Gambling on Diplomacy:
Bargaining in the Shadow of Uncertain Shifting Power

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Abstract

How do states decide whether to pursue diplomacy with rivals they suspect, but do not *know* are developing new weapons systems? One the one hand, preventive war may prove unnecessary *ex post*; on the other hand, the diplomatic route may allow the rival to acquire new weapons. We analyze a bargaining model in which the decision to negotiate allows a change in power of uncertain size to occur, while preventive wars are fought at a known distribution of capabilities. We show that the risk of war exists even after acquisition of new weapons, as the rising state can neither credibly convey limited ambitions before a shift nor newfound capabilities after a shift. The model also indicates that war is more likely to occur, be it before or after the change, when the two sides have roughly equal military capabilities. Statistical analysis of all dyad-years from 1945 to 2001 confirms the primary observable implications of the model.

When uncertain about whether an adversary is developing new weapons systems, states face a difficult choice between potentially unnecessary preventive war and diplomatic engagement that might grant their adversaries the time they need to acquire new weapons. The outcome of a war fought at the current distribution of capabilities might be relatively easy to anticipate, but the consequences of waiting for the diplomatic process to work itself out are likely to be less clear. Thus, states who face adversaries that are suspected, but not *known*, to be developing new weapons must decide whether to decisively, and destructively, solve a problem that may not even exist or gamble on diplomacy. This choice is made all the more difficult by uncertainty over what terms the rising state will accept or reject.[1]

At this point, two observations about the development of major weapons programs are in order. First, the impact of the acquisition of any particular weapons system is rarely clear, for a variety of reasons. Second, states who pursue new weapons systems have a strong incentive to either claim that the weapons system is intended solely for defensive purposes or even deny that the program is military in nature. For example, Iran's rivals are uncertain both over whether Iran intends to acquire nuclear weapons and the impact it would have on future interactions if such weapons were acquired. Thus, they must choose between waging a war today and continuing a negotiation process that may—or may not—empower Iran to reject terms in the future that it would begrudgingly accept today.

It is well established that the anticipation of a rapid shift in the distribution of capabilities can create an incentive for preventive war (Fearon 1995, Powell 2004, 2006). If a rival is known to be developing a new weapons system, this can create an incentive to attack and

[1]Note that the mere possession of new weapons allows states to credibly threaten to reject terms they would otherwise find acceptable. For this reason, attempts to acquire new weapons are of concern to other states even if there is no reason to expect an unprovoked, offensive use thereof.

eliminate the rival's program before it can be leveraged in future bargaining. But existing work has treated shifting power as a short-term problem, and recent empirical work appears to confirm this. Sobek, Foster and Robison (2012) find that states pursuing nuclear weapons are likely to be the target of militarized interstate disputes, but when and if they successfully acquire them, they enjoy a significant decrease in the probability of being targeted.[2] We show, however, that changes in capabilities can be destabilizing even after they occur.

The key problem is that an inability to credibly convey limited ambitions prior to a power shift often translates into an inability to convey the size of a shift after it has occurred. Those who successfully convince rivals that their development programs lack military application may find it hard to convince those same states that they will no longer tolerate outcomes they've lived with for decades. In other words, when states appear to be developing new weapons systems, this presents not only a potential commitment problem, but introduces an information problem—one that may not be resolved when and if the weapons are acquired.[3] Thus, the risk of war does not just increase temporarily due to an incentive for a preventive attack in a window of opportunity; relations may be destabilized for some time after.[4] To be sure, the level of uncertainty that remains will vary from case to case.[5] But when states

[2]This argument is sufficiently prevalent, and intuitive, that the authors refer to it as "conventional wisdom" in the title. See, however, Narang (2013), who argues that nuclear weapons only bring deterrent benefits conditional upon asymmetric escalation postures.

[3]On the importance of information problems, as distinct from commitment problems, see (see Blainey 1988, Fearon 1995, Powell 1996, Slantchev and Tarar 2011).

[4]Presumably, states learn over time and so interactions sufficiently far into the future may be unaffected. We are agnostic on this matter. The question is whether the completion of a power shift removes the risk of war (or returns it to some baseline level). Existing work suggests that it does. We argue otherwise.

[5]For example, successfully detonating a nuclear weapon leaves less room for doubt about the likely outcome of future conflicts than merely enriching uranium does. But even if there is no uncertainty over whether a rival has gone nuclear, there may be uncertainty over the conditions under which they would deploy such weapons, or how many warheads they possess, or the geographic reach of their delivery system.

gamble on diplomacy, they need not discover whether the gamble paid off as a poker player does after calling a bluff.

Thankfully, at any given time, relatively few states in the international system are even suspected to be in the process of acquiring major new weapons systems. Nonetheless, the scenario we envision occurs frequently enough to warrant a better understanding thereof. For example, the International Atomic Energy Agency (IAEA) often reports on Iran's nuclear program, and, unsurprisingly, the members of the United Nations Security Council follow this case closely. Some have called for an end to the lengthy, difficult bargaining process in favor of an immediate attack on Iran. "The international community must stop Iran before it's too late," Israeli Prime Minister Benjamin Netanyahu warned in a speech to the United Nations.[6] "If Iran is not stopped, we will all face the specter of nuclear terrorism, and the Arab Spring could soon become an Iranian winter... The world around Israel is definitely becoming more dangerous." Likewise, the United States is currently gambling in a similar sense on diplomacy with North Korea, just as concerns of the same type characterized past interactions with Iraq, Libya (Takeyh 2001), Pakistan (Ahmed 1999), Egypt (Levite 2003), Brazil (Gall 1976), and Argentina (Solingen 1994). These cases did not all play out the same way, however. In some, diplomacy was chosen and proved successful. In others, attempts to peacefully prevent proliferation failed. And when the Bush administration suspected (falsely, as we now know) that Iraq was stockpiling weapons of mass destruction, it launched a war that is widely regarded as a mistake. What accounts for these differences?

To shed light on this question, we analyze a model of bargaining in the shadow of a power shift whose size is uncertain. Our analysis goes beyond existing work, where it is typically

[6] Israel Ministry of Foreign Affairs (2011).

assumed that all parties know that power is changing, and by how much (see, inter alisa, Fearon 1995, Powell 1999, 2006), or where one side does not know whether power is shifting (Debs and Monteiro 2014).[7] The key insight of this model is that, while war can be caused by the *ex ante* fear of shifting power, it can also occur *after* the acquisition of new weapons systems and the distribution of capabilities is no longer changing. Moreover, the risk of war—both before and after the change—is greater the nearer the two sides are to parity. This is because shifts in power are most threatening when they break ties, and uncertainty over their size matters most when the likely outcome of war is already difficult to predict, as is more likely to be true when the two sides are evenly matched on observable indicators of capabilities (Arena N.d., Reed 2003). We then demonstrate the relevance of *ex post* uncertainty by analyzing the likelihood of dispute initiation against states with nuclear programs from 1945 to 2001.[8] Consistent with our expectations, we find that both the pursuit and acquisition of nuclear weapons are associated with an elevated risk of being the target of a militarized interstate dispute, particularly if the initiator and target possess roughly equal material capabilities.

The rest of this paper proceeds as follows. First, we elaborate on the shortcomings of previous scholarship on the dangers posed by shifting power. We then present and analyze a bargaining model with uncertainty over the size of a looming shift. Next, we turn to empirical analysis of the relationship between nuclear programs at various stages of development, the distribution of capabilities, and interstate disputes. Finally, we discuss the implications as well as the limitations of our work before concluding.

[7] See also Wolford, Reiter and Carrubba (2011), where information and commitment problems overlap. Note, however, that in their model, the information problem is neither caused by, nor resolved by, shifting capabilities. Rather, the authors assume uncertainty over one side's costs of war.

[8] We thank David Sobek for sharing data from Sobek, Foster and Robison (2012).

Shifting Power and the Risks of Bargaining

International relations scholarship has long linked changes in the distribution of capabilities to the onset of war, both theoretically (Gilpin 1981, Lemke 2002, Organski 1968, Organski and Kugler 1981, Powell 1999) and empirically (DiCicco and Levy 1999, Kim 1992, Kim and Morrow 1992, Lemke 2003, Werner 1999). When the promise of increased relative power undermines a rising state's commitment to the present distribution of benefits, a declining side may fight a war at the present distribution of power rather than tolerate a future stream of unfavorable bargains. Such commitment problems can explain war despite its *ex post* inefficiency even under complete information (Fearon 1995, Powell 2004), as long as states are unable or unwilling to bargain over the sources of military capabilities (Chadefaux 2011, Wolford, Reiter and Carrubba 2011).

Standard approaches to commitment problems treat both the size and probability of a change in power as common knowledge (Fearon 2004, Leventoğlu and Slantchev 2007, Powell 1999, 2004, 2006). Even those models that integrate shifting power with incomplete information allow for some bargain to be struck before power shifts. For example, Wolford, Reiter and Carrubba (2011) allow for a declining side to be uncertain over a rising side's willingness to take advantage of increased capabilities, though offers can be exchanged and a deal struck before any such change in the distribution of power occurs.[9] This allows rising states to reveal how strong they expect to become via their negotiating behavior, as declining states can "screen" them through a series of proposals. Yet in the context of weapons programs, where the development of specific technologies—say, weaponizing nuclear material—

[9]See also Powell (1999, Ch. 4), though note that Powell limits the per-period size of the change so that it never causes war under complete information.

allows for both rapid and discontinuous changes in the distribution of capabilities, *any* delay caused by negotiation may be sufficient to tip the scales of power. Finally, Debs and Monteiro (2014) analyze a model in which the decision to increase capabilities is endogenous, allowing for threats of preventive war to deter some weapons programs from beginning in the first place. They also allow for uncertainty over whether the decision to build new weapons has been made. However, in their model, the acquisition of new weapons is observable and their impact on the likely outcome of war in the second stage is transparent. Thus, there is no information problem after the shift in power occurs.

However, some cases of changing power—secret weapons programs in particular—involve uncertainty both before and after the (potential) shift. Specifically, a declining state must assess just how strong its rising opponent is likely to become, which creates three specific problems. First, if convincing a declining side of limited ambitions will avert war, then even those rising states that will grow intolerably strong have an incentive to claim that they will not. This makes communication about the size of ongoing or future changes in capabilities inherently incredible.[10] Second, this obstacle to revealing limited ambitions makes committing to a diplomatic process risky for the declining state, particularly if negotiations create time and space to for the rising side to complete its efforts to effect a shift in the distribution of power. As a result, the declining state must decide between war in the present and a potentially lengthy negotiation process that may see the rising state become so strong that the declining state will regret not having initiated a preventive war when it had the chance. Finally, once a declining side has allowed power to change in its opponent's favor, the same

[10]See Fearon (1995, pp. 395-401) for an intuitive discussion of the problem of credible diplomatic communication in crisis bargaining.

uncertainty that prevented a revelation of limited ambitions beforehand now stands in the way of conveying newfound strength; a state that has not grown too much stronger will wish to convey that it actually *has*, making it difficult for those states that have grown powerful to convey and use their newfound capabilities peacefully.

We therefore require a model in which forgoing the chance to attack allows for a shift in power whose size is uncertain. The model we analyze expands upon those previously used to study information and commitment problems in two ways. First, we relax the assumption that the size of the expected change in power is common knowledge, giving a rising side private information over just how strong it will become if given the opportunity. Second, we assume that the diplomatic process allows the rising state sufficient time to realize a shift in relative bargaining power. Thus, gambling on diplomacy ensures that the rising state will grow stronger, albeit by an unknown amount.

Second, the uncertainty faced by the declining state creates its own problem. While the window of opportunity for a preventive attack is still open, the rising state has every incentive to claim that the impending shift is small, regardless of its actual size; but once that window has closed, it will have an incentive to claim that the change that just transpired was relatively large. Thus, diplomatic communication is incredible both before and after the shift. Military demonstrations can sometimes reveal the size of the shift, but uncertainty over the *willingness* of a state to deploy nuclear weapons in certain situations may remain even when doubts about their *ability* to do so have been removed. Those who would be unwilling to risk a global backlash over the use of nuclear weapons in pursuit of peripheral interests have an incentive to appear as though they are undeterred by such concerns. Yet some states might well be willing to go nuclear even if survival of the state is not on the line.

Thus, the practical implications of a shift, in terms of which outcomes a state will tolerate, can be difficult to communicate credibly. Moreover, states do not always wish to reveal their capabilities (see Slantchev 2010). Israel, for example, is widely believed to possess nuclear weapons, but has never confirmed this. We therefore argue that if the declining state gambles on diplomacy, allowing the change in capabilities to occur, it forgoes preventive war but gives rise to an information problem that may yet cause war.

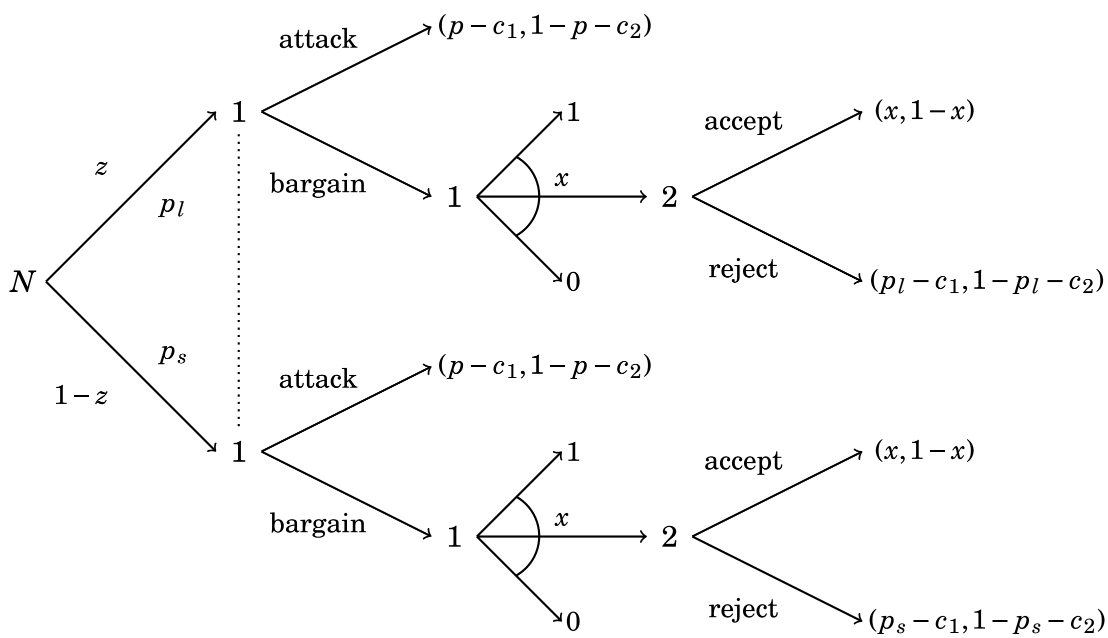
The Model

Suppose that two states, 1 and 2, dispute some continuously divisible good worth one to each side. At the outset, state 1 must decide whether to attack preventively or to gamble on diplomacy. Should 1 forgo the attack and enter negotiations, state 2 sees its military capabilities increase during the resulting bargaining process, which we model using the standard ultimatum protocol. Because 2's weapons program comes to fruition in this period, we label state 2 "rising" and state 1 "declining." Note that while 2 knows how strong it will become if given the time, 1 has only an imperfect forecast of the size of the likely change in power.[11] As a result, 1 must choose between a costly war at a known distribution of capabilities and negotiation, which leads to both a change in relative power *and* the introduction of uncertainty.

The game tree in Figure 1 presents the sequence of moves and payoffs over terminal nodes. First, Nature randomly chooses the distribution of power that will prevail between

[11] In contrast to Debs and Monteiro (2014), the shift in power is here assumed to be exogenous. But while their model assumes that the shift is of known size and that its occurrence is perfectly observable after the fact, we allow uncertainty over the size of the shift, and this uncertainty remains in place after the shift has occurred.

Figure 1: Crisis bargaining, shifting power, and asymmetric information



the disputants if state 1 forgoes the opportunity for preventive attack, though it reveals this information only to 2.[12] With probability z, there will be a large shift in 2's favor, increasing its capabilities by $\overline{s}$, and with probability $1-z$, the shift in 2's favor will be relatively small, adding only $\underline{s}$, where $0 \leq \underline{s} < \overline{s}$. Thus, z represents 1's prior belief that 2 will experience a large change in power.

Formally, if 1 attacks in its first move, it defeats 2 with probability $p = \dfrac{m_1}{m_1+m_2}$, receives nothing in defeat, and pays costs $c_1 > 0$, such that its expected utility for preventive war is $p-c_1$. For its part, 2's expected utility for a pre-shift war is $1-p-c_2$, where $c_2 > 0$ represents its own costs for war. If, on the other hand, 1 chooses to bargain, 2 realizes the shift in power and thus wins any subsequent war with probability $1-p_l = \dfrac{m_1}{m_1+m_2+\overline{s}}$ in the event of a

[12]The information set linking 1's initial choices of attack/bargain ensures that it cannot distinguish between Nature's choice of small or large change in capabilities, while the absence of an information set linking 2's choices indicates that it can distinguish between large and small shifts in power.

large change and $1-p_s = \dfrac{m_1}{m_1+m_2+\underline{s}}$ if the shift was small, where $m_i > 0$ denotes the initial capabilities of $i \in 1,2$. Thus, war at the new distribution brings 1 and 2 payoffs of $p_l - c_1$ and $1-p_l-c_2$, respectively, if the shift was large, and $p_s - c_1$ and $1-p_s-c_2$ if the change was small. Should the two reach an agreement, 1 receives x and 2 receives $1-x$, where $x \in [0,1]$ reflects 1's proposed division.

Equilibrium Analysis

Each state in our model faces a difficult strategic problem. The declining side must choose between war and diplomacy, and while the former is costly, the latter might allow its opponent to become substantially stronger and still result in war. For its part, the rising side faces a dual credibility problem; it cannot credibly communicate that the shift in power will be small prior to bargaining, nor can it credibly convey that is has undergone a large change in relative capabilities after the fact. In this section, we analyze how these challenges interact to produce three types of equilibrium: (a) preventive war, (b) gambling on diplomacy with terms that risk war, and (c) gambling on diplomacy with terms that ensure peace (though not on particularly favorable terms for 1).[13] As discussed below, which equilibrium occurs depends on the relative dominance of commitment and information problems.

Figure 2 characterizes the equilibrium space as a function of the declining side's initial probability of military victory (p) and the probability that the shift in power that will occur if 1 does not attack will be relatively large (z). Substantively, we can think of the horizontal axis as tracking the impact of the shift. As 1's initial chances of winning the war increase relative to p_l and p_s, then the expected change in power becomes increasingly severe. Note

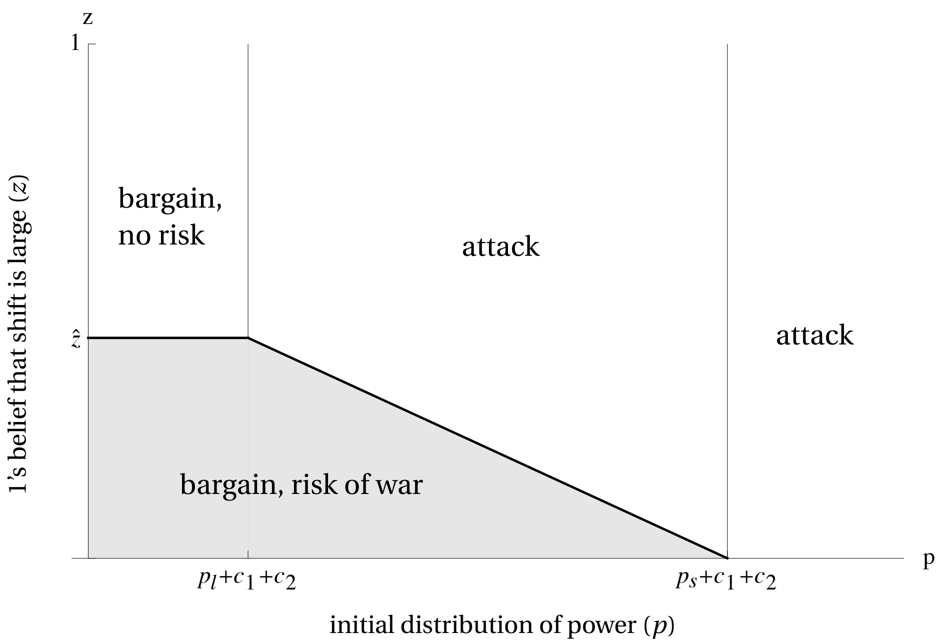
[13]Each of these equilibria occupies a unique portion of the parameter space.

that the figure treats p_l and p_s as fixed. As we discuss below, the initial distribution of capabilities, which fully determines the size of p, conditions the impact of $\underline{s}$ and $\overline{s}$. That is, the differences between p and both p_s and p_l initially increase in m_1 then begin to decrease, with the change occurring roughly around the time that m_1 surpasses m_2. Thus, the far right portion of Figure 2, where preventive war always occurs, does not correspond to cases where 1 is initially preponderant over 2 but where the two states are relatively close to parity. The vertical axis tracks 1's relative pessimism about 2's chances of experiencing a large shift in capabilities. As z approaches one, 1 is relatively certain that the shift in power will be the larger of the two possible values (that is, 1 is more pessimistic), but as z approaches zero, 1 is increasingly confident that the change will be relatively small (and thus is relatively optimistic).[14]

The impact of the shift, in terms of the difference between p and p_s, on the one hand, and p_l on the other, divides the equilibrium space naturally into three regions. First, when $p \leq p_l + c_1 + c_2$, which is of course equivalent to $p - p_l \leq c_1 + c_2$, even the larger shift will have but a modest impact, and thus there is no incentive to launch a preventive war. As a result, the information problem dominates. If war occurs in this equilibrium, it is simply the result of the risk-return trade-off (Powell 1999, Slantchev and Tarar 2011). That is, 1 never attacks preventively here, choosing always instead to gamble on diplomacy. When sufficiently optimistic that the shift 1 will allow by pursuing diplomacy will be the smaller of the two (i.e., when z is not too big), 1 will make an offer that 2 accepts if and only if the change is in fact small. In this way, 1 accepts a risk of war in hopes of securing a better

[14]Note that we make minimal about the absolute size of $\underline{s}$ or $\overline{s}$, requiring only that $0 \leq \underline{s} < \overline{s}$. Thus, the larger of the two possible shifts may nonetheless represent a small change in 1's likelihood of victory. Similarly, the smaller of the two shifts may nonetheless be fairly devastating.

Figure 2: Equilibrium outcomes by initial distribution of power and probability of large shift



deal. If 1 is sufficiently pessimistic (i.e., if z is sufficiently large), however, it neither attacks preventively nor risks war with its proposal, choosing terms that are generous enough that 2 will accept them regardless of the size of the shift.

Proposition 1 (Private information dominates)**.** *When $p \leq p_l + c_1 + c_2$, 1 never attacks. 1 negotiates and makes a proposal that entails a risk of war when $z < \hat{z}$; otherwise, when $z \geq \hat{z}$, it negotiates but makes a proposal entailing no risk of war.*

As stated in Proposition 1, when even the worst case scenario entails a change in power so small that a preventive war would be unattractive, the declining side commits to negotiating with 2 and allows the shift to occur. However, after the shift, 1 may still make proposals that entail a risk of war, just as in standard treatments of private information and war (Fearon 1995). Note, though, that the information problem only becomes relevant when 1 chooses to forgo preventive war. That is, while 1 is uncertain about the state of the world from the very outset in our model, it is only if 1 gambles on diplomacy that this uncertainty becomes relevant. Rather than the anticipation of a future change in capabilities leading to war, then, a *realized* shift in power can destabilize relations.

At the right of Figure 2, with $p > p_s + c_1 + c_2$, or $p - p_s > c_1 + c_2$, we have the other extreme. Here, a shift of either size will have a sufficiently large impact to prevent 1 from gambling on diplomacy, since there is no winning when even the smaller shift has unacceptable consequences. In this case, 1's uncertainty over the precise size of the looming shift becomes irrelevant. Even in the best case scenario, the change is going to be larger than the bargaining surplus (cf. Powell 2004, 2006)—that is, the total costs of war—and so 1 will not allow it to occur. The commitment problem generated by the anticipation of a future shift in power dominates the information problem its occurrence would create, and 1 attacks preventively regardless of its beliefs.[15]

Proposition 2 (Shifting power dominates)**.** *When $p > p_s + c_1 + c_2$, 1 never negotiates, attacking for any beliefs $z \in (0,1)$ it might hold about the shift in power.*

Propositions 1 and 2 show that, when the impending shift in power is either very small or very large in expectation, bargaining in the shadow of an uncertain change in power produces dynamics more or less identical to those found in standard models of asymmetric information and commitment problems (cf. Wolford, Reiter and Carrubba 2011).

What happens, however, at a middling initial distribution of capabilities, as in the central region of Figure 2? In this case, where $p_l + c_1 + c_2 < p \leq p_s + c_1 + c_2$, state 1 would attack

[15]For Debs and Monteiro (2014), war does not occur if the threat of preventive war is credible, because the rising side will be discouraged from investing in the technology that would produce a change in capabilities in the first place.

preventively if it knew the looming shift would be relatively large, but it would rather accommodate the rising state if it knew the change would be relatively small. It is here that state 2's inability to credibly signal limited ambitions becomes a problem. If the looming shift is relatively large, 2 has strong incentives to claim otherwise so that it might avert a preventive war and enjoy the increased bargaining leverage its shift in power will ultimately bring. As a result, state 1 relies on its prior beliefs, though they are but an imperfect forecast, to determine whether it is best to attack preventively or to gamble on diplomacy. In these cases, 1 has nothing but bad options. Should 1 attack, it may later learn that there was no need to have done so.[16] Should 1 instead choose to negotiate, it will remain uncertain about whether it has allowed 2 to acquire weapons that dramatically change the distribution of capabilities, and war will remain a possibility. Moreover, if war occurs, it will occur under less favorable conditions than had been previously available.

Proposition 3 (Private information and commitment problems relevant)**.** *When $p_l + c_1 + c_2 < p \le p_s + c_1 + c_2$, 1 attacks when $z > \tilde{z}$. Otherwise, when $z \le \tilde{z}$, it negotiates and makes a proposal that entails a risk of war; it never makes a proposal that entails no risk of war.*

As stated in Proposition 3, the intermediate case where both private information and commitment problems are relevant produces a rather different set of equilibria. When 1 believes that the shift in power is sufficiently likely to be large, it attacks, waging a preventive war that it would never consider fighting if it were in the leftmost region of Figure 3. Recall

[16] For ease of exposition, we generally assume that *some* change in power is sure to occur, implying that unnecessary preventive wars are not wars fought against states who weren't building weapons, but wars fought against states whose secret weapons programs weren't going to benefit them much. However, as $\underline{s} \to 0$, the smaller shift increasingly approximates no change at all. Thus, our results speak to cases where there is uncertainty over *whether* a shift is occurring in addition to those where there is uncertainty over *the size* of a certain shift.

that, when the looming shift is expected to be relatively small, 1 is inclined to negotiate when it is sufficiently pessimistic about the size of the shift, i.e. when $z > \hat{z}$. In the middle region, though, pessimism translates into the belief that negotiation will likely allow 2 to grow so strong that 1 will regret not having attacked. Thus, when 1 is pessimistic enough, 1 attacks before power can change.

When $z \leq \tilde{z}$, 1 is relatively more certain that the shift will be small, and thus that 2 will not become so strong as to justify preventive war. This discourages 1 from launching a preventive war, leading it to instead gamble on diplomacy. However, two more factors still stand in the way of a peaceful resolution. First, even though 1 is optimistic enough not to launch a preventive war, it remains uncertain over precisely how strong 2 will become during negotiations. Second, because 2 would have an incentive to claim that it has experienced the large change even if it hasn't, 2 cannot credibly reveal itself as strong. In fact, 1 always makes a proposal that risks war in this region of Figure 2. This is because 1 only attempts negotiations when 1 deems it unlikely that doing so will permit 2 to undergo a large shift in capabilities. Put differently, the very optimism that discourages 1 from attacking outright leads 1 to offer terms that 2 will accept if and only if the change in power was relatively small. 2 will sometimes accept those terms, but it won't always. More formally, when $p_l + c_1 + c_2 < p \leq p_s + c_1 + c_2$ and $z \leq \tilde{z}$, 1 chooses not to attack preventively, but will propose terms that ensure war will nonetheless occur with probability z. When $\tilde{z}$ takes on relatively small values, this presents but a modest risk of war. However, if $\tilde{z}$ is large enough, 1 need not have been *that* optimistic, and war may be fairly likely.

Again, when negotiations in this middle region of the parameter space break down in war, they do so because 1 chooses a proposal that 2 accepts if the shift is small but rejects if the shift is relatively large. Therefore, negotiations end in a war against precisely the type of 2—one that has experienced a large shift in power—that 1 would have attacked preventively had it known the size of the change at the outset. Should such a war occur, then, it will carry with it two types of *ex post* regret; not only would 1 have been better off fighting a preventive war at the outset, but even once 1 forgoes this opportunity, war could have been averted if 1 had offered 2 better terms. That 1 has no incentive to do so *ex ante* does nothing to change the fact that war is inefficient. If state 2 could credibly reveal its strength, thereby inducing 1 to update its beliefs and craft an acceptable proposal, both sides could be saved the costs of war.

This tells us that when the differences between p and p_s and between p and p_l take on moderate values, war can occur in two distinct ways: first, if the declining side is sufficiently pessimistic about the size of the looming shift, it will fight a preventive war; and second, if the declining side is sufficiently optimistic to gamble on diplomacy, it will nonetheless propose terms that 2 will accept if and only if 2 undergoes a more modest shift during negotiations—which sometimes won't be the case. Pursuing major weapons programs is thus doubly dangerous when their potential impact is difficult to discern. In other words, modeling changes in capabilities resulting from the acquisition of major new weapons systems as *faits accomplis*, the way Debs and Monteiro (2014) do, may be problematic. With ordinary *faits accomplis*, such as land grabs, the target state often knows what happened to it and no information problem is necessarily introduced.[17] The development of major

[17] If the land has strategic value, however, and if that value depends on how well its occupant makes use of it, then an information problem may be introduced. It is well known that bargaining over objects that influence future power—as new weapons systems necessarily do, and as *some* tracts of territory do—is more complicated than bargaining over objects of strictly intrinsic value (Fearon N.d.). We therefore do not wish to draw too stark a distinction here. We thank Alex Debs for pointing this out.

new weapons systems is often different, however. Even after a state detonates a nuclear weapon, doubts may remain about how many other bombs the state can build, to say nothing of its ability to deliver them over great distances. For example, North Korea recently authorized the use of nuclear weapons against the US, warning that "the moment of explosion is approaching fast," and that war might arrive "today or tomorrow" (Washington Times, 4/3/2013), even though North Korea is not generally believed to currently possess missiles capable of reaching the United States.[18] There may also be uncertainty over the conditions under which the state would be willing to deploy nuclear weapons (Powell 1990).

Finally, note that equilibrium behavior under the hybrid information-commitment problem in Figure 2 differs markedly from behavior under similar conditions in Wolford, Reiter and Carrubba (2011) (hereafter WRC). In their analysis, when a declining side is relatively pessimistic over the rising side's strength, it offers terms that are sure to be accepted (see p. 565, Figure 2). The unique nature of bargaining over major weapons programs explains why the two analyses diverge. In WRC, power shifts *after* a round of negotiations, allowing the declining side to use bargaining behavior as a screening mechanism. Striking a deal means enjoying the terms of that deal until an uncertain change in power and more negotiations.[19] No such possibility exists for our model. Thus, the declining side is forced to attack when pessimistic about the size of the shift, as war is the only mechanism by which it can enjoy the present distribution of capabilities in any way; either power changes so rapidly or negotiations will be so lengthy that forgoing attack ensures that the rising

[18]The Pentagon recently stated that North Korea could soon develop such a capacity, however (CNN 4/11/2013).

[19]In WRC, war does follow in subsequent periods after some non-risky initial proposals, but such wars turn out to be off the equilibrium path; the declining side would prefer to separate in the present to avoid such a possibility.

side will grow stronger and that even war-averting bargains will reflect the rising side's newfound strength.

Comparative Statics and Empirical Implications

With equilibrium behavior characterized, we turn in this section to a more detailed analysis of the conditions supporting the more interesting equilibria. We focus first on characterizing the prevalence of the middle range, where both preventive war and war due to miscalculation are possible. Next, we discuss how key parameters affect the size of the threshold $\hat{z}$, which has an important impact on behavior in both the middle and leftmost region.

The broader the range of possibilities resulting from a shift in power, as indicated by the difference between p_l and p_s, the more likely a declining state is to find itself facing our hybrid bargaining problem. One factor that obviously affects the difference between p_l and p_s is the difference between the small ($\underline{s}$) and large ($\overline{s}$) change in capabilities. Intuitively, the more uncertainty there is regarding how much 2's capabilities will increase if 2 completes the new weapons system, the more likely it is that 1's decision of whether to gamble on diplomacy or not depends on 1's beliefs. As $|\overline{s} - \underline{s}| \to 0$, and thus $|p_s - p_l| \to 0$, the middle region vanishes and 1 either never gambles on diplomacy (the rightmost region of Figure 2) or always does so (the leftmost).

This is not the only determinant of the difference between p_l and p_s, however. When 1's military capabilities (m_1) take on either very large or very small values, relative to 2's initial capabilities (m_2), shifts in power matter less, be they large or small. Simple comparative statics demonstrate that increases in m_1 increase the difference between p_l and p_s up until

m_1 reaches a threshold, after which further increases in m_1 shrink the gap between p_s and p_l. More formally, $\frac{\partial(p_s - p_l)}{\partial m_1}$ is positive while $m_1 < \hat{M}$, where

$$\hat{M} \equiv m_2 + \sqrt{m_2(\underline{s} + \overline{s}) + \underline{s}\overline{s}}.$$

Since $\hat{M}$ lies somewhere north of m_2, we can say that the middle region of Figure 2 is at its most expansive when 1 and 2 are roughly equal in capabilities. It is not precisely parity that maximizes this region's share of the parameter space, but very small and very large values of m_1 cause it to shrink. This might make us think that the relationship between parity and war is ambiguous, since enlarging the leftmost region favors peace while the rightmost region involves certain war. However, the rightmost region also shrinks as $m_1 \to 0$ or $m_1 \to 1$. More formally, the rightmost region, where $p - p_s > c_1 + c_2$, shrinks as $p - p_s \to 0$, and the difference between p and p_s increases in m_1 up until $\underline{m}$, then decreases with further increases in m_1, where $\underline{m} \equiv m_2 + \sqrt{m_2 \underline{s}}$. Again, $\underline{m}$ is arbitrarily larger than m_2, so we can't say that the rightmost region, where war is certain to occur, is maximized at parity, but we *can* say that very large and very small values of m_1, relative to m_2, minimize it. Also, note that the leftmost region—the *only* region containing an equilibrium where peace is sure to obtain—increases as the difference between p and p_l shrinks. This difference also takes on smaller values as $m_1 \to 0$ or $m_1 \to \infty$. That is, the difference between p and p_l is increasing in m_1 up until $\overline{m}$, where $\overline{m} \equiv m_2 + \sqrt{m_2 \overline{s}}$.

Thus, the model tells us that peace is more likely to be possible (as it is not in the rightmost region), or perhaps even certain (in the upper portion of the leftmost region), as the initial distribution of capabilities grows more imbalanced in either direction. The intuition here is simply that 1 has less reason to either wage preventive war, or risk war by proposing terms that 2 might not accept, when changes in capabilities do little to alter the expected outcome of war because one side has such an overwhelming advantage. For example, the United States would certainly have preferred that North Korea remain outside the nuclear club, but the consequences of it joining the ranks of nuclear powers appear to have been quite modest. When the development of new weapons is likely to break a tie, however, the problems we identified above grow more severe.

This becomes even clearer when we consider the relationship between the distribution of capabilities and the two thresholds defining behavior within the leftmost and middle regions. First, consider $\hat{z}$, which determines whether 1 risks war with its proposal, per Proposition 1. As shown in the appendix,

$$\hat{z} \equiv \frac{p_s - p_l}{p_s - p_l + c_1 + c_2}.$$

Examining $\hat{z}$ allows us to add several details to this story. First, the threshold falls, ensuring that a larger range of values of z lie above it, discouraging 1 from issuing proposals that 2 will only accept if the shift in power is relatively small, as the total costs of war, $c_1 + c_2$, increase. Intuitively enough, state 1 has an incentive to avoid war when it would be especially destructive. Second, the larger the difference between p_s and p_l, the more attractive it is to risk war, as indicated by an increase in $\hat{z}$. As we've already seen, this difference is maximized when the two sides start out with relatively equal capabilities. When m_1 is either very large or very small relative to m_2, $\hat{z}$ takes on values close to 0 and 1 plays it safe whenever choosing the diplomatic route—which it is more likely to do in the first place.

Next consider $\tilde{z}$, which determines whether 1 risks war with the terms it offers 2 in negotiations or attacks outright, per Proposition 3. As shown in the appendix,

$$\tilde{z} \equiv \frac{p_s - p + c_1 + c_2}{p_s - p_l + c_1 + c_2}.$$

Again, we see that an increase in the costs of war favors peace. In this case, it increases $\tilde{z}$, ensuring that 1 will gamble on diplomacy despite higher levels of pessimism. We also see that larger differences between p and p_s favor war by decreasing $\tilde{z}$. The same goes for p_s and p_l. As we've already seen, these differences shrink as $m_1 \to 0$ or $m_1 \to \infty$. When m_1 is close in size to m_2, however, $\tilde{z}$ takes on values arbitrarily close to 0, and 1 chooses war unless it is very optimistic about the size of the shift.

To sum up, then, the model tells us that 1 becomes less likely to gamble on diplomacy, choosing preventive war instead, as it approaches (points arbitrarily close to) parity with 2. Moreover, should 1 even attempt negotiations, it is more likely to propose terms that generate a risk of war as the two approach parity. Thus, war is more likely to occur—be it before or after 2's acquisition of new weapons—if the two sides are relatively evenly matched. If, on the other hand, either side has a preponderance of power, then 1 is not only more likely to gamble on diplomacy, but also to choose terms that are so generous that 2 accepts regardless of type. In contrast with previous work, we expect the risk of war to remain elevated even after a change in capabilities. We turn now to a brief discussion of empirical evidence in support of these expectations.

Statistical Analysis

We analyze all directed-dyad-years from 1945 to 2001. Our dependent variable, *INIT*, takes on a value of 1 if the potential initiator (a) initiated a militarized interstate dispute against the target in that year and (b) the resulting dispute involved the use of force by the initiator (since we are not particularly interested in the generation of threats or shows of force).[20] The data come from the Militarized Interstate Dispute project (Ghosn, Palmer and Bremer 2004), and the dataset was generated using EUGene (Bennett and Stam 2000).

Our key independent variables come from two sources. First, we generate a proxy for the initial distribution of capabilities (p), *CAPSHARE*, using the initiator's share of material capabilities in the dyad—that is, the initiator's Composite Index of National Capabilities (CINC) score over the sum of dyadic CINC scores (Singer, Bremer and Stucky 1972). The mean value for this variable is 0.5, but observations tend to cluster near the ends of the spectrum; *CAPSHARE* takes on values less than 0.05 or greater than 0.95 one third of the time. Since our theoretical model emphasizes the importance of parity, we also include the square of *CAPSHARE*. Second, we use two measures from Sobek, Foster and Robison (2012) on target state nuclear programs. *PURSUIT* takes on a value of one for every year in which the target state actively attempts to develop nuclear weapons until it either gives up or succeeds. If the target state has succeeded in its pursuit of nuclear weapons, *ACQUIRED* takes on a value of one if the target is in possession of nuclear weapons. The theoretical model analyzed above is general enough to apply to situations where states seek to increase their capabilities through acquisition of any new technology, such as aircraft carriers or

[20]We code revisionist states as initiators, rather than the state that took the first hostile action. Similar results were obtained when using the alternative coding, however.

intercontinental ballistic missiles, but the nuclear context is an appropriate one to assess our claims. The examples we discussed above all concern nuclear weapons, and the data compiled by Sobek, Foster and Robison (2012) suits our needs perfectly.

Although our model does not lead us to expect the relationship between the distribution of material capabilities and war to depend meaningfully on the status of the target's weapons program—just its existence—we create separate interactions between *CAPSHARE* and *CAPSHARE*^{2} and both *PURSUIT* and *ACQUIRED*. This allows us to conduct a fair test of the model's implications. If, for example, parity was associated with a greater risk of interstate disputes once the target acquired nuclear weapons, but preponderance promoted conflict while the target was still developing them, our research design would allow us to uncover evidence of that.[21]

Finally, to correct for potential confounding and/or temporal dependence in the dependent variable, we also include a measure of the capital-to-capital distance between the states in each dyad (Bennett and Stam 2000) and a cubic expansion of the number of years since the last use of force in the dyad (Carter and Signorino 2010). It is quite likely that some states are more driven to pursue and/or acquire nuclear weapons precisely because they are more likely to be the target of hostility in the first place, and both distance and time since the last dispute are likely to be related to the probability of being targeted at any given time and, as such, the desire to pursue nuclear weapons.

The method of estimation is a simple binary logit, the results of which can be found in Table 1. Given the presence of multiplicative interaction terms, to ease interpretation

[21] Sobek, Foster and Robison (2012) include interactions between the initiator's share of capabilities and the different stages of the target's nuclear program, but they do not include the square term and so implicitly force these relationships to be monotonic.

Table 1: Material Capabilities, Nuclear Status, and Dispute Initiation

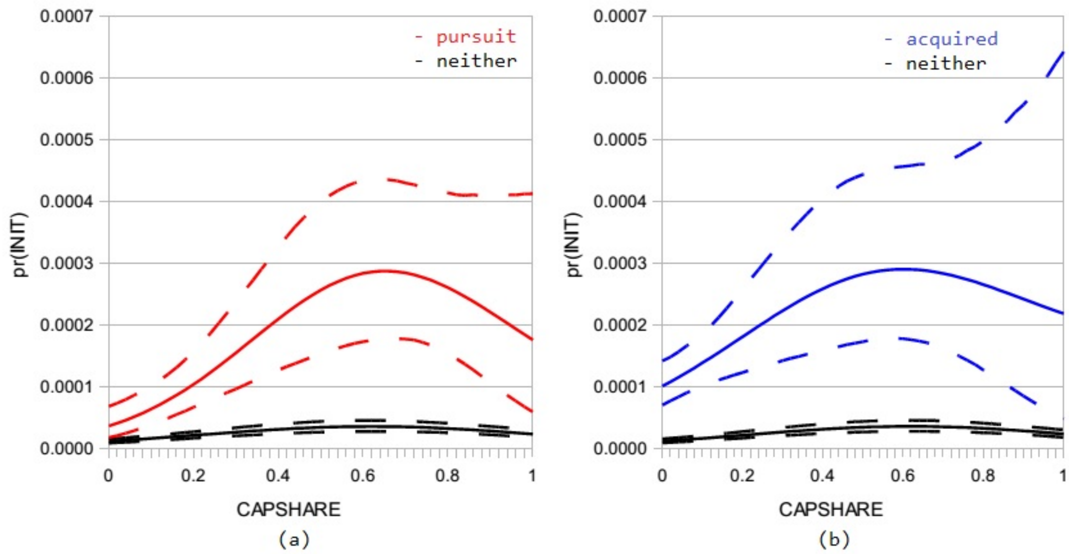
Pr(INIT = 1)	
Variable	**Estimates**
— *Theoretical variables* —	
CAPSHARE	3.63 (0.45)*
CAPSHARE^2	-2.93 (0.41)*
PURSUIT	1.09 (0.35)*
ACQUIRED	2.16 (0.18)*
CAPSHARE∗*PURSUIT*	2.78 (1.79)
CAPSHARE^2∗*PURSUIT*	-1.95 (1.87)
CAPSHARE∗*ACQUIRED*	-0.13 (1.40)
CAPSHARE^2∗*ACQUIRED*	-0.01 (1.80)
— *Control variables* —	
DISTANCE	-8.1e-4 (2.5e-5)*
PEACE	-0.25 (0.01)*
PEACE^2	5.3e-3 (2.9e-4)*
PEACE^3	2.9e-5 (2.2e-6)*
Intercept	-4.29 (0.11)*
Model Statistics	
N	1,115,892

∗ indicates statistical significance at $p < 0.05$.

we present Figure 3, which graphs the predicted probability of dispute initiation for the full range of values of the initiator's share of capabilities, along with simulated confidence intervals (Brambor, Clark and Golder 2006). The predicted probabilities were generated holding the distance and peace terms constant at their means.

As Figure 3 makes clear, the model in Table 1 generates the predicted probability of a dispute being initiated against a target who is in pursuit of nuclear weapons that differs little from that of a target who has already acquired nuclear weapons. Moreover, we see a curvilinear relationship between the initiator's share of capabilities and the probability that it initiates a dispute against the target in both cases (as well as in the baseline, though the

Figure 3: Predicted Probability of Dispute Initiation by Relative Military Power and Nuclear Status



curve appears flat in comparison). The inflection points are to the right of 0.5, but recall that while our theoretical model clearly anticipates a curvilinear relationship, it does not suggest that the greatest risk of conflict should occur precisely at parity. The confidence interval for targets who've acquired nuclear weapons facing initiators who control a dominant share of material capabilities is relatively wide, but overall, the results are quite consistent with our theoretical expectations. Yet they stand in stark contrast to those of previous treatments of shifting power, where the completion of a shift in the rising side's favor should be coincident with a decline in the probability of war; however, when states acquire weapons that can generate new uncertainty themselves—like nuclear weapons—then the destabilizing effects of power shifts do not end once the distribution is again stable.

Conclusion

We have argued that foreign policy decision makers often face the difficult choice between using force to resolve a crisis now and waiting for diplomacy to work. The risk of gambling on diplomacy is greatest when the time necessary for diplomacy to work may also be accompanied by a change in relative power. When it is unclear how waiting on diplomacy might affect future bargaining leverage, a crisis that could be resolved through negotiation may nonetheless escalate to costly conflict. Because of uncertainty and a shift in power that may cause a commitment problem, conflict can break out even when both of the states would prefer a negotiated settlement. Notably, uncertainty over the size of shifting power can cause war either before or after such a shift occurs, due to a sequence of obstacles to credible communication. Prior to a change in power, a rising side cannot credibly convey limited ambitions, which may tempt a declining side to launch a preventive war, but following a shift in power, the newly-risen side may be unable to convince the now-declined side that it actually *has* grown substantially stronger, creating an incentive for conflict driven by a risk-return trade-off.

The analysis makes two important contributions. First, the theoretical model and the results of the statistical analysis provide a useful lens to understand important foreign policy dynamics that involve diplomatic efforts to curtail the diffusion of nuclear weapons. In states such as Iran and North Korea, the United States and its allies are gambling on diplomacy. Diplomacy is a gamble in these cases because there is a real risk that Iran and North Korea may use the time afforded them by diplomatic efforts to transition a limited nuclear program to a fully operational one. Yet, given the preponderance of power enjoyed by the US over these rogue states, it is perhaps unsurprising that the US is willing to take that gamble.[22] Second, the paper makes an important contribution to the formal literature on crisis bargaining. The analysis shows commitment problems and uncertainty can interact to produce interesting expectations about crisis outcomes. When the commitment problem dynamic dominates, the model shows that there is little hope for diplomacy. When the information problem dominates, states are more inclined to gamble on diplomacy, though they may also gamble in the sense of proposing terms that carry a risk of rejection. When the commitment problem and the information problem are both relevant and interact, leaders may gamble on diplomacy only to realize that they would have been better off using force in lieu of waiting for diplomacy to work.

For the sake of simplicity, we have treated power shifts as exogenous. One obvious way to extend our analysis would be allow these changes to be endogenous—to allow 2 to choose whether to develop a new weapons system at all. Negotiations with states believed to be pursuing new weapons systems, after all, often revolve around that very point. While we believe our analysis sheds important light on the trade-offs between military and diplomatic responses to situations where policymakers are uncertain about the size of a looming power shift, deeper insights still may come if we allow 1 and 2 to negotiate directly over 2's investment in new technology.[23] Another important extension would be to allow for other sources of uncertainty. For our purposes, it was sufficient to abstract away from the usual suspects and introduce a potential source of uncertainty that has thus far been overlooked, but in-

[22]The decision to invade Iraq, however, is more difficult to reconcile with our argument. One could perhaps argue that the unique domestic political context following the 9/11 attacks lowered the effective cost of war for the administration, making war optimal despite the vast capability advantage enjoyed by the United States, but such arguments are beyond the scope of this paper.

[23]Though he assumes complete information before and after a shift, see (Spaniel N.d.).

corporating more traditional assumptions might generate additional insights beyond those highlighted here.

Mathematical Appendix

Proof of Proposition 1. First, consider 2's decision of whether to accept x. Letting p represent 1's generic probability of victory, 2 accepts if and only if (iff) $u_2(A) \geq EU_2(R) \Leftrightarrow 1 - x \geq 1 - p - c_2$, which simplifies to $x \leq p + c_2$. Thus, after a relatively small shift, 2 accepts iff $x \leq p_s + c_2 \equiv \overline{x}$ while after a relatively large shift, 2 accepts iff $x \leq p_l + c_2 \equiv \underline{x}$, where $p_l < p_s$ ensures that $\underline{x} < \overline{x}$.

Next, we demonstrate that in any perfect Bayesian equilibrium, 1 either sets x precisely equal to $\underline{x}$ or $\overline{x}$, never setting $x < \overline{x}$, $x > \underline{x}$ or $x \in (\underline{x}, \overline{x})$.

To see this, first consider what happens when 1 proposes $x > \overline{x}$, which provokes war regardless of 2's type. For $x > \overline{x}$ to be preferred to $x = \overline{x}$, which only leads to war if 2 underwent a relatively large change, then $EU_1(x > \overline{x}) > EU_1(x = \overline{x})$ must hold. This is equivalent to

$$z(p_l - c_1) + (1 - z)(p_s - c_1) > z(p_l - c_1) + (1 - z)(\overline{x}),$$

or

$$z(p_l - c_1) + (1 - z)(p_s - c_1) > z(p_l - c_1) + (1 - z)(p_s + c_2).$$

This reduces to $c_1 + c_2 < 0$, which cannot be true. Thus, 2 never sets $x > \overline{x}$, since at least one strategy, that of setting $x = \overline{x}$, strictly dominates it.

Next consider the $x < \underline{x}$, which 2 accepts regardless of the size of the shift it has just undergone. This strategy cannot be preferred to $x = \underline{x}$, because 2 is also certain to accept when $x = \overline{x}$, and 1's payoff from a negotiated agreement is strictly increasing in x.

Finally, 1 never selects a value of x strictly in between $\underline{x}$ and $\overline{x}$, which we'll temporarily denote $\hat{x}$. To do so is only preferred to setting $x = \overline{x}$ when

$$z(p_l - c_1) + (1-z)\hat{x} \geq z(p_l - c_1) + (1-z)\overline{x},$$

which cannot hold, since $\overline{x} > \hat{x}$ by definition.

Thus, we need only consider two proposals: $x = \underline{x}$ and $x = \overline{x}$. Should 1 even gamble on diplomacy, 1 selects terms designed to ensure peace iff $u_1(x = \underline{x}) \geq EU_1(x = \overline{x})$, which is equivalent to

$$\underline{x} \geq z(p_l - c_1) + (1-z)\overline{x},$$

or

$$z \geq \frac{p_s - p_l}{p_s - p_l + c_1 + c_2}.$$

Letting $\hat{z}$ denote the right hand side of the previous inequality, we can thus say that 1 sets $x = \underline{x}$, which carries with it no risk of war, when $z \geq \hat{z}$.

Having characterized 1's choice of x in the event that 1 gambles on diplomacy, we now turn our attention to whether 1 is even willing to do so. When $z \geq \hat{z}$, indicating that 1 believes it so likely that gambling on diplomacy means allowing a relatively large change to occur that 1 will play it safe by setting $x = \underline{x}$ during negotiations, 1 prefers gambling on diplomacy to attacking preventively when

$$\underline{x} \geq p - c_1,$$

or

$$p \leq p_l + c_1 + c_2.$$

On the other hand, when $z < \hat{z}$, and thus 1 believes the probability of a relatively large shift small enough that 1 will risk war in the negotiation phase anyway by setting $x = \overline{x}$, 1 gambles on diplomacy when

$$z(p_l - c_1) + (1 - z)\overline{x} \geq p - c_1,$$

or

$$z \leq \frac{p_s - p + c_1 + c_2}{p_s - p_l + c_1 + c_2}.$$

Letting $\tilde{z}$ denote the right hand side of the previous inequality, we can thus say that 1 attacks preventively when 1's prior is such that 1 would risk war during negotiations anyway when $z > \tilde{z}$.

Note that it is not always possible for z to simultaneously fall below $\hat{z}$ yet above $\tilde{z}$. When $\tilde{z} \geq \hat{z}$, if 1 if sufficiently optimistic about the size of the looming shift that 1 would risk war during the negotiation phase, then 1 is necessarily also optimistic enough to forgo a preventive attack. This is the case when

$$\frac{p_s - p + c_1 + c_2}{p_s - p_l + c_1 + c_2} \geq \frac{p_s - p_l}{p_s - p_l + c_1 + c_2},$$

or

$$p \leq p_l + c_1 + c_2.$$

Recall that we established above that 1 gambles on diplomacy provided that $z \geq \hat{z}$ iff $p \geq p_l + c_1 + c_2$. Thus, when $p \leq p_l + c_1 + c_2$, 1 gambles on diplomacy regardless of the size of z, setting $x = \overline{x}$ iff $z < \hat{z}$; otherwise setting $x = \underline{x}$. As $\overline{x}$ carries with it a risk of war while $\underline{x}$ does not, this establishes Proposition 1. □

Proof of Proposition 2. It is also sometimes impossible for z to fall below $\tilde{z}$. That is, while $\hat{z}$ is strictly bounded between 0 and 1, $\tilde{z}$ can take on negative values. When it does, 1 must prefer a preventive attack to negotiations if 1 anticipates risking war anyway during those negotiations. This holds when

$$\frac{p_s - p + c_1 + c_2}{p_s - p_l + c_1 + c_2} < 0,$$

or

$$p > p_s + c_1 + c_2.$$

Recall that when $z \geq \hat{z}$, 1 attacks so long as $p > p_l + c_1 + c_2$. This must be true if $p > p_s + c_1 + c_2$, since $p_s > p_l$. Thus, when $p > p_s + c_1 + c_2$, 1 always attacks preventively, no matter the size of z. This establishes Proposition 2. □

Proof of Proposition 3. We have now established that when $z < \hat{z}$, 1 gambles on diplomacy rather than attacking preventively so long as $z \leq \tilde{z}$, and also that at least some values of z satisfy this condition so long as $p \leq p_s + c_1 + c_2$. We have also established that when $z \geq \hat{z}$, 1 refuses attacks preventively whenever $p > p_l + c_1 + c_2$. Thus, if $p_l + c_1 + c_2 < p \leq p_s + c_1 + c_2$, 1 attacks preventively iff $z \geq \hat{z}$, choosing to propose $\overline{x}$ otherwise. In this range, 1 either guarantees war by attacking preventively or tolerates a risk of war with by making a proposal that 2 only accepts if 2 underwent a relatively small change—1 never sets $x = \underline{x}$. This establishes Proposition 3. □

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