Power Transfers, Military Uncertainty, and War*

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Abstract

In many contexts, patrons wish to simultaneously increase a protégé's military power while reducing the probability of war between that protégé and its enemy. Are these goals compatible? I show that the answer is yes when states face uncertainty over a class of military allotments. Arms transfers mitigate the information problem by making both strong and weak types behave more similarly. This encourages uninformed states to make safer demands, which decreases the probability of war. As a result, transfers to the informed actor both increase bargaining power and enhance efficiency under these conditions.

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1 Introduction

Military aid has become commonplace in international relations. According to the SIPRI Arms Transfers Database, the world accumulated more than $28 billion in arms exports in 2012. The United States alone transfered about $630 billion from 1950 to 2012, with per annum exports routinely going above $12 billion during the Cold War. Military aid extends to the realm of civil conflicts, with about four in five rebel groups receiving assistance during some eras (Grauer and Tierney, 2017).

One reason states give aid is obvious. If a protégé and a mutual enemy were to fight a war, the patron would like to see the protégé emerge triumphant more often. Military aid achieves that goal. Meanwhile, if a protégé and a mutual enemy were to negotiate a settlement, the patron would like to see the protégé receive a better share. Because peaceful settlements must be commensurate with the distribution of power (Fearon, 1995; Powell, 1999), military aid again achieves that goal.

Nevertheless, patron states often have a competing incentive. The United States, for example, would like South Korea to better coerce North Korea. But the United States does not want to see war on the Korean Peninsula, if for no other reason than the deleterious effects on the world economy. Transfers are therefore beneficial holding fixed either a peaceful outcome or a war outcome. However, transfers could backfire if they take an otherwise peaceful outcome and subvert it into a war outcome, even if that war outcome is better than a war outcome without a transfer.

Can transfers affect the probability of conflict? The existing literature provides a mix of answers. Kuperman (2008) worries the answer is yes—by aiding potential rebels, patrons cause protégés to take more risks than they would otherwise, leading to more wars occurring. Kinsella (1994) provides evidence in the affirmative, at least in regard to some U.S. transfers during the Cold War. And in a related topic area, scholars debate whether alliances—which also endow their benefactors with greater military capacity—have a deterrent, provocative, or moral hazard inducing net effect (Waltz, 1979; Leeds, 2003; Benson, Meirowitz and Ramsay, 2014).

In this paper, I provide a clear, if partial, theoretical answer: when a state is uncertain about its opponent's military resources, transfers to that informed opponent suppress conflict. Put differently, patron states can have their cake and eat it too in these cases, both empowering their protégés and reducing the probability of war.

Despite generating an expectation similar to what the deterrence literature offers, the mechanism is distinct and rests on informational concerns. An extreme example helps illustrate the intuition. Suppose that A faces uncertainty over B's *military resources*, like its quantity of weapons, vehicles, or soldiers.[1] To put more structure on the problem, imagine that A does not know whether B has 1 or 100 tanks. The true quantity determines the offer A would want to make, as the type with only 1 tank is helpless whereas the type with 100 stands a real chance at winning a war. Obtaining peace with the 100 tank type requires a vast overpayment to the 1 tank type. When such a "peace premium" is large, safe demands looks less attractive. As such, A may prefer making an aggressive demand that only the 1 tank type would accept, leading to war with the 100 tank type.

Now suppose a patron gives B 1000 additional tanks. The substantive difference between the 1 tank type and the 100 tank type becomes less relevant. After all, the marginal difference in power a country has with 1100 tanks and 1001 tanks is relatively small compared to 100 tanks versus 1 tank. Making peace with the more powerful type therefore requires a smaller overpayment to the less powerful type. In turn, A has more incentive to issue safer demands, and thus the probability of war declines. Put differently, the transfer mitigates A's information problem. I show that this same general principle applies to transfers that act as substitutes for the military technology the opposing state faces uncertainty over.

From a research question perspective, my work is closest to Benson, Meirowitz and Ramsay (2016). They also broadly ask how observable power transfers change the probability of war. We differ in the sources of uncertainty, however, which generates different results. Benson, Meirowitz and Ramsay assume that the source of the information problem is on an actor's cost term. Thus, altering military capabilities does not directly change the parameter the opposing state faces uncertainty over; it only alters the location of the bargaining space negotiations center around.[2] When states are risk averse, they show that transfers decrease the probability of war when the weaker actor

[1] Such uncertainty can arise from previous investment decisions (Meirowitz and Sartori, 2008) or the inability to observe existing military resources (Walter, 1999; Fearon, 2007). It is also the basis of the "German tank problem," in which the Allies tried to estimate the quantity of Nazi tanks produced during World War II based on the serial numbers observed in battle.

[2] One might believe that the costs of war depend on the military allocation, and thus transfers ought to have that effect. See Spaniel and Malone (2019) for a discussion of how cost changing costs shift the probability of war when resolve is the cause of cost uncertainty.

is the recipient but increase the probability of war when the stronger actor is the recipient. As such, I do not claim that power transfers have a universally pacifying effect on crisis bargaining. Rather, I show this to be true for the scope conditions I analyze—i.e., uncertainty over military resources.

From a mechanism standpoint, my work is closest to Arena (2013). Both our papers address how weapons flows alter the probability of war with uncertainty over power.[3] Arena focuses on uncertainty over "martial effectiveness," defined as the marginal value of each unit of military resource. Thus, in his model, martial effectiveness and military units are *complements*; the greater the state's underlying effectiveness, the greater value each new military resource brings. As a result, larger resource endowments can increase the overpayment necessary to pay a weaker type to ensure a stronger type's acceptance. Larger overpayments make peace less attractive, and thus larger resource endowments can cause war more often in his model. In contrast, I conceptualize my source of uncertainty as the quantity of existing military resources.[4] Here, military units are *substitutes*; the more resources the state already has, the less value it obtains from having more. Transfers therefore decrease the overpayment and in turn reduce incentives for war.[5]

From a methodological standpoint, my work is closest to Banks (1990) and Fey and Ramsay (2011). We all use mechanism design to describe what is true for a broad class of games rather than focus on a particular extensive form. This paper is similar to Banks in that I explore one-sided uncertainty. However, whereas Banks examines how equilibrium settlements and war probability vary based on types, my central question is the circumstances that permit always-peaceful equilibria to exist. This interest draws a parallel to Fey and Ramsay, who also investigate the existence of such equilibria with

[3] On the surface, this comparison may seem strange, as the substantive contexts of our papers greatly diverge. Arena examines an environment with costly signaling, where the signal sent is the construction of armaments. There is no signaling in my model. However, the incentives during the bargaining phase are similar, and thus it is worth understanding the differences between his model and mine.

[4] As the formal assumptions clarify, however, the argument applies to any source of uncertainty that follow a set of signs on its derivatives. The quantity of existing resources just serves as an obvious example.

[5] This logic provides further insight into why changes to power do not alter the probability of war for Benson, Meirowitz and Ramsay's (2016) uncertainty over costs with risk-neutral actors. As power increases, the difference between any two types' reservation values remains static, and thus the overpayment remains constant. As such, the probability of war also stays constant.

uncertainty over power. By placing more structure on that uncertainty, I can derive a relationship between transfers and the availability of settlements.[6] In addition, the differences between my work and Benson, Meirowitz and Ramsay's (2016) underscore Fey and Ramsay's point that the type of uncertainty states face has different theoretical and empirical implications. International relations scholars should not treat uncertainty as a monolithic mechanism. Instead, they should consider how specific types of uncertainty affect conflict patterns.

2 The Mechanism

I begin with a simple model that illustrates the mechanism before obtaining a more general result. The first hurdle in the analysis is modeling uncertainty over the probability of victory. Standard models—e.g., Reed (2003) and Slantchev (2003)—blackbox this as various different possible p values. This is suitable for most research questions, but my research question asks how power transfers affect crisis bargaining with uncertainty over the probability of victory. Thus, I need to explicitly account for what causes those p values to vary and how transfers affect them.

Consider situations where the uncertainty over p stems from one side not knowing the quantity of the other's military allotments. For example, Arena and Pechenkina (2016) model a game in which the probability of victory is a function of a standard ratio contest function, but State A does not know whether State B has $\underline{m}_B > 0$ resources or $\overline{m}_B > \underline{m}_B$ resources.[7] I speak to this source of uncertainty. However, I generalize the functional form over the probability of victory to better understand the properties of military transfers necessary to incentivize peace.[8]

[6] Another difference here is that Fey and Ramsay allow for two-sided uncertainty, whereas I limit the discussion to one-sided uncertainty.

[7] Given ratio contest functions, A would win with probability $\frac{m_A}{m_A+\underline{m}_B}$ in the first case and $\frac{m_A}{m_A+\overline{m}_B}$ in the second case. Thus, not knowing B's allotments means A does not know whether it is more or less likely to win.

[8] As previewed in the introduction, an alternative source for uncertainty over the probability of victory is *martial effectiveness*, or "unit cohesion, esprit de corps, professionalism, leadership, bravery, ingenuity, and morale" (Arena, 2013). That is, one state may know whether its opponent has 1 or 100 tanks, but it does not know how well its tank drivers are trained or whether they will follow commands as prescribed. In the appendix, I show that the results are more nebulous than the case with uncertainty over military allotments. Transfers interact with the source of the information problem here, which can exacerbate the information problem in the short term.

I consider a two player game because the interesting question is how the bargaining outcomes change as a function of the transfer; later, I briefly describe what the results imply about an endogenous transfer from a third party. The game begins with Nature drawing B's military resources as $\underline{m}_B$ with probability q and $\overline{m}_B$ with probability $1-q$; the draw determines B's probability of victory in a manner I describe in a moment. B observes the draw but A does not. In the dark, A demands $x \in [0, 1]$, a share of the policy in dispute between the two. B sees the demand and accepts or rejects. Accepting implements the settlement while rejecting yields war.

Payoffs are as follows. If B accepts, each receives its share of the division: x for A and $1 - x$ for B. If B rejects, the states fight a war. The payoffs for both sides depend on B's type. The function $p(m_B, t) \mapsto [0, 1]$ maps the quantity of military resources B possesses—through its domestic capacity (m_B) and resources transferred to it (t)—to A's probability of victory.[9] If B has fewer resources, A earns $p(\underline{m}_B, t) - c_A$ and B earns $1 - p(\underline{m}_B, t) - c_B$. As in the standard model, $c_i > 0$ represents each party's cost of war.[10] If B has more resources, the war payoffs are $p(\overline{m}_B, t) - c_A$ and $1 - p(\overline{m}_B, t) - c_B$.

These utility functions clarify what A knows and what it does not. In particular, it cannot observe B's own military capacity. It can, however, see any transfer B receives. This is the interesting case. It would not be surprising if an uncertain transfer exacerbated A's information problem and increased incentives for war. Nevertheless, given the substantive pitch, this is a reasonable assumption to make. A government may be unable to observe a rebel groups' own capabilities, but they can see agreements that the United States makes to transfer armaments.[11]

I assume that the p function is twice continuously differentiable. Moreover, both of its first partial derivatives are strictly negative and its second partial derivatives

[9]Because the "probability of victory" in crisis bargaining models represents a more general interdependent war payoff, the complete interpretation of t goes beyond standard military transfers. For example, any endowment that stops A from conquering B in the event of a loss has the effect of increasing B's effective power in a manner consistent with this model (Spaniel and Bils, 2018).

[10]In this manner, the costs of war are not a function of the transfer. As the cutpoints derived below clarify, the central result holds as long as the net total costs (i.e., $c_A + c_B$) increase in the transfer. This is a reasonable expectation—more guns ought to lead to more overall deaths, even if they shift the distribution away from their recipient.

[11]Moreover, a patron state wishing to minimize war between the two states has incentive to make the transfer transparent so as to not induce war. An uncertain quantity of transfers can still have a pacifying effect if the variance-reducing property of possible transfers dominates the variance-increasing property of the uncertain transfer. Put differently, opaque transfers with sufficiently small noise still induce peace.

(including the cross partial) are strictly positive. Substantively, the first derivatives mean that A's probability of victory decreases as B's total resources increase. For example, the more tanks B has or transfers B receives, the more likely B is to win and the more likely A is to lose. The second derivatives implies that military resources have diminishing marginal returns for B.[12] That is, the benefit B gains going from 5 tanks to 6 is greater than the benefit B gains going from 900 tanks to 901. This is a critical assumption for the results below, but it is also the natural way to think about how military resources aggregate.[13]

Now to the game's equilibrium. I focus on cases where the weakest type of of B has a positive value for war in the absence of a transfer.[14] Although this may seem to be for mathematical convenience, it has critical theoretical implications, which I return to below. A's optimal demand must be either $p(\overline{m}_B, t) + c_B$ and $p(\underline{m}_B, t) + c_B$. The first is just enough to induce both types to accept, while the second is just enough to induce only the low type to accept.[15] Comparing the expected utilities for each decision, A prefers making the risky demand $p(\underline{m}_B, t) + c_B$ if:

$$q(p(\underline{m}_B, t) + c_B) + (1 - q)(p(\overline{m}_B, t) - c_A) > p(\overline{m}_B, t) + c_B$$

$$q > q^* \equiv \frac{c_A + c_B}{p(\underline{m}_B, t) - p(\overline{m}_B, t) + c_A + c_B} \tag{1}$$

Analogously, A makes the safe demand $p(\overline{m}_B, t) + c_B$ if $q < q^*$.

My main substantive interest is how incentives for war change as a function of the parameters. Note that increasing q^* contracts the range for which A makes the risky offer and expands the range for which A makes the safe offer. Therefore, if increasing

[12] The direction of these derivatives may be confusing because p maps to A's probability of victory. From B's perspective, its probability is $1 - p(m_B, t)$. This has a positive first derivative and a negative second derivative, which are the intuitive directions.

[13] In fact, for all but one result, I only need to assume that the cross partial derivative is negative. However, to draw a direct comparison to a special case where p is just a function of B's total military resources (i.e., $m_B + t$), I need the other second derivatives to be positive to match the cross partial.

[14] Formally, this requires $\frac{m_B}{m_A + \underline{m}_B} - c_B > 0$. Results for what occurs when transfers become arbitrarily large also hold for functions where decreasing marginal returns on m_B eventually take hold, even if the are increasing marginal returns in the short term.

[15] Any other demand makes an unnecessary concession to B or triggers certain war. The standard proof strategies show that neither of these options is optimal for A. Moreover, B must accept when indifferent due to the best response problem standard to ultimatum games.

a parameter increases q^*, then an increase to that parameter shrinks the parameters under which war occurs.[16] The transfer is just such a parameter:

Proposition 1. *As t increases, the parameter space for which war occurs decreases in size, and the probability of war weakly decreases.*

The proof is a simple derivative on q^* with respect to t. For war to occur, q must exceed the cutpoint. Thus, if increasing t increases q^*, it becomes more difficult for q to fulfill the condition. The condition for this is:

$$\frac{(c_A + c_B)\left(\frac{\partial}{\partial t}(p(\overline{m}_B, t) - p(\underline{m}_B, t))\right)}{(p(\underline{m}_B, t) - p(\overline{m}_B, t) + c_A + c_B)^2} > 0$$

$$\frac{\partial}{\partial t} p(\overline{m}_B, t)) > \frac{\partial}{\partial t} p(\underline{m}_B, t)$$

This is true—it simply states that transfers incentivize peace as long as baseline military power matters more for lower transfers than higher transfers.

Figure 1 captures the central logic, using the special case of $p(m_B, t) = p(m_B + t)$ to illustrate. It maps A's probability of victory as a function of the size of all military resources. As the transfer increases, B's probability of winning increases, and correspondingly A's decreases. This is the primary effect of transfers. But diminishing marginal returns distort the difference between low resource and high resource types. Indeed, their respective probabilities of victory converge together. Thus, transfers have a second-order effect of mitigating A's information problem. With the functional importance of domestic military resources diminished, A finds buying off both types more attractive.[17]

For further intuition, consider the underlying dynamics in A's risk-return trade-off. Larger offers secure peace more often but require concessions sufficient to appease stronger types. These amounts result in a larger overpayment given to the weaker type, which Figure 2 illustrates. When that premium is large, making aggressive offers looks more attractive so that A can secure a greater share through the peaceful settle-

[16] Doing so also weakly decreases the probability of war because it can flip that probability from $1 - q$ (when A makes the risky offer) to 0 (when A makes the safe offer).

[17] Bringing potential reservation values together in this manner reduces the probability of conflict across a variety of other mechanisms (Reed, 2003; Spaniel, 2018). From a technical standpoint, this paper therefore contributes by showing that arms transfers have this effect with uncertainty over military resources.

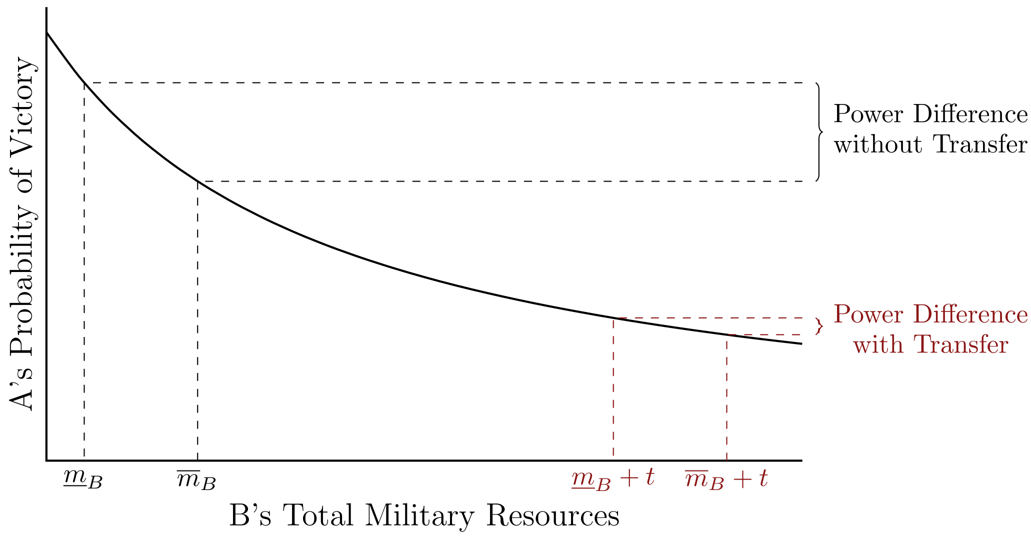

Figure 1: The difference in A's possible probability of victories with and without a transfer. Larger transfers mitigate the source of A's information problem and therefore reduce incentives for war.

ment. But when the premium is tiny, safe offers appear wiser—attempting to grab a sliver more of the pie is not worth a great increase in the probability of war. Figure 1 shows that transfers make the possible types' reservation values increasingly similar and therefore has the calming effect that Proposition 1 describes.

This intuition explains why assuming non-negative war payoffs in the absence of a transfer has critical theoretical implications. If both types of B are so weak that they accept any offer from A in the absence of a transfer, then the peace is guaranteed. Increasing B's allotments can cause the stronger type's reservation value to exceed 0. At that point, further increases create a larger difference in what the types are willing to accept. This exacerbates the information problem and incentivizes A to make risky offers. However, yet further transfers put both types' reservation values above 0. Transfers then begin to exhibit the behavior described in Proposition 1.

Regardless, two questions natural questions follow from the main result. First, what do these results imply for endogenous transfer decisions from the (unmodeled) third party? To be clear, the model only provides insight in cases where a protégé's opponent does not know the protégé's military resources. However, under this informational structure, a patron's desire to strengthen its protégé does not run contrary

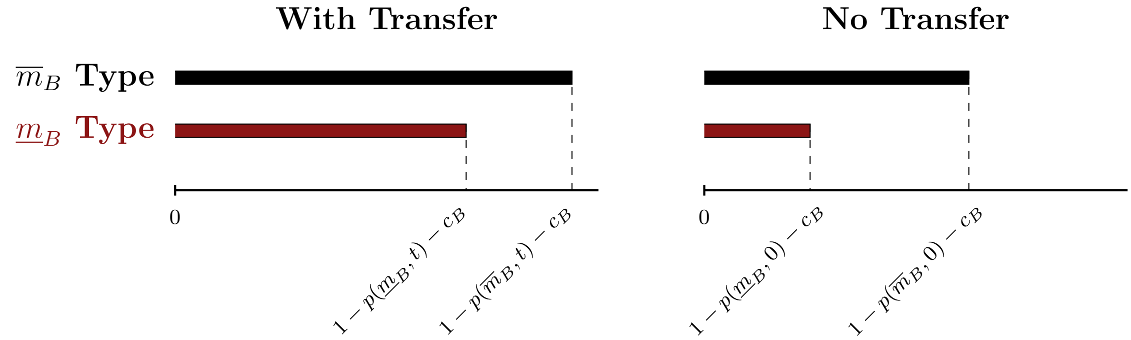

Figure 2: The difference in reservation values for each type, with and without a transfer. The safe offer requires overpaying the $\underline{m}_B$ type by a greater margin without the transfer. Thus, as transfers increase, A is more inclined to make a safe proposal.

to a secondary desire to maintain peace. In fact, it actually creates an incentive to arm the protégé beyond where the marginal benefit exceeds the marginal cost. This is because sufficient arming generates something analogous to a "deterrence surplus" (Benson, Meirowitz and Ramsay, 2014) by reducing the likelihood that the patron suffers an externality from the two players fighting. Thus, with uncertainty over military allotments, the model predicts higher overall transfers.

The second natural question is what the third party needs to know to reduce the circumstances where war occurs. The answer is not much. It does not need private information, it does not need to know one side's belief about the other, and it does not need any projections of higher orders of beliefs. All it needs to know is that the possible types of the recipient have positive values for war and that the recipient's opponent does not know the recipient's baseline capabilities. The comparative static shows that any transfer whatsoever can only promote peace in this setup.

3 A General Result

The above result helped illustrate a clear intuition for the mechanism: increasing transfers makes both low capability and high capability types act more similarly, mitigating A's information problem. Nevertheless, one may wonder how robust the result is. After all, the setup could be broadened on many levels—there could be more than two types, the distribution may not have a simple functional form, and the bargaining protocol could be far more detailed than a simple ultimatum.

I therefore investigate whether the result generalizes. Mechanism design provides the proper framework for this.[18] It permits investigation of what must hold across every possible extensive form one could write down that meets some minimal criteria. Moreover, I can also incorporate continuous type spaces and distributions that do not have simple functional forms.[19]

In particular, consider the standard class of crisis bargaining games in which states can either negotiate a settlement or fight a war. As before, a settlement generates x as A's utility and $1 - x$ as B's utility. Meanwhile, war generates $p(m_B, t) - c_A$ and $1 - p(m_B, t) - c_B$, where m_B reflects B's type. Note that war payoffs are a function of type but settlement payoffs are not. Also note that, as in the example in the previous section, the costs of war are not a function of the type or transfer. In the appendix, I show that the main result extends to a more generalized setting that allows for this.[20]

To incorporate uncertainty into the class of models, let $F(m_B) : [\underline{m}_B, \overline{m}_B] \mapsto [0, 1]$ be the cumulative distribution function of B's types. B privately observes the draw whereas A only knows the prior distributions. I assume that $F(m_B)$ is continuously differentiable everywhere on the interval and let $f(m_B)$ represent the associated density function.

Following Banks (1990) and Fey and Ramsay (2011), I restrict my attention to games that satisfy the *voluntary agreements* axiom. Voluntary agreements requires that each player, through some unilateral set of strategies, can force the game into a war outcome. Games that do not follow this do not accurately reflect the anarchical

[18] See Fey and Ramsay (2011) for a primer on mechanism design in militarized conflict.

[19] Another advantage of mechanism design is that the general result I describe below does not require an explicit solution to a particular extensive form. This is useful because even simple continuous type distributions with explicit but basic $p(m_t + t)$ functions quickly become intractable when solving for the first order condition, which still requires filtering the optimal offer back through the cumulative distribution function and taking a derivative on t to obtain the ultimate solution. For readers concerned that Proposition 1 is an artifact of the binary type space, note that the result holds regardless of how close or far apart $\underline{m}_B$ and $\overline{m}_B$ are. It therefore does not exploit a sufficiently large gap in types.

[20] To provide more detail, two jointly sufficient conditions for the result to hold are that (1) A's war payoff decreases in t but has a diminishing marginal effect as m_B increases and (2) the total inefficiency from war involving the most powerful type of B weakly increases in the transfer. The second part therefore allows for B's cost of war to decrease as long as A's cost of war increases to compensate. In fact, as the appendix shows, the exact condition has more slack—the overall inefficiency can decrease for the result to hold provided it does not decrease too much.

nature of international relations—states cannot be forced into a peaceful settlement that makes them worse than if they were to just fight. This setup falls in the class of models that Banks studies. All his monotonicity results therefore apply to this setting. However, like Fey and Ramsay, my interest is how a transfer (not present in either existing paper) changes the availability of an *always-peaceful equilibrium*, defined as an equilibrium with 0 probability of war. This setup allows me to leverage the functional form of $p(m_B, t)$ to answer that question, and the following shows that transfers help make such outcomes available:

Theorem 1. *If a game form with an always peaceful equilibrium exists without a transfer, then a game form with an always peaceful equilibrium still exists for any sized transfer. If no game form exists with an always peaceful equilibrium without a transfer, then a game form with an always peaceful equilibrium may exist for after a transfer.*

Roughly, Theorem 1 states that it is “easier” in some sense to achieve peace with larger transfers. The first part states that transfers cannot eliminate the existence of game forms with always peaceful equilibria. If the parties could negotiate in a way that ensures peace without a transfer, they can still do that with a transfer. The second part says that the result does not run the other way. If the states have to fight with some probability without a transfer, it is possible that the transfer solves the problem.

The intuition for the first two parts has a similar flavor to the binary type game analyzed previously. Incentive compatibility and voluntary agreements require that the concession given to B must be at least the value of the high type's war payoff. If not, the high type's voluntary agreements condition would be violated. Moreover, this concession must be equivalent across types, otherwise some type would have incentive to lie and thus violate incentive compatibility.

Meanwhile, A's voluntary agreements constraint requires that such a concession must still leave A at least as much as if it fights a war against all types. As t increases, diminishing marginal returns imply that the difference between the most powerful type and all other types decreases. Thus, weaker types behave more like stronger types. In turn, the overpayment to weaker types shrinks. Eventually, A may prefer the minimum amount necessary to buy compliance from all types to its war payoff against all types. At that point, game forms exist in which the equilibrium probability of war is 0.[21]

[21]That intuition only describes the necessary conditions for an always peaceful equilibrium. How-

So far, I have only described whether increasing transfers pushes the strategic situation closer to or further from game forms with always peaceful equilibria. I have not yet described whether transfers can guarantee a solution. The following corollary gives conditions where they can:

Corollary 1. *Suppose that the marginal value of existing resources goes to 0 as the transfer becomes arbitrarily large (i.e.,* $\lim_{t\to\infty} \frac{\partial p}{\partial m_B} = 0$*). Then a sufficiently large transfer guarantees the existence of a game form with an always peaceful equilibrium.*

That is, *some* transfer ensures the availability of always peaceful equilibria. This is because the assumption on the derivative on m_B guarantees that the transfer eventually causes B's power to level off. As such, the transfer not only moves the game toward a complete information interaction—it converges the game to complete information as t approaches infinity.

Of particular note is the special case where $p(m_B, t) = p(m_B + t)$. Recall that the function captures situations where the capabilities are "source blind"—all that matters is how many weapons the actor has, not whether they are existing or transfered. This function has the required property from the corollary.[22] As such, if uncertainty is over the quantity of a particular type of armament, transferring more of that armament ensures the ability to write down a game with an always peaceful equilibrium.[23]

To be clear, this result is *not* a traditional comparative static. It simply describes the conditions under which games exist that result in a peaceful equilibrium. However, an alternative pitch of the corollary is as follows. Imagine a world in which the costs of

ever, sufficiency is trivial: a game in which the players must mutually consent to a division x that fits the described constraints is such a game.

[22]If it did not, then the function would force B's probability of victory to exceed 1, which is not possible. This logic is the basis for a proof of the claim in the appendix.

[23]One might wonder how a functional form could exist that does not satisfy the condition. One such case is the earlier example of a resource endowment that stops A from achieving a tactical goal in one arena but not in another. For example, imagine that the transfer gives B defensive fortifications that guarantee it some portion of the pie regardless of whether it wins a conventional war. Then B's war payoff increases in both m_B (it wins more often) and t (it utility for losing is larger). Moreover, the cross partial is negative (winning matters less because a loss still guarantees some portion of the pie). As a more explicit example, the function $p(m_B, t) = \left(\frac{2}{2+m_B}\right)\left(\frac{t}{4t+1}\right) + \frac{m_B}{2+m_B}$ represents the previous case and delivers the desired properties. The value 2 represents A's share of the military power and maps it using a ratio contest success function, and the function $\frac{t}{4t+1}$ represents the share that B keeps even if it loses. Note that as t approaches infinity, that share only represents a quarter of the overall bargaining good. Because the remaining three-quarters is still up for grabs, the derivative with respect to m_B does not go to 0.

war are sufficiently low, a patron state supplies a protégé state with arms, and peace certainly prevails between the protégé and its opponent. If the patron were to terminate the transfer, then the probability of war *must* increase. It *cannot* remain at zero no matter the crisis bargaining game. The extra portion of the time war occurs is directly attributable to the absence of the transfer.

The proof for the theorem also characterizes the minimum transfer a patron state would have to donate to give rise to game forms with peaceful equilibria. In particular, the incentive compatibility and voluntary agreements constraints require:

$$c_A + c_B \geq - \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} p(m_B, t) \right) F(m_B) dm_B \tag{2}$$

The right hand side strictly increases in t, and a sufficiently large t guarantees the inequality holds under the corollary's scope condition.[24] Thus, the minimum transfer necessary for game forms with always peaceful equilibria is the minimum t such that Condition 2 holds.[25] Call that value t^*. Note that if Condition 2 holds for $t = 0$, then $t^* = 0$. And per the theorem, game forms with peaceful equilibria would continue to exist if a third party issued a transfer anyway.

Further analysis reveals how two other parameters influence the size of t^*. The first is straightforward. Recall that A's concern of overpaying low capability types is the barrier to settlement. The solution to the problem is to make settlements to A more attractive and war less attractive. Higher overall war costs do this.[26] In turn, the transfer has less to compensate for when overall costs are high than when they are low. As such, the minimum transfer necessary to obtain game forms with always peaceful equilibria decreases as the costs increase.

The second is less obvious. Consider two prior distributions of m_B: $F(m_B)$ and $\tilde{F}(m_B)$. Suppose that $F(m_B)$ first order stochastically dominates $\tilde{F}(m_B)$. Substantively, first order stochastic dominance means that the $F(m_B)$ distribution has more

[24]This is because the derivative goes to 0, and thus the right hand side as a whole goes to 0. Note that the corollary's scope condition is not necessary for the inequality to hold.

[25]Due to the leading negative on the right hand side, one might expect that Condition 2 holds for all t. However, the integral is negative, thereby making the overall right hand side positive.

[26]More precisely, higher values of c_A make always fighting less attractive to A. Meanwhile, higher values of c_B mean that A can receive a larger share of the bargain while still maintaining the compliance of all types of B. This provides further explanation as to why the main result does not change if costs are a function of p, so long as $c_A + c_B$ increases in t.

types at higher values of m_B throughout the entire distribution.[27] The minimum necessary transfer is smaller for $F(m_B)$ than it is for $\tilde{F}(m_B)$. The intuition falls back to A's overpayment dilemma. Achieving certain peace requires granting a concession at least equal to the most powerful type's war payoff, otherwise the most powerful type would not comply with the deal. When more types are concentrated in the lower existing armaments, that overpayment expands. State A becomes more reluctant to participate in a process that ensures the peace. The transfer must in turn do more work to converge the lower types' war payoffs to the higher types' war payoffs.

Condition 2 also provides insight as to how a third party might weigh this policy intervention as opposed to another. Also using a mechanism design framework, Fey and Ramsay (2011) calculate the minimum peace subsidy necessary to obtain game forms with always peaceful equilibria. Because peace subsidies essentially act as additional costs of war, including a subsidy s and rearranging Condition 2 shows that the minimum necessary subsidy is:

$$s^* = -\int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} p(m_B, t) \right) F(m_B) dm_B - c_A - c_B$$

Thus, a third party only interested in peaceful outcomes—and agnostic about the distribution of the good implemented through war or peace—has an interesting option. It can push the game into parameters with peaceful equilibria either through offering s^* or t^*. Let $k(t)$ be a function that maps a transfer of weapons to a production cost k for the third party. Then, supposing that the always peaceful game form is played, the third party prefers transfers to subsidies if $k(t^*) < s^*$. This generates the intuitive implication that countries with relatively advanced military production techniques will more often keep the peace with armaments, while opposite countries use subsidies instead.

4 Conclusion

How do arms transfers affect the prevalence of war? This paper showed that, under broad conditions, additional armaments promote peace when states face uncertainty over their opponents' military resources. Intuitively, the source of a state's uncertainty becomes increasingly irrelevant when the quantity of known transfers overwhelms what-

[27] Formally, $F(m_B) \leq \tilde{F}(m_B)$ for all m_B, with the inequality holding strictly for some m_B.

ever else could possibly matter. Screening offers look less attractive under these circumstances. As such, the equilibrium offer is less likely to end in fighting.

I conclude with three comments. First, for researchers, this result underscores Fey and Ramsay's (2011) finding that the sources of uncertainty matter. Since Brito and Intriligator (1985), scholars of international relations have become intimately familiar with the notion that uncertainty causes war. But common solutions to the problem remain vague and mostly recommend information provision.[28] This is despite the fact that the relationship between information and war is ambiguous—worried states that receive positive information can become overly optimistic and switch to making offers that generate some risk of war (Arena and Wolford, 2012; Fey, 2014). International relations as a field would benefit from more work that investigates how changing parameters manipulates incentives under specific sources of uncertainty. Put differently, "uncertainty" should not be treated as some uniform mechanism for war.

Second, the core mechanism also applies going in the opposite direction. That is, "negative" third-party transfers exacerbate an information problem between two states. For example, suppose an international intervention destroyed a government armory. Suppose further that potential revolutionaries were aware of this armory's existence and could also observe its destruction. Such an informational structure might suggest that the consequences of the mission on would give the revolutionaries more bargaining power and not have clear implications on the probability of war. It could even reduce conflict because destruction is observable and provides information. However, my results show that this would incentivize riskier demands from the revolutionaries if they faced uncertainty about what other military resources the government might control. Future research could investigate this further and integrate the underlying theory with the broader literature on the perverse incentives of interventions (Kuperman, 2008). It is also worth revising the bargaining-while-fighting literature in this light (Slantchev, 2003; Powell, 2004). By conventional wisdom, information problems cannot explain long wars, as the information exchanged should move states closer to settlement (Walter, 1999).[29] However, fighting destroys military resources. For the power function here, this exacerbates the information problem. As such, it is not clear that fighting

[28] For example, (Kydd, 2010, 104) writes that "if uncertainty leads to cooperation failure, then information can lead to conflict resolution."

[29] See Fey (2014) for a critique on the general idea that information aggregation generates peace peace.

is helpful. Bargaining while fighting has subtle incentives, though, so a more thorough investigation could be fruitful.

Finally, for policymakers, my results combined with Benson, Meirowitz and Ramsay's (2016) urges caution in crafting broad strategies to manipulate worldwide rates of conflict. Single strategies—like military transfers—may work in some cases, like with uncertainty over existing allotments. Given the literature's stance on uncertainty in intrastate disputes (Walter, 1999; Fearon, 2007), potential civil wars seem to be a likely application. But they might backfire in other cases. As such, successful interventions require that policymakers think carefully about which scope conditions apply to a particular issue area. They can then adopt of a solution that matches what the situation calls for. Broad solutions may be ideal, but they simply do not have general theoretical support. In short, readers should not takeaway from this paper that peace-seeking states ought to blindly supply weapons to their protégés.

5 Appendix

Here, I prove the mechanism design results, solve an extension where the costs of war are a function of the transfer, and investigate how transfers influence uncertainty over martial effectiveness.

5.1 Proof of Theorem 1

Proving the theorem requires considering B's voluntary agreements and incentive compatibility constraints and A's voluntary agreements constraint. First, consider B's side. Voluntary agreements requires that each type receive at least its war payoff for participating in the mechanism. In particular, the $\overline{m}_B$ type must receive at least $1 - p(\overline{m}_B, t) - c_B$. This is the largest of the individual constraints.

Incentive compatibility also requires that no type wish to falsely report a different type. An always peaceful mechanism can only induce this behavior through the settlement quantity $1-x$. Because settlement payoffs are *not* a function of type, this implies that all types must receive the same settlement value—otherwise a type would want to deviate to reporting a type that received a larger settlement value. Recalling that the $\overline{m}_B$ type must receive at least $1 - p(\overline{m}_B, t) - c_B$, *all* types must receive that amount.

This generates the first constraint on x:

$$\begin{aligned} 1 - x &\geq 1 - p(\overline{m}_B, t) - c_B \\ x &\leq p(\overline{m}_B, t) + c_B \end{aligned} \tag{3}$$

Now consider A's voluntary agreements constraint. To participate in the mechanism, A must receive at least its value for fighting a war against all types. This generates the second constraint on x:

$$x \geq \int_{\underline{m}_B}^{\overline{m}_B} p(m_B, t) f(m_B) dm_B - c_A \tag{4}$$

For an always peaceful mechanism to exist, Conditions 3 and 4 must hold simultaneously. This is only possible if:

$$p(\overline{m}_B, t) + c_B \geq \int_{\underline{m}_B}^{\overline{m}_B} p(m_B, t) f(m_B) dm_B - c_A$$

Using integration by parts, I can rewrite this as:

$$p(\overline{m}_B, t) + c_B \geq p(\overline{m}_B, t) - \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} p(m_B, t) \right) F(m_B) dm_B - c_A$$

$$c_A + c_B \geq - \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} p(m_B, t) \right) F(m_B) dm_B \tag{5}$$

I am interested in how the right hand side changes as a function of t. Specifically, if the right hand side of Condition 5 decreases in t, then increasing transfers facilitates the existence of game forms with peaceful equilibria:

$$\frac{\partial}{\partial t} \left(- \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} p(m_B, t) \right) F(m_B) dm_B \right) < 0$$

Differentiating under the integral yields:

$$\int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial^2}{\partial m_B \partial t} p(m_B, t) \right) F(m_B) dm_B > 0$$

The cross partial of $p(m_B, t)$ is strictly positive, and so too is $F(m_B)$. The product of the two is therefore strictly positive. The left hand side takes the integral of a function that is strictly positive, implying that the result is strictly positive. Thus, the condition holds.

5.2 Proof and Discussion of Corollary 1

The proof is a simple examination of Condition 5. The corollary gives $\lim_{t\to\infty} \frac{\partial p}{\partial m_B} = 0$ as its premise. Because $F(m_B)$ is not a function of t, the integrand goes to 0. Thus, the positively-valued c_A and c_B are always greater. $\square$

The related claim that $\lim_{t\to\infty} \frac{\partial p}{\partial m_B} = 0$ when $p(m_B+t)$ is less obvious. To show this, for proof by contradiction, suppose it does not. Then the slope of the curve remains fixed below some value $-\epsilon$ for all values of t, where $\epsilon > 0$.[30] But then for any $t > \frac{1}{\epsilon}$, the output of $p(m_B, t)$ must decrease by at least 1. This is not possible for a function strictly bounded between 0 and 1, a contradiction.

5.3 Extension: Transfers and the Costs of War

I now allow the cost of war to be a function of the transfer. To do this, define A's payoff from war as $w_A(m_B, t)$ and B's payoff from war to be $w_B(m_B, t)$. To make war inefficient, assume that $w_A(m_B, t) + w_B(m_B, t) < 1$ for all m_B and t. To match the earlier assumptions from the text, I assume that the first derivative of w_A is decreasing in its input and its second derivative is positive. Likewise, the first derivative of w_B is positive in its input and its second derivative is negative.

Consider the conditions for an always peaceful equilibrium to exist. Like before, incentive compatibility requires that all types of B receive the same settlement quantity. Voluntary agreements require that the settlement be at least as large as the highest type's war payoff. Therefore, the first constraint is:

$$1 - x \geq 1 - w(\overline{m}_B, t)$$
$$x \leq 1 - w(\overline{m}_B, t) \tag{6}$$

[30] The slope is negative because $p(m_B + t)$ is decreasing in m_B. It must remain below that point because the second derivative is positive, so that all slopes before a point must be less (that is, more sharply downhill) than the current slope.

Second, voluntary agreements requires that A's share of the settlement be at least as large as its war payoff against all types. Taking the expectation generates the second constraint:

$$x \geq \int_{\underline{m}_B}^{\overline{m}_B} w_A(m_B, t) f(m_B) dm_B \tag{7}$$

For an always peaceful mechanism to exist, Conditions 6 and 7 must hold simultaneously. This is only possible if:

$$1 - w(\overline{m}_B, t) \geq \int_{\underline{m}_B}^{\overline{m}_B} w_A(m_B, t) f(m_B) dm_B$$

Using integration by parts, I can rewrite this as:

$$1 - w(\overline{m}_B, t) \geq w_A(\overline{m}_B, t) - \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} w_A(m_B, t) \right) F(m_B) dm_B$$

$$- \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} w_A(m_B, t) \right) F(m_B) dm_B - (1 - w_A(\overline{m}_B, t) - w(\overline{m}_B, t)) \leq 0$$

To prove the claim, I must examine when the left hand side decreases in t:

$$\frac{\partial}{\partial t} \left(- \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial}{\partial m_B} w_A(m_B, t) \right) F(m_B) dm_B - (1 - w_A(\overline{m}_B, t) - w(\overline{m}_B, t)) \right) < 0$$

Differentiating under the integral for the first half generates:

$$- \int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial^2}{\partial m_B \partial t} w_A(m_B, t) \right) F(m_B) dm_B - \frac{\partial}{\partial t} \left((1 - w_A(\overline{m}_B, t) - w(\overline{m}_B, t)) \right) < 0$$

$$\int_{\underline{m}_B}^{\overline{m}_B} \left(\frac{\partial^2}{\partial m_B \partial t} w_A(m_B, t) \right) F(m_B) dm_B + \frac{\partial}{\partial t} \left((1 - w_A(\overline{m}_B, t) - w(\overline{m}_B, t)) \right) > 0 \tag{8}$$

This is the critical condition for the result to hold. The main text claimed that two jointly sufficient condition are that (1) A's war payoff has a negative cross partial and (2) the total inefficiency for war involving the most powerful type of B weakly increases in the transfer. If (1) holds, then the first half of Condition 8 is positive. It is the area under the curve of the cross-partial of A's war payoff and the CDF of the distribution. Both of these values are positive, so the area is also positive. Meanwhile, the second half of Condition 8 represents the derivative of the total inefficiency of war involving the high capacity type. Thus, if (2) holds, then it is also weakly positive. Overall, then, the left hand side is positive, thereby completing the proof.

5.4 Proof of Uncertainty over Martial Effectiveness

I now show that the result applies to uncertainty over military resources and not uncertainty over p more generally. Borrowing from Arena's (2013) setup, suppose that A's probability of victory is now $p(\alpha m_B, \alpha t)$, where $\alpha \geq 0$ captures martial effectiveness; larger values of α indicate that B can better wield each unit of its military armaments. Intuitively, $p(\alpha m_B, \alpha t)$ strictly decreases in α; that is, A wins less often when B's effectiveness is larger. Unlike before, A is certain about m_B. Instead, A is unsure whether B's martial effectiveness is $\underline{\alpha}$ or $\overline{\alpha}$, where $\overline{\alpha} > \underline{\alpha}$. I maintain the same assumptions about the functions first and second partial derivatives with respect to m_B and t as in the main model.

The core mechanics of the game remain the same, rewriting earlier probabilities of victory as $p(\underline{\alpha} m_B, \underline{\alpha} t)$ and $p(\overline{\alpha} m_B, \overline{\alpha} t)$. A's two possible optimal demands are $p(\underline{\alpha} m_B, \underline{\alpha} t) + c_B$ and $p(\overline{\alpha} m_B, \overline{\alpha} t) + c_B$. The riskier offer is preferable when:

$$q > \frac{c_A + c_B}{p(\underline{\alpha} m_B, \underline{\alpha} t) - p(\overline{\alpha} m_B, \overline{\alpha} t) + c_A + c_B}$$

Recall that the circumstances for war decrease when the cutpoint increases. Taking the derivative of the right hand side with respect to t and checking when it is positive yields:

$$\frac{(c_A + c_B)\left(\frac{\partial}{\partial t}(p(\overline{\alpha} m_B, \overline{\alpha} t) - p(\underline{\alpha} m_B, \underline{\alpha} t))\right)}{(p(\underline{\alpha} m_B, \underline{\alpha} t) - p(\overline{\alpha} m_B, \overline{\alpha} t) + c_A + c_B)^2} > 0$$

$$\frac{\partial}{\partial t}(p(\overline{\alpha} m_B, \overline{\alpha} t)) > \frac{\partial}{\partial t}(p(\underline{\alpha} m_B, \underline{\alpha} t))$$

Applying the chain rule generates:

$$\overline{\alpha}\left(\frac{\partial}{\partial t}p(\overline{\alpha}m_B, \overline{\alpha}t)\right) > \underline{\alpha}\left(\frac{\partial}{\partial t}p(\underline{\alpha}m_B, \underline{\alpha}t)\right) \tag{9}$$

Recall that $\overline{\alpha} > \underline{\alpha}$. However, because giving B armaments decreases A's probability of victory, both derivatives are negative. And due to diminishing marginal returns, $\frac{\partial}{\partial t}p(\overline{\alpha}m_B, \overline{\alpha}t) > \frac{\partial}{\partial t}p(\underline{\alpha}m_B, \underline{\alpha}t)$. Taking stock, the left hand side consists of a large positive number multiplied by a negative number with a small magnitude; the right hand side consists of a small positive number multiplied by a negative number with a large magnitude. As such, the effect of transfers varies—it depends on the specific functional forms, the baseline level of B's armaments, and the exact quantity of transfers.

This proof also generates clear insight that Arena's result requires the assumption that the source of uncertainty over martial effectiveness impacts both existing armaments and new ones. If it only affected the existing armaments, then the function would look like $p(\alpha m_B, t)$. The chain rule is unnecessary to obtain Condition 9, and thus the leading α terms disappear. The model converges to the one found in the main text. Substantively, this could be because A's uncertainty of martial effectiveness is not knowing how accurate B's aerial bombers are, and the transfer is automated targeting technology that renders the issue irrelevant.

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