How Does War Resolve Commitment Problems?*
Reevaluating Power Shifts as a Source of Rational War

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Abstract

Previous research has recognized commitment problems as a potentially significant cause of rational war. However, for commitment problems to cause war, war must be able to resolve the commitment problem. The resolution of commitment problems has gone largely unstudied. In this paper, I use formal models to examine six ways that war or negotiation can resolve commitment problems posed by exogenous power shifts. Of these six models, war never occurs in three: disputes over military capabilities, disputes over resources that provide both benefits and power, and disputes in the presence of defensive advantages. War only occurs if there is a dispute over the existence of one state, the regime type of one state, or an indivisible object that influences bargaining power. These models thus show that considering how war resolves the commitment problem, and why such a resolution is unavailable peacefully, is necessary in explaining commitment problem wars.

Scholars have long suggested that shifting power might be a major cause of war. For instance, power shifts may have helped cause World War I (e.g. Levy and Mulligan 2017; Maurer 1997) and the US invasion of Iraq (Debs and Montiero 2014). Others fear that China's economic and military development will heighten the risk of war with the United States (e.g. Allison 2017). 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.

However, these models simply assume that war solves the commitment problem by assuming that the war outcome is locked in forever. In this paper, I fill this gap in the literature by examining how war resolves the commitment problem, and why no equivalent peaceful resolution is possible. Using a series of formal models, I examine six ways that war can resolve commitment problems posed by exogenous power shifts using a series of formal models. First, I examine whether destroying some of the opponent's military capabilities can resolve the commitment problem. Second, I examine a situation where there is a dispute over resource rich territory or some similar source of both military power and direct benefits. Third, I examine whether defensive advantages might make it easier to hold captured territory, and thus ameliorate the exogenous power shift. Fourth and fifth, I examine models where one state eliminates the other or changes the second's regime to resolve the commitment problem. Finally, I examine a situation where there is a dispute over some indivisible strategic object that substantially changes the power balance.

Of these six models, war only occurs in the last three. For war to occur, war must be able to resolve the commitment problem, and an equivalent peaceful settlement must be unavailable. A fundamental principle of the bargaining framework is that anything that can be achieved by war can be achievable in a peaceful settlement. Since the resolution to the commitment problem in the first three models is continuously divisible, there is always some settlement that is mutually preferable to war. War occurs in the last three models because

the resolution to the commitment problem is indivisible. Accordingly, the conditions for commitment problems to cause war are more limited than previously recognized. Substantively, commitment problem wars could be caused by disputes over the existence of a state or its regime, strategic territory or the possession of nuclear weapons, but not most other factors.

Two other interesting results emerge from these models. First, war can happen absent an exogenous power shift, provided that one state has a longer time horizon. Second, war depends on the relationship between the two states' time horizons. The exact relationship required for war varies, but generally war is more likely when one state has a significantly longer time horizon than the other.

1   Theoretical Background

In this section, I will first discuss why it is necessary to examine how war solves the commitment problem. Then, I will discuss two basic tenets or assumptions guiding my examination of how war solves the commitment problem.

1.1   The need to examine how war solves the commitment problem

The bargaining model of conflict (e.g. Fearon 1995) has become a prominent approach to understanding why wars occur. According to the bargaining model, because war is costly there should generally be some peaceful settlement that both parties prefer to fighting. One possible reason that states or other actors might fight is that they are unable to credibly commit to implementing a war avoiding settlement. Possible sources of commitment problems include large and rapid power shifts (Fearon 1995; Powell 2006), first-strike advantages (Beard and Strayhorn 2018, Fearon 1995, Powell 2006), indivisible issues (Powell 2006), and differing time horizons (Spaniel, Bils, and Judd 2020). A number of other studies have further developed our understanding of commitment problems (e.g. Wolford, Reiter and

Carruba 2011; Walter 1997; Fearon 2004; Bas and Schub 2017; Garfinkel and Skaperdas 2000; Krainin 2017; Leventoglu and Slantchev 2007). Among the different causes of commitment problems, exogenous power shifts have received the majority of attention. Informal theory and empirical analysis has generally supported the belief that power shifts can cause war (e.g. Organski 1968; Organski and Kugler 1980; Levy 1987; Van Evera 1999; Reiter 2009; Kadera 1999; Copeland 2000; Renshon 2006; 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; Lebow and Valentino 2009; Lemke 2003; Renshon, Lee and Tingley 2017).

However, previous research into commitment problems and war has largely ignored how war resolves the commitment problem. Nearly all previous models, including Fearon (1995) and Powell (2006), have simply assumed that war locks in the war outcome forever. Substantively, this could be interpreted as one state completely destroying the other, but state death is quite rare (Fazal 2004). While there may be other ways that war can resolve the commitment problem, these have generally been unexplored. The one exception is Wolford (2012), which shows that leadership changes could both cause and resolve a commitment problem, albeit only under some circumstances.

The ability of war to resolve the commitment problem is central to commitment problems as a cause of war. Obviously, if war does not resolve or otherwise affect the commitment problem, war would be irrational. However, not all wars can resolve the commitment problem. There may be also equivalent peaceful solutions to the commitment problem. Thus, an additional condition for commitment problems to cause war is that the situation and war type contemplated allow war to resolve the commitment problem, and that no corresponding peaceful solution exists. The lack of previous research into how war resolves the commitment problem presents a significant limitation in our understanding of how commitment problems cause war.

In this paper, I will rectify this gap by examining different ways that war can resolve

commitment problems caused by rapid exogenous power shifts.

1.2   Basic tenants

Any examination of how war resolves the commitment problem must follow two basic principles.

First, if a commitment problem is to cause war, war must be able to resolve the commitment problem through the use of force alone. Thus, capturing or destroying something that would resolve the commitment problem could allow war to occur. However, things that cannot be captured or destroyed through force cannot resolve the commitment problem, and thus war would not occur. So, for instance, using war to pressure an adversary to agree to a non-aggression pact could not cause war as this only be achieved voluntarily.

To understand this, consider a situation where there is a commitment problem that cannot be resolved through force alone. In this case, one side may attempt to pressure the second to do something that would resolve the commitment problem under the threat of war. However, assume that the second actor refused to agree. If the first attacked, the commitment problem would still exist, as war would not resolve it. The threat of force might be useful to resolve the commitment problem, but the actual use of force would not. Thus, it would be irrational to attack in the first place. Accordingly, only in situations where force alone can directly resolve the commitment problem without the consent of the other side could war occur.

Second, a basic principle of the bargaining framework is that anything that can be achieved through force can also be achieved voluntarily through a negotiated settlement. Materially, this is almost certainly true. If nothing else, the actors could themselves destroy whatever war would destroy. Even the existence of one state can be up for negotiations, and states have surrendered their existence peacefully. Thus, any way that war can resolve the commitment problem must also be achievable peacefully through the agreement of the actors.

It is possible that some things might be perceived as non-negotiable, even if negotiations would be technically possible. For instance, it is possible that some states would refuse to peacefully surrender their existence, even if they know they will lose. However, if some things are considered non-negotiable, there is no reason to confine the non-negotiable issues to the resolution of the commitment problem. For instance, some territory might be considered sacred or central to a state's identity, and hence non-negotiable even if the territory does nothing to affect the power balance. In such cases, it would be the non-negotiability of the issue that would be the cause of war, rather than any commitment problems. Note that previous models of commitment problems generally did not include any surrender option, while allowing war to resolve the issue by eliminating one state. Thus, these models are actually misspecified according to the basic principles of the bargaining framework. While the substantive implications may be limited, it is necessary to develop models that correct this misspecification.

2 Modeling how war resolves the commitment problem

Based on the two principles limiting how war can resolve commitment problems, there are six obvious ways that war can resolve the commitment problem: the destruction of military forces, capturing of territory that is either resource rich or provides military advantages that also provides other benefits, defensive advantages making it easier to retain captured territory, the destruction of one party to the conflict, changing the regime of one party, and the capture of indivisible strategic objects that enhance bargaining power. I analyze each with a formal model. In only the last three, destruction of one actor, regime change or capturing indivisible strategic objects, does conflict occur.

All six models are fundamentally similar. I will describe the basic model form here, and then describe variations from this basic form when I examine each model. I assume that there are two states, A and B, in a dispute over some continuously divisible good, with a total

normalized value of 1. The states can settle the division of the disputed good by fighting or bargaining in two separate periods. Between the two periods, an exogenous power shift may occur and the bargaining situation in the second period may be affected what happened in the first period.

The first stage begins with A making an offer comprising two elements. First, A will propose a division of the disputed good, retaining x_1 portion and giving B $1 - x_1$. Second, A makes a proposal related to resolve the commitment problem. Typically, the resolution of the commitment problem is a separate element of the offer, although in the resource model and the defensive advantage model, the division of the disputed good directly affects the resolution of the commitment problem.

B can accept or reject the proposal, but must accept or reject both elements together. If B accepts the proposal, the proposal is implemented and the game moves to the second stage. If B rejects the proposal, a war is fought. The war is decided probabilistically. The probability of victory depends partly on what occurs in the first stage, but also includes a potential exogenous power shift. The winner gets both the entire disputed good in the first stage, and their preferred outcome on resolving the commitment problem. Both sides pay war costs, c_A and c_B anytime a war is fought.

The second stage is generally similar, but ends the game. A makes a proposal to redivide the disputed good, retaining x_2 portion and giving B $1 - x_2$.[1] B can accept the proposal, in which case the division is implemented. Alternatively, B can reject the proposal, in which case a war is fought with the victor getting the entire disputed good in the second stage. Both sides again pay war costs, c_A and c_B if a war is fought.

The second stage is discounted by δ_A and δ_B. Many previous models have included a common discount parameter. However, as Spaniel, Bils, and Judd (2020) point out, there is no reason to assume that actors have the same time horizon. Given that the mathematical inconvenience of allowing different time horizons is minor, I see no reason not to include the

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[1]Note, this is not a stream of benefits, but simply a second one time payment. Accurately modeling a stream of benefits would require an infinite horizon model.

more general and realistic assumption of separate discount parameters.

For all models, I will adopt the solution concept of subgame-perfect Nash equilibrium (SPNE), as all models are extended, perfect information games. For brevity, I only display the actual conditions for war. The full solutions and mathematical proofs are available in online appendices.

2.1 Bargaining and fighting over continuously divisible military capabilities

First, I will examine whether the destruction of military forces and other capabilities in war can resolve the commitment problem in such a way to cause war. War almost inevitably involves the destruction of military forces and equipment. This destruction of military forces will likely change the power balance, at least in the short term, as one side will likely suffer greater proportionate losses than the other. This change in the power balance could counteract any exogenous power shifts, thus potentially allowing war to resolve the commitment problem.

However, changes in military capabilities can also be achieved peacefully. States can refrain from developing certain military capabilities and can demobilize existing forces. The ability to control military size is at least approximately continuous. In addition, the peaceful demobilization of forces can be as enduring as any destruction of military forces in battle. It takes as long to replace a battleship that has been scrapped as one sunk in battle. Thus, models relying on the destruction of military forces to resolve the commitment problem must also allow these forces to be demobilized peacefully.

The model examining whether the destruction of military forces can resolve the commitment problem follows the same basic form described above. A makes an offer both for the immediate division of the disputed good, x_1, and some peaceful change in military capabilities, m. If B rejects the offer, a war is fought, which A wins with probability π_1. The victor of the war gets the entire disputed good. If A wins, A will also destroy a portion of

B's forces, with μ representing the power shift caused by war.

In the second stage, which occurs regardless of the outcome of the first stage, the probability of victory is decided by the combination of several factors. The base probability of winning in the second stage is π_2, allowing for an exogenous power shift. If a bargain is reached, A's probability of winning is $\pi_2 + m$. If A wins a war, A's probability of winning is $\pi_2 + \mu$, while if B wins the probability remains at π_2. I assume that m is continuous and can take any value between $0 \leq m \leq 1 - \pi_2$, so A can demand anything between no change to B's capabilities and the complete elimination of B's military.

War never occurs in this model, as formally stated in propositions 1. War does not occur because the impact of war on military power is matched by the ability to peacefully demobilize military forces. Since demobilization is continuously divisible, power and benefits in the second stage are also continuously divisible. There is thus always some change in military power that both sides prefer to war

Proposition 1. *War never occurs in the military capabilities model.*[2]

2.2 Bargaining and fighting over continuously divisible resources that affects both direct benefits and power

Second, I will examine situations where the two sides fight over resources or other sources of national power. While the chances of winning a war directly depend on the actors' military forces, the capabilities of these forces themselves depend on the states access to other means of national power, including people, natural resources, and industrial capacity. Each of these can be captured in war or peacefully transferred, and thus could affect the commitment problem. However, these resources also provide economic and other benefits to the state. This means that power cannot be shifted without simultaneously shifting the benefits that each state receives, which restricts the available bargains that can be made. However, each of these resources is still continuously divisible.

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[2]See appendix B (pg. 43) for details

To model the effect of these resources, I assume that the two states are in a contest over some resources with value 1, which provides both economic benefits and serves as a source of military power. Initially, A possesses q portion of the territory. In the first stage, A proposes to redivide the territory, keeping x_1. Then, in the second stage, A proposes to redivide it again, keeping x_2.

In both stages, A's probability of victory will be determined using the standard function of A's capabilities divided by their combined capabilities. Each side will have some capabilities that are exogenously determined and some that depend on the proportion of the territory they possess. Therefore, A's probability of victory in the first stage is $\frac{f_{A,1}+m_1*q}{f_{A,1}+f_{B,1}+m_1}$. A's probability in the second stage is $\frac{f_{A,2}+m_2*x_1}{f_{A,2}+f_{B,2}+m_2}$ if there is a peaceful settlement, $\frac{f_{A,2}+m_2}{f_{A,2}+f_{B,2}+m_2}$ if A wins the war in the first stage, and $\frac{f_{A,2}}{f_{A,2}+f_{B,2}+m_2}$ if B wins. The parameters $f_{A,1}$, $f_{A,2}$, $f_{B,1}$, and $f_{B,2}$ represent each sides exogenous capabilities or forces, while m_1 and m_2 represent the added capabilities given by the disputed resources. Thus, both sides exogenous capabilities can change and the importance of the resources for their capabilities can change.

However, war still doesn't happen in equilibrium, as stated in proposition 2. The correlation of benefits and future power presents restrictions on the types of settlements available, and the actors are no longer able to trade present benefits for future power. However, despite this restriction, there is still always a mutually preferable bargain. In essence, the actors are bargaining over the entire pool of benefits in both periods, as changes in power only change future benefits. Since the resources are continuously divisible, the actors can divide this entire pool of benefits in a way that they both find preferable to war.

Proposition 2. *War never occurs in the resource model.*[3]

Note that I have assumed the probability of victory follows a particular functional form. However, this form is both an intuitive and a commonly used function for determining the probability of victory. This functional form also allows considerable flexibility in the impact of both exogenous factors and possession of the resources on the probability of victory.

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[3]See appendix C, (pg. 45) for details

While it may be useful to examine alternate functional forms, studies doing so will have to justify why the particular functional form used is superior to that presented here.

2.3 Bargaining and fighting in the presence of defensive advantages

Third, I will examine whether tactical and operational defensive advantages can resolve the commitment problem. It has been well established that it is usually easier to defend rather than attack (e.g. Mearsheimer 1989). Beard and Strayhorn (2018) showed that defensive advantages played a significant role in causing war through first-strike advantages, as states could more easily hold territory captured by surprise. A similar logic might apply to commitment problems caused by exogenous power shifts. A state facing an adverse power shift might want to capture disputed territory quickly before the power shift occurs, and then rely on defensive advantages to hold the captured territory.

Because defensive advantages are exogenous to the player's actions, neither the bargain nor war will directly shift power. I assume that A initially possesses q portion of the disputed territory. In both stages, A can propose a redistribution of the disputed territory, retaining x_1 in the first stage, and x_2 in the second stage. If B rejects the proposal, a war is fought.

However, unlike war in the other models, three outcomes are possible. A can have a successful offensive, with probability $\frac{\pi_1}{\alpha_1}$ in the first stage and $\frac{\pi_2}{\alpha_2}$ in the second, gaining the entire territory in that stage. B can have a successful offensive, with probability $\frac{1-\pi_1}{\alpha_1}$ in the first stage and $\frac{1-\pi_2}{\alpha_2}$ in the second, likewise gaining the entire territory. If neither side has a successful attack, a stalemate occurs and the status quo remains. In the first stage, A's status quo portion is simply q. In the second stage, A's status quo portion is x_1 if there was a peaceful settlement. If a war occurred in the first stage, A's status quo portion in the second is 1 if A won, 0 if B won, and remains q if there was a stalemate. The parameters α_1 and α_2 represent the defensive advantages, and are presumed to be greater than one. Both

the power balance and the defensive advantages can shift between stages, such as if new technology would alter the offense-defense balance.

War never occurs in the defensive advantage model, even when the defensive advantages shift, as detailed in proposition 3. In the second stage, defensive advantages would make it easier to hold any territory taken in the first round. However, a negotiated settlement in the first stage can approximately match the expected outcome of war. Therefore, neither side would enter the second stage in a significantly better position by choosing to fight rather than bargain. The costs of war thus open a bargaining range in the first stage, even if power and/or defensive advantages shift.

Proposition 3. *War never occurs in the defensive advantage model.*[4]

While war did not occur in this model, defensive advantages can contribute to war in the presence of first-strike advantages (Beard and Strayhorn 2018). The difference is that negotiating in the presence of first-strike advantages allows the opponent to mobilize, and thus negotiations directly change the power balance. Attacking by surprise gives a better chance of overcoming the defensive advantages when there is a first-strike advantage. Exogenous power shifts do not present a similar opportunity to overcome the defensive advantages by attacking first, and so war does not occur in this case.

2.4 Bargaining and fighting over the existence of one state

The fourth potential way war could resolve the commitment problem is by eliminating one of the states. If a state facing an adverse power shift can conquer their opponent, they obviously no longer need to worry about the power shift. The conquest of one state is the closest substantive interpretation to the assumption in previous models that war locks in the war outcome forever. However, as noted, states can and have surrendered their existence peacefully. Thus, unlike previous models of commitment problems, I also allow peaceful

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[4]See appendix D (pg. 46) for details

surrenders that have the same effect as conquest in war. For mathematical simplicity, I only allow B to surrender their existence or be conquered, and State A always continues to the second round. I believe the general substantive implications would also occur in a model where both states face elimination, and future research can more fully explore such a model.

The model follows the basic form specified earlier. In addition to the offer dividing the disputed good, x_1, A can also choose whether to include a demand that B surrender. Both parts must be accepted together, so B accepting an offer with a surrender demand means they actually surrender. If B rejects the offer, a war is fought, which A wins with probability π_1. The victor gets the entire disputed good in the first stage. In addition, if A wins, there is a probability, κ that A conquers B.

If B surrenders or A conquers B in the first stage, no further play occurs and A gets the entire disputed good in the second stage as well. If B neither surrenders nor is conquered, the second stage occurs, in which A offers to redivide the disputed good, retaining x_2. B accepts or rejects, in which case a war is fought in which A wins with probability π_2.

War can happen in wars where the existence of one state is at stake. Disputes over the existence of one state can cause war. The conditions under which war happens are detailed in proposition 4. Basically, war occurs in one of two cases. First, if B would demand more than the entire disputed good in order to surrender, and B is unwilling to make the concessions A requires to allow B to continue to exist. Second, if A requires more than the entire disputed good to allow B to continue to exist, and A prefers war to making the concessions B requires to surrender. In essence, A will try to buy B's surrender by giving B more of the disputed good in the present, while B will try and convince A not to demand B's surrender by giving A more in the present. War only occurs if they cannot reach some agreement to trade present benefits for B's surrender or B's continued existence.

Proposition 4. *In the decisive war model, war can occur if:*[5]

$$0 > -\pi_1\kappa(\delta_A - \delta_B) + (\delta_A - \delta_B)\pi_1\kappa(\pi_2 + c_B) + c_A + c_B \text{ and } 0 > \pi_1 - (1 - \pi_1\kappa)\delta_B +$$

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[5]See appendix E (pg. 47) for details

$(1 - \pi_1\kappa)\delta_B(\pi_2 + c_B) + c_B$

or

$0 > (\delta_A - \delta_B)(1 - \pi_1\kappa) - (\delta_A - \delta_B)(1 - \pi_1\kappa)(\pi_2 + c_B) + c_A + c_B$ *and* $1 < \pi_1 + \pi_1\kappa\delta_A -$
$\pi_1\kappa\delta_A(\pi_2 + c_B) - c_A$

2.5 Bargaining and fighting over the regime of one state

My fifth model examines the case where states are in a dispute over the regime of one state. A natural extension to the previous model is to examine disputes over the regime of one state. While regime change does not eliminate the other state or directly change the power balance, a new regime may care less about the issues under dispute. Thus, a new regime may present less of a threat or be willing to make more concessions on a disputed issue. In addition, leadership or regimes are at least potentially indivisible - a leader can either retain power or give it up. While power sharing agreements may make leadership and regimes divisible, these power sharing agreements are not necessarily available. In this model, I will consider the case where regime type is indivisible, and power sharing agreements are not available.

This model varies from previous models in that there are two potential players in state B, the initial regime B_i and a potential replacement regime, B_r. The two regimes vary in their costs of fighting (i.e. resolve), with B_i paying war costs c_{Bi} and B_r paying c_{Br}. I assume that $c_{Br} \geq c_{Bi}$, such that the potential replacement regime is less resolved than the initial regime. It makes little sense that A would attempt to resolve the commitment problem by attempting to install a more resolved opponent, and so this restriction is reasonable. A always pays war costs c_A. Otherwise, the model proceeds similar to the decisive war model.

In the first stage, in addition to proposing a division of the disputed good, x_1, A can choose to demand that the initial regime of B step down, to be replaced by the replacement regime. B_i can accept the offer, in which case both elements are implemented. If they reject a war is fought where A wins with probability π_1. The victor gets the entire disputed good

in the first stage. If A wins, there is a chance, ρ, that A successfully changes B's regime.

In the second stage, whether A faces the initial regime or the replacement regime depends on what happened in the first stage. If B_i stepped down or war resulted in regime change, they gain no utility in the second stage, and A faces B_r. Otherwise, A continues to face B_i. The second stage begins with A making an offer to redivide the disputed good, retaining x_2. If B_i or B_r (as appropriate) accepts, it is implemented. If they reject, a war is fought. A wins with probability π_2 and the victor gets the entire disputed good.

War can occur in the regime change model, as described in proposition 5. The basic logic of war is the same as in the decisive war model, simply substituting peaceful regime change for B's surrender.

Proposition 5. *In the regime change model, war can occur if:*[6]

$$0 > (1-\pi_1\rho)(\delta_A(c_{Br}-c_{Bi})-\delta_{Bi}(1-\pi_2-c_{Bi}))+c_A+c_{Bi} \text{ and } 1 < \pi_1+\pi_1\rho\delta_A(c_{Br}-c_{Bi})-c_A$$
and $\pi_2 + c_{Br} \leq 1$ *and* $\pi_2 + c_{Br} \leq 1$

or

$$0 > \pi_1 - \delta_{Bi}(1 - \pi_1\rho)(1 - \pi_2 - c_{Bi}) + c_{Bi} \text{ and } 0 > \pi_1\rho(\delta_{Bi}(1 - \pi_2 - c_{Bi}) - \delta_A(c_{Br} - c_{Bi})) + c_A + c_{Bi} \text{ and } \pi_2 + c_{Br} \leq 1 \text{ and } \pi_2 + c_{Br} \leq 1$$

or

$$0 > (1 - \pi_1\rho)(1 - \pi_2 - c_{Bi})(\delta_A - \delta_{Bi}) + c_A + c_{Bi} \text{ and } 1 < \pi_1 + \pi_1\rho\delta_A(1 - \pi_2 - c_{Bi}) - c_A$$
and $\pi_2 + c_{Br} > 1$ *and* $\pi_2 + c_{Br} \leq 1$

or

$$0 > \pi_1 - \delta_{Bi}(1 - \pi_1\rho)(1 - \pi_2 - c_{Bi}) + c_{Bi} \text{ and } 0 > \pi_1\rho(1 - \pi_2 - c_{Bi})(\delta_{Bi} - \delta_A) + c_A + c_{Bi}$$
and $\pi_2 + c_{Br} > 1$ *and* $\pi_2 + c_{Br} \leq 1$

Note that there are various ways to model regime change, and the specific results are likely sensitive to assumptions about how regime change is modeled. I have assumed that the primary effect of regime change is on resolve or how much the regime cares about the disputed issue relative to the costs of war. Furthermore, I have assumed that A always

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[6]See appendix F (pg. 50) for details

captures the bargaining surplus and gets their most favorable agreement that B will accept. Finally, I assumed that governments and regimes are indivisible. If power sharing agreements are possible, the likelihood of war would probably decrease or disappear. Within this model, if A did not get their most favorable agreement within the bargaining range, the likelihood of war would also decrease or disappear. However, regime change could have other impacts. For instance, if the replacement regime had a different ideal point on a disputed issue rather than simply different resolve, the likelihood of war would differ from this model, and could increase. This model shows that regime change, in certain circumstances, can cause war. However, future research should explore different ways of modeling regime change to determine the exact conditions under which regime change can cause war.

2.6   Bargaining and fighting over indivisible strategic objects

The final model that I examine is the case where there is some dispute over some indivisible strategic object that affects bargaining power. The previous models showed that when power is continuously divisible, war does not occur. However, there may be some indivisible objects that affect the power balance. This presents another restriction on the available bargains, and so could cause war. Indivisible strategic objects that affect bargaining power could include a state developing nuclear weapons or the possession of strategic barriers, such as rivers.

I thus develop a model where the two parties contest an indivisible strategic object that affects future bargaining power. The strategic object can be transferred peacefully or captured in war. The model begins with A making an offer to divide the disputed good, retaining x_1, and over which state gets the strategic object in the second round. B accepts or rejects both elements of the offer together. If B rejects, a war is fought which A wins with probability π_1. The victor gets the entire disputed object in the first stage and the strategic object in the second stage.

In the second stage, A makes an offer to redivide the disputed good, which B can

accept or reject. If B rejects, a war is fought. The probability of winning the war depends on which side has possession of the strategic object. If A has the strategic object, either through winning the war or making an accepted offer where A gets the strategic object, A wins with probability $\pi_2 + \sigma$. If B has the strategic object, either through winning the war or a peaceful settlement, A's probability of winning in the second stage is the base probability of π_2.

War can occur in disputes over an indivisible strategic object, under the conditions detailed in proposition 6. The basic logic of war is the same as in the decisive war model, simply substituting peacefully gaining the strategic object for B's surrender.

Proposition 6. *In the strategic object war model, war can occur if:*[7]

$\pi_1 - (1 - \pi_1)\delta_B\sigma + c_B < 0$ *and* $(\delta_B - \delta_A)\pi_1\sigma + c_A + c_B < 0$ *and* $\pi_2 + \sigma + c_B \leq 1$ *and* $\pi_2 + c_B \leq 1$

or

$1 < \pi_1 + \pi_1\delta_A\sigma - c_A$ *and* $(\delta_A - \delta_B)(1 - \pi_1)\sigma + c_A + c_B < 0$ *and* $\pi_2 + \sigma + c_B \leq 1$ *and* $\pi_2 + c_B \leq 1$

or

$\pi_1 - \delta_B(1 - \pi_1)(1 - \pi_2 - c_B) + c_B < 0$ *and* $\pi_1(\delta_B - \delta_A)(1 - \pi_2 - c_B) + c_A + c_B < 0$ *and* $\pi_2 + \sigma + c_B > 1$ *and* $\pi_2 + c_B \leq 1$

or

$1 < \pi_1 + \pi_1\delta_A(1 - \pi_2 - c_B) - c_A$ *and* $(\delta_A - \delta_B)(1 - \pi_1)(1 - \pi_2 - c_B) + c_A + c_B < 0$ *and* $\pi_2 + \sigma + c_B > 1$ *and* $\pi_2 + c_B \leq 1$

3 Discussion

These models show that only some wars can resolve commitment problems without an equivalent peaceful settlement. In particular, it seems that commitment problems can only cause

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[7]See appendix G (pg. 53) for details

war if the existence or regime of one state is at stake or there is a dispute over an indivisible strategic object.

The models also complicates our understanding of how exogenous power shifts cause commitment problems leading to war. Exogenous power shifts can cause war in some cases, in line with the commitment problem logic of preventive war. However, war can also happen absent the power shift. Extending these points, predicting a power shift might prevent a war that would have otherwise occurred. Finally, whether war occurs depends on both the absolute and relative length of the actors' time horizons.

3.1 How does war resolve the commitment problem differently than bargaining?

My primary substantive finding is that only some wars can resolve the commitment problem in a way that cannot be achieved peacefully. Of the six ways presented here that war can resolve the commitment problem, in only three does war actually occur. War only occurs in the models where the war is over the existence of one state, over the regime type of one state, or over the possession of an indivisible strategic object that affects bargaining power. War does not occur in the models where war is over military capabilities or resources that affect both power and benefits, nor does war occur in the model with defensive advantages. This means that the ability of war to resolve the commitment problem, and the inability of peace to similarly resolve the commitment problem presents another constraint on when commitment problems can cause war.

The primary difference between the models where war does and does not occur is whether the resolution of the commitment problem is indivisible. Recall that a fundamental principle of the bargaining framework is that anything that can be achieved by war must also be able to be achieved peacefully. Thus, military forces can be destroyed in battle or demobilized peacefully. Similarly, resources or other sources of bargaining power can be captured in war or transferred through negotiations. Military forces and resources that

create power are continuously divisible, and thus can be divided in some way that both actors prefer to war. While power affects future benefits, the war can be considered a contest over those future benefits as well as present benefits. When power is continuously divisible, the future benefits are also continuously divisible, and so there is a peaceful settlement. Thus, if war would solve the commitment problem in some way that is continuously divisible, there would also be a peaceful way to solve the commitment problem.

In the three models where war occurs, the means of resolving the commitment problem are fundamentally indivisible. Eliminating one actor, changing an actor's regime, or transferring an indivisible strategic object are all indivisible. Thus, the impact on future benefits is also indivisible, creating a situation where both sides prefer to use war to resolve the commitment problem rather than any available peaceful settlement. Note, that the ability to peacefully resolve the commitment problem is still available. War occurs simply because the indivisibility means the actors cannot agree on an available peaceful settlement.

There are two additional restrictions on when war can occur. First, the indivisibility must so large that one side cannot buy off the other to peacefully resolve the commitment problem. One side might attempt to get the other to surrender, change regime, or give up the strategic object peacefully by offering more benefits in the present. Similarly, the other actor may attempt to achieve a peaceful settlement without surrendering, changing regime, or giving up the strategic object by offering the first more benefits in the present. Thus, war requires that the change in future benefits achieved through surrender, regime change or possessing the strategic object be large enough that there are insufficient current benefits to buy off the other side. Formally, the conditions for war in propositions 4, 5 and 6 each require that one side would require more than the entire disputed good to accept their less preferred outcome in resolving the commitment problem.

The second restriction is that there must be no other ways of resolving the commitment problem that are more continuous. For instance, if state A felt that the commitment problem could be resolved either through eliminating state B or restricting state B's mili-

tary, war would be impossible. Since military forces are continuously divisible, a peaceful settlement reducing B's military would be achievable, even if B would be eliminated through war.[8]

Substantively, the models thus suggest four primary means that war could resolve the commitment problem where an equivalent peaceful settlement may be unavailable. First, disputes over the existence of one state could cause war. Second, disputes over the regime type of one state are also indivisible, and likely could resolve commitment problems.[9] Third, possession of nuclear weapons might represent a strategic object, and thus cause war. Since the power balance shifts considerably when a state goes from zero to one nuclear weapon, nuclear technology would be an indivisible strategic object.[10] Fourth, major geographic strategic barriers, such as rivers, might considerably shift the power balance depending on whether the border was on the barrier or even slightly away from it. Thus, strategic barriers might also represent an indivisible strategic object.

It is possible that there are some other ways that war can resolve the commitment problem posed by a power shift, where an equivalent peaceful settlement is impossible. There may be other examples of indivisible strategic objects. There may also be other mechanisms through which war can resolve the commitment problem that are not modeled. However, war would still require that any other means of resolving the commitment problem not allow an equivalent peaceful settlement.

3.2 Ambiguous effects of exogenous power shifts

The most commonly cited form of commitment problem is rapid, exogenous power shifts which make the declining state prefer war now rather than later. However, the relationship between exogenous power shifts and war is more complicated than previously understood,

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[8]Chadefaux (2011) made a similar argument.

[9]See also Wolford (2012)

[10]However, it is also possible that nuclear technology can be more continuously divided, allowing the possibility to nuclearize quickly without actually developing a weapon. Such a scenario might be represented by the JCPOA with Iran.

and may be non-monotonic. In some cases, large exogenous power shifts are required for war, as in previous models. However, in other cases war happens without any exogenous power shift, and peace occurs with a large power shift. Here, I will focus on the decisive war model and the strategic object model. The regime change model has the same overall findings, but the specific relationships are more complex, and are discussed in appendix A (pg. 38).

Figure 1:
A's Probability of Victory and War, $\delta_A < \delta_B$
Decisive War Model
$\kappa = 0.8$, $c_A = c_B = 0.01$, $\delta_A = 0.6$, $\delta_B = 0.9$
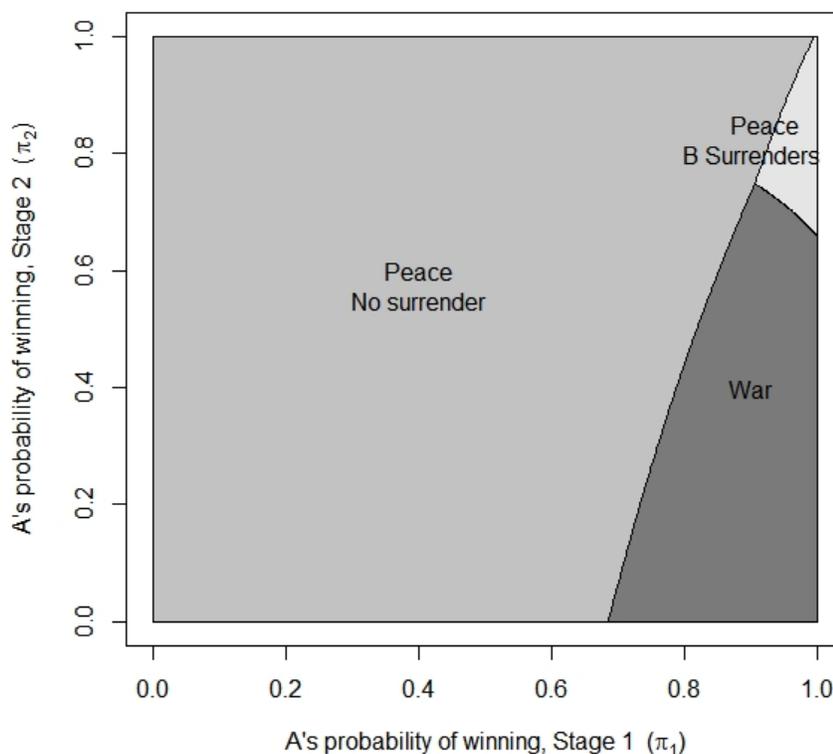
Figures 1 and 2 show the situation when A has a shorter time horizon ($\delta_A < \delta_B$) for the decisive war model and the strategic object model, respectively. Note that the war range is in the bottom-right, away from the diagonal where $\pi_1 = \pi_2$. Thus, war requires an

Figure 2:
A's Probability of Victory and War, $\delta_A < \delta_B$
Strategic Object Model
$\sigma = 0.5$, $c_A = c_B = 0.01$, $\delta_A = 0.6$, $\delta_B = 0.9$
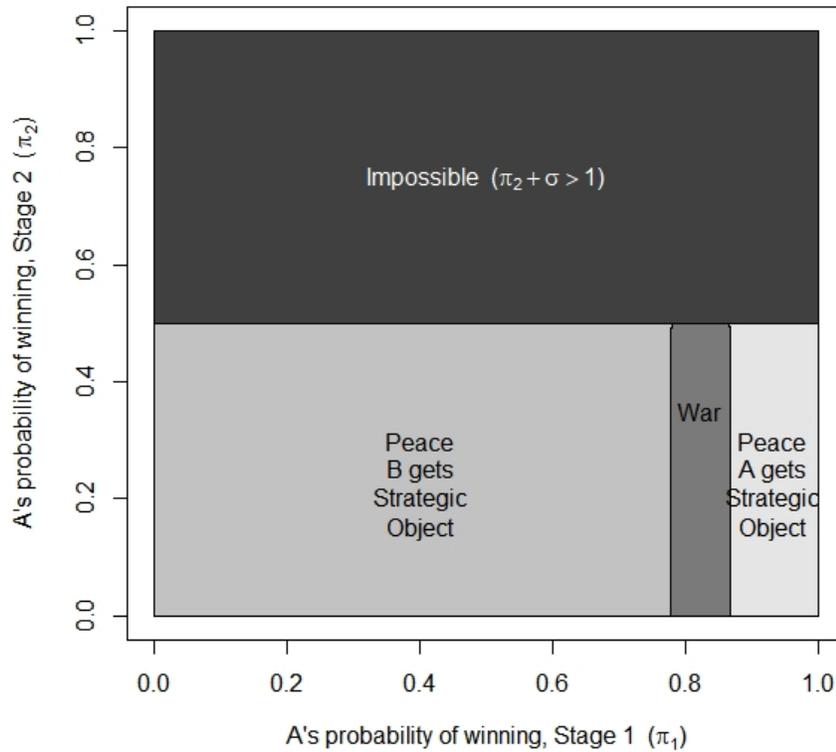
exogenous power shift. When A has a shorter time horizon, A is most concerned about their present benefits, while B is relatively more concerned about their future benefits. However, if A has a large chance of victory in the present, A may still want B to surrender or give A the strategic object so that A gets more future benefits as well. B may be unable to offer sufficient benefits in the present to convince A not to demand B's surrender or the strategic object. Thus, negotiations break down and war occurs. Accordingly, the classic understanding of the relationship between power shifts and war occurs when A has a shorter time horizon.

Note however, that the war range in figures 1 and 2 is stretched vertically. In fact,

in figure 2, the sides of the war range are vertical for almost the entire range. Thus, the primary determinant of whether war occurs is the present power balance. If A is significantly more likely to win, A is willing to fight to gain more benefits in the future. However, if A's chances of winning are not very high, A is willing to settle for a peaceful settlement. The power balance in the second stage can still matter, and thus exogenous power shifts are necessary for war when $\delta_A < \delta_B$. However, the second stage balance, and thus the exogenous power shift has a relatively limited further effect.

Figure 3:
A's Probability of Victory and War, $\delta_A > \delta_B$
Decisive War Model
$\kappa = 0.8$, $c_A = c_B = 0.01$, $\delta_A = 0.9$, $\delta_B = 0.6$
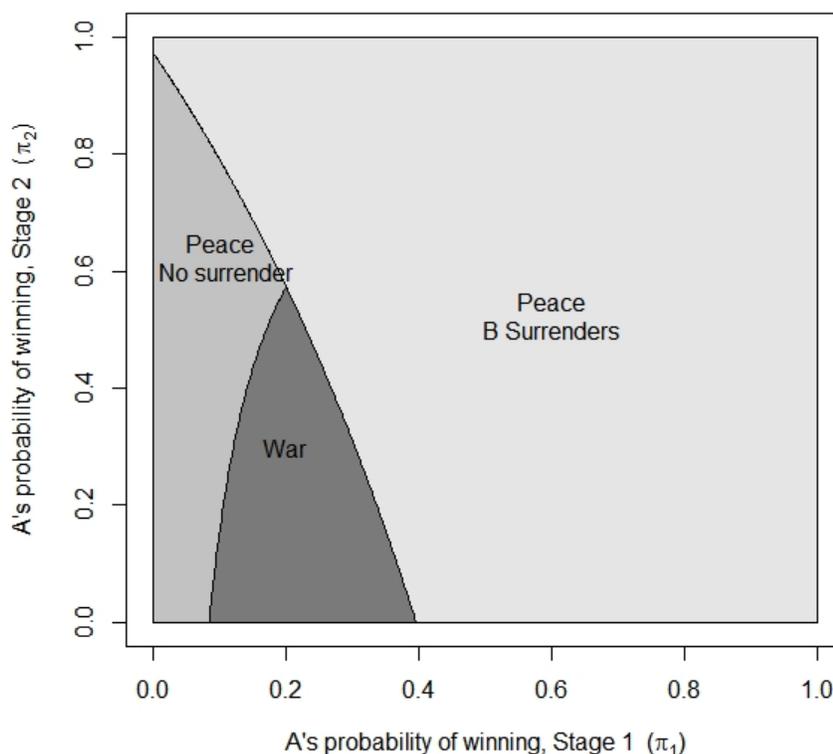
In contrast, when A has a longer time horizon, war can happen without an exogenous power shift. In addition, peace occurs when there is a large an exogenous power shift. Figures

Figure 4:
A's Probability of Victory and War, $\delta_A > \delta_B$
Strategic Object Model
$\sigma = 0.5$, $c_A = c_B = 0.01$, $\delta_A = 0.9$, $\delta_B = 0.6$
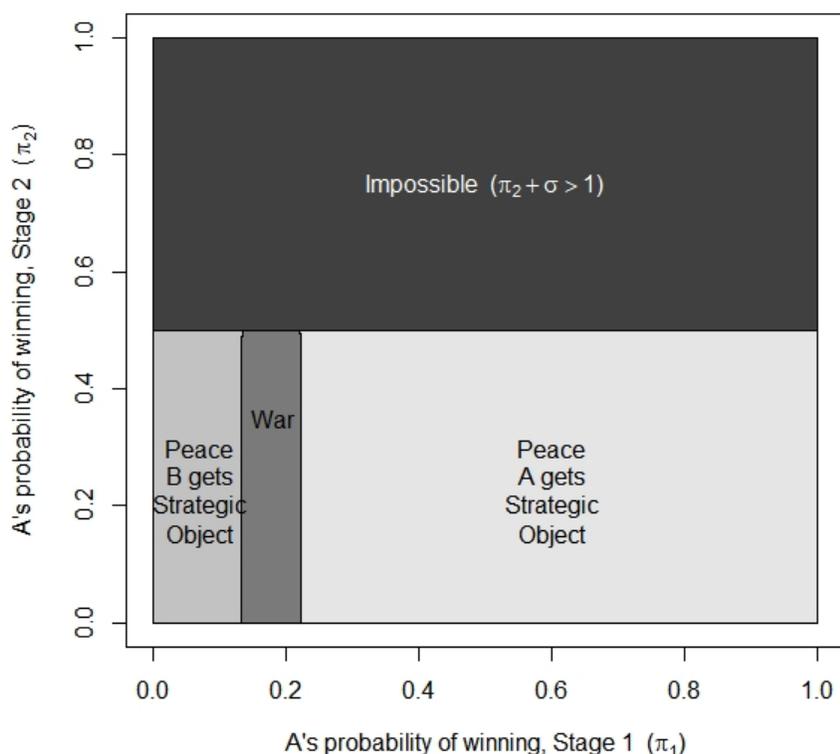
3 and 4 show the situation when $\delta_A > \delta_B$. First, note that war can occur along the diagonal where $\pi_1 = \pi_2$, when there is no exogenous power shift. Thus, when A has a longer time horizon, exogenous power shifts are not needed to cause war. Because A cares more about the second stage benefits than B, A is highly willing to fight in order to gain B's surrender or the strategic object even without an exogenous power shift. However, there may not be sufficient present benefits to induce B to surrender or give up the strategic object without a fight. [11]

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[11]Spaniel, Bils, and Judd (2020) showed that war can occur when there are different time horizons, but without an exogenous power shift, matching my findings. Spaniel, Bils, and Judd (2020) interpret war as one state attempt to stall defeat. However, my models show that an additional required element for war is

In addition, note that war does not occur in the upper-left or lower-right corners, where there is a significant exogenous power shift. In the upper-left corner, A will gain significant future benefits without war, and thus they are content to allow the favorable power shift to occur. In the lower-right corner, A faces a significant adverse power shift. However, because A is likely to win the war and B cares most about the present benefits, B is willing to surrender or give up the strategic object peacefully. While this may require A concede more in the present, A can give B enough to induce B to surrender.

Extending this last finding further suggests that predicting an adverse exogenous power shift can avert war entirely, whereas war might occur if the power shift happens without being predicted. If A predicts an adverse power shift in the future, A can peacefully take measures to avert the power shift. A might be able to convince B to surrender or give A the strategic object. However, if A fails to take these preventive measures, A may find themselves in a position where the power shift occurs, and A is willing to fight to regain their lost power.

3.3   Asymmetric time horizons and war

As alluded in the previous section, the actors' time horizons also play a critical role in whether war occurs. I will again focus on the decisive war model and the strategic object model. For war to occur, both actors need to have sufficiently long time horizons. In addition, if A is facing a significant adverse power shift, war only occurs if A has a shorter time horizon than B. If no power shift occurs or if the power shift will favor A, war only occurs if A has a longer time horizon than B. In these two models, war never occurs if the actors have equal time horizons.[12] The regime change model has similar overall findings, although war can occur if A faces an adverse power shift and the two actors have equal time horizons.[13]

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that one state is deliberately seeking to change the power balance in their favor, which they do not note. Thus, while one state is seeking to stall a loss of power, the other is actively seeking to gain power through war.

[12]I believe war can occur with equal time horizons in similar models with more than two stages.

[13]See appendix A (pg. 38) for details.

In all cases, both sides need a reasonably long time horizon. If their time horizon is too short, they will not care either about gaining power through war or any exogenous power shifts. If state A has a short time horizon, they would let B continue to exist or have the strategic object, as they would not care much about the power balance in subsequent stages. Similarly, if B has a short time horizon, they would be willing to surrender or give A the strategic object. Both of these statements are true regardless of any exogenous power shifts. Thus war would not occur. While the need for sufficiently long time horizons is not novel (e.g. Fearon 1998), it is worth reiterating given the general perception that the shadow of the future promotes cooperation (e.g. Axelrod 1984).

Figure 5:
Time Horizons and War, no power shift
Decisive War Model
$\pi_1 = \pi_2 = 0.2$, $\kappa = 0.8$, $c_A = c_B = 0.01$,
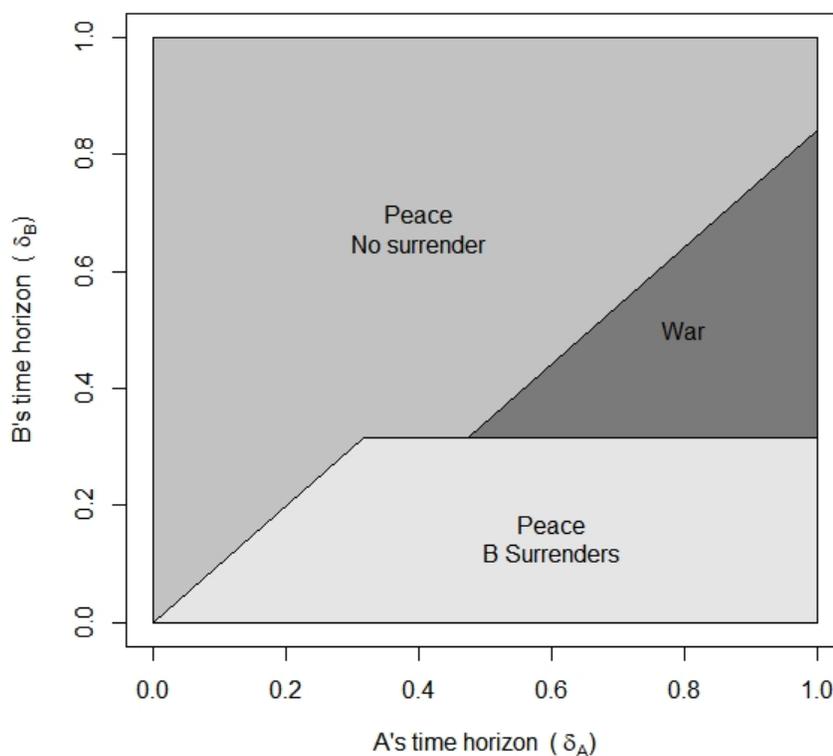
In addition, war depends on the relationship between the two actors' time horizons. Figures 5 and 6 display the relationship between time horizons and war when there is no exogenous power shift. War only occurs when A has a longer time horizon than B. Of the peaceful offers, A gets more benefits in the present if they do not demand B's surrender or demand the strategic object, but would lose benefits in the future. When A has a shorter time horizon, A would prefer the present benefits over the future gains of demanding B's surrender or the strategic object. Since B is always willing to make a deal where B does not surrender or B gets the strategic object, war does not occur.
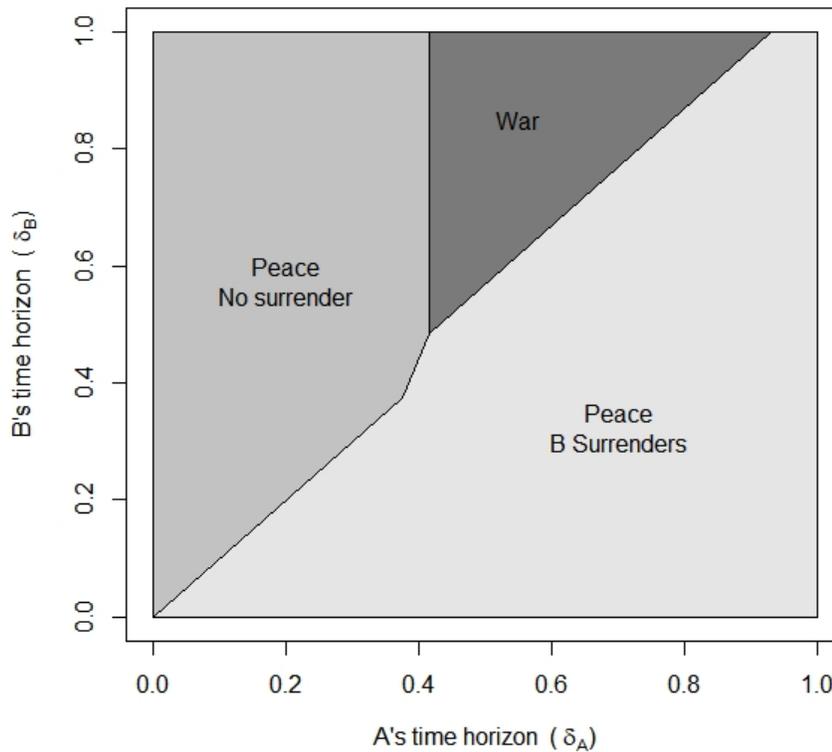
Figure 6:
Time Horizons and War, no power shift
Strategic Object Model
$\pi_1 = \pi_2 = 0.2$, $\sigma = 0.5$, $c_A = c_B = 0.01$,
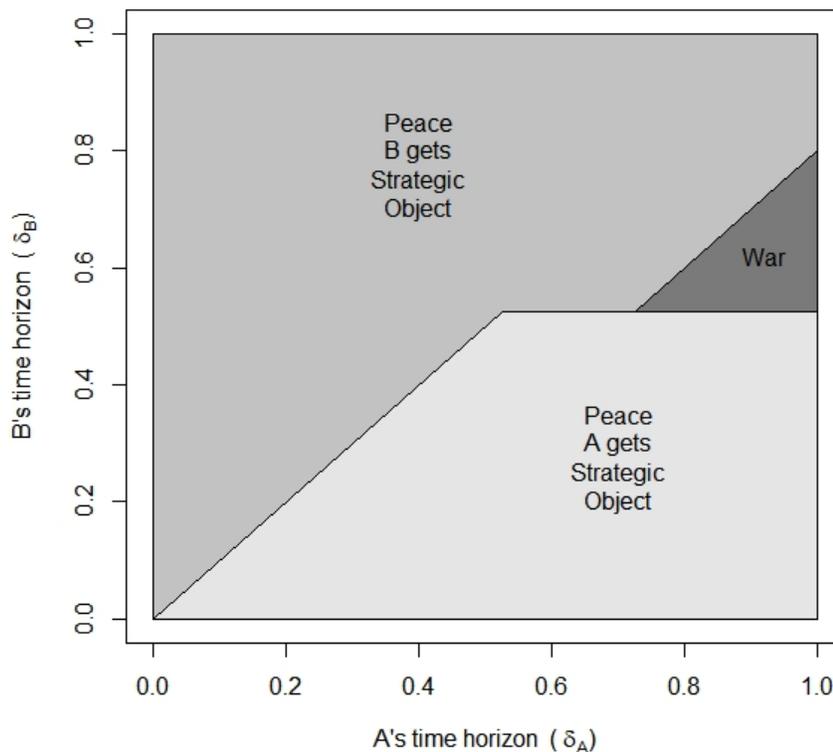
However, if A has a longer time horizon, they would prefer more future gains at the

expense of less present gains, and so would prefer to demand B's surrender or demand the strategic object. In some cases, B would be unwilling to surrender or give A the strategic object, even if given the entire disputed good. A may still value the potential future gains enough to be willing to fight. Thus, war can occur if there is no power shift (or A faces a favorable power shift) and A has a longer time horizon.

Figure 7:
Time Horizons and War, A faces adverse power shift
Decisive War Model
$\pi_1 = 0.8$, $\pi_2 = 0.2$ $\kappa = 0.8$, $c_A = c_B = 0.01$

The situation is reversed when A is facing a substantial exogenous power shift. Figures 7 and 8 display the relationship between time horizons and war for the decisive war model and the strategic object model when A's probability of winning declines from 0.8 in the first stage to 0.2 in the second. In this case, war only happens when A is facing a shorter time

Figure 8:
Time Horizons and War, A faces adverse power shift
Strategic Object Model
$\pi_1 = 0.8, \pi_2 = 0.2 \; \sigma = 0.5, \; c_A = c_B = 0.01$
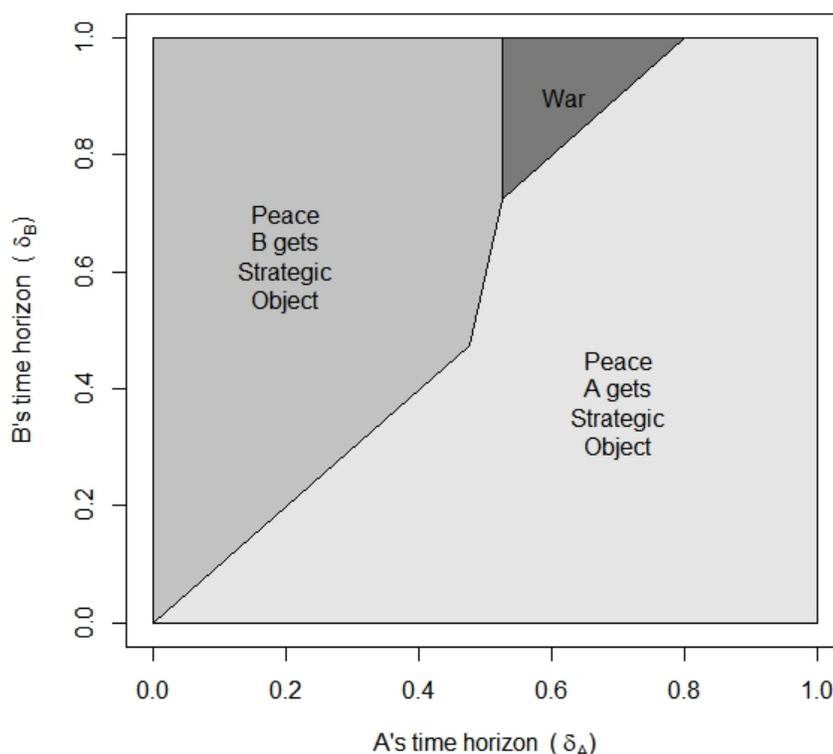
horizon than B.

When A has a longer time horizon, it is relatively easy to get B to surrender or give up the strategic object without a fight. When A faces a significant adverse power shift, A must by definition have a substantial probability of winning in the first stage. When A has a longer time horizon, A is also willing to give B a larger portion of the disputed good to buy B's surrender or the strategic object. B is thus willing to surrender or give A the strategic object in order to avoid war costs and in exchange for more of the disputed good in the present. Thus, war does not occur.

When A has a shorter time horizon, A faces a twin dilemma that may result in war.

To get B to surrender or give A the strategic object, A would have to offer substantial benefits in the present. This is especially true given that B would gain power in the future. However, A still cares some about future benefits, and does not want to see the loss of benefits in the future. Thus, A may demand more than the entire territory to allow B to survive. Thus, war could occur.

4   Conclusion

In this paper, I have examined how war can solve commitment problems posed by exogenous power shifts. In examining the means by which war can solve the commitment problem, I was guided by two fundamental principles. First, the solution to the commitment problem must be directly achievable by force of arms. If the commitment problem could only be solved through voluntary concessions by the state's opponent, war would be irrational if the opponent failed to make these concessions and unnecessary if they did. Second, a fundamental principle of the bargaining framework is that anything that can be achieved through war must also be subject to negotiations. Thus, any solution to the commitment problem must also be achievable peacefully if the parties desire. Given these principles, why do states fight to solve the commitment problem rather than choose to solve it peacefully?

To answer this question, I developed formal models to analyze six ways that war could solve the commitment problem. These are: disputes over conventional military capabilities, disputes over sources of power that also provide other benefits such as resource rich territory, disputes in the presence of defensive advantages, disputes over the existence of one state, disputes over the regime change, and disputes over indivisible strategic objects such as strategic territorial barriers (e.g. rivers) or nuclear weapons. Of these six, war can only occur in the last three models.

These findings have several substantive implications. Most importantly, the ability of war to solve the commitment problem in a way not available peacefully represents an

additional constraint on when commitment problems can cause war. Simply reducing one side's military capabilities or capturing resources or other continuously divisible sources of power are not sufficient to cause war. Because both are continuously divisible, there is always some agreement that adjusts power in such a way that it is preferable to war.

Based on the models presented, there are four obvious ways that war can solve the commitment problem, and an equivalent peaceful settlement may not be available. First, disputes over one state's existence can cause war. Second, attempts to change the regime of one state can cause war, although as noted whether war occurs will be sensitive to the assumptions of the model. Third, gaining nuclear weapons may represent a dispute over an indivisible strategic object, as even a single nuclear warhead substantially changes the power balance. Finally, strategic geographic barriers, such as rivers, may also represent indivisible strategic objects. There may be other ways in which war can solve the commitment problem and no equivalent peaceful solution exists. However, any hypothesized way that war solves the commitment problem *must* be able to explain why the commitment problem cannot be solved peacefully. Based on the results of these models, it is likely that the solution to the commitment problem must be indivisible for war to occur.

Two other interesting implications arise from this model. First, war can happen absent any exogenous power shift. In each of the models where war occurs, war can also happen with no exogenous power shift, provided that the side attempting to eliminate the second, change the second's regime, or gain control of a strategic object has a longer time horizon. Second, in all cases, war depends on the relationship between the two actors' time horizons. While the exact relationship depends on the other parameters, war generally is more likely when one actor has a significantly longer time horizon than the other.

Future research can expand on these findings in a couple ways. First, future empirical research should compare the types of disputes that can resolve commitment problems to actual wars. This should help determine the extent to which commitment problems cause war. In addition, future formal models can reevaluate how these causes of war interact with

other sources of conflict. In particular, it would be interesting to determine the impact of uncertainty or private information on the disputes that can cause commitment problem wars.

In addition, I have only examined how wars resolve commitment problems caused by exogenous power shifts or different discount factors. However, other commitment problems have been noted, including first-strike advantages (Beard and Strayhorn 2018), cases where civil war degrades state capacity (Fearon 2004, Powell 2012), and indivisible issues (Powell 2006). Future research can determine how wars resolve these other commitment problems. These commitment problems operate differently than exogenous power shifts, as they are directly caused by the decision over whether to fight. However, there are still likely additional conditions for when war occurs in these cases.

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. It is unlikely that either the United States or China would go to war to conquer the other or forcibly impose regime change. In addition, there do not appear to be any indivisible strategic objects at stake. Both sides already possess nuclear weapons, and there do not appear to be any geographic features that are both indivisible and likely to significantly shift the power balance. Thus, managing uncertainty and other forms of instability should allow a peaceful power transition.

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