When Do Power Shifts Cause War?*

Reexamining Commitment Problems as a Source of Rational War

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Abstract

Previous research (Fearon, 1995; Powell, 2006) has suggested that power shifts can cause commitment problems leading to war. Power shifts are widely used to explain both interstate and civil wars. In this paper, I develop a formal model to reevaluate the logic of how power shifts cause war. I relax the unrealistic assumption, included in previous models, that power shifts settle disputes permanently. In addition, I include multiple possible causes of commitment problems in the same model. Surprisingly, this model shows that rapid shifts in the underlying power balance can never be a proximate cause of rational war. This model thus undermines the "better now than later" understanding of preventive war. Instead, commitment problem wars are driven by disputes over indivisible sources of bargaining power, such as strategic territory, or regime type. Among other interesting implications, a longer shadow of the future can make war more likely.

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Two thousand years ago, Thucydides ascribed the Peloponnesian war to "increasing Athenian greatness and the resulting fear among the Lacedaemonians (Thucydides 1998, 15)." More recently, similar power shifts have been cited as a cause of World War I - Germany feared the growth of Russian military power, while Great Britain feared the development of German naval power (e.g. Levy and Mulligan 2017; Maurer 1997). The invasion of Iraq by the US was partly justified as an attempt to prevent Iraq from gaining nuclear weapons, which would have enhanced Iraqi power (Debs and Montiero 2014). Projecting similar concerns into the future, some have predicted that the emergence of China as a peer competitor to the United States could cause a major war in the coming decades (e.g. Allison 2017). In which of these cases is the power shift a possible explanation for war?

Formal models suggest that power shifts can lead states to rationally choose war, even with perfect information. Fearon (1995) and others (e.g. Powell 2006) have argued that power shifts can create commitment problems, making war preferable to negotiations. Most models assume that commitment problems are caused by exogenous power shifts, created by factors outside the immediate bargaining environment such as economic or technological development (e.g. Wolford, Reiter and Carruba 2011). However, these models assume that war "locks-in" a given settlement permanently, which could only occur in the rare event of one state being eliminated from the international system. As I will show, this unrealistic assumption is quite consequential to their results. Other models (e.g. Fearon 1996) focus on endogenous power shifts, created by bargaining over objects that influence bargaining power.

In this paper, I develop an alternative formal model to more accurately describe power shifts as a cause of war. This model differs from previous models in two key respects. First, the game repeats infinitely, and neither negotiated settlements or war outcomes ever end the game. Second, I include both endogenous and exogenous power shifts in the same model to compare their effects. I do not include a separate possibility of decisive war, as decisive war is simply an extreme form of an endogenous power shift. This model has several interesting

implications.

Most importantly, exogenous power shifts can *never* be the sole cause of rationalist war. In other words, power shifts due to long term changes outside states' immediate control, such as economic development or population growth, cannot on their own cause states to rationally initiate war. Since each of these changes occur regardless of what states do, war would not affect future power, and thus would not be rational. Exogenous power shifts may make war caused by other factors more likely, although the effect is relatively modest. For instance, exogenous power shifts could exacerbate uncertainty about power or make disputes over endogenous power shifts more intense. However, only in combination with these other factors could war occur.

In contrast, endogenous power shifts may be sufficient to cause war, as negotiations and war could change the future bargaining environment. However, the dispute over power must be indivisible (Fearon 1996), otherwise there would always be a negotiated settlement that adjusts power at a rate that is mutually preferable to war. Thus, war could be caused by disputes over the existence of a state or its regime, strategic territory or the possession of nuclear weapons. While seemingly subtle, I believe that this observation has profound implications. Most importantly, these findings show that theoretical research should emphasize state strategies to achieve their goals over the external environment as a cause of war.

Among other interesting implications, longer shadows of the future make war more likely, as the change in future power more easily outweighs the war costs in the present. This is notable, as typically the shadow of the future is thought to enhance cooperation. In addition, war is especially likely when the two parties have shadows of the future of different length. This could have significant implications for understanding the influence of regime tupe on war. In addition, wars caused by power shifts are not necessarily long and intense, but generally end when the source of bargaining leverage is captured by the party that did not previously possess it. Finally, even commitment problem wars may be probabilistic.

Below, I first provide a brief overview of previous research into commitment problems

and power shifts as a cause of war. I then present the model and the model solution. Finally, I use this solution to draw substantive conclusions about when power shifts may cause war and additional implications from the model.

1 Background

A large body of international relations theory has suggested that shifting power can cause war (e.g. Organski 1968; Organski and Kugler 1980; Levy 1987; Van Evera 1999; Kadera 1999; Copeland 2000; Renshon 2006). Rising powers may to want initiate war to accelerate their adversary's decline and reshape the system's rules and norms in their favor. At the same time, declining states may believe that power shifts force them to choose war now rather allow their power to erode. The empirical record appears to support the idea that power shifts can lead to war (e.g. Bremmer 1992; Kim and Morrow 1992; Geller 1993; Lemke and Werner 1996; de Soysa, Oneal and Park 1997; Moul 2003; Reed 2003; Hwang 2010; Bell and Johnson 2015; Sample 2017), although a few studies find more mixed results (e.g. Lebow and Valentino 2009; Lemke 2003).

Formal models have significantly enhanced our understanding of the role of power shifts in causing war. According to bargaining model of conflict (e.g. Fearon 1995), there should always exist a bargain that both sides prefer to fighting a war as long as war is costly. One possible reason that war could occur or continue is if power shifts make it impossible to credibly commit to this war avoiding bargain (e.g. Fearon 1995; Powell 2006; Reiter 2009; Wolford, Reiter and Carruba 2011; Walter 1997; Fearon 2004). Several different commitment problems can lead to war, including first-strike advantages (e.g. Beard and Strayhorn 2018) and indivisible issues where only probabilistic settlements are mutually preferable. I focus on commitment problems created by two types of power shifts.

First, there are *exogenous* power shifts, created by factors outside the direct control of the disputing states. Possible sources of exogenous power shifts are economic growth

and technological development. The current power transition between the United States and China would represent an exogenous power shift, as it is due primarily to China's economic development. Exogenous power shifts have probably been a major explanation for commitment problem wars, and are centrally described in both Fearon's (1995) and Powell's (2006) models. They suggest that when one side is expected to grow stronger in the future, it would have difficulty credibly promising to implement any bargain made in the present after the power shift. The declining state may thus feel pressure to fight a war now rather than see its bargaining position erode in the future. However, I show below that this account is at best incomplete

In addition, there can be *endogenous* power shifts, created by disputes over indivisible sources of bargaining power (Fearon 1996). Endogenous power shifts occur as an outcome of negotiations or war. Thus, states control the future balance of power and can bargain over it. Sources of endogenous power shifts include disputes over strategic territory (such as high ground, mountain ranges, or rivers) and nuclear weapons among others. I describe the disputed sources of bargaining power that create endogenous power shifts as strategic objects. North Korea's nuclear program is one example of a strategic object. Endogenous power shifts may cause war, as the state that gains a strategic object could not credibly promise not to use its enhanced bargaining power to gain additional concessions. Thus, ceding a strategic object also means ceding future benefits. This may create situations where neither side will voluntarily allow the other to possess a strategic object. Debs and Monteiro (2014) have suggested that endogenous power shifts are more common than exogenous shifts, although few other researchers focus on endogenous shifts.

Previous work, especially on exogenous power shifts, has made the assumption that war will "lock-in" the war outcome forever (e.g. Fearon 1995; Powell 2006; Leventoglu and Slantchev 2007; Wolford, Reiter and Carrubba 2011). Such a decisive outcome could only occur if one state ceased to exist. As long as the defeated state remains in existence, it could demand alterations to the war outcome, just as it could demand alterations to a negotiated

settlement. Thus, the only way that war could truly lock-in a settlement would be if one state were eliminated from the international system. Even regime change would not necessarily lock-in a settlement, as there would be no guarantee that the new regime would honor the settlement and the new regime could itself be replaced.

However, this assumption has two problems. First, state death actually represents an endogenous power shift. The elimination of one state from the international system has the same effect as reducing its power to zero. War can lead to state death, but seeking to eliminate the opponent through war is actually a choice of war aims. Negotiations can also lead to state death - a country can voluntarily surrender its autonomy, as Latvia, Lithuania, and Estonia did in World War II (Kasekamp 2010, 124-131). Because state death is a result of either the war outcome or negotiations, it is thus endogenous to the bargaining process. As the only way to truly lock-in a war outcome is state death, the models that show that exogenous power shifts cause war all tacitly include, and in fact rely on, an endogenous power shift.

Empirically, Fazal (2004) has shown that state death became exceedingly rare after World War II, although it was more common in the past. In addition, she finds that buffer states, which would not themselves be central to major power disputes, are more likely to die. Similarly, I identify only four wars out of fifty-six since 1918 that eliminated a state from the international system: World War II, the Italian invasion of Ethiopia, the Vietnam War, and Iraq's invasion of Kuwait (see Sarkees and Wayman, 2010). Note that of these, only North Vietnam's takeover of South Vietnam was permanent, with the independence of all other captured states quickly restored.[1] In addition, few of the conquests seem to be centered on power disputes or fears of changes in future power between the conquered state and their conqueror.

[1]The Soviet Union's incorporation of Latvia, Lithuania and Estonia into the Soviet Union in 1940 might be another exception. However, while these seizures were related to World War II, they occurred without centrally organized resistance.(Kasekamp 2010, 124-131)

Thus, a model of commitment problems must allow war outcomes to be challenged in addition to negotiated settlements. I describe such a model in the next section. I also explicitly incorporate both endogenous power shifts (e.g. those due to negotiating over bargaining power) and exogenous power shifts (due to factors beyond direct state control) in the same model. These additions significantly alter the current understanding of when power shifts can lead to war.

A couple of papers have made moves in this direction. Chadefaux (2011) allows power to be transferred through negotiations. His model thus includes both exogenous and endogenous power shifts together. Chadefaux shows that when power is negotiable, there is a negotiated bargain where the rising state can increase its power gradually enough that the declining state no longer prefers to fight in the present. Similarly, McCormack and Pascoe (2017) show that economic sanctions might slow down power transitions sufficiently to prevent war. However, both models still allow war to permanently lock-in an outcome. Thus, if there are restrictions on the ability to negotiate power, war could still occur in equilibrium. Below, I show that exogenous power shifts are never sufficient to cause war, and thus the ability to transfer power is not necessary to cause peace.

2 The Model

To examine when power shifts may lead to war, I construct a simple, infinitely repeated bargaining model. This model examines both exogenous and endogenous power shifts together. In addition, and crucially, the model allows both war outcomes and negotiated settlements to be reconsidered.

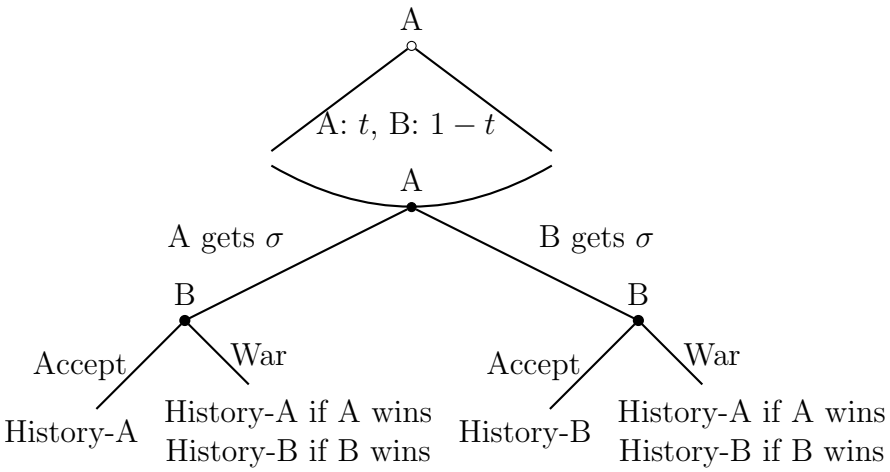
I assume two states, A and B, are in a dispute over some continuously divisible territory or other good with a normalized value of 1.[2] I also assume that there is some indivisible strategic object that will change the probability of winning the war. In each

[2]I assume the territory is continuously divisible following Fearon's (1995) belief that most things that provide value could be divided and that side-payments would render even

stage, A will make an offer that includes both a division of the territory (with A receiving proportion t and B receiving $1-t$) and who possesses the strategic object in the next period. B may accept the offer, but must accept both parts together. Alternatively, B may reject the offer, in which case the two states will fight a war, modeled as a costly lottery. Whoever wins the war receives the entire territory in that period and the strategic object in the next period. To account for the costliness of war, each side pays war costs c_A and c_B in any period that war is fought.

Regardless of whether a settlement or war occurs, the game is repeated infinitely, with each side discounting subsequent periods by δ_A and δ_B. Except for the probability of winning the war, each period is identical, with the basic structure displayed in Figure 1. Thus, this model assumes that both states survive even if war is fought, and allows both war outcomes and negotiated settlements to be renegotiated.

Figure 1: The Stage Game



I account for power shifts through the probability of winning the war. To account for exogenous power shifts, the probability of state A winning changes from π_1 in the first period to a base probability of π_2 in all subsequent periods (the infinite horizon phase). This change occurs regardless of the actions played in the first period, as exogenous power

indivisible objects divisible. As some some things may be socially constructed as indivisible (Goddard 2006), future research could examine the implications of relaxing this assumption.

shifts are caused by factors largely outside of states' control, such as economic development, natural population growth, and technological advancement. Again, China's growing power would represent an exogenous power shift.

To account for endogenous power shifts, I assume there is also a dispute over an indivisible strategic object that affects bargaining power, such as strategic territory or nuclear weapons. Thus, North Korea's nuclear program would represent an endogenous power shift. In the infinite horizon phase, the probability of A winning increases by σ over the base probability π_2 whenever A possesses the strategic object.[3] This strategic object can be obtained either as part of the negotiated settlement or by winning a war. Within the infinite horizon phase, any stage where A possesses the strategic object is labeled "history-A", while any stage where B possesses the strategic object is labeled "history-B".

Combining the exogenous and endogenous power shifts gives the following probabilities of victory in war. The probability of state A winning a war is always π_1 in period 1. In all subsequent periods, the probability that state A wins is π_2 in history-B (i.e. in the previous period, A made an accepted offer allowing B to have the strategic object or B won the war). Conversely, the probability that state A wins is $\pi_2 + \sigma$ in history-A.

This model makes several important assumptions about the endogenous power shifts. First, note that in the model, war only affects future power through affecting possession of the strategic object. War is never decisive on its own. As noted above, decisive war is simply an extreme form of endogenous power shift, as a decisive war outcome effectively reduces one side's power to zero. Thus, I believe that it would be theoretically inappropriate to allow war to have any effects except through the σ parameter. The model does allow for near decisive outcomes at certain parameter values. Where $\sigma = 1 - \pi_2$, A gaining σ eliminates state B's military power, and would in essence lock-in the outcome forever. Similarly, if $\pi_2 = 0$, A's

[3]The probability of victory in the first period, before the exogenous power shift, could be interpreted as either side possessing the strategic object. Thus as long as $\pi_1 \geq \sigma$, the model is agnostic as to which player initially possesses the strategic object.

failure to gain σ would eliminate A's military power.[4] Thus, I explicitly model how war can affect future power, rather than simply assuming that war automatically locks-in an outcome.

Second, I assume that any transfer of the strategic object that can be achieved through war can also be achieved through negotiations. In principle this is almost certainly true, as a state could voluntarily do whatever is done to them in war. For instance, they could voluntarily cease a weapons program or even deliberately take measures to curtail economic growth. State's can even, and have, deliberately surrender their independence.[5] In practice, some things may be seen as non-negotiable, although this would require an explanation for why power could not be transferred voluntarily.

Third, I assume that the offer over the strategic object and the division of the territory are separable: regardless of whether A demands the strategic object, A can propose any division of the territory. Thus, even if strategic territory both creates power and gives some direct benefits, I assume that side payments restore the ability to make distinct offers over the strategic object and the direct benefits. Finally, I assume that there are no restrictions on when the strategic object can be transferred; it can be transferred through bargaining or war in any period and transfers are not necessarily permanent. Future research can examine whether there are plausible situations in which these assumptions could be violated, and the potential consequences of relaxing these assumptions.

Finally, I assume that the objects causing endogenous power shifts are indivisible, as they are represented by the single σ parameter. This assumption is in line with previous research, as Fearon (1996) showed that for endogenous power shifts to cause war, the objects

[4]Given that there is only a single strategic object, the decisive outcomes can only eliminate one state's power. Future research can add additional σ parameters to allow decisive outcomes in both directions.

[5]This means that while the model can include decisive outcomes, I do assume they can result from negotiations as well as war.

influencing future power must be indivisible. Otherwise, salami tactics allow for power to be adjusted at a slow enough rate that there would always be a credible negotiated settlement preferable to war, even if one side eventually loses all of its bargaining power.

2.1 Model Solution

Because the model is a complete information game, I use the solution concept of subgame perfect Nash equilibrium (SPNE). As this is an infinite horizon game, there are an infinite number of solutions according to the Folk Theorem. In order to reduce the number of possible solutions and focus on the most sensible, I only formally examine solutions which employ stationary strategies, as is common in bargaining models. With this restriction, there is a unique solution for each combination of the parameter values.[6] I discuss how punishment strategies may affect the results later in the paper.

As the model includes an infinite horizon phase including two different interdependent histories, the solution still becomes quite complex. Thus, I present and discuss the basic strategy profile for each stage or history in terms of the offers made (t-values) and the expected continuation values (CVs). Throughout, I notate the t-values and CVs according to table 1. I define the actual t-values and CVs more explicitly in Appendix A.

I first discuss which offers state B will accept, and then discuss how this acceptance profile determines state A's actions. In each period, B will accept any offer that gives it a total expected utility equal or greater than war. The maximum proportion of the territory B will allow A to have (t^*) is always less if A demands strategic object (σ) in the next round than if A allows B to have the strategic object. In demanding the strategic object, A's probability of winning the war in the next period is increased, reducing B's future bargaining power. Thus, B will demand a greater share of the territory in the present to compensate for its loss of bargaining power (and territory) in the future. B's acceptance profile is essentially the same in each history, only changing with the different expected value or war. Lemma 1

[6] discussion in online Appendix B

Table 1: t-value and CV notation

Notation	Description
	Subscripts to describe offer or CV
A, B	Which State the value pertains to.
1, hA, hB	Occurs in Stage 1, History-A, or History-B (respectively)
σ	Offer where A will possess σ in next round
$\neg\sigma$	Offer where A will not possess σ in next round
war	War is fought in that round
warmix	A will mix between choosing war, and offering $t_{hA,\neg\sigma} = 1$
peacemix	A will mix between offering $t^{\ddagger\ddagger\dagger}_{hA,\sigma}$ $t_{hA,\neg\sigma} = 1$
	Signs to describe specific situations
No sign	Generic offer or CV
$*$	Generic minimal offer B will accept
$\dagger$	Base value - A makes minimal offer in both histories
$\ddagger$	A makes an offer of $t_{hA,\neg\sigma} = 1$ in history-A
$\ddagger\dagger$	A makes an offer of $t_{hA,\sigma} = 1$ in history-A
$\ddagger\ddagger$	A mixes between choosing war, and offering $t_{hA,\neg\sigma} = 1$ in history-A
$\ddagger\ddagger\dagger$	A mixes between offering $t^{\ddagger\ddagger\dagger}_{hA,\sigma}$ and $t_{hA,\neg\sigma} = 1$ in history-A
$\ddagger\ddagger\ddagger$	A makes an accepted offer of $t = 1$ in both histories

describes the minimum offers that B will accept.

Lemma 1. *State B's Acceptance Profile*

- *If A demands the strategic object, B will accept the offer if:* $1-t^*_\sigma+\delta_B CV_{B,hA} \geq CV_{B,war}$.
- *If A allows B to have the strategic object, B will accept if:* $1 - t^*_{1,\neg\sigma} + \delta_B CV_{B,hB} \geq CV_{B,war}$.
- *If the appropriate condition is not true, then B will reject the offer and war will occur.*

This acceptance profile dictates the choices that A can make. A can avoid war by making any offer meeting B's minimal criteria. Alternatively, A could make an unserious offer that does not meet B's criteria, leading to war. Among these choices, A will make the offer that maximizes A's utility.

A few observations help structure A's decision. First, if A wishes to avoid war, A would never wish to offer B more territory than the minimum needed for B to accept. However, there may be cases where one or both of these minimally acceptable offers is not

possible. B may only B willing to allow A to have the strategic object if B gets more than the entire territory in the present, which would eliminate the ability of A to peaceably get the strategic object. On the other hand, B may be willing to allow A to have the entire territory if B receives the strategic object. In this case, A could still make an offer ceding the strategic object to B, but would not be able to gain all of the concessions that B would allow in the present.

The second element structuring A's decision is A's preference on whether to demand the strategic object or allow B to have the strategic object. In all cases, A prefers to demand the strategic object when $\delta_A > \delta_B$. A would prefer to to allow B to have the strategic object if $\delta_A < \delta_B$.[7] In essence, in the first case ($\delta_A > \delta_B$), A is willing to settle for less in the present for the future gains of possessing the strategic object. In the second case ($\delta_A \delta_B$), A would have to give up too much in the present to induce B to cede the strategic object, and so prefers the present gains of allowing B to have the strategic object. Thus, A's choices in each stage can be divided into two situations depending on whether $\delta_A > \delta_B$ or $\delta_A < \delta_B$.

Finally, note that because war is costly, A's most preferred offer would always be mutually preferable to war as long as that offer is possible.[8] Thus, when $\delta_A > \delta_B$, A would prefer to make the offer demanding the strategic object rather than fight as long as B is willing to accept this offer for less than the entire territory. Similarly, when $\delta_A < \delta_B$, A would prefer to make the offer allowing B to have the strategic object rather than fight as long as A can gain all of the concessions that B would allow. Thus, war would only occur if the A's most preferred offer is not possible.

Having reviewed these basic elements, it is possible to describe A's choices in more detail. Lemmas 2 through 4 describe A's strategies in each history for the situation where $\delta_A > \delta_B$. In this case, A would generally prefer to give B more in the present to gain the strategic object and the associated long term gains. In this case, war can occur if A cannot

[7]Proof in online Appendix C.

[8]Proof in online Appendix D.

make enough concessions to induce B to cede the strategic object peacefully.

In history-A, A already possesses the strategic object. Thus A's power is increased such that A can always make an offer that B will accept, as $t^*_{hA,\sigma} \geq 0$ always. Thus, A will offer $t^*_{hA,\sigma}$ as long as that is less than one. If it is greater than one, then A can demand the entire territory and retain the strategic object. This is A's best possible outcome, and so A will do so. Lemma 2 describes A's strategies in History-A when $\delta_A > \delta_B$

Lemma 2. *A's strategies in History-A when* $\delta_A > \delta_B$

- *If* $0 \leq t^*_{hA,\sigma} \leq 1$*, then A will offer* $t^*_{hA,\sigma}$
- *If* $t^*_{hA,\sigma} > 1$*, then A will offer* $t_{hA,\sigma} = 1$*, as this gives A's best possible outcome*

A's choices can be more complicated in history-B. If A's most preferred offer ($t^*_{hB,\sigma}$) is possible, then A will make that offer. At the opposite extreme, if $t^*_{hB,\neg\sigma}$, such that A can retain the entire territory, then A will go ahead and make that offer, even if it involves allowing B to have the strategic object, as A can do no better. Finally, it is possible that $t^*_{hB,\sigma} < 0$, such that A would have to give B more than the entire territory to induce B to give up the strategic object peacefully. In this case, A has to choose between making its less preferred offer by allowing B to retain the strategic object, and making an unserious offer that would result in war. In the later case, A would have to pay war costs, but has a chance of gaining the strategic object and accordingly more future benefits. Lemma 3 describes A's strategies in History-B when $\delta_A > \delta_B$

Lemma 3. *A's strategies in History-B when* $\delta_A > \delta_B$

- *If* $0 \leq t^*_{hB,\sigma} \leq 1$*, then A will offer* $t^*_{hB,\sigma}$
- *If* $t^*_{hB,\sigma} < 0 \leq t^*_{hB,\neg\sigma} \leq 1$*, then A will offer* $t^*_{hB,\neg\sigma}$ *if* $t^*_{hB,\neg\sigma} + \delta_A CV_{A,hB} \geq CV_{A,war}$*, and make an unserious offer resulting in war otherwise*
- *If* $t^*_{hB,\neg\sigma} > 1$*, then A will offer* $t_{hB,\neg\sigma} = 1$*, as this gives A's best possible outcome*

A's strategies in history-0 generally track those in history-B, as A prefers to gain the strategic object. The only difference is that A may still choose war when $t^*_{1,\neg\sigma} > 1$. Offering $t_{1,\neg\sigma} = 1$ would not necessarily give A their maximum long term benefit, as this does not also mean that A could get their maximum benefit in history-B. Thus, there is a second potential war range where $t^*_{1,\neg\sigma} > 1$. Lemma 4 describes A's strategies in History-0 when $\delta_A > \delta_B$

Lemma 4. *A's strategies in History-0 when* $\delta_A > \delta_B$

- *If* $0 \leq t^*_{1,\sigma} \leq 1$*, then A will offer* $t^*_{1,\sigma}$
- *If* $t^*_{1,\sigma} < 0 \leq t^*_{1,\neg\sigma} \leq 1$*, then A will offer* $t^*_{1,\neg\sigma}$ *if* $t^*_{1,\neg\sigma} + \delta_A CV_{A,hB} \geq CV_{A,war}$ *and make an unserious offer resulting in war otherwise*
- *If* $t^*_{1,\sigma} < 0 \leq 1 \leq t^*_{1,\neg\sigma}$*, then A will offer* $t_{1,\neg\sigma} = 1$ *if* $1 + \delta_A CV_{A,hB} \geq CV_{A,war}$ *and make an unserious offer resulting in war otherwise*
- *If* $t^*_{1,\sigma} > 1$*, then A will offer* $t_{1,\sigma} = 1$*, as this gives A's best possible outcome*

Having described A's strategies where $\delta_A > \delta_B$, I now describe A's strategies where $\delta_A < \delta_B$. Where $\delta_A < \delta_B$, A would generally prefer to make offers allowing B to have the strategic object, as A would prefer greater gains in the present in exchange for allowing B to have greater gains in the future. The most complicated of these strategies occurs in history-A. Again, if both of the optimal t-values are less than 1, then A will make the offer allowing B to have the strategic object. Both offers may also be greater than 1, in which case A would retain the strategic object, as A can both retain the strategic object and get all possible benefits in the present. In essence, B would have insufficient power to demand anything.

The complicated scenarios occur where the offer giving B the strategic object is greater than 1 ($t^*_{hA,\neg\sigma} > 1$), while the offer where A retains the strategic object is less than 1 ($t^*_{hA,\sigma} < 1$). A could still get B to accept an offer where B has the strategic object, but would be unable to get all the concessions that B would accept as A cannot get more than the entire territory in a given period. This means that the offer giving up the strategic

object is not always optimal, as A cannot gain all possible concessions. A would prefer to make the offer giving up the strategic object and retaining the entire territory if this offer gives a greater total value than either war or making the offer where A retains the strategic object. Conversely, A can make the offer where A retains the strategic object for fewer current concessions. A would do this if this offer gives a greater expected value than either war or retaining the entire territory while giving up the strategic object. A can also choose to make an unserious offer resulting in war if this war gives a greater expected value than either of the peace offers. Each of these scenarios can occur for certain parameter values.

However, it is also possible that none of the pure strategy scenarios (war, $t^*_{hA,\sigma}$, t=1 while giving up the strategic object) are stable with stationary strategies. This instability occurs because of the way the different histories interact. If A chooses to give up the strategic object and retain the entire territory in the present, the offers that B would accept in history-B change, which would than affect A's overall expected value. However, if A chooses war or retains the strategic object (offering $t^*_{hA,\sigma}$), then the minimum offer that B would accept remains unchanged. This means that A might prefer a one-time deviation from either war or making the offer retaining the strategic object ($t^*_{hA,\sigma}$), but returning to those strategies as an off path threat in history-B.

Thus, there are also certain combinations of parameter values where A plays one of two mixed strategies.[9] First, A can mix between war and ceding the strategic object while retaining the entire territory. Second, A can mix between making the offer retaining the strategic object ($t^*_{hA,\sigma}$) and the offer ceding the strategic object while retaining the entire territory. In both, A is the only player playing a mixed strategy, and only in history-A. These mixed strategies work because A is basically making both players uncertain about A's actions if history-A occurs in the future. Because this uncertainty reverberates through all of the infinite horizon offers, A becomes indifferent in the present between the two actions A is mixing between.

[9]Proof that these mixed strategies exist is in online Appendix E.

Lemma 5 formally describes A's strategies in history-A when $\delta_A < \delta_B$.

Lemma 5. *A's strategies in History-A when* $\delta_A < \delta_B$

- *If* $0 \leq t^*_{hA,\neg\sigma} \leq 1$, *then A will offer* $t^*_{hA,\neg\sigma}$
- *If* $0 \leq t^*_{hA,\sigma} \leq 1 < t^*_{hA,\neg\sigma}$, *then A will:*
  - *offer* $t_{hA,\neg\sigma} = 1$ *if* $1 + \delta_A CV_{A,hB} \geq CV_{A,war}$ *and* $1 + \delta_A CV_{A,hB} \geq t^{\ddagger}_{hA,\sigma} + CV_{A,hA}$
  - *offer* $t^{\dagger}_{hA,\sigma}$ *if* $t^{\dagger}_{hA,\sigma} + CV_{A,hA} > 1 + \delta_A CV_{A,hB}$ *and* $t^{\dagger}_{hA,\sigma} + CV_{A,hA} \geq CV_{A,war}$
  - *make an unserious offer resulting in war if* $CV_{A,war} > 1 + \delta_A CV_{A,hB}$ *and* $CV_{A,war} > t^{\dagger}_{hA,\sigma} + CV_{A,hA}$
  - *A will play a mixed strategy, making an unserious offer resulting in war with probability* α *and offering* $t_{hA,\neg\sigma} = 1$ *with probability* $1 - \alpha$ *if* $CV_{A,hA,war} < 1 + \delta_A CV^{\dagger}_{A,hB,\neg\sigma}$ *and* $CV_{A,hA,war} > 1 + \delta_A CV^{\ddagger}_{A,hB,\neg\sigma}$ *and* $\alpha CV_{A,hA,war} + (1-\alpha)(1 + \delta_A CV^{\ddagger\ddagger}_{A,hB,\neg\sigma}) > t^{\ddagger\ddagger}_{hA,\sigma} + \delta_A CV_{A,hA,warmix}$
  - *A will play a mixed strategy, offering* $t^{\ddagger\ddagger\dagger}_{hA,\sigma}$ *with probability* β, *and offering* $t_{hA,\neg\sigma} = 1$ *with probability* $1 - \beta$ *if* $1 + \delta_A CV^{\ddagger}_{A,hB,\neg\sigma} < t^{\ddagger}_{hA,\sigma} + \delta_A(1 + \delta_A CV^{\ddagger}_{A,hB,\neg\sigma})$ *and* $t^{\dagger}_{hA,\sigma} + \delta_A CV_{A,hA,\sigma}\dagger < 1 + \delta_A CV^{\dagger}_{A,hB,\neg\sigma}$ *and* $\beta(t^{\ddagger\ddagger\dagger}_{hA,\sigma} + \delta_A CV_{A,hA,peacemix}) + (1 - \beta)(1 + \delta_A CV^{\ddagger\ddagger\dagger}_{A,hB}) > CV^{\ddagger\ddagger\dagger}_{A,hA,war}$
- *If* $1 \leq t^*_{hA,\sigma} \leq t^*_{hA,\neg\sigma}$, *then A will offer* $t_{hA,\sigma} = 1$ *always, as this gives A's best possible outcome*

Comparatively, A's strategies in history-B when $\delta_A < \delta_B$ are quite simple. Because A generally prefers to be in history B, if the offer where B gets the strategic object is less than 1, A will make that offer. If that t-value is greater than 1, then A will still allow B to have the strategic object, while retaining the entire territory. Since A can already get the entire territory while allowing B to have the strategic object, A still maximizes its overall expected utility. Lemma 6 formally describes A's strategies in history-B when $\delta_A < \delta_B$.

Lemma 6. *A's strategies in History-B when* $\delta_A < \delta_B$

- *If* $0 \leq t^*_{hB,\neg\sigma} \leq 1$, *then A will offer* $t^*_{hB,\neg\sigma}$
- *If* $t^*_{hB,\neg\sigma} > 1$, *then A will offer* $t_{hB,\neg\sigma} = 1$, *as this gives A's best possible outcome.*

Since A prefers to allow B to have the strategic object, A's strategies in history-null generally mirror those in history-A. However, there are no mixed strategies, as history-null only occurs once, and thus A's actions in history-null do not affect the potential offers in other histories. Lemma 7 formally describes A's strategies in history-null when $\delta_A < \delta_B$

Lemma 7. *A's strategies in History-0 when* $\delta_A < \delta_B$

- *If* $0 \leq t^*_{1,\neg\sigma} \leq 1$*, then A will offer* $t^*_{1,\neg\sigma}$
- *If* $t^*_{1,\neg\sigma} > 1$ *and* $t^*_{1,\sigma} \geq 0$*, then A will:*
  - *offer* $t_{1,\neg\sigma} = 1$ *if* $1 + \delta_A CV_{A,hB} \geq CV_{A,war}$ *and* $1 + \delta_A CV_{A,hB} \geq t^*_{1,\sigma} + CV_{A,hA}$
  - *offer* $t^*_{1,\sigma}$ *if* $t^*_{1,\sigma} + CV_{A,hA} > 1 + \delta_A CV_{A,hB}$ *and* $t^*_{1,\sigma} + CV_{A,hA} \geq CV_{A,war}$
  - *make an unserious offer resulting in war if* $CV_{A,war} > 1 + \delta_A CV_{A,hB}$ *and* $CV_{A,war} > t^*_{1,\sigma} + CV_{A,hA}$
- *If* $t^*_{1,\neg\sigma} > 1$ *and* $t^*_{1,\sigma} < 0$*, then A will offer* $t_{1,\neg\sigma} = 1$ *if* $1 + \delta_A CV_{A,hB} \geq CV_{A,war}$*, and make an unserious offer resulting in war otherwise*
- *If* $1 \leq t^*_{1,\sigma} \leq t^*_{1,\neg\sigma}$*, then A will offer* $t_{1,\sigma} = 1$ *always, as this gives A's best possible outcome*

In the following section I examine how exogenous and endogenous power shifts affect war. After that, I discuss several other interesting findings from the model.

3 Which power shifts cause war?

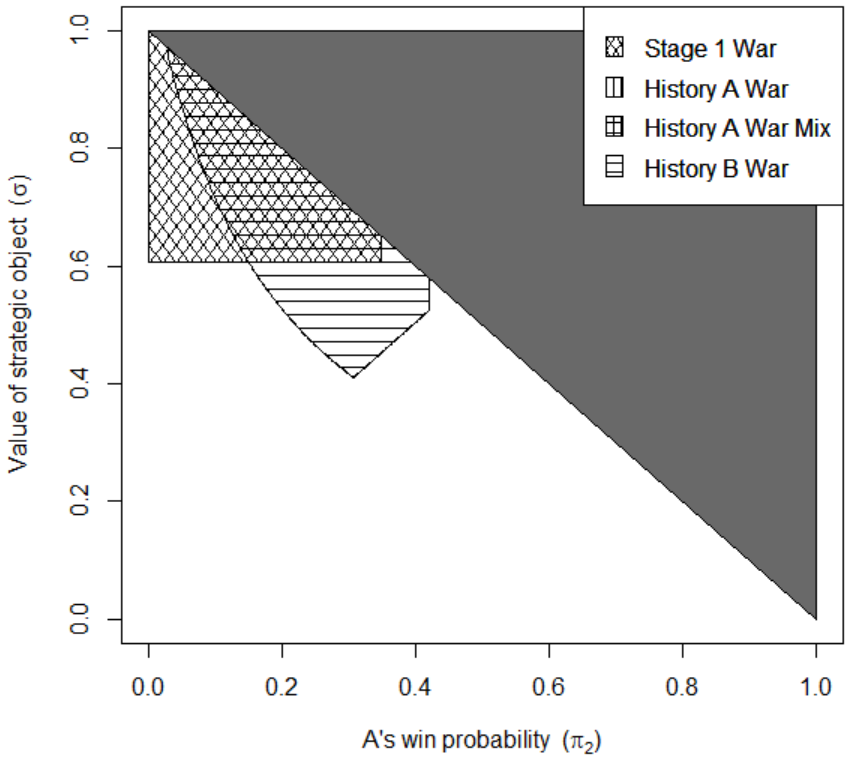
The model helps clarify which types of power shifts can cause war. In contrast to previous research, exogenous power shifts are never sufficient to cause war. Even combined with other causes, they have a surprisingly modest effect. However, endogenous power shifts can cause war on their own, and would be a necessary component for power shifts to lead to war.

3.1 Exogenous power shifts are never sufficient

Exogenous power shifts are never sufficient to cause war. Figures 2 and 3 show the war range (for situations where $\delta_A > \delta_B$ and $\delta_A < \delta_B$, respectively) for values of π_2 and σ, with

$\pi_1 = 0.5$. Note that there is no war range when $\sigma = 0$, which is the situation where there is no strategic object under dispute, and only exogenous power shifts are possible. Thus, even the largest exogenous power shifts are insufficient to cause war on their own.

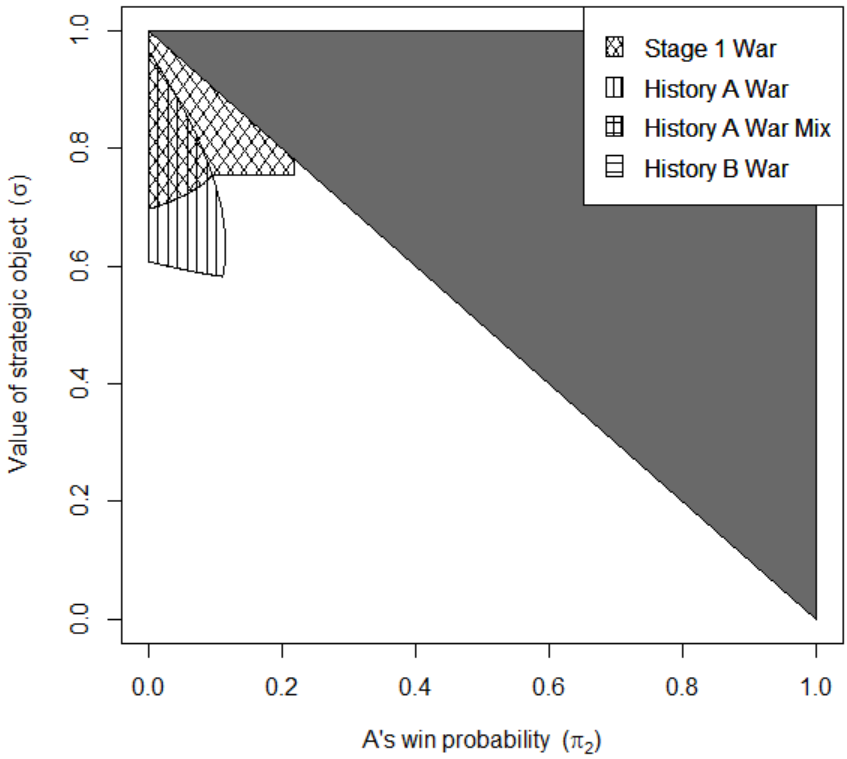
Figure 2: Power shifts and War, $\delta_A > \delta_B$;
$\pi_1 = 0.5$, $c_A = c_B = 0.1$, $\delta_A = 0.95$, $\delta_B = 0.9$



In fact, with stationary strategies, war is always impossible when $\sigma = 0$ and only exogenous power shifts occur.[10] In such a situation, histories A and B are identical, and A has the same chance of winning a war in both histories. For obvious reasons, this eliminates any rational reason to prefer war over a negotiated settlement in the infinite horizon phase. Given that there would be no possibility of achieving a power shift through war, a stable bargaining range opens up regardless of the value of the other parameters.

[10]Proof in online Appendix F

Figure 3: Power shifts and War, $\delta_A < \delta_B$;
$\pi_1 = 0.5$, $c_A = c_B = 0.1$, $\delta_A = 0.9$, $\delta_B = 0.95$



Somewhat less obvious, situations where $\sigma = 0$ also eliminate conflict in stage 1. Regardless of the outcome of stage 1, the parties will end up in the same infinite horizon phase. This in turn forces A's optimal offers in stage 1 to be identical. Since at least one of these offers is always preferable to war, both offers must be preferable to war and war becomes impossible in stage 1. This occurs regardless of the magnitude of the exogenous power shift (represented by the difference between π_1 and π_2). Accordingly, this model proves that exogenous power shifts cannot lead to war without the existence of other factors.[11]

[11]Note that this general finding would carry over even to situations where power can be affected by war, but is not negotiable. In such a case, the proximate cause of war would still be the ability of war to affect the power balance. If there were no way for war to affect

This finding largely generalizes to equilibria with punishment strategies. In this case, Slantchev (2003) showed that there could be equilibria where war occurs, even absent a strategic object. However, every war equilibrium would coexist, and would in fact rely on the existence of, a peace equilibrium that is Pareto superior to the war equilibrium. In other words, when there is no strategic object, there would always be a stable peaceful settlement that both sides would prefer to war. In addition, the strategy profile required for a war equilibrium are substantively odd, as they require each side to punish the other for offering a mutually preferable peace. The war equilibria thus do not make substantive sense. We can conclude that in nearly every case, if there is perfect information and no strategic object under dispute, rational actors will not go to war.[12] Thus, exogenous power shifts are likely never sufficient to cause rational war, even with punishment strategies.

In essence, if a power shift will occur regardless of whether a war is fought, then war does nothing to solve commitment problems created by the power shift. In such cases, as nothing can alter the future benefits of the actors, there is no rational reason to fight a war. Thus, exogenous power shifts should not be considered a sufficient or proximate cause of war.

3.2 Indivisible endogenous power shifts may be sufficient to cause war

The previous discussion showed that endogenous power shifts are a necessary cause of commitment problem wars. In addition, endogenous power shifts can be sufficient to cause war on their own. Note that figures 2 and 3 show a war range in the infinite horizon phase (history-B and history-A respectively). Since there is no exogenous power shift possible in the model after stage 1, only endogenous power shifts could be the cause of these wars. Thus, the power balance, exogenous power shifts would never cause war. In addition, the ability of war to affect the power balance could still cause war absent an exogenous power shift.

[12]Further discussion and proofs in online Appendix F

the model proves that in some cases, endogenous power shifts may be sufficient to cause war.

In essence, when the outcome of the war or negotiations may affect the relative power balance, it would also affect the future distribution of other goods. This may lead to situations where there is no agreement that both sides prefer to war. The concessions that one side is willing to make in the present division of benefits may be insufficient to make up for the other side's loss of power and future benefits. Thus, endogenous power shifts alone can cause war.

However, as noted above, Fearon (1996) showed that the endogenous power shift would have to be indivisible for war to be rational. Where power is continuously divisible, salami tactics can adjust power at a slow enough rate that there would always be a peaceful settlement that both sides would prefer to war.

3.3 Exogenous power shifts can modestly increase the war range

While exogenous power shifts cannot cause war on their own, they can make war caused by endogenous power shifts more likely, although this effect is relatively modest. In essence, there may be a window of opportunity before an expected exogenous power shift that would give one state a better chance of capturing the strategic object.

Figures 2 and 3 show the situation for a fixed probability of winning in period 1. This means that locations further to the left represent increased exogenous power shifts that are disadvantageous for state A. Interestingly, in most cases it seems that exogenous power shifts have little effect on the probability of war. Note that much of the war range boundaries for period 1 are horizontal. Within these regions, increasing the exogenous power shift has absolutely no effect on the probability of war.

However, there are other cases where larger exogenous power shifts do increase the war range. For instance, in figure 3, as the value of π_2 becomes smaller at the left, the necessary σ to cause war also decreases. This would occur for the traditional explanation - given a window of opportunity when its power is relatively high, state A would want to use

this opportunity to adjust the future balance of power in its favor. B may not be willing to accommodate A's attempt peacefully, thus resulting in war.

There are also a few cases where an adverse exogenous power shift can allow a state to take advantage of its temporary power advantage to gain the strategic object peacefully. Note that in both figure 2 and 3, there are areas where war occurs after the exogenous power shift, but not before. Also, interestingly in both figures, war can occur in the infinite horizon phase at lower values of σ than in stage 1. In these cases, a state may be willing to fight to gain the strategic object to increase their power only after the exogenous power shift. However, before the exogenous power shift, they may have a sufficient advantage to induce the other state to cede the strategic object peacefully.

Why don't exogenous power shifts have a larger effect? The primary reason is that it is the ability to affect future power that matters most in decisions about war and peace. This is determined by two factors. First, the magnitude of σ and second the power ratio in the present. A larger σ means that any changes will have larger impacts in the future. Second, the current power ratio, and not any expected future power shifts, is what determines the ability of a state to change its future situation. While exogenous power shifts can create windows of opportunity to alter the future balance of power, they do not necessarily do so. Thus, exogenous power shifts play a relatively small role in determining whether states fight.

3.4 Substantive implications

Overall, the model shows that exogenous power shifts are never sufficient to cause rational states to go to war, and likely have a relatively modest effect on other causes of conflict. Thus, we can rule out power transitions caused by economic development or population growth as proximate causes of war.

This finding substantially alters our understanding of power shifts and conflict. Most previous formal models of war (e.g. Fearon 1995; Powell 2006) have suggested that exogenous power shifts are a potential cause of war. Even Chadefaux's (2011) finding that continu-

ously divisible endogenous powers shifts could prevent war is backwards. In fact *indivisible* endogenous power shifts would be *necessary* for war to occur. Similarly, non-formal theories about great power transitions leading to war may have to be re-thought. While there may still be reasons that power transitions can make war more likely, they can never be a direct cause of rational war.

This finding also has clear implications for empirical examinations of power shifts and wars. For instance, several recent experiments (Tingley 2017; Renshon, Lee, and Tingley 2017; Shirkey 2017) have examined how people react to power shifts, to see whether actual behavior is likely to match the predictions of formal models. However, each of these experiments focuses on exogenous power shifts, and so the results would have to be reinterpreted since exogenous power shifts cannot directly cause war.

Accordingly, the shifting US-China power balance is not sufficient to cause war. This power shift is driven primarily by China's economic growth. This economic growth is largely beyond the control of the Chinese or US governments, and so represents an exogenous power shift. Thus, it is insufficient to cause war. While the power transition may still increase the risk of war, it would have to do so through other mechanisms, such as by increasing uncertainty about what the power balance is or the intentions of the two powers.

At the same time disputes over indivisible sources of bargaining leverage may be sufficient to cause war, and thus should be seen as the central mechanism creating commitment problem wars. Endogenous power shifts could be created by several things. First, the very existence of one of the states would represent an endogenous shift, as eliminating a country is equivalent to reducing its bargaining power to zero.[13] Second, as Wolford (2012) showed, replacing the government or regime of an adversary could also change the bargaining power of the two sides, as different regimes have different views of the costs and benefits of war

[13]Note that this means that previous models of commitment problems that assume that war settles the dispute permanently are simply a special case of the more general model I have presented.

and negotiations. Third, possession of strategic territory, such as mountains or rivers could in some cases sufficiently alter the states' relative power to cause war. Finally, disputes over the possession of nuclear weapons could lead to war, as long as a state could be disarmed (or prevented from arming) through force, as nuclear weapons are both indivisible and have a major effect on the power balance.

However, remember that a critical requirement is that the source of the bargaining leverage is indivisible. This means that disputes over resource rich territory are likely insufficient to cause rational war, as the resources could be continuously divisible. It also calls into question Walter's (1997) argument that commitment problems the requirement that rebels disarm may be a major barrier to civil war termination, as there may be power sharing agreements (including over arms) that would essentially make power divisible. It is likely that there is a power sharing agreement or that disarmament and reintegration could be phased such that there would always be a negotiated settlement dividing power such that both sides would agree.

Iraq's, Iran's, and North Korea's suspected nuclear programs would represent a potential endogenous power shift, and so could cause war. This does not mean that war is inevitable, as one side or the other may not believe that gaining or eliminating nuclear weapons is worth war. However, the First World War is not plausibly caused by power shifts. The development of German naval power and Russian military power would represent endogenous power shifts, as they represent deliberate state policies. However, neither case is indivisible, so there would be some settlement that both sides would prefer to war. Thus, for these power shifts to lead to war, there would have to be some other reason the states were fundamentally unwilling to negotiate over the power shift, such as pride. This unwillingness to negotiate would be the direct cause of war.

Future research into power shifts and war needs to focus more on state strategies to alter the power balance rather than changes in the power balance caused by external factors. Only disputes over indivisible sources of bargaining power can cause rational war

under perfect information.

4 Additional findings

The model provides several other interesting findings. First, contrary to some previous theories, longer shadows of the future can make war more likely. Interestingly, war also seems to become more likely when the two sides have different length shadows of the future. Second, commitment problem wars are not necessarily long. Finally, there may be cases when wars due to commitment problems occur probabilistically.

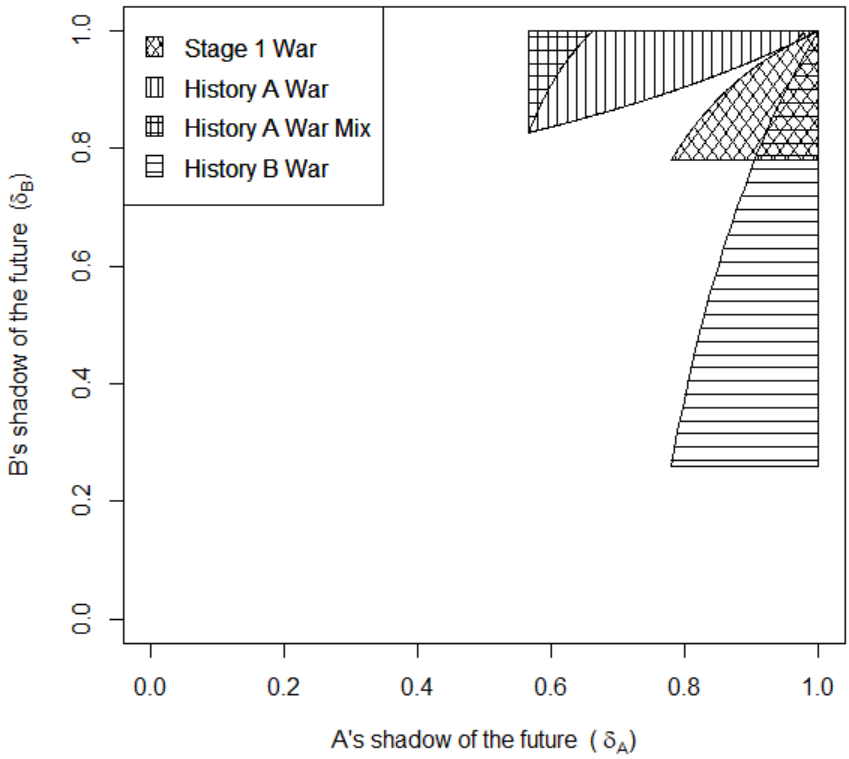
4.1 Longer and asymmetric shadows of the future can make war more likely

The first additional finding is that longer shadows of the future tend to make war more likely. Figure 4 shows the war range in each stage over the range of the δ parameters.

This graph clearly shows that higher values of the δ parameters make war more likely. This occurs because as the shadow of the future increases, each state cares more about securing the strategic object in order to secure long term benefits. B demands increased concessions for ceding the strategic object, while A becomes more willing to bear the short term costs of fighting to gain the strategic object. In essence, as states care more for future gains, they become more willing to pay short term war costs to try and shift the power balance in their favor. Although other papers have made similar claims (e.g. Fearon 1998; Garfinkel and Skaperdas 2000), this is still interesting as the classic view (e.g. Axelrod 1984) is that an increased shadow of the future should enhance cooperation by permitting greater punishment for non-cooperation.

Interestingly, within the infinite horizon phase, it appears that asymmetric shadows of the future make war particularly likely. Note that in figure 4 there is no war range along the diagonal where the two δ parameters are equal. When demanding the strategic object,

Figure 4: The Shadow of the Future and War;
$\pi_1 = 0.5$, $\pi_2 = 0.1$, $\sigma = 0.7$, $c_A = c_B = 0.1$



A cannot demand as much territory in the present. When $\delta_A = \delta_B$, the tradeoff between present and future gains exactly balances out, and A is indifferent about whether to demand the strategic object. Since at least one offer is always preferable to war, when the shadows of the future are similar, both offers are superior to war. This logic carries over to offers with different but similar shadows of the future, making it likely that the less preferred peace offer is also preferable to war.

The finding that asymmetric shadows of the future are especially likely to cause war warrants further research given observations that different regime types are more likely to fight (e.g. Werner 2000). Different regime types are likely to have different shadows of the future. For instance, personalist dictators may have a shorter shadow of the future given

that the benefits they perceive are limited to their own lifetime. In contrast, single party regimes or democracies[14] may have longer shadows of the future as they care about the state as an institution, beyond the scope of any individual. This finding may thus be relevant in understanding the empirical observation that democracies do not fight each other, while democracies and dictatorships appear relatively prone to conflict.

4.2 Wars due to power shifts are not necessarily long

Previous research (e.g. Gartzke 1999; Reiter 2009; Weisiger 2013) has often used commitment problems to explain unusually long and destructive wars. However, another interesting implication of this model is that wars due to power shifts and commitment problems are not necessarily long wars.

Within the infinite horizon phase, war only occurs in history-A or history-B, never in both. Whenever the strategic object is possessed by the side with the longer shadow of the future, A can always make an offer that is mutually preferable to war. Thus, if war begins, it continues as long as the strategic object is possessed by the side with the shorter shadow of the future. However, once the strategic object has changed hands, war will cease and a negotiated settlement will be implemented, even if neither side is completely defeated.

Also note that in both figures 2 and 3, there are areas where war occurs in stage 1, but not in the corresponding history within the infinite horizon phase. Thus, there are also situations where A's decision to fight is driven by a window of opportunity provided by an exogenous power shift. However, once the exogenous power shift has occurred, war is no longer preferred, even if the strategic object was not transferred. For instance, this could occur if A no longer has a reasonable chance of winning and gaining the strategic object. Alternatively, A may have gained the strategic object, but A's power with the strategic object is so great that B is no longer willing to fight to get it back. Thus, in the presence

[14]It is also conceivable that democracies have short shadows of the future due to the frequency of elections.

of exogenous power shifts, wars driven by power shifts can end even if the strategic object is not transferred.

At the same time, wars driven by power shifts could still be long or intense. When the strategic object dramatically changes the power balance, it may be necessary for one state to almost completely defeat the other in order to gain the strategic object. In such cases, wars may still be long and intense, as it would take significant fighting to gain the strategic object. In addition, additional exogenous power shifts or changes in the sides' shadows of the future may change the situation sufficiently to reopen the war range. Thus, even a conflict that ended with the capture of the strategic object could begin again.

4.3 In a few cases, commitment problem wars may be probabilistic.

Gartzke (1999) noted that wars caused by private information may be inherently probabilistic, as misperceptions of relative power or resolve may include a random component. In contrast, commitment problem wars would seem to be deterministic, as they are modeled assuming that both sides have perfect information. While this model generally supports a deterministic view of commitment problem wars, it does show that some of these wars may be probabilistic as well. As can be seen in figure 4 and lemma 5, there is a region in history-A where state A plays a mixed strategy, probabilistically choosing either war or a peace offer that cedes the strategic object.[15] Thus in this region, A's decision on whether to fight is inherently probabilistic.

This mixed strategy is rather unusual in two respects. First, mixed strategies are not usually found in bargaining games, as there is a continuous range of possible offers that can be made. This generally allows the players to choose a single optimal strategy, rather than being forced into a mixed strategy. Second, the mixed strategy in this game only involves

[15]There is a similar mixed strategy between offering $t_{\neg\sigma} = 1$ while ceding the strategic object and offering $t_{\sigma}^{\ddagger\ddagger\dagger}$ while demanding it, but this is less substantively interesting.

state A making a probabilistic choice, whereas mixed strategies typically involve both players making probabilistic decisions.

This mixed strategy occurs due to the combination of three factors: the game lasting indefinitely, the game having multiple histories with different probabilities of military victory, and the zero-bound of the possible offers. The infinite horizon nature of the game and the multiple histories means that A's expected future decisions impact B's minimal acceptable offer, which in turn affects A's decisions in the present.

Recall that in history-A there are cases where B will allow A to retain the entire territory if A surrenders the strategic object. A can thus be faced with a situation where it is unable to obtain as many concessions as B would allow. A is forced to choose between accepting the limited concessions, making a less preferred offer where A retains the strategic object, or war.

However, A's expected choice in future rounds affects B's minimally acceptable offer in both history-A and history-B. In particular, in history-A, if A retains the entire territory while allowing B to have the strategic object, B will demand more than if A had made one of the other offers. However, because it is the future expectation of A's behavior that matters, any of the stationary pure strategy offers may be unstable, with A preferring one strategy in the present while non-credibly promising to play a different strategy in the future. The only solution is for A to make its future strategies probabilistic, making A indifferent in the present between two of the different options.

At the same time, note that the mixed strategy region is relatively small. It seems to occur primarily when there is a significant imbalance in the two sides shadow of the future. Thus, commitment problems do seem to deterministically cause war or peace in most cases. The underlying parameters, such as costs and power, may have probabilistic components and commitment problems may interact with other probabilistic incentives for war (such as private information). However, once these conditions are met, commitment problem wars do seem to be deterministic in most cases. Future research can examine the extent to which

commitment problem wars are probabilistic versus deterministic in the empirical record.

5 Conclusion

In this paper, I attempted to clarify the basic logic behind how commitment problems lead to war. By relaxing the assumption that war "locks-in" a given outcome and by including both exogenous and endogenous power shifts in the same model, this paper presents a more general model of commitment problems than previous work. This model reveals several surprising conclusions.

First, and most prominently, exogenous power shifts due to factors beyond states immediate control are neither necessary nor sufficient to cause war. Instead, the proximate cause of war in this model is endogenous power shifts caused by fighting or negotiating over factors that influence bargaining power. While exogenous power shifts can make war more likely, they can only cause war when combined with endogenous power shifts. At the same time, endogenous power shifts can cause war without a corresponding exogenous power shift. Moreover, the effect of exogenous power shifts is relatively mild, and at times increased changes in future power have absolutely no effect on the likelihood of war.

Other forms of commitment problems may exist, including situations where the only settlement includes a probabilistic bargain such as arbitration (e.g. Powell 2006) or situations where the decision to bargain itself creates power shifts, such as where there are first-strike advantages (e.e. Beard and Strayhorn 2018). However, this model shows that a prominent source of commitment problems leading to war are disputes over indivisible sources of bargaining power. This suggests that war could be caused by disputes over one state's existence or regime type, nuclear weapons, or major pieces of strategic territory.

This model also reveals several other interesting implications. First, longer and asymmetric shadows of the future tend to make war more likely. This challenges the prevailing view that the shadow of the future tends to make cooperation more likely despite incentives

to defect from agreements. Second, this finding may have implications for understanding the democratic peace, as different regime types likely have different shadows of the future.

A second interesting finding is that wars due to commitment problems never last forever, with continued fighting until one state is exhausted. Given that for a given set of parameters, the states only fight in history-A or history-B, wars will naturally terminate once the source of bargaining power is captured. While near total wars may still occur if capturing the source of bargaining leverage requires one state to be largely defeated, this observation still counters the previous belief that commitment problem wars are necessarily long lasting.

Future research can expand on these results in several ways. First, as noted above, the model clarifies which factors can create commitment problems that can cause war. Future empirical research can determine the extent to which these factors occur in actual wars, helping determine the prevalence of commitment problems as a cause of war. In addition, future research can examine how commitment problems interact with other sources of conflict when the assumption that wars "lock-in" a settlement is dropped. For instance, while Wolford, Reiter, and Carrubba's (2011) results likely largely hold up, additional interesting results on the interaction of commitment problems and private information may be revealed by dropping the assumption that war creates a permanent outcome.

This research also has practical implications. Most importantly, it suggests that conflict prevention efforts may find it more beneficial to focus on potential state strategies to alter their bargaining position rather than exogenous shifts in power. Similarly, this model suggests that concerns about the rise of China causing war may be somewhat overstated. China's increasing power is largely due to exogenous factors, especially rapid economic growth. As there are no clear indivisible sources of bargaining power under disputed by the US and China, war is likely not inevitable. Managing uncertainty and other forms of instability should allow a peaceful power transition.

A Actual CVs, t-values, α and β

A.1 Offers (t-values)

Basic t-values, which occur as long as $t^{\dagger}_{hA,\neg\sigma} \leq 1$ or when A fights in history-A.

$t^{\dagger}_{hB,\sigma} = \frac{\pi_2 - \sigma\delta_B}{1-\sigma\delta_B} + c_B$

$t^{\dagger}_{hB,\neg\sigma} = \frac{\pi_2}{1-\sigma\delta_B} + c_B,$

$t^{\dagger}_{hA,\sigma} = \frac{\pi_2+\sigma-\sigma\delta_B}{1-\sigma\delta_B} + c_B,$

$t^{\dagger}_{hA,\neg\sigma} = \frac{\pi_2+\sigma}{1-\sigma\delta_B} + c_B$

Alternate history-B offers

$t^{\ddagger}_{hB,\sigma} = \frac{\pi_2+2\pi_2\delta_B-\delta_B+c_B+\delta_B c_B}{1+\pi_2\delta_B}$ (If A makes an offer of $t_{hA,\neg\sigma} = 1$ in history-A)

$t^{\ddagger}_{hB,\neg\sigma} = \frac{\pi_2+\pi_2\delta_B+c_B}{1+\pi_2\delta_B}$ (If A makes an offer of $t_{hA,\neg\sigma} = 1$ in history-A)

$t^{\ddagger\dagger}_{hB,\sigma} = \frac{\pi_2-\delta_B+\pi_2\delta_B+c_B}{1-\delta_B+\pi_2\delta_B}$ (If A makes an offer of $t_{hA,\sigma} = 1$ in history-A)

$t^{\ddagger\dagger}_{hB,\neg\sigma} = \frac{\pi_2+c_B-\delta_B c_B}{1-\delta_B+\pi_2\delta_B}$ (If A makes an offer of $t_{hA,\sigma} = 1$ in history-A)

Offers related to mixing strategies

$t^{\ddagger}_{hA,\sigma} = \pi_2 + \sigma + c_B - \delta_B(1-\pi_2-\sigma)\frac{1-\pi_2-c_B}{1+\pi_2\delta_B}$ (One round off-path offer in history-A if A makes an accepted offer $t_{hA,\neg\sigma} = 1$ in history-A.)

$t^{\ddagger\ddagger}_{hB,\neg\sigma} = \frac{(\pi_2+\sigma)(1+\delta_A)-1-c_A}{\pi_2\delta_A+\sigma\delta_A}$ (offer in history-B, if A mixes between war and offering $t_{hA,\neg\sigma} = 1$ in history-A)

$t^{\ddagger\ddagger}_{hB,\sigma} = \frac{1+c_A-c_A\pi_2+\pi_2^2+2\delta_A\pi_2^2-\sigma-\delta_A\sigma+c_B\delta_A\sigma-2\pi_2+\pi_2\sigma-\delta_A\pi_2+c_B\delta_A\pi_2+2\delta_A\pi_2\sigma}{\delta_A\pi_2(\pi_2+\sigma)}$ (Corresponding value to the above)

$t^{\ddagger\ddagger\dagger}_{hB,\neg\sigma} = \frac{\delta_A\pi_2+c_B-c_B\sigma}{1-\pi_2+\delta_A\pi_2-\sigma}$ (offer in history-B, if A mixes between offering $t_{hA,\neg\sigma} = 1$ and $t^{\ddagger\ddagger\dagger}_{hA,\sigma}$ in history-A)

$t^{\ddagger\ddagger\dagger}_{hB,\sigma} = \frac{1-\pi_2+2\pi_2\delta_A-\sigma-\delta_A+c_B\delta_A-c_B\sigma}{1-\pi_2+\pi_2\delta_A-\sigma}$ (Corresponding value to the above)

$t^{\ddagger\ddagger\dagger}_{hA,\sigma} = 1-\delta_A+\delta_A t^{\ddagger\ddagger\dagger}_{hB,\neg\sigma}$ (Corresponding value to the above in history-A)

Offers in stage 1

$t^{\dagger}_{1,\neg\sigma} = \pi_1 + c_B + \pi_1\delta_B\frac{\sigma-\sigma\delta_B}{1-\delta_B-\sigma\delta_B+\sigma\delta_B^2})$ (Basic offers)

$t^{\dagger}_{1,\sigma} = \pi_1 + c_B - (\delta_B - \pi_1\delta_B)\frac{\sigma-\sigma\delta_B}{1-\delta_B-\sigma\delta_B+\sigma\delta_B^2}$

$t^{\ddagger}_{1,\neg\sigma} = \pi_1 + c_B + (\pi_1\delta_B - \pi_1\delta_B^2)\frac{1-\pi_2-c_B}{1-\delta_B+\pi_2\delta_B-\pi_2\delta_B^2}$ (If A makes an accepted offer of $t_{hA,\neg\sigma} = 1$ in history-A)

$t^{\ddagger}_{1,\sigma} = \pi_1 + c_B - (\delta_B - \delta_B^2 - \pi_1\delta_B + \pi_1\delta_B^2)\frac{1-\pi_2-c_B}{1-\delta_B+\pi_2\delta_B-\pi_2\delta_B^2}$ (If A makes an accepted offer of $t_{hA,\neg\sigma} = 1$ in history-A)

$t^{\ddagger\dagger}_{1,\sigma} = \pi_1 + c_B - (1-\pi_1)\delta_B\frac{1-\pi_2-c_B}{1-\delta_B+\pi_2\delta_B}$ (If A makes an accepted offer of $t_{hA,\sigma} = 1$ in history-A)

$t^{\ddagger\dagger}_{1,\neg\sigma} = \pi_1+c_B+\pi_1\delta_B\frac{1-\pi_2-c_B}{1-\delta_B+\pi_2\delta_B}$ (If A makes an accepted offer of $t_{hA,\sigma} = 1$ in history-A)

$t^{\ddagger\ddagger\ddagger}_{1,\sigma} = t^{\ddagger\ddagger\ddagger}_{1,\neg\sigma} = \pi_1 + c_B$ (If A makes accepted offers of $t = 1$ in both history-A and history-B)

$t^{\ddagger\ddagger}_{1,\sigma} = \pi_1 + c_B - (1-\pi_1)\delta_B\frac{1-t^{\ddagger\ddagger}_{hB,\neg\sigma}-\alpha(1-\pi_2-\sigma-c_B)}{1-\alpha\delta_B(\pi_2+\sigma)}$ (If A plays a mixed strategy between war and offering $t_{hA,\neg\sigma} = 1$ in history-A)

$t^{\ddagger\ddagger}_{1,\neg\sigma} = \pi_1\delta_B\frac{1-t^{\ddagger\ddagger}_{hB,\neg\sigma}-\alpha(1-\pi_2-\sigma-c_B)}{1-\alpha\delta_B(\pi_2+\sigma)} + \pi_1 + c_B$ (If A plays a mixed strategy between war and offering $t_{hA,\neg\sigma} = 1$ in history-A)

$t^{\ddagger\ddagger\dagger}_{1,\sigma} = \pi_1 + c_B - (1-\pi_1)\delta_B\frac{(1-\beta\delta_A)(1-t^{\ddagger\ddagger\dagger}_{hB,\neg\sigma})}{(1-\beta\delta_B)}$ (If A plays a mixed strategy between the two peace offers in history-A)

$t^{\ddagger\ddagger\dagger}_{1,\neg\sigma} = \pi_1\delta_B\frac{(1-\beta\delta_A)(1-t^{\ddagger\ddagger\dagger}_{hB,\neg\sigma})}{(1-\beta\delta_B)} + \pi_1 + c_B$ (If A plays a mixed strategy between the two peace offers in history-A)

A.2 Continuation values

B's CVs:

$CV_{B,hB} = \frac{1-t^*_{hB,\neg\sigma}}{1-\delta_B} = 1 - t^*_{hB,\sigma} + \delta_B\frac{1-t^*_{hA,\sigma}}{1-\delta_B}$ if A makes an accepted offer of $t^*_{hB,\neg\sigma}$ or $t^*_{hB,\sigma}$ or if A chooses to fight.

$CV_{B,hA} = 1 - t^*_{hA,\neg\sigma} + \delta_B\frac{1-t^*_{hB,\neg\sigma}}{1-\delta_B} = \frac{1-t^*_{hA,\sigma}}{1-\delta_B}$ if A makes an accepted offer of $t^*_{hA,\neg\sigma}$ or $t^*_{hA,\sigma}$ or if A chooses to fight.

$CV^{\ddagger\ddagger\ddagger}_{B,hB} = 0$ if A makes an accepted offer of $t_{hB,\neg\sigma} = 1$ or $t_{hB,\sigma} = 1$.

$CV^{\ddagger\dagger}_{B,hA,\sigma} = 0$ if A makes an accepted offer of $t_{hA,\sigma} = 1$ in history-A.

$CV^{\ddagger}_{B,hA,\neg\sigma} = 0 + \delta_B \frac{1-t^{\ddagger}_{hB,\neg\sigma}}{1-\delta_B}$ if A makes an offer of $t_{hA,\neg\sigma} = 1$ in history-A, and makes an offer of $t^{\ddagger}_{hA,\neg\sigma}$ in history-B.

$$CV_{B,hA,warmix} = \frac{\alpha(1-\pi_2-\sigma-c_B)+(1-\alpha(\pi_2-\sigma))\delta_B \frac{1-t^{\ddagger\ddagger}_{hB,\neg\sigma}}{1-\delta_B}}{1-\alpha\delta_B(\pi_2+\sigma)}$$

$$CV_{B,hA,peacemix} = \frac{\beta-\beta t^{\ddagger\ddagger\dagger}_{hA,\sigma}+(1-\beta)\delta_B \frac{1-t^{\ddagger\ddagger\dagger}_{hB,\neg\sigma}}{1-\delta_B}}{1-\beta\delta_B}$$

A's CVs

$CV_{A,hB,\neg\sigma} = \frac{t^*_{hB,\neg\sigma}}{1-\delta_A}$

$CV_{A,hB,\sigma} = t^*_{hB,\sigma} + \delta_A \frac{t^*_{hA,\sigma}}{1-\delta_A}$

$CV_{A,hA,\neg\sigma} = t^*_{hA,\neg\sigma} + \delta_A \frac{t^*_{hB,\neg\sigma}}{1-\delta_A}$ and

$CV_{A,hA,\sigma} = \frac{t^*_{hA,\sigma}}{1-\delta_A}$

$CV^{\ddagger\ddagger\ddagger}_{A,hB} = \frac{1}{1-\delta_A}$ if A makes an accepted offer of $t_{hB,\neg\sigma} = 1$ or $t_{hB,\sigma} = 1$ in history-B.

$CV^{\ddagger\dagger}_{A,hA,\sigma} = \frac{1}{1-\delta_A}$ if A makes an accepted offer of $t_{hA,\sigma} = 1$.

$CV^{\ddagger}_{A,hA,\neg\sigma} = 1 + \delta_A \frac{t^{\ddagger}_{hB,\neg\sigma}}{1-\delta_A}$ if A makes an offer of $t_{hA,\neg\sigma} = 1$ in history-A, and makes an offer of $t^{\ddagger}_{hB,\neg\sigma}$ in history-B.

$$CV_{A,hB,war} = \frac{\pi_2-c_A+\pi_2\delta_A \frac{t^*_{hA,\sigma}}{1-\delta_A}}{1-\delta_A+\pi_2\delta_A}$$

$$CV_{A,hA,war} = \frac{\pi_2+\sigma-c_A+(1-\pi_2-\sigma)\delta_A \frac{t^*_{hB,\neg\sigma}}{1-\delta_A}}{1-\pi_2\delta_A-\sigma\delta_A}$$

$$CV_{A,hA,warmix} = \frac{1-\alpha+\alpha\pi_2+\alpha\sigma-\alpha c_A+(1-\alpha\pi_2-\alpha\sigma)\delta_A \frac{t^{\ddagger\ddagger}_{hB,\neg\sigma}}{1-\delta_A}}{1-\alpha\delta_A(\pi_2+\sigma)}$$

$$CV_{A,hA,peacemix} = \frac{1-\beta+\beta t^{\ddagger\ddagger\dagger}_{hA,\sigma}+(1-\beta)\delta_A \frac{t^{\ddagger\ddagger\dagger}_{hB,\neg\sigma}}{1-\delta_A}}{1-\beta\delta_A}$$

A.3 The mixing probabilities

$\alpha = \frac{(1+\pi_2\delta_B)(1-\pi_2-\sigma+c_A)-(1-\pi_2-c_B)(\pi_2\delta_A+\sigma\delta_A)}{(\pi_2\delta_B+\sigma\delta_B)(1-\pi_2-\sigma+c_A)-(\sigma\delta_B+\pi_2 c_A\delta_B-\pi_2 c_B\delta_B-\sigma c_B\delta_B)(\pi_2\delta_A+\sigma\delta_A)}$The probability A chooses war in history-A when A mixes between war and offering $t_{hA,\neg\sigma} = 1$

The mixing probability where A mixes and offering $t_{hA,\neg\sigma} = 1$ and $t^{\dagger}_{hA,\sigma}$:

$\beta = \frac{(1+\delta_B)(1-\pi_2-\sigma)-\delta_A(1-\pi_2)-c_B(1-\delta_A+\delta_B(1-\sigma))}{\delta_B(1-c_B-\pi_2-\sigma-\delta_A\sigma+c_B\delta_A\sigma)}$The probability that A chooses to offer$t^{\ddagger\ddagger\dagger}_{hA,\sigma}$ when A mixes between offering $t_{hA,\neg\sigma} = 1$ and $t^{\ddagger\ddagger\dagger}_{hA,\sigma}$:

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