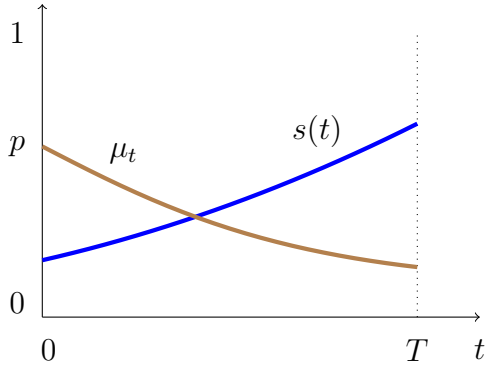
Proposition 4 below shows that, unlike in the case with a known election date, here the incumbent either enacts the policy immediately or never does—there is no delay. Also, the opponent's effort to sabotage (if positive) is decreasing over time, in contrast to the model in Section 2.

Proposition 4.

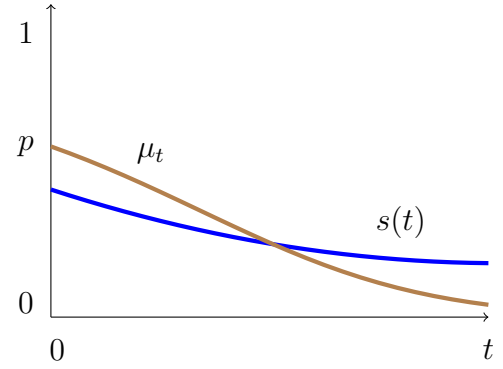
- (i) *If $p > \bar{p}$, the the incumbent enacts the policy at $t = 0$, and then immediately calls for a new election, and wins.*
- (ii) *For $p < \bar{p}$, if the incumbent enacts the policy, the opponent will always sabotage it on the equilibrium path, i.e., $s(t) > 0$ for all t . Moreover, as long as δ is not too sensitive to μ , the intensity of sabotage decreases over time. The incumbent enacts the policy at time $t = 0$, if at all.*

The logic behind the incumbent's actions when $p > \bar{p}$ is similar to the case of a fixed election date: she can ensure reelection by enacting the policy and then calling for an election right away, while the public's confidence in the policy is still high. The difference is that now the incumbent has no need to wait until shortly before a future date T .

It is worth noting that, when $p < \bar{p}$, the opponent's behavior with an uncertain deadline (as illustrated in Figure 3b) is dramatically different than in the case of a fixed election



(a) Sabotage with a certain deadline



(b) Sabotage with an uncertain deadline

Figure 3: Effect of an uncertain deadline

date (illustrated in Figure 3a): the intensity of sabotage when the election date is uncertain is *decreasing* over time. The intuitive reason is that the longer the policy goes without generating a success, the more pessimistic all agents—including the opponent—become about it, i.e., μ_t decreases over time. When the opponent believes the policy is unlikely to ever succeed, sabotage is no longer necessary. Of course, this intuition also applies in the case with a known deadline. However, a known deadline generates a countervailing incentive for the opponent to increase the intensity of sabotage over time, because preventing a success right before the election is especially valuable.

7 Conclusion

In this paper we developed a dynamic model of policymaking under the threat of sabotage. Our model shows firstly that electoral concerns will often induce the incumbent to make socially suboptimal choices: she will delay enacting popular policies, and she may be too cautious or too eager to enact moderately popular policies. Secondly, we find that the opponent will sabotage only policies that are not too popular. Hence, the prospect of sabotage may deter the incumbent from enacting moderately popular policies, but not very popular ones. Thirdly, we show that the opponent’s incentive to sabotage increases as the election draws near.³¹

³¹There is anecdotal evidence of obstructionism that intensifies close to elections. An example is found in Supreme Court appointments: after the death of Antonin Scalia in February of 2016, Senate Republicans refused to fill the vacant seat until after the next presidential election. Presumably, they would have behaved differently if the next election had been years away, or if they did not know when it would happen.

We also explore policy sabotage under an alternative electoral system in which the incumbent can call elections or exogenous circumstances may trigger an election. As shown in Section 6, in this case the incumbent has no incentive to delay enacting policies, and the opponent's incentive to sabotage decreases over time. These results suggest that presidential and parliamentary systems may induce systematically different patterns of policy sabotage.

Putting the substantive insights aside, we believe our paper also makes a methodological contribution by developing a novel framework to study dynamic political conflicts over policymaking. The framework is parsimonious and various extensions are possible in addition to the ones covered in this paper. For example, one could consider policies that have immediate benefits but potential long-term costs, such as an expansive monetary policy.³² We could also allow for costly effort by the incumbent, unobserved sabotage, etc.

A more challenging extension would be to allow for the incumbent—or the opponent—to have private information about the policy or the cost of sabotage. Any such addition to the model will introduce signaling concerns: the incumbent's decision to enact a policy may signal to the voters that the policy is promising, a force that would make the incumbent more willing to enact policies, even unsound ones. On the other hand, the opponent may choose *not* to sabotage the policy in an attempt to show voters that the policy is of low quality, and so sabotaging is unnecessary. Alternatively, the opponent may heavily sabotage the policy early on in order to signal to the incumbent that his cost of sabotage is low, and so to deter the incumbent from continuing with the policy.

Another potential avenue to be explored in future work is to allow for more sophisticated responses by the voters. In the current paper, in order to focus on the strategic interaction between the incumbent and her opponent, we have made simplifying assumptions about the voters' behavior—namely, we have assumed that votes are based purely on beliefs about the incumbent's policy. However, voters may find blatant policy sabotage distasteful and punish the opponent for it. Alternatively, they may interpret the incumbent's inability to overcome sabotage as a sign of weakness.

³²Such a policy increases output but may cause an inflationary spike later. Another example could be the building of a nuclear power plant, which may cause a nuclear disaster if built improperly; or the deployment of a new technology, such as self-driving cars. We can accommodate these examples formally by assuming that the reform generates *failures* at some rate if it is unsound.

A Proofs

Proof of Proposition 1. If $p\lambda \geq \alpha$, i.e., if $p \geq \bar{p} = \frac{\alpha}{\lambda}$, I can guarantee herself reelection by initiating the reform at time T , or more generally at any time t such that $\lambda\mu_t \geq \alpha$, i.e.,

$$\frac{pe^{-\lambda(T-t)}}{pe^{-\lambda(T-t)} + 1 - p} \geq \frac{\alpha}{\lambda}.$$

Consider the left-hand side as a function of t . This function is strictly and continuously increasing in t , weakly greater than the right-hand side for $t = T$, and strictly smaller than the right-hand side for arbitrarily negative t . Therefore, there is a unique value of t , denoted by $t^*(p)$, for which the equality holds. (Of course, if $t^*(p) < 0$, then I can initiate the reform at any feasible time, i.e., $t \in [0, T]$.)

If $p\lambda < \alpha$, then no matter when I initiates the reform she then needs to succeed to be reelected. Indeed, if the reform is initiated at t_0 , $\mu_{t_0} = p < \frac{\alpha}{\lambda}$ and μ_t is strictly decreasing in t , so reelection after an unsuccessful reform is impossible.

Clearly, in that case it is best to initiate the reform as early as possible, if at all, to maximize the chance of having a success. $p(1 - e^{-\lambda T})$ is the probability of a success by time T , conditional on starting the reform at time 0. If this expression is greater than $\frac{1}{2}$, I is better off reforming at $t = 0$; if it is smaller, I is better off not reforming at all. \square

Proof of Proposition 2. In the first case, when $p \geq \bar{p} = \frac{\alpha}{\lambda}$, I can win with probability 1 no matter what O does, by picking a reform time $t \in [t^*(p), T]$. Clearly, in equilibrium I picks any such t and O strictly prefers not to obstruct, as obstruction is costly, but any level of obstruction cannot prevent I from winning for sure.

Else if $p < \bar{p}$, whenever I reforms, she must succeed to be reelected. Suppose then that $p < \bar{p}$ and I reforms at time t_r . Given an obstruction path s , let $\Lambda(t) = \int_0^t (\lambda - s(t'))dt'$ be the amount of experimentation up to time t , and let $q(t) = pe^{-\Lambda(t)} + 1 - p$ be the probability that I has not succeeded by time t .³³ Then O 's expected utility is

$$U(s) = q(T) - \int_0^T q(t)c(s(t))dt$$

and O chooses s to maximize this expression, subject to $s(t) = 0$ for $t < t_r$.

³³Formally, we only consider obstruction strategies s that are Lebesgue-measurable, as otherwise the probability of success is undefined.

We solve O 's problem by using techniques from variational calculus (see Kamien and Schwartz (1991), Section 3; Evans (2010), Chapter 8).

Consider first the case $t_r = 0$. Suppose that s is an optimal obstruction strategy, and that $s(t) \in [\epsilon, \lambda - \epsilon]$ for all t , for some $\epsilon > 0$. (We discuss what happens if these assumptions do not hold at the end.) For any $t_0 \geq 0$, the FOC at time t_0 requires that

$$pe^{-\Lambda(T)} - q(t_0)c'(s(t_0)) - \int_{t_0}^T c(s(t))pe^{-\Lambda(t)}dt = 0. \quad (3)$$

This can be formalized as follows. Define $s(t, \eta) = s(t) + \eta h(t)$, where $h(t)$ is a Lebesgue-measurable, bounded function from $[0, T]$ to \mathbb{R} . Denote $s(\eta) = s(\cdot, \eta)$. Then

$$U(s(\eta)) = q(T, \eta) - \int_0^T q(t, \eta)c(s(t, \eta))dt.$$

This expression is differentiable as a function of η . Since $s = s(0)$ is optimal, it must be a critical point, i.e.,

$$\frac{\partial U(s(\eta))}{\partial \eta} = \frac{\partial q(T, \eta)}{\partial \eta} - \int_0^T \left[\frac{\partial q(t, \eta)}{\partial \eta} c(s(t, \eta)) + q(t, \eta)c'(s(t, \eta)) \frac{\partial(s(t, \eta))}{\partial \eta} \right] dt$$

must vanish for $\eta = 0$. Note that $\frac{\partial s(t, \eta)}{\partial \eta} = h(t)$, $\frac{\partial \Lambda(t, \eta)}{\partial \eta} = -\int_0^t h(t')dt' := -H(t)$ and $\frac{\partial q(t, \eta)}{\partial \eta} = -p \frac{\partial \Lambda(t, \eta)}{\partial \eta} e^{-\Lambda(t, \eta)}$. Thus

$$0 = pH(T)e^{-\Lambda(T)} - \int_0^T [pH(t)e^{-\Lambda(t)}c(s(t)) + q(t)c'(s(t))h(t)] dt.$$

Now suppose Equation 3 does not hold a.e., and without loss of generality the left-hand side is positive on a set of positive measure $A \subseteq [0, T]$. Take $h(t) = \mathbb{1}_{t \in A}$. Then

$$\begin{aligned} 0 &= p|A|e^{-\Lambda(T)} - \int_0^T (|A \cap [0, t]|pe^{-\Lambda(t)}c(s(t)) + q(t)c'(s(t))\mathbb{1}_{t \in A}) dt = \\ &= \int_A \left(pe^{-\Lambda(T)} - q(t)c'(s(t)) - \int_t^T c(s(t'))pe^{-\Lambda(t')}dt' \right) dt > 0, \end{aligned}$$

a contradiction. Hence Equation 3 holds a.e. Since obstruction strategies differing in a set of measure zero are equivalent, we can assume WLOG that Equation 3 holds everywhere.

Now, taking the difference between the FOC at two times $t_0 < t_1$, we obtain

$$\begin{aligned} c'(s(t_0))q(t_0) + \int_{t_0}^T c(s(t))pe^{-\Lambda(t)}dt &= c'(s(t_1))q(t_1) + \int_{t_1}^T c(s(t))pe^{-\Lambda(t)}dt \\ \int_{t_0}^{t_1} c(s(t))pe^{-\Lambda(t)}dt &= c'(s(t_1))q(t_1) - c'(s(t_0))q(t_0), \end{aligned}$$

which implies that $c'(s(t))q(t)$ is continuous in t . Since $q(t) > 0$ is continuous in t , so is $c'(s(t))$. As $c' > 0$ and $c'' > 0$, c' is invertible, so this implies $s(t)$ is itself continuous, and Λ , q are differentiable. In addition, it now follows that $c'(s(t))q(t)$ is differentiable, with derivative $c(s(t))pe^{-\Lambda(t)}$. In turn, $c'(s(t))$ is differentiable, so $s(t)$ is differentiable. Then we can write

$$\begin{aligned} c(s(t))pe^{-\Lambda(t)} &= (qc'(s))'(t) = q'(t)c'(s(t)) + q(t)c''(s(t))s'(t) \\ c(s(t))pe^{-\Lambda(t)} &= -p(\lambda - s(t))e^{-\Lambda(t)}c'(s(t)) + (pe^{-\Lambda(t)} + 1 - p)c''(s(t))s'(t) \\ c(s(t))p &= -p(\lambda - s(t))c'(s(t)) + (p + (1 - p)e^{\Lambda(t)})c''(s(t))s'(t) \\ s'(t) &= \frac{c(s(t))p + p(\lambda - s(t))c'(s(t))}{c''(s(t))(p + (1 - p)e^{\Lambda(t)})}. \end{aligned} \quad (4)$$

Together with $\Lambda'(t) = \lambda - s(t)$, this is a system of ODEs that pins down $s(t)$ given the following boundary conditions:

$$0 = \frac{\partial U}{\partial s(T)} = pe^{-\Lambda(T)} - c'(s(T))q(T) \quad (5)$$

$$\Lambda(0) = 0. \quad (6)$$

In the quadratic case $c(s) = \frac{\epsilon}{2}s^2$, we obtain

$$s'(t) = \frac{\frac{\epsilon}{2}s(t)^2 + p(\lambda - s(t))s(t)}{p + (1 - p)e^{\Lambda(t)}} = \frac{p\lambda s(t) - \frac{\epsilon}{2}s(t)^2}{p + (1 - p)e^{\Lambda(t)}}.$$

We now discuss the assumptions made at the beginning. First, it can be shown that the same ODE shown in Equation 4 is obtained for $t_r > 0$; the only difference is that the mapping from $s(T)$ to $\Lambda(T)$ changes.

Second, if s does not map into $[\epsilon, \lambda - \epsilon]$ for some $\epsilon > 0$, our variational argument breaks down because the perturbed function $s(t) + \eta h(t)$ may violate the constraint $s(t) \in [0, \lambda]$ even for arbitrarily small η . However, it can be shown directly that, for small enough $\epsilon > 0$, deviating to \tilde{s} given by $\tilde{s}(t) = \min(\max(s(t), \epsilon), \lambda - \epsilon)$ strictly increases O 's payoff, so any

optimal strategy for O must lie in the space we study. Finally, in principle it is not obvious that there is an optimal obstruction strategy s . However, general theorems on the existence of optima from variational calculus apply (see Theorem 2 from Evans (2010), Section 8.2).

Note that the conditions we have found are necessary but not sufficient, as they do not necessarily yield a unique solution. Indeed, there may be several values of $s(T)$ for which Equation 5 holds.

We now derive the results in the statement of Proposition 2. First, as we argued, the solution must be interior so, in particular, $s(t) > 0$ for all $t \geq t_r$. Second, it follows from Equation 4 that, whenever $s(t) > 0$, it must be that $s'(t) > 0$, whence $s(t)$ is strictly increasing on $[t_r, T]$.

Finally, we argue that, if I chooses to reform at all, it is optimal to choose $t_r = 0$. Consider two reform times $t_r = 0$, $t'_r > 0$. For the latter to be optimal it must be that $\mu_T(t'_r) \leq \mu_T(t_r)$. Consider the paths $\mu_t(t_r)$, $\mu_t(t'_r)$ for $t \in [t'_r, T]$. We claim that $\mu_t(t'_r) > \mu_t(t_r)$ everywhere. Clearly $\mu_{t'_r}(t'_r) = p > \mu_{t'_r}(t_r)$ as $o_{t_r}(t) < \lambda$ for $t < t'_r$, so let \hat{t} be the infimal time for which the inequality is reversed. By continuity, $\mu_{\hat{t}}(t'_r) = \mu_{\hat{t}}(t_r)$. But then, as the problems faced by O at time \hat{t} are the same under both reform times, the uniqueness of the ODE solution—guaranteed by the Picard-Lindelöf Theorem—implies that $\mu_t(t'_r) = \mu_t(t_r)$ for all $t > \hat{t}$ and also for $t \geq \hat{t} - \epsilon$ for small $\epsilon > 0$. But this contradicts the infimality of \hat{t} .

□

Proof of Proposition 4. Let $V(\mu)$ be O 's expected utility conditional on I having initiated a reform, and with O having a posterior belief μ that the reform is good.

First, it is easy to argue that $s(\mu) = 0$ for $\mu > \frac{\alpha}{\lambda}$, as in that case delaying experimentation just increases O 's chances of losing, at a cost. Assume then that $\mu < \frac{\alpha}{\lambda}$.

Assume an initial belief $\mu < \frac{\alpha}{\lambda}$, let $s(t)$ be a candidate strategy for O , and let $s(t, x) = s(t) + xD(t)$, where $D(t) = \mathbb{1}_{t \in [0, \epsilon]}$.³⁴ To simplify notation, we will write this argument for the special case in which $\delta(\mu) = \delta$ is constant, but it generalizes to any continuous function $\delta(\mu)$.

O 's utility under strategy $s(\cdot, x)$ is

$$U(x) = - \int_0^\epsilon c(s(t) + x)r(t, x)dt + \int_0^\epsilon \delta r(t, x)dt + r(\epsilon, x)V(\mu(\epsilon, x)),$$

³⁴For this argument it is more convenient to denote s as a function of t instead of μ but the two are formally equivalent.

where $\rho_1(t, x) = e^{-\lambda t - \delta t + \int_0^t (s(s) + x) ds}$ is the probability that there have been no successes or evaluation if the state is good; $\rho_0(t, x) = e^{-\delta t}$ is the corresponding probability conditional on the state being bad; $r(t, x) = \mu \rho_1(t, x) + (1 - \mu) \rho_0(t, x)$ is the corresponding probability unconditioned on the state; and $\mu(t, x) = \frac{\mu e^{-\lambda t + \int_0^t (s(s) + x) ds}}{\mu e^{-\lambda t + \int_0^t (s(s) + x) ds} + 1 - \mu}$ is the posterior belief at time t given no successes or evaluation. The first term represents O 's flow cost from opposition, the second term is the probability that I is evaluated at some time $t \in [0, \epsilon)$ before any successes have occurred and O wins, and the third term is O 's continuation utility if no successes or evaluation have been observed up to time ϵ .

For simplicity we will denote $r(t) = r(t, 0)$, $\rho_i(t) = \rho_i(t, 0)$ $\mu(t) = \mu(t, 0)$.

Assume there is an optimal s , and that V is differentiable. It must be that

$$0 = \frac{dU(x)}{dx} \Big|_{x=0} = \int_0^\epsilon \left(-c'(s(t))r(t) + (-c(s(t)) + \delta) \frac{\partial r(t, x)}{\partial x} \right) dt + \\ + \frac{\partial r(\epsilon, x)}{\partial x} V(\mu(\epsilon)) + r(\epsilon) V'(\mu(\epsilon)) \frac{\partial \mu(\epsilon, x)}{\partial x}.$$

Note that $\frac{\partial r(\epsilon, x)}{\partial x} \Big|_{x=0} = \epsilon \mu \rho_1(\epsilon)$ and $\frac{\partial \mu(\epsilon, x)}{\partial x} \Big|_{x=0} = \frac{\mu(1-\mu)}{(\mu e^{-\lambda \epsilon + \int_0^\epsilon s(t) dt} + 1 - \mu)^2} \epsilon e^{-\lambda \epsilon + \int_0^\epsilon s(t) dt}$. Then

$$0 = \frac{1}{\epsilon} \int_0^\epsilon (-c'(s(t))r(t) + (-c(s(t)) + \delta) t \mu \rho_1(t)) dt + \mu \rho_1(\epsilon) V(\mu(\epsilon)) + \\ + r(\epsilon) V'(\mu(\epsilon)) \mu(1 - \mu) \frac{e^{-\lambda \epsilon + \int_0^\epsilon s(t) dt}}{(\mu e^{-\lambda \epsilon + \int_0^\epsilon s(t) dt} + 1 - \mu)^2}.$$

Taking $\epsilon \rightarrow 0$, we obtain

$$0 = -c'(s(0)) + \mu V(\mu(0)) + V'(\mu(0)) \mu(1 - \mu).$$

In our original notation,

$$(\mu - \mu^2) V'(\mu) = c'(s(\mu)) - \mu V(\mu). \quad (7)$$

In addition, since $U(0) = V(\mu)$, we have that

$$\frac{V(\mu) - r(\epsilon) V(\mu(\epsilon))}{\epsilon} = -\frac{1}{\epsilon} \int_0^\epsilon c(s(t)) r(t) dt + \frac{1}{\epsilon} \int_0^\epsilon \delta r(t) dt.$$

Taking $\epsilon \rightarrow 0$,

$$\begin{aligned} & (\mu(\lambda + \delta - s(0)) + (1 - \mu)\delta) V(\mu) + V'(\mu)\mu(1 - \mu)(\lambda - s(0)) = \\ & = -r'(0)V(\mu) - V'(\mu)\frac{\partial \mu(t, 0)}{\partial t}\Big|_{t=0} = -\frac{d(r(\epsilon)V(\mu(\epsilon)))}{d\epsilon}\Big|_{\epsilon=0} = -c(s(0)) + \delta. \end{aligned}$$

In other words,

$$(\mu - \mu^2)(\lambda - s(\mu))V'(\mu) = -c(s(\mu)) + \delta - \delta V(\mu) - \mu(\lambda - s(\mu))V(\mu). \quad (8)$$

This gives us a system of two differential equations—Equations 7 and 8—that pin down $V(\mu)$ and $s(\mu)$. (Note that the Equation 7 is the FOC for the optimality of $s(\mu)$ while Equation 8 is a continuous-time Bellman equation.)

In order to show that the solution (V, s) is the true solution of our problem, it is sufficient to verify that it satisfies the Hamilton-Jacobi-Bellman equation, i.e.,

$$(\mu - \mu^2)(\lambda - s(\mu))V'(\mu) = -c(s(\mu)) + \delta - \delta V(\mu) - \mu(\lambda - s(\mu))V(\mu).$$

for the optimal $s(\mu)$, and

$$(\mu - \mu^2)(\lambda - s)V'(\mu) \geq -c(s) + \delta - \delta V(\mu) - \mu(\lambda - s)V(\mu) \quad (9)$$

for all other values of s .

The first part is satisfied by construction. The second part holds because Equation (9), rewritten as

$$(\mu - \mu^2)(\lambda - s)V'(\mu) + c(s) - (\delta - \delta V(\mu)) + \mu(\lambda - s)V(\mu) \geq 0,$$

has a left-hand side that is convex in s , and Equation 7 guarantees that $s(\mu)$ is a local minimum of it.

The same system of equations is obtained if δ is a function of μ :

$$\begin{aligned} & (\mu - \mu^2)V'(\mu) = c'(s(\mu)) - \mu V(\mu) \\ & (\mu - \mu^2)(\lambda - s(\mu))V'(\mu) = -c(s(\mu)) + \delta(\mu) - \delta(\mu)V(\mu) - \mu(\lambda - s(\mu))V(\mu). \end{aligned}$$

Next, we show that, if $\delta(\mu)$ is constant, then $s(\mu)$ is increasing in μ .

Plugging the Equation 7 into Equation 8, we obtain:

$$\begin{aligned}(\lambda - s(\mu))(c'(s(\mu)) - \mu V(\mu)) &= -c(s(\mu)) + \delta - \delta V(\mu) - (\lambda - s)\mu V(\mu) \\(\lambda - s(\mu))c'(s(\mu)) + c(s(\mu)) &= \delta - \delta V(\mu)\end{aligned}$$

This implies that $s(\mu) > 0$ whenever $V(\mu) < 1$, i.e., whenever $\mu > 0$. Moreover, note that the derivative of the expression $(\lambda - s)c'(s) + c(s)$ with respect to s is $(\lambda - s)c''(s) > 0$. It follows that, as t increases and learning takes place, μ decreases (conditional on seeing no successes); V increases (clearly V is decreasing in μ , as O is better off the worse I 's reform is); $\delta - \delta V$ decreases; $(\lambda - s(\mu))c'(s(\mu)) + c(s(\mu))$ decreases; and so s decreases. To summarize, O 's effort to obstruct decreases over time.

Next, we provide conditions under which this result extend to non-constant functions $\delta(\mu)$. For our previous argument to go through, it is necessary and sufficient that

$$\delta(\mu) - \delta(\mu)V(\mu)$$

be increasing in μ . Equivalently, we require that

$$\begin{aligned}\delta'(\mu) - \delta'(\mu)V(\mu) - \delta(\mu)V'(\mu) &\geq 0 \\ \iff \delta(\mu) [-V'(\mu)] &\geq [-\delta'(\mu)] (1 - V(\mu))\end{aligned}$$

Assume that $\delta(\mu) \in [\underline{\delta}, \bar{\delta}]$ and $\delta'(\mu) \in (-\eta, 0)$ for all μ . Then it is sufficient that

$$\underline{\delta} [-V'(\mu)] \geq \eta.$$

Next, we obtain a lower bound for $|V'(\mu)|$ in the following way. Let μ_t be the posterior belief at time t conditional on no successes under the assumption that $\mu_0 = \mu$ and the equilibrium obstruction strategy $(o_t)_t$ is played. By the envelope theorem,

$$-V'(\mu) = \int_0^\infty r(t) \frac{\partial \mu_t}{\partial \mu} (\lambda - o_t) V(\mu_t).$$

Now note that, for all μ ,

$$V(\mu) \geq V(1) \geq \frac{\underline{\delta}}{\underline{\delta} + \lambda}.$$

In other words, O 's continuation value is lowest when $\mu = 1$, but even in this case and if she uses no obstruction at all, she obtains utility $\frac{\underline{\delta}}{\underline{\delta} + \lambda}$. In addition, $r(t) \geq e^{-\lambda t - \bar{\delta} t}$. And, denoting

$\mu_t = \frac{\mu e^{-\lambda t + \int_0^t s(s) ds}}{\mu e^{-\lambda t + \int_0^t s(s) ds} + 1 - \mu} = \frac{\mu E}{\mu E + 1 - \mu}$, we have that

$$\frac{\partial \mu_t}{\partial \mu} = \frac{E}{(\mu E + 1 - \mu)^2} \geq E = e^{-\lambda t + \int_0^t s(s) ds} \geq e^{-\lambda t}.$$

Finally, we can bound o_t as follows. Let $H(s) = (\lambda - s)c'(s) + c(s)$, and let \bar{s} be such that $H(\bar{s}) = 1$. Since H is strictly and continuously increasing in s ; $H(0) = 0$ and $H(s) \xrightarrow{s \rightarrow \lambda} \infty$; and $\delta - \delta V(\mu) \leq 1$, we conclude that \bar{s} is uniquely defined; $\bar{s} \in (0, \lambda)$; and $s(\mu) \leq \bar{s}$ for all μ . Putting this all together,

$$-V'(\mu) \geq \int_0^\infty e^{-(\lambda + \bar{\delta})t} e^{-\lambda t} (\lambda - \bar{s}) \frac{\underline{\delta}}{\underline{\delta} + \lambda} = \frac{\lambda - \bar{s}}{2\lambda + \bar{\delta}} \frac{\underline{\delta}}{\underline{\delta} + \lambda}.$$

Hence, to guarantee that $s(\mu)$ is increasing in μ it is enough to require

$$\eta \leq \frac{\lambda - \bar{s}}{2\lambda + \bar{\delta}} \frac{\underline{\delta}^2}{\underline{\delta} + \lambda}.$$

In the special case $c(s) = \frac{c}{2}s^2$, we can go some way towards a closed-form solution as follows. The system of ODEs becomes:

$$\begin{aligned} (\mu - \mu^2)V'(\mu) &= c o(\mu) - \mu V(\mu) \\ (\mu - \mu^2)(\lambda - s(\mu))V'(\mu) &= -\frac{c}{2}s(\mu)^2 + \delta - \delta V(\mu) - (\lambda - s(\mu))\mu V(\mu) \\ \implies c(\lambda - s(\mu))s(\mu) + \frac{c}{2}s(\mu)^2 &= \delta - \delta V(\mu). \end{aligned}$$

The last equation yields $s = \lambda - \sqrt{\lambda^2 - 2\frac{\delta}{c}(1 - V)}$, which, substituted into the first ODE, gives us

$$V'(\mu) = \frac{c\lambda - c\sqrt{\lambda^2 - 2\frac{\delta}{c}(1 - V(\mu))} - \mu V(\mu)}{\mu - \mu^2}.$$

□

Proof of Proposition 3. Denote by $V_I(t)$ and $V_O(t)$ the incumbent and opposition's continuation utilities at time t , respectively, under the assumption that the reform has just passed at time t . Denote by $W_I(t)$ and $W_O(t)$ the continuation utilities at time t if the reform has not yet passed. Note that $V_I(t)$ and $V_O(t)$ can be calculated using the results of Section 4. We will start by proving some auxiliary results.

Lemma 1 (Continuation Values).

(i) $V_I(t)$ is decreasing in t for $t < t^*(p)$. For $t \geq t^*(p)$, $V_I(t) = 1$.

(ii) $V_O(t)$ is increasing, continuous and convex in t for $t < t^*(p)$. For $t \geq t^*(p)$, $V_O(t) = 0$.

Proof. $V_I(t) = 1$ and $V_O(t) = 0$ for $t \geq t^*(p)$ are trivial. For the rest of the proof we consider $t \in [0, t^*(p))$.

Denote by $\mu_T(t)$ the equilibrium posterior at time T if the reform started at time t and there were no successes. Generalizing the argument at the end of Proposition 2, we can show that $\mu_T(t)$ is strictly increasing in t . By the law of iterated expectations, I 's probability of having a success, $V_I(t) = 1 - q_t(T)$, is strictly decreasing in t .

That $V_O(t)$ is increasing is obvious: if the reform starts at a later time, O can use the same obstruction strategy as if it had started earlier and get a higher payoff. Continuity can be proven in a similar fashion: if the reform starts at an earlier time $t' < t$, O can shift her obstruction strategy back in time by $t - t'$ and not obstruct at all during $[T - (t - t'), T]$. This provides an upper bound on $V_O(t) - V_O(t')$ (in fact, this argument can be used to show $V_O(t)$ is Lipschitz).

For the convexity, assume that if a reform starts at time t , O 's optimal obstruction path is $s : [t, T] \rightarrow \mathbb{R}_+$. Define $\hat{s} : [t, T + a] \rightarrow \mathbb{R}_+$ by $\hat{s}(s) = s(s)$ for $s \leq T$, $\hat{s}(s) = s(T)$ for $s > T$. Denote by $U_O(s, t)$ O 's continuation utility if a reform passes at time t and he uses the obstruction path s . Using the envelope theorem,

$$V_O(t)' = \frac{\partial U_O(\hat{s}, t)}{\partial t} = q(T) [(\lambda - s(T))\mu_T + c(s(T))] = q(T) [(\lambda - s(T))c'(s(T)) + c(s(T))].$$

As shown in Proposition 2, $c'(s(T))q(T) = pe^{-\Lambda(T)}$, or equivalently $c'(s(T)) = \mu_T$. Now note that, as argued above, $q(T)$ is an increasing function t . Because μ_T is increasing in T and c' is increasing, $s(T)$ is increasing in t . In addition $H(s) = (\lambda - s)c'(s) + c(s)$ is increasing in s . Hence $V_O(t)' = q(T)H(s(T))$ is increasing in t . \square

I 's campaigning behavior. Assume that I campaigns on a measurable set of times $A \subseteq [0, T]$ and O 's blocking strategy is $b(t)$. Then, for any $z > t$,

$$W_I(t) = \int_{A \cap [t, z]} \hat{p}_t(\tau) V_I(\tau) d\tau + \left(1 - \int_{A \cap [t, z]} \hat{p}_t(\tau) d\tau \right) W_I(z), \quad (10)$$

where $\hat{p}_t(\tau)$ is the equilibrium probability density that the reform will pass at exactly time τ . Note in particular that $W_I(T) = \frac{1}{2}$.

Assume $p \leq \bar{p}$ and take $t = t_*(p)$. Then, by construction, for all $\tau > t$ we have $V_I(\tau) < \frac{1}{2}$. Using Equation 10 with $z = T$, we can see that the highest $W_I(t)$ can possibly be is $\frac{1}{2}$, and this is attained only if the incumbent chooses $A = \emptyset$. In other words, it is uniquely optimal for I not to campaign to pass the reform after $t_*(p)$.

Now note that, since $V_I(\tau)$ is decreasing in τ , for any $t < t_*(p)$, $\max_{\tau \in [t, t_*(p)]} V_I(\tau) = V_I(t)$. Hence $W_I(t)$ is a weighted average of values between $\frac{1}{2}$ and $V_I(t)$, whence $W_I(t) \in (\frac{1}{2}, V_I(t))$.

It follows that I wants to campaign at all times $t \in [0, t_*(p)]$. To see why, note that, if at some time $t \in (0, t_*(p))$ I is not expected to campaign during the period $[t, t + \epsilon]$ and she switches to campaigning, the net impact on her expected utility is approximately

$$\epsilon \left(\tilde{\lambda} - b(t) \right) (V_I(t) - W_I(t)) > 0.$$

(This argument can be formalized using Equation 10.)

Now assume $p > \bar{p}$. Clearly $W_I(t) < 1$ for all t . Hence, using the same argument as above, I strictly prefers to campaign for all $t \geq t^*(p)$, as $V_I(t) = 1 > W_I(t)$. Assume now that $t_*(p) < t^*(p)$.³⁵ For $t \in [t_*(p), t^*(p)]$, the same argument as in the case $p < \bar{p}$ implies that I will prefer not to campaign. Define \tilde{t}_* by the condition $V_I(\tilde{t}_*) = W_I(t^*(p))$. Then the latest time before $t^*(p)$ when I wants to campaign will be \tilde{t}_* . I also wants to campaign for all times $t \in [0, \tilde{t}_*]$; the proof is analogous to the case $p < \bar{p}$.

O 's blocking effort. If, at time t , O slightly increases his blocking effort by ϵ for an amount of time η , the marginal impact on his expected utility is approximately

$$\epsilon \eta (W_O(t) - V_O(t)) - \epsilon \eta \tilde{c}'(b(t)).$$

Hence, if $V_O(t) > W_O(t)$, O chooses $b(t) = 0$. If $V_O(t) < W_O(t)$, O 's optimal choice of effort at time t satisfies

$$\tilde{c}'(b(t)) = W_O(t) - V_O(t).$$

³⁵This assumption is not essential for the results. If $t_*(p) > t^*(p)$, it may simply happen that I campaigns for all t —that is, there is no gap between early and late reforms.

Characterization of $W_O(t)$. Using the HJB equation as in Proposition 4, we can show that

$$\begin{aligned} W_O(t)' &= (\tilde{\lambda} - b(t)) (W_O(t) - V_O(t)) + \tilde{c}(b(t)) \\ &= (\tilde{\lambda} - b(t)) \tilde{c}'(b(t)) + \tilde{c}(b(t)). \end{aligned}$$

Define $M : [0, \tilde{\lambda}] \rightarrow \mathbb{R}$ by $M(b) = (\tilde{\lambda} - b) \tilde{c}'(b) + \tilde{c}(b)$, and note M is strictly increasing. Denote $N = M \circ (\tilde{c}')^{-1}$, and note N is a C^1 , strictly increasing function from \mathbb{R} to \mathbb{R} , such that $N(0) = 0$. Then

$$W_O(t)' = M(b(t)) = N(W_O(t) - V_O(t)). \quad (11)$$

$b(t)$ is increasing in t for $t \geq t^*(p)$. Because \tilde{c}' is increasing, it is enough to show $W_O(t) - V_O(t)$ is increasing in t . This follows from two facts. First, $V_O(t) \equiv 0$ for $t \geq t^*(p)$. Second, $W_O(t)$ is increasing in t , as for any $z > t$,

$$W_O(t) = \int_{A \cap [t, z]} \hat{p}_t(\tau) V_O(\tau) d\tau + \left(1 - \int_{A \cap [t, z]} \hat{p}_t(\tau) d\tau\right) W_O(z) - \int_{A \cap [t, z]} \tilde{q}_t(\tau) \tilde{c}(b(\tau)) d\tau, \quad (12)$$

where $\tilde{q}_t(\tau)$ is the probability the reform has not passed by time τ , conditional on it not having passed by time t . Taking $t \geq t^*(p)$ and $z > t$, we find that the first term vanishes, the third term is negative and the second term is smaller than $W_O(z)$, so $W_O(t) < W_O(z)$.

Blocking effort is higher against late reforms than against early ones. Formally, we prove that, holding everything else but \tilde{c} constant, there is η such that, if $\tilde{c}((\tilde{c}')^{-1})(1) < \eta$, then $b(t) > b(t')$ for all $t \geq t^*(p)$, $t' \leq \tilde{t}_*$. Since $b(t)$ is increasing for $t \geq t^*(p)$, we can take $t = t^*(p)$ WLOG. Once again, it is sufficient to show that $V_O(t) < V_O(t')$ and $W_O(t) \geq W_O(t')$. That $V_O(t) < V_O(t')$ is immediate, as $V_O(t) = 0$ while $V_O(t') > 0$.

Next we show $W_O(t') \leq W_O(t^*(p))$. We will proceed in two steps. First, we will show that, if $V_O(\tilde{t}_*) \leq W_O(t^*(p))$, the result holds. Second, we will provide conditions on \tilde{c} that guarantee $V_O(\tilde{t}_*) \leq W_O(t^*(p))$.

For the first part, note first that $W_O(\tilde{t}_*) = W_O(t^*(p))$. For any $t' < \tilde{t}_*$, use Equation 12 over the interval $[t', \tilde{t}_*]$. It follows that $W_O(t')$ is a weighted average of $V_O(\tau)$ for $\tau \in [t', \tilde{t}_*]$ and $W_O(\tilde{t}_*)$, minus some blocking costs. By Lemma 1, $V_O(\tau)$ is increasing in τ , so it is bounded above by $V_O(\tilde{t}_*) \leq W_O(\tilde{t}_*)$. Hence $W_O(t') \leq W_O(\tilde{t}_*)$.

For second part, note that

$$V_O(\tilde{t}_*) = q_{\tilde{t}_*}(T) - C = 1 - V_I(\tilde{t}_*) - C,$$

where C is O 's expected cost of obstructing a reform that started at time \tilde{t}_* . In similar fashion

$$W_O(t^*(p)) = 1 - W_I(t^*(p)) - \tilde{C},$$

where \tilde{C} is O 's expected cost of blocking I 's attempts to pass a reform after time $t^*(p)$. Recall that \tilde{t}_* is defined by the condition $V_I(\tilde{t}_*) = W_I(t^*(p))$. Then the condition $V_O(\tilde{t}_*) \leq W_O(t^*(p))$ holds iff $\tilde{C} \leq C$.

If we hold everything but \tilde{c} constant, C remains constant, as the cost of legislative blocking \tilde{c} has no impact on behavior after a reform passes. Now note that, because $b(t)$ is chosen at each time to satisfy $\tilde{c}'(b(t)) = W_O(t) - V_O(t) \leq 1$, we must have $b(t) \leq \bar{b}$ for all t , where \bar{b} is such that $\tilde{c}'(\bar{b}) = 1$. Then $\tilde{C} \leq T\tilde{c}(\bar{b}) < \eta T$. Hence it is sufficient to take $\eta \leq \frac{T}{C}$.

$b(t)$ is single-peaked in t for $t \in [0, t_*(p)]$. It is enough to show that $\Delta(t) = W_O(t) - V_O(t)$ is single-peaked, or equivalently, that if $\Delta'(t) \geq 0$ for some $t \in [0, t_*(p)]$ then $\Delta(z) < \Delta(t)$ for all $z < t$.³⁶

Define $\hat{V}_O(\tau) = V_O(t) + V'_O(t)(z - \tau)$. Note that, as V_O is strictly convex by Lemma 1, $V_O(z) > \hat{V}_O(z)$ for all $z \neq t$. Define $\hat{\Delta}(z)$ as the unique solution to the ODE $\hat{\Delta}'(z) = N(\hat{\Delta}(z)) - \hat{V}'_O(z) = N(\hat{\Delta}(z)) - V'_O(t)$ for $z < t$, with terminal condition $\hat{\Delta}(t) = \Delta(t)$. If $\Delta'(t) = 0$, the unique solution is constant: $\hat{\Delta}(z) \equiv \Delta(t)$ for $z < t$. If $\Delta'(t) > 0$, the unique solution is strictly increasing over $[0, t]$.³⁷ Define $\hat{W}_O(z) = \hat{\Delta}_O(z) + V_O(z)$.

Using Equation 12 for W_O and \hat{W}_O over the interval $[z, t]$, we obtain

$$\begin{aligned} \hat{W}_O(z) &\geq \int_{[z,t]} \hat{p}_z(\tau) \hat{V}_O(\tau) d\tau + \left(1 - \int_{[z,t]} \hat{p}_z(\tau) d\tau\right) \hat{W}_O(t) - \int_{[z,t]} \tilde{q}_z(\tau) \tilde{c}(b(\tau)) d\tau \\ &= \int_{[z,t]} \hat{p}_z(\tau) \hat{V}_O(\tau) d\tau + \left(1 - \int_{[z,t]} \hat{p}_z(\tau) d\tau\right) W_O(t) - \int_{[z,t]} \tilde{q}_z(\tau) \tilde{c}(b(\tau)) d\tau \\ &= \int_{[z,t]} \hat{p}_z(\tau) \left(\hat{V}_O(\tau) - V_O(\tau)\right) d\tau + W_O(z) > \hat{V}_O(z) - V_O(z) + W_O(z). \end{aligned}$$

In the right-hand side of the first line, $\hat{p}_z(\tau)$, $\hat{p}_z(\tau)$, $\tilde{q}_z(\tau)$ and $\tilde{c}(b(\tau))$ are the costs and probabilities resulting from O 's equilibrium strategy when the continuation value after reform is $V_O(\tau)$, rather than $\hat{V}_O(\tau)$. (This is why the first line is an inequality.) In the last inequality, we use that V_O is strictly convex while \hat{V}_O is linear, so $V_O - \hat{V}_O$ strictly grows as s moves away from t .

³⁶Note that Δ is differentiable a.e. This follows from the fact that $V_O(t)$ is convex and $W_O(t)$ is determined by Equation 11.

³⁷The proof is by a standard application of the Picard-Lindelöf Theorem.

Rearranging terms, we then have $W_O(z) - V_O(z) < \hat{W}_O(z) - \hat{V}_O(z)$, i.e., $\Delta(z) < \hat{\Delta}(z) \leq \hat{\Delta}(t) = \Delta(t)$, as desired.

□

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