Reasons for Peace

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Since 1914, interstate wars have prolonged fighting by an average of 142 days compared to the prior century. Despite more frequent and longer formal peace negotiations, wars are now 19.5 percentage points less likely to conclude post-negotiation. This paper extends the standard reputational bargaining framework to explain these trends. I prove that imposing ceasefires during peace talks prolongs conflicts by allowing combatants to posture with little cost and risk irreversibly damaging the goodwill for further talks. Using detailed war data since the 1820s, I confirm model predictions. Lastly, I propose a welfare-maximizing use of ceasefires: never stop the fighting during a negotiation if the probability of a negotiated peace is non-zero.

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Since 1914, interstate disputes are 10 percentage points (pp) less likely to end in war relative to the preceding century. But when wars broke out, combatants spent 142 more days fighting and wars were 12 pp more likely to end inconclusively. Wars further had an average of 5 peace lasting a month each, but ended post-negotiation less than 28.5 percent of the time. In contrasts, wars fought in the preceding century had half as many negotiations and were an average of 12 days shorter, but ended post-negotiation 19.5 pp more often.

This paper studies the factors behind lengthier wars and less effective negotiations since 1914. I first build a new, reputational model of wars that rationalizes the trends discussed above. My main result is that negotiations coinciding with ceasefires—which rose by 8 pp after 1914—play a key role. In addition, the model predicts that deterrence strategies, although improving a nation's military capacity, hinder a combatant's ability to attain favorable terms in a peace negotiation. I further test this and other model predictions using a war panel with day-level battlefield and negotiation information as well as granular information on military capacity. A standard IV estimate further suggests that the model predictions are bore in the data and have a sizable effect.

The model extends a standard, reputational bargaining setting in key ways. I firstly assume that combatants attain a unilateral victory allowing them to keep the full surplus arriving at

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an infrequent rate. But before said victory arrives, combatants incur fighting costs and run the risk of destroying the surplus. Combatants can, nonetheless, exert hidden effort preserving said surplus. They further incur costs to maintain the lines of through which offers are exchanged intact and have the option to irreversibly and unilaterally sever said lines.

Lastly, combatants may be non-strategic i.e., obstinate. An obstinate combatant seeks a fixed, substantial portion of the surplus and is uninterested in exerting any effort to preserve said surplus. They go to war driven by non-strategic motivations, such as vengeance or ethnic tensions (Jackson and Morelli 2009), unlike the "rational" bargaining failure rationale posited by Fearon (1995). Moreover, they initially have the goodwill to keep the lines of communication open, but this good will is destroyed at a constant Poisson rate.

This is a bargaining model of war like Schelling (1967), Pilar (1983), Filson and Werner (2002), Powell (2004), Leventoglu and Stanchev (2007), and others. But the addition of a non-strategic type and setting the model in continuous time allows me to yield a unique, analytically tractable predictions that are unaffected by stringent timing assumptions. Furthermore, the model highlights that incomplete information regarding a combatant's rationality, rather than considerations of relative strength as proposed by Brito and Intriligator (1985), Garfinkel (1990), etc., can sustain armed conflicts.

The model further clarifies the role of battlefield specific information on the duration of war as previously suggested by Weisiger (2016), Min (2020), among others. Being a simple model with a unique, precise prediction, however, the model explicitly characterizes how battlefield outcomes translate into a war's end through military or diplomatic means.

The model yields two key results: ceasefires prolong wars and seldom improve welfare, while deterrence hinders a combatant's ability to bargain. Ceasefires have long been advocated as a customary policy tool for ending wars, stemming from their formalization during the Hague Convention of 1907 and their efficacy in World War I Davion (2020). Nevertheless, ceasefires remain central in contemporary policy debate. Indeed, this use of ceasefires remains central in current policy discussions. Rosemary di Carlo (United Nations' Under Secretary-General for Political and Peace-building Affairs) stated that "... ceasefires are a major opportunity to set the foundation for inclusive and comprehensive peace talks" (2022).[1]

In the model, ceasefires avoid surplus destruction, costs of fighting, or decisive victories. Combatants, however, face the remaining risks and costs. The model posits that the absence of these risks prolongs a conflict and increases the probability that the negotiation fails. In addition, I study the welfare maximizing use of ceasefires while the lines of communication are open i.e., let the social planner organize talks while negotiating remains feasible.

[1]This policy had been implemented before 1907 but that it was not commonplace and supported by international organizations. Ceasefires are also implemented to give both sides a chance to tend to the wounded and their dead. Min (2020), however, finds that these ceasefires primarily serve for armies to re-organize and re-arm.

My main result is that it is optimal to never negotiate during a ceasefire while combatants fight if combatants are not certain that their peer is obstinate i.e., a formal or informal peace agreement could be met. Intuitively, strategic combatants' equilibrium concession internalizes the risks and costs of fighting so the potential benefits of holding a ceasefire only leads to increased posturing. This result is further robust to the welfare weights that the planner assigns each combatant.

In the empirical analysis, I expand a day-level panel of 92 interstate wars held since 1823 (Min 2021) by incorporating data on battlefield-specific outcomes and granular estimates of military capacity. A standard panel regression estimate reveals that each day spent in formal peace negotiations is associated with 20 fewer days of fighting. However, when combatants cease fighting simultaneously, this reduction false to one day and is no longer statistical significant.

To address endogeneity concerns, I construct an instrument based on each coalition's changes in factors affecting military capacity i.e., demographic and industrial metrics. Governments are able to force conscription and re-direct existing resources towards a war effort. But they are incapable of promptly increasing and changing the makeup of their population or the raw material deposits found withing their borders. These changes prompt combatants to reconsider holding peace negotiations as they re-dress the viability of sustained fighting.

Kaniewski and Marriner (2020) provide some evidence that a decline in population or resources *does not* directly prompt combatants to exit armed conflicts. Europe was constantly affected by plagues from 1450 to 1670 and since wars displace large populations from regions near the fighting to localities away from it. Thus, the authors argue that wars led to a marked increase in plague-driven military and civilian mortality rates. Said period, nonetheless, coincided with a significant increase in the number of wars and the duration of armed conflicts.

In as far as the instruments are sensible, I find that holding a peace negotiation while combatants fight is associated with a large decline in the duration of wars and time spent fighting. The results further suggests that the raw, panel estimates significantly undermine the degree to which time spent negotiating reduces the time spent fighting. Meanwhile, I find that the opposite is true when negotiations coincide with pause in fighting. Holding peace negotiations during a pause in fighting prolongs the duration of armed conflicts and the time spent fighting by a factor of months.

The second main result is that increasing a combatant's military advantage over their opponents, hinders their ability to negotiate during a war. A combatant is stronger than their opponent if and only if they face lower flow costs of fighting net of the rate at which they attain a unilateral victory, while the weaker combatant is his opponent. In the equilibrium, the weak combatant concedes to the strong combatants' terms from the offset: thus, preventing the war from taking place. If the weak combatant does not concede, incurring the costs of fighting and risks of fighting allows him to costly signal that he is likely obstinate. In response, the strong combatant gradually concedes at a large rate than his weaker opponent.

This result rationalizes why military powers can readily defeat conventional but not poor, guerrilla armies e.g., United States versus Afghanistan and North Vietnam and Israel vs Palestine in the early 2000s. Guerrilla tactics hinders a strong combatants ability to deliver a decisive blow against their opponent, so military investments *only* increases the costs that a strong combatants (e.g., the US) inflicts upon the weak. The model, hence suggests, that these investments allows the strong to impose their will without fighting. But once fighting ensues, negotiations do not ultimately favor them. Note, however, that the US State Department (2009), Ibrahimi (2022), and Morris (2002) argue that North Vietnam, the Taliban, and Arafat, respectively, did not negotiate in earnest against a more powerful opponent.

An implication of the result above is that as military technology improved since 1914, wars became more rare but they are more likely to pit combatants with similar military capabilities. Using data from Braithwaite (2010), Bezerra and Braithwaite (2019), and Singer et al. (1987) on interstate disputes, I corroborate this prediction. During the Pax Britannica (1816-1913), 20 percent of disputes escalated to war, with an additional 37 percent involving some use of force. After 1914, on the other hand, only 5 percent of disputes led to war, while overall use of force rose by 14 percentage points. In addition, in the Pax Britannica, aggressors typically had superior estimated military capacity relative to their adversaries, although this discrepancy smaller among combatants opting to go to war. This trend declined post-1914, with aggressors in a war having less military capacity than their foe.

The rest of the paper goes as follows. Section 1 first presents the model. I then characterize the equilibrium in section 2, while section 3 presents the optimal use of ceasefires. Meanwhile, section 4 presents the paper's empirical section. Section 5 lastly concludes.

1. Model

Two combatants (i and j) bargain over a surplus (s_t) that at time 0 equals to 1 i.e., $s_0 = 1$. But at time $t \in (0, \infty)$ it irreversibly transitions to 0 a at a Poisson rate of $\psi_t \lambda \sum_i (1 - e_{it})$ where $\lambda \geq 0$ is a constant, $\psi : [0, \infty) \to \{0, 1\}$ measurable function , and $e_{it} \in \{0, 1\}$ is combatant i's private effort. The function ψ_t denotes when combatants are fighting: $\psi_t = 1$ means that combatants are fighting and $\psi_t = 0$ means that the fighting is paused. For technical reasons, I assume that in all but a Lebesgue measure zero set of points in $[0, \infty)$, $\psi(\cdot)$ is a locally Lipschitz function.

At time t, i demands a surplus share of $\omega_{it} \in [0, 1]$ or concedes to $j(\neq i)'s$ demands; exerts effort $e_{it} \in \{0, 1\}$; and decide whether or not to irreversibly cut off communications. Once line of communication are cut, i must pick $\omega_{it} \in \{1\}$ and $e_{it} \in \{0, 1\}$, while $\psi_t = 1$ from henceforth. Lastly, i wins the entire surplus at time t if it remains positive at a rate of $\xi_i \psi_t$ where $\xi_i > \lambda$ is a constant. This last assumption captures the fact that wars are more likely to end with a unilateral victory rather than by outright destroying the surplus at hand.

I now describe the reputational type. With a probability $\mu \in (0,1)$, a combatant i is obstinate. If i is obstinate, then at each time $t \geq 0$, i is picks $\omega_{it} = 1, e_{it} = 0$ and exercises his option to cut off negotiations at a Poisson rate of $\phi > 0$. Otherwise, i is said to be strategic and thus freely capable of choosing ω_{it}, e_{it}, and when to exercise his option to cut off communications. Intuitively, reputational types models a "non-rational" combatant brought to war for non-strategic reasons. Such combatant is motivated to make large, intransigent surplus demands and has no interest in preserving the surplus in contention. I further assume that these combatants may, nonetheless, have the goodwill necessary to seek a negotiation, but they are fickle and stochastically opt to expunge the possibility to negotiate.

Next, I define payoffs. First assume that each combatant i picked an effort process (e_{it}) that is (s_t)-adapted, the times when combatants is given y (ψ_t), and the times when combatants keep the lines of communication are describe by indicator (γ_s), then the costs incurred by time t are

$$C_{it} \equiv -\int_0^t [\psi_s(\kappa_j + \kappa e_{i\tau}) + c\gamma_s]e^{-rs}\mathrm{ds} \tag{1}$$

where $\kappa > 0$ is the cost of exerting effort, $r > 0$ is a common discount factor, and $\kappa_j > \xi_i$ are the flow costs that j inflicts on i while fighting, and $c > \phi$ is the cost of maintaining the lines of communication open. Note that if $\kappa_j \leq \xi_i$ or $\kappa_i \leq \xi_j$, then combatants close off negotiations from the outset.

Next, the game ends by time t in one of three mutually exclusive ways: either the surplus is destroyed, a combatant attains a unilateral victory, or combatants reach an agreement first. If the game ends because the surplus is destroyed or j wins the surplus outright, i nets a payoff of $-C_{it}$. If the game ends with i winning an intact surplus, i's payoffs are $e^{-rt} - C_{it}$. Lastly, if combatants reach an agreement giving i a surplus share of $\omega_{it} \in [0,1]$ before the surplus is destroyed or a combatant reaches a unilateral victory, then i's payoff is $e^{-rt}\omega_{it} - C_{it}$ and j nets a payoff of $e^{-rt}(1-\omega_{it}) - C_{jt}$. Note that j's payoffs are derived in a similar fashion.

I conclude the game by presenting formal definitions. First note that the only event that does not bring the whole game to an end is when either party exercises their option to close talks. For this reason, at each time $t \geq 0$ the histories are $h_t = \{\emptyset\} \equiv h_0$ denoting that neither combatant has yet exercised their option to cutoff communication. There are also time t histories of the form $h_t = \{i, \tau\}$ where i is the combatant that exercises their option and $\tau \in [0,t]$ is the time when said option was exercised.

As a consequence, a strategic combatant strategy is a tripe $\{H_i, (e_{it}), \tau_i\}$ where at each time $t \geq 0$, $H_i(t)$ denotes the probability that i concedes before time t conditional on $h_t = h_0$ and the surplus remaining intact. At each time t and history h_t, for its part, $e_{it}(h_t)$ denotes the probability that i exerts effort. Lastly, $\tau_i \geq 0$ is a stopping time denoting when a strategic combatant i exercises their option conditional on the surplus remaining intact and j not exercising his option first. Next, at each time t and history h_t, $\mu_{it}(h_t) \in [0,1]$ denotes j's belief that i is obstinate. Lastly, I focus on PBE.

I conclude this section by making certain, key assumptions about how the game ends when multiple events happen at the same. If the game ends because both parties concede to their opponent's demands, I assume that each receives a payoff of 0. Meanwhile, if i concedes at the same time that j exercises his option to close communications or when the surplus is destroyed, then the game ends with no surplus to split. Lastly, define $\Delta_i \equiv \kappa_j - \xi_i > 0$ and I say that i is (strictly) *stronger* than j if and only if (iff) $\Delta_i (<) \leq \Delta_j$. This definition simplifies the equilibrium characterization.

2. Equilibrium Characterization

In this section, I characterize the equilibrium. I first derive an expression for the payoff that strategic combatants net from cutting off communications. Next, I characterize how said negotiation proceeds when combatants bargain during a ceasefire i.e., $\psi_t = 0$ almost surely. This is yields a simplified description of how the game proceeds by abstracting away the risks that are salient durig a war. Next, I characterize how the general war proceeds.

A. No Communication Payoffs

I now characterize how the game proceeds when combatants hold a ceasefire. To ease exposition, I suppress history notation whenever possible and first characterize strategies once the combatants cut off negotiations. I find that no strategic combatant gains from cutting off communication and provide a closed form solution for equilibrium payoffs for some combatant i when j cuts off communication. The statement is given below.

LEMMA 1: *Strategic combatants never cut off communication in any PBE. In addition, if obstinate j cuts off communication at time $s \geq 0$, strategic $i (\neq j)$'s time $t \geq s$ payoff conditional on the fighting continuing and the surplus remaining intact is $-B_i$ for $B_i \equiv \frac{\Delta_i}{\bar{r}+\bar{\xi}} > 0$ where $\bar{r} \equiv r + 2\lambda$, $\bar{\xi} \equiv \sum_i \xi_i$.*

This result follows from a rather standard derivation of an ordinary differential equation. I then show that the payoffs are negative, so no strategic combatant would have exercised the option to go to war. In turn, this observation implies that a strategic combatant learns that his peer is obstinate, so the payoffs from fighting without communicating can be expressed as shown above.

B. Gradualism

The next result establishes that both combatants become certain that their opponent is obstinate for certain by the same time. I state the result below.

LEMMA 2: *Fix some PBE. If strategic i expects that j is obstinate with probability* 1, *i strictly prefers to concede immediately.*

The next result establishes that combatants concede gradually at times $t > 0$ conditional on neither side being certain that their opponent is obstinate, the surplus remains intact, and the lines of communication remain open. I state the lemma below.

LEMMA 3: *Fix a PBE and time $t > 0$. If the war continues, the lines of communication remain open (i.e., $h_t = h_0$), and neither combatant is certain that the opponent is obstinate (i.e., $\max_i\{\mu_{it}\} < 1$), then $c_{it} \gg 0$ and is well-defined.*

This observations imply that so long as $\xi_i \leq \kappa_j$ for each i and j. Wars proceed in much the same way as any other bargaining scenario.

C. Ceasefires

I now return to the case that $\xi_i \leq \kappa_j$ for each i and j and characterize the equilibrium. Fix some time $t > 0$ such that neither combatant is certain that their opponent is obstinate (i.e., $\max_i\{\mu_{it}\} < 1$) and both the surplus and lines of communication remain intact ($h_t = h_0$). Define strategic i's equilibrium payoff W_{it}. Since the risk of surplus destruction and the risk of obstinate j closing lines of communication are independent Poisson processes while the concession probability is a function of time, then the Feynman-Kac formula implies that W_{it} satisfies a standard, differential equation. In particular, it satisfies the equation

$$rW_{it} = -c + \overbrace{\phi\mu_{jt}[-B_i - W_{it}]}^{\text{Communication breaks}} + \overbrace{c_{jt}(1 - W_{it})}^{j \text{ concedes}}. \tag{2}$$

Intuitively, equilibrium payoff times the discount factor r is equalize to the sum of the net payoff from j conceding to i's demands plus the net payoff from communications breaking down. Since both combatants are indifferent between making demands and conceding (as shown in lemma 3), then equilibrium payoffs must equal the payoff of conceding right away i.e., $W_{it} = 0$. Plugging this observation into the equation above and then simplifying for c_{jt} implies the following result

LEMMA 4: *Fix PBE taking place during a ceasefire (i.e., $\lambda = \kappa = \xi_i = \kappa_i = 0$ for each i as long as communication remains intact), time $t > 0$, and history $h_t = h_0$ such that $\max_i\{\mu_{it}\} < 1$. The unconditional rate at which i expects j to concede is c_{jt} such that $c_{jt} = \bar{c}_{jt}$ such that*

$$\bar{c}_{jt} \equiv c + \mu_{jt}\phi B_i = c + \mu_{jt}\Delta_i\left(\frac{\phi}{\bar{r} + \bar{\xi}}\right) \tag{3}$$

Intuitively, this result implies that the risk of communication lines being cut off by an obstinate combatant prompts both sides to expedite making concessions. And the rate at which they concede given this risk increase with their belief that the opponent is obstinate. Further note that if i is stronger than j, then i concedes at a faster rate than j at each time $t > 0$.

Evolution of Beliefs During a Ceasefire.

Next, i's beliefs that j is obstinate conditional on $h_t = h_0$ evolve via Bayes rule i.e., at each time t and small dt>0,

$$\mu_{jt+\mathrm{dt}} = \frac{\overbrace{\mu_{jt}e^{-\phi \mathrm{dt}}}^{\text{Communication remains}}}{\underbrace{(1-\mu_{jt})[1-(H_{jt+\mathrm{dt}}-H_{jt})]}_{\text{No concession}}+\mu_{jt}e^{-\phi \mathrm{dt}}}. \tag{4}$$

If j were obstinate, then one expects him to never concede but cuts off communication at a rate $e^{-\phi \mathrm{dt}} = 1 - \phi \mathrm{dt} + o(\mathrm{dt})$ for $\lim_{x \searrow x} o(x)/x = 0$. Meanwhile, strategic j never cuts off communication but expects to concede during the interval $[t, t+\mathrm{dt}]$ with a probability of $H_{jt+\mathrm{dt}} - H_{jt})$ and $(1-\mu_{jt})(H_{jt+\mathrm{dt}} - H_{jt}) = \bar{c}_{jt}\mathrm{dt} + o(\mathrm{dt})$. This implies that the difference in beliefs (i.e., $\mu_{jt+\mathrm{dt}} - \mu_{jt}$) is approximately equal to

$$\begin{aligned} \mu_{jt+\mathrm{dt}} - \mu_{jt} &= \mu_{jt}[1-\phi\mathrm{dt}] - \mu_{jt}[(1-\mu_{jt}) - \bar{c}_{jt}\mathrm{dt} + \mu_{jt}(1-\phi\mathrm{dt})] + o(\mathrm{dt}) \\ &= \mu_{jt}[\bar{c}_{jt} - \phi(1-\mu_{jt})]\mathrm{dt} + o(\mathrm{dt}). \end{aligned} \tag{5}$$

Dividing both sides of this expression by dt and taking the limit as dt goes to 0, it holds that

$$\frac{\dot{\mu}_{jt}}{\mu_{jt}} = \bar{c}_{jt} - \phi(1-\mu_{jt}) = c + \phi[\mu_{jt}B_i - (1-\mu_{jt})] \tag{6}$$

Next, the ordinary differential equation (ODE) above for beliefs describes how $\ln \mu_{jt}$ evolves and since $\ln(\cdot)$ is a smooth and strictly increasing function on $(0,1]$, characterizing $\ln \mu_{jt}$ directly implies μ_{jt}. Next, it remains unknown the time T_C when belief first converge to 1 given that $h_{T_C} = h_0$ and the initial concessions. Time T_C is the earliest time that a combatant i's belief that j is obstinate converges to 1 if i's belief right after j does not concede immediately at time 0 is just μ i.e., i does not expect that j concedes at time 0. Thus implicitly define $T_i > 0$ as the earliest time satisfying that $0 = \ln \mu + \int_0^{T_i} \frac{\mathrm{d}}{\mathrm{dt}} \ln \mu_{it}\mathrm{dt}$ and $T_C = \min_i\{T_i\}$.

From equation 6, it is immediate that if i is stronger than j (i.e., $\Delta_i \leq \Delta_j$), then $\bar{c}_{it} \geq \bar{c}_{jt}$, so $T_i \leq T_j$. This implies that if $T_i < T_j$, then only strategic j concedes at time 0 with a probability q_j. In order to calculate the probability q_j, however, it is best to derive i's posterior belief that j is obstinate conditional on him not conceding at time 0 i.e., μ_{j0^+}. This is because Bayes rule implies that $\mu_{j0^+} = \mu/[\mu + (1-\mu)(1-q_j)]$.

At time $T_C(=T_i)$, it must be the case that $\mu_{jT_C} = 1$ or that $\ln \mu_{jT_C} = 0$. This implies that μ_{j0^+} must simply satisfy that $0 = \ln \mu_{j0^+} + \int_0^{T_C} \frac{\dot{\mu}_{jt}}{\mu_{jt}}\mathrm{dt}$. Figure I lastly plots beliefs obstinate in the benchmark case where $\phi = 0$ (in purple) versus the case when$\phi > 0$—in blue. Note that this figure assumes that $\Delta_i = \Delta_j$ i.e., combatants have a comparable military capacity.

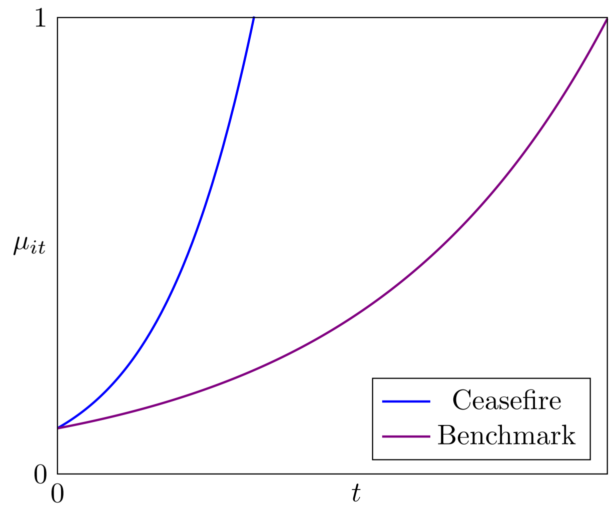


Figure I. : Combatants' beliefs that their opponent is obstinate over time when $\kappa_i = \kappa_j$ and $\xi_i = \xi_j$.

D. General Case

I now re-do the same calculation above, but now assume that combatants fight as they negotiate. Fix some time $t > 0$ such that neither combatant is certain that their opponent is obstinate (i.e., $\max_i\{\mu_{it}\} < 1$) and both the surplus and lines of communication remain intact ($h_t = h_0$). Define strategic i's equilibrium payoff W_{it}. Since the risk of surplus destruction and the risk of obstinate j closing lines of communication are independent Poisson processes while the concession probability is a function of time, then the Feynman-Kac formula implies that W_{it} satisfies a standard, differential equation. In particular, it satisfies the equation

$$\begin{aligned}(7)\quad rW_{it} = -c + &\overbrace{\phi\mu_{jt}[-B_i - W_{it}]}^{\text{Communication breaks}} + \overbrace{c_{jt}[1 - W_{it}]}^{j\text{ concedes}} - \overbrace{\psi_t[\kappa_j + \kappa e_{it}]}^{\text{Costs}} \\ &+ \underbrace{\psi_t\lambda[(1-e_{it}) + (1-\mu_{jt})(1-e_{jt}) + \mu_{jt}][0 - W_{it}]}_{\text{Destruction}} + \underbrace{\psi_t\xi_i[1 - W_{it}] + \xi_j[0 - W_{it}]}_{\text{Battle Outcome}}\end{aligned}$$

A similar argument as provided above implies that $W_{it} = 0$ and the rate in which concessions arrive can be derives in a similar fashion. This implies that for each strategic combatant i, $e_{it} \in \{0, 1\}$ solves $\max_{e\in\{0,1\}} -\kappa e + 0e\lambda$, so $e = 0$. I then can plug in $W_{it} = 0$ and the aforementioned definitions to provide a closed form solution for the concession rates.

LEMMA 5: *Fix PBE taking place while combatants fight, time $t > 0$, and history $h_t = h_0$ such* *that* $\max_i\{\mu_{it}\} < 1$. *The unconditional rate at which* i *expects* j *to concede is* c_{jt} *is*

$$c_{jt} \equiv \bar{c}_{jt} + \psi_t[\Delta_i + 2\lambda] = c + \Delta_i\left(\frac{\phi\mu_{jt}}{\bar{r}+\bar{\xi}} + \psi_t\right) + \psi_t 2\lambda \tag{8}$$

where $\bar{c}_{jt}$ *is the rate at which combatants concede. In addition, at each time* $t > 0$ $e_{it} = 0$.

An immediate implication of this result is that if i is strictly *stronger* than j, then the rate that i concedes to j is larger than the rate at which j concedes to i *and* fighting magnifies this difference. In addition, it is clear that pauses in fighting (i.e., $\psi_t = 0$) just serve to stall out negotiations.

Evolution of Beliefs.

Likewise, I can derive beliefs held by a strategic combatant that their peer is obstinate as in the previous sub-section. Fix some time $t > 0$ and small time interval dt> 0, then the only difference between the case of ceasefires and active fighting is that i further infers j's type from a lack of surplus destruction. The probability that the surplus is not destroyed between time t and t+dt is $e^{-\lambda(1-e_{it})\text{dt}}$ when j is obstinate and $e^{-2\lambda(1-e_{it})\text{dt}}$ when he is strategic. Since the rate at which surplus is destroyed is independent of the risk that an obstinate combatant exercises their option to cut off communication and (conditional on agent types) the rate of concession, then the Bayes posterior belief is

$$\mu_{jt+\text{dt}} = \frac{\mu_{jt}e^{-(\phi+2\lambda)\text{dt}}}{(1-\mu_{jt})[1-(H_{jt+\text{dt}} - H_{jt})]e^{-2\lambda\text{dt}} + \mu_{jt}e^{-(\phi+2\lambda)\text{dt}}}. \tag{9}$$

The difference in beliefs (i.e., $\mu_{jt+\text{dt}} - \mu_{jt}$) can be approximated linearly for small enough dt and it not yields

$$\begin{aligned}\frac{\mu_{jt+\text{dt}} - \mu_{jt}}{\mu_{jt}} &= (1-\mu_{jt})\frac{[1-(\phi+2\lambda)\text{dt}] - [1-(H_{jt+\text{dt}} - H_{jt} + 2\lambda)\text{dt}]}{(1-\mu_{jt})[1-(H_{jt+\text{dt}} - H_{jt})]e^{-2\lambda\text{dt}} + \mu_{jt}e^{-(\phi+2\lambda)\text{dt}}} + o(\text{dt}) \\ &= [c_{jt} - \phi(1-\mu_{jt})]\text{dt} + o(\text{dt}).\end{aligned} \tag{10}$$

Dividing both sides by dt and taking the limit as dt goes to 0, it holds that

$$\frac{\dot{\mu}_{jt}}{\mu_{jt}} = c_{jt} - \phi(1-\mu_{jt}) = \bar{c}_{jt} - \phi(1-\mu_{jt}) + \psi_t(\Delta_i + 2\lambda) \tag{11}$$

Earlier Resolution

The earliest time when combatants become certain that their peer is obstinate (call it T) given that $h_T = h_0$ is the smallest time $t \geq 0$ that μ_{it} converges to 1 if $\mu_{i0} = \mu$ for some combatant i. Equivalently, define $\bar{T}_i$ as the time when $\ln\mu_{i\bar{T}_i} = 0$ if $\mu_{i0} = \mu$ i.e., $\bar{T}_i$ solves

$$(12)\quad 0 = \ln\mu + \int_0^{\bar{T}_i} \frac{\dot{\mu}_{jt}}{\mu_{jt}}\mathrm{dt} = \ln\mu + \int_0^{\bar{T}_i} \bar{c}_{it} - \phi(1-\mu_{it})\mathrm{dt} + (\Delta_j + 2\lambda)\int_0^{\bar{T}_i} \psi_t \mathrm{dt}$$

Note that $\bar{T}_i \leq T_i$ and the inequality is strict when $\psi(\cdot)$ equals to one on a strictly positive Lebesgue measure subset of $[0, T_C]$, because for each such function it holds that

$$\int_0^{T_i} \bar{c}_{it} - \phi(1-\mu_{it})\mathrm{dt} = \int_0^{\bar{T}_i} \bar{c}_{it} - \phi(1-\mu_{it})\mathrm{dt} + (\Delta_i + 2\lambda)\int_0^{\bar{T}_i} \psi_t \mathrm{dt}$$

or that $\int_{\bar{T}_i}^{T_i} \bar{c}_{it} - \phi(1-\mu_{it})\mathrm{dt} = (\Delta_i + 2\lambda)\int_0^{\bar{T}_i} \psi_t\mathrm{dt} > 0$ and $\bar{c}_{it} - \phi(1-\mu_{it}) \gg 0$. Since both combatants become certain that their peer is obstinate at the same time and at most one combatant concedes from the offset with a positive probability, then $T = \min\{\bar{T}_i\}$. And if $\Delta_j \geq \Delta_i$, then the functional form of $\bar{c}_{jt}$ and equation 12 imply that $\bar{T}_i < \bar{T}_j$. Consequently, it remains the case that the weak combatant makes an initial concession to his stronger peer. Combatant i's belief that j is obstinate conditional on him not conceding from the outside is μ_{j0^+} satisfying that

$$(13)\qquad 0 = \ln\mu_{j0^+} + \int_0^{T} \bar{c}_{jt} - \phi(1-\mu_{it})\mathrm{dt} + (\Delta_i + 2\lambda)\int_0^{T} \psi_t \mathrm{dt}.$$

If q_j is the probability that j concedes, then Bayes rule further implies that

$$(14)\qquad \mu_{j0^+} = \frac{\mu}{\mu + (1-\mu)(1-q_j)}$$

COROLLARY 6: *Suppose that $\Delta_j < \Delta_i$ i.e., i is strictly stronger than j. Then, in every PBE, j concedes to i at time 0 with a strictly positive probability q_j satisfying the equation 14; where μ_{j0^+} satisfies equation 13 and the time when combatants become certain that their peer is obstinate is $T = \bar{T}_i$ satisfying 12.*

It is important to note that in the case where $\Delta_i = \Delta_j$, both combatant beliefs converge to 1 by the same time $\bar{T}_i$, so neither combatant concedes with a positive probability. Figure II illustrates how beliefs evolve when $\Delta_i = \Delta_j$ in a benchmark setting when $\phi = 0$, when combatants negotiate during a ceasefire (i.e., $\psi_t = 0$ for each t), and when they always fight: at each time t, $\psi_t = 1$.

Secondary Result

I now characterize how the initial probability of a concession changes as one increases the strong combatants *power* or decreases the weak combatant's *power*. Assume that $\Delta_i < \Delta_j$ i.e., i is strictly *stronger* than j. From 14, it is clear that q_j as a function of μ_{j0^+} equals to , $q_j(\mu_{j0^+}) = 1 - [\mu/(1-\mu)](1/\mu_{j0^+} - 1)$; meanwhile, μ_{j0^+} as function of T is implicitly given by equation 13 and T as a function of Δ_j is also implicitly given by equation 12. I am interested

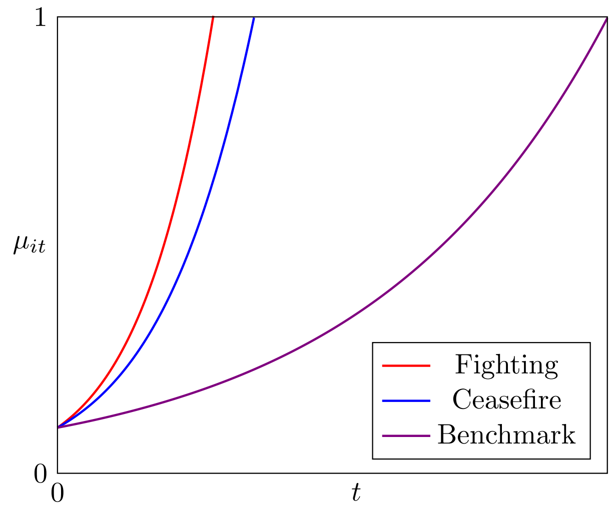


Figure II. : Evolution of beliefs when fighting never stops (in red), during a ceasefire (in blue) and in the benchmark (purple).

in calculating the derivative of q_j as a function of Δ_j i.e., how does the initial concession evolve as i becomes marginally stronger. Applying the Leibniz integral rule and the implicit function theorem on equation 12, it holds that the derivative of T with respect to Δ_j is

$$T'(\Delta_j) = \frac{-\int_0^{T(\Delta_j)} \frac{\partial \bar{c}_{it}}{\partial \Delta_j} + \psi_t \mathrm{dt}}{\bar{c}_{iT} + \Delta_j + \lambda} < 0 \tag{15}$$

If one repeats the same steps for the derivative of μ_{j0^+} as a function of T, if holds that

$$\frac{\mu'_{j0^+}(T)}{\mu_{j0^+}(T)} = -[\bar{c}_{jT} + \psi_T(\Delta_i + \lambda)] < 0. \tag{16}$$

Lastly, so $q'_j(\mu_{j0^+}) = \mu_{j0^+}^{-2}[\mu/(1-\mu)]$. This observation implies that as i's strength becomes stronger, the probability of an initial concession increases.

Next, I calculate the derivative of q_j as the Δ_i changes. By the implicit function theorem, the derivative of μ_{j0^+} with respect to Δ_i is

$$\frac{\mu'_{j0^+}(T)}{\mu_{j0^+}(T)} = -\int_0^T \frac{\partial \bar{c}_{jt}}{\partial \Delta_j} + \psi_t \mathrm{dt} = -\int_0^T \frac{\partial \bar{c}_{it}}{\partial \Delta_j} + \psi_t \mathrm{dt}. \tag{17}$$

Consequently, I can immediately summarize the results below.

COROLLARY 7: *Either when the strong becomes stronger or the weak becomes weaker, the probability that the weak combatant concedes immediately increases. Yet, this rise is larger with the weakening of the weak than with the strengthening of the strong combatant. Formally, assume that $\Delta_j > \Delta_i$, then the partial derivative of q_j with respect to Δ_i is*

$$\frac{\partial q_j}{\partial \Delta_i} = -\frac{1}{\mu_{j0^+}}\left(\frac{\mu}{1-\mu}\right)\int_0^T \frac{\partial \bar{c}_{jt}}{\partial \Delta_j} + \psi_t dt. \tag{18}$$

Meanwhile, the partial derivative of q_j with respect to Δ_j is

$$\frac{\partial q_j}{\partial \Delta_j} = -\frac{\partial q_j}{\partial \Delta_i}\left[\frac{\bar{c}_{jT} + \psi_T(\Delta_i + \lambda)}{\bar{c}_{iT} + \Delta_j + \lambda}\right] < -\frac{\partial q_j}{\partial \Delta_i}. \tag{19}$$

3. Welfare impact of ceasefires

In the previous section, I showed that holding negotiations during a ceasefire prolongs when combatants reach an agreement but said combatants avoid the costs and destruction associated with fighting. It, therefore, does not follow that combatants are better off in one setting relative to another. In this section, however, I prove that ceasefires, even if implemented in a flexible fashion, yield not welfare benefit.

A benevolent social planner decides, at each time $t \geq 0$, whether combatants negotiate during a ceasefire or while they fight provided that $h_t = h_0$. This means that the planner decides the conditions of the negotiation so long as the surplus as well as the lines of communication remain intact and neither side reaches a decisive victory. Formally, the social planner picks a Lebesgue measurable function $\psi : [0,\infty) \to \{0,1\}$ where $\phi_t = 1$ implies that combatants negotiate as they fight and $\psi_t = 0$ implies that negotiations coincide with a ceasefire at each time $t \geq 0$ provided that $h_t = h_0$.

Assume that the planner gives a welfare weight of $\beta_i \geq 0$ to i such that $\sum_i \beta_i = 1$. At each time $t > 0$ such that $h_t = h_0$, define welfare as

$$W_t = E_t\left[\sum_i \beta_i e^{rt}[U_{i\tau} + C_{it}]\right]. \tag{20}$$

Intuitively, welfare is the weighted average of combatants payoffs. I have to add back to forgone costs by time to discount payoffs starting from time t. Next, the Feynman-Kac formula (as in the derivation of W_{it}) implies that W_t satisfies

$$\begin{aligned} rW_t = \dot{W}_t + &\overbrace{\phi\sum_i \mu_{it}[-(B_{-i}\beta_{-i} + B_i\beta_i) - W_t]}^{\text{Communication loss}} + \overbrace{\sum_i \bar{c}_{it}[\beta_{-i} - W_t]}^{\text{Base Concessions}} \\ &- \overbrace{\sum_i \beta_i[c + \psi_t\kappa_{-i}]}^{\text{Costs}} + \overbrace{\sum_i \lambda\psi_t[0 - W_t]}^{\text{Destruction}} + \overbrace{\psi_t\sum_i \xi_i[\beta_i - W_t]}^{\text{Military outcome}} + \overbrace{\psi_t\sum_i \Delta_{-i}[\beta_{-i} - W_t]}^{\text{Additional Concession}} \end{aligned} \tag{21}$$

In the following lemma, I characterize the ordinary differential equation (ODE) solved by the welfare of a fixed control (ψ_t) and welfare weights (β_i).

LEMMA 8: *For each welfare weights* (β_i)*, policy* (ψ_t)*, and each time* $t \geq 0$ *and history* $h_t = h_0$*, welfare is* $W_t \ll 0$ *and satisfies the following ODE*

$$rW_t = \dot{W}_t - \sum_i \beta_i \phi B_i \mu_{it} - W_t \sum_i \phi\mu_{it} + \bar{c}_{it} + (\lambda + \xi_i + \Delta_{-i})\psi_t \tag{22}$$

The proof reduces to a series of non-trivial, algebraic manipulations of equation 21 and it implies that welfare is a negative number and isolates the role of ψ_t at each time t in the expression of the ODE. This is important, because the optimal control (ψ_t) given welfare weights β_i is a function just a function of time and satisfies the following HJB equation:

$$rW_t = \dot{W}_t - \sum_i \beta_i \phi B_i \mu_{it} - W_t \sum_i (\phi\mu_{it} + \bar{c}_{it}) + \max\left\{0, -W_t \sum_i (\lambda + \xi_i + \Delta_i)\psi_t\right\} \tag{23}$$

The first argument is the maximizer is the marginal gain from pausing fighting at time t, while the second argument states the marginal gain from continuing to fight. Since for each control (ψ_t) and welfare weight (β_i), it holds that $W_t \ll 0$. Meanwhile $\lambda > 0$ and for each combatant i, $(\xi_i, \Delta_i) \gg 0$. These observations implies that , $-W_t \sum_i (\lambda + \xi_i + \Delta_i)\psi_t > 0$ at each time t i.e., the social planner always prefers to allow the combatants to fight so long as he is not certain that they are obstinate.

Define T_F as the earliest time that combatants become certain that their peer is obstinate when $\psi_t = 1$ at each time $t \leq T_F$. Then the optimal mechanism states that $\psi_t = 1$ for $t \in [0, T_F]$, but it remains unclear what the mechanism requires for $t \geq T_F$. Nevertheless, note that the only factor in the statement of welfare changing over time are beliefs and at times $t \geq T_F$ said beliefs do not change, so welfare at said times is not changing. Consequently, $\dot{W}_t = 0$ at each time $t \geq T_F$ and it is without loss of generality to assume that the optimal policy from henceforth if a fixed action $\bar{\psi} \in \{0, 1\}$. And from the proof of lemma 8, I establish that the optimal policy solves

COROLLARY 9: *For each set of welfare weights* (β_i) *and times* $t \geq T_F$*, welfare solves*

$$W_t = -\min\left\{\frac{2\big[c + \phi\sum_i \beta_i B_i\big]}{r + 2\phi}, \frac{2\big[c + \phi\sum_i \beta_i B_i\big] + \sum_i \Delta_i}{\bar{r} + 2\phi + \bar{\xi}}\right\}$$

where the expression on the left of the maximizer assumes that $\bar{\psi} = 0$ *and the one on the right assume that* $\bar{\psi} = 1$*. Consequently,it is without loss of generality to assume that* $\bar{\psi} = 1$ *iff*

$$\frac{r + 2\phi}{\bar{r} + 2\phi + \bar{\xi}} \leq \frac{2\big[c + \phi\sum_i \beta_i B_i\big]}{2\big[c + \phi\sum_i \beta_i B_i\big] + \sum_i \Delta_i} \tag{24}$$

Given this corollary, I can now state the paper's main, welfare theorem.

THEOREM 1: *Given welfare weights* (β_i)*, an optimal mechanism at each time* $t \geq 0$ *is given* *by*

$$\psi_t = \begin{cases} 1 & t \leq T_F \\ \bar{\psi} & t > T_F \end{cases} \tag{25}$$

where $\bar{\psi} \in \{0, 1\}$ *equals to* 1 *iff equation* 24 *holds.*

The theorem implies that it is optimal to never hold a ceasefire when combatants are not certain that their peer is obstinate. But once it is certain that combatants *are* obstinate, whether or not it is optimal for the social planner to call for a ceasefire crucially depends on model parameters and welfare weights.

4. Empirical Section

This section now shifts attention to the empirical trends in wars and peace negotiations since the early 1800s. The section begins by describing the data at hand as well as the in which the panel was constructed. I then describe the general trends in wars and interstate disputes i.e., not only disputes escalating to war. This allows me to describe how the disputes leading to war differed from the disputes that did not escalate to outright war as well as analyze how this difference between conflicts changed after 1914.

I then study the salient dynamics pertaining peace negotiations across time in the panel. In particular, I show how the timing of negotiations, their duration, and war related factors are associated with its evolution. These panel regression results are not intended to show a causal relation, because the timing and condition of when combatants accept to negotiate is far from exogenous. Nevertheless, the estimates suggest that negotiations are associated with less subsequent time spent fighting but that this relation is null and void when said negotiations coincide with ceasefires. I then present an identification strategy that tries to ascertain a causal link between negotiations and the conditions when they take place with the subsequent amount of time spent fighting.

A. Data Sources and panel construction

I now describe my data and how the panel was constructed. The core of the panel consists of day-level data of 92 interstate conflicts held from 1823 to 2003 from Min (2020). From Min (2021), I then match battle-specific information. In particular, I match the precise dates in which battles began and ended; whether someone won; and the days in which combatants were not involved in a major, recorded battle.

I then compiled (from public, internet records) the official dates that historians states that wars started and ended. This step allows me to disregard battles that took place after combatants signed an agreement. For example, Andrew Jackson defeated General Edward Pakenham in the

Battle of New Orleans on January 8^{th} 1815 expecting that the War of 1812 still raged on (Maclemore 2016). The treaty of Ghent, which brought an end to the aforementioned conflict, was nonetheless signed on December 14^{th} 1814. This implies that this battle should be excluded from the analysis since it was an artifact of the period's lackluster communication technology. Such battles would further confuse the factors leading the heads of state to sign a peace.

Next, for each war, participating combatant, and year in which the war took place, I merged in the six measurements of military capability made standard since Singer et al (1972) using the Reiter et al (2016) data on the participating war coalitions. Singer et al (1972) came up with the Composite Index of National Capability (CINC) as a descriptor of a nation's capacity to wage a war. the CINC of a given country A is a simple average of the share of the world's total population, urban population, military expenditure, military personnel, production of iron and steel, and energy production held or produced by country A. For each war, coalition and year, I then calculate multi-dimensional estimates of each sides military capability.

B. General War and interstate trends

In this subsection, I describe how (in the data) wars changed since 1823.

I begin the data analysis by characterizing how wars changed over the centuries. Figure I categorizes the 41 wars fought in the Early period (1823-1913) as well as the 51 wars fought in the Modern period (1914-2003) into 4 categories. A war is either a border dispute, regime change, foreign conquest, commercial war, or other type of conflict. A border conflict is a war between conflicts sharing a border where the conquest of some territory is central. When these wars are prompted by nations that do not share a border, they are denoted as wars of foreign conquest. Wars that were not categorized in the previous categories and have as a chief objective to change a nation's government are known as regime change wars. Likewise, conflicts that were not border disputes or wars of foreign conquest that were motivated by conflicting claims were denoted as commercial wars. The remaining set of wars were denoted a "other".

Why and which type of wars are prevalent?

The plurality of wars (i.e., 46.3 percent) fought in the Early period were wars of foreign conquest, while an additional 51 percent of wars were roughly equal parts of border disputes and regime change wars. The other types of wars are minimal e.g., the category of "other" includes no wars and only has a positive percent as a way of dealing with rounding to 1 decimal place. By the Modern period, wars of conquest accounted for 18.8 pp fewer wars than in the preceding period, while commercial disputes rose from 2.4 percent of wars to 7.8 and "other" consisted of 2 percent of all wars. As a consequence, the types of wars has diversified in the modern relative to the early period.

A similar trend emerges when one looks at the primary issue prompting combatants to war. Following Holsti (1993), conflicting territorial claims accounted for 56 percent of wars by issue; meanwhile, an additional 37 percent of wars were prompted by a nation or regime's desire to survive. By the modern period, only 43 percent of wars were prompted by conflicting territorial claims and a plurality of conflicts (i.e., 45 percent) were prompted by a nation or regime's desire to survive.

	1823-1913	1914-2003
Type of War		
Foreign Conquest	46.3 %	27.5 %
Regime Change	24.4	33.3
Border Dispute	26.8	29.4
Commercial Dispute	2.4	7.8
Other	0.1	2
Leading issue		
Territorial	56.1 %	43.1 %
Survival	36.6	45.1
Commercial	2.4	7.8
None	4.9	4.0

Table I: Distribution of wars by category and the distribution of issues prompting wars.

Observing conflicts that escalated to war exclusively only provides a partial view of the change in interstate conflicts held over the same period. If dispute that did not escalate to war were brought up by similar issues or can be categorized in a similar fashion, then the facts that the type of wars changing is simply a reflection of a larger trend. Otherwise, there is key selection that has been left unresolved. Using data from Braithwaite (2010), I categorize 347 interstate disputes held from 1816-1913 and 1,900 disputes beginning after 1914. In both periods, the majority of disputes are primarily motivated by one's nation's disagreement with another nation's foreign policies. If anything, these type of conflict has become more common since 1914.

Territorial disputes, for their pair, made up nearly 39 percent of the remaining disputes in the Early Period and it fell slightly to roughly 34 percent in the Modern period. Relative to wars, territorial disputes are more prevalent among conflicts that escalated to war than they are in general. In addition, the marked decline in the prevalence of wars fought due to territorial disputes is not reflected by a decline of comparable magnitude in all interstate disputes. The last, and significantly less common type of disputes, are those prompted by a wish to remove a nation's regime. Such category of interstate dispute has been roughly constant over time account for 6 to 7 percent of all disputes. Nevertheless, these disputes account for roughly a quarter (in the Early period) or a third (in the Modern period) off disputes that get escalated to wars.

Table II further plots the initial act done in a given dispute. More than 64 percent of all disputes began with a threat or use of force. In the Early period, disputes that did not begin with uses or threats of force primarily began with blockades or seizures. This changed in the Modern period. Disputes that did not begin with use or threat of force were more likely to begin with some sort of border movement e.g., fortification or occupation of contested territory.

	1823-1913	1914-2003
Type of hostilisty		
Border forticiations, violations,		
and territory occupation	16.6 %	22.0 %
Seize of assets/ bockades	18.1	13.5
Threats and use of force	65.3	64.5
Type of issue		
Territorial	38.5 %	33.7 %
Foreign Policy	50.3	56.6
Regime Change	6.4	6.5
Other	4.8	3.2

Table II: Distribution of disputes (i.e., not only wars) by category and the distribution of issues prompting the disputes.

Table III points out the initial act of hostility, but I now study the maximum degree to which the dispute escalated. First, I note that 11.3 percent of all disputes held in the early period escalated to war and this rate fell to 3.4 percent in the modern period. This observation, nevertheless, hides the fact that nearly 68 percent of all interstate disputes held since 1914 escalated to a use of force that fell short of going to war. In contrasts, disputes were significantly more likely to escalate to war in the Early period but less than 46 percent of disputes that did not escalate to war had states use force directly. This means that interstate disputes have been (overall) prevented from crossing the line into war but nations are more willing to use force.

	1823-1913	1914-2003
No military action	0 %	0.6 %
threat or display of force	42.9	28.1
Use of force	45.8	67.9
War	11.3	3.4

Table III: Distribution of hostility levels for disputes over time.

Relative strength of aggressors

Next, I look at the relative military capacity of a war's opposing coalitions. Table IV plots the CINC ratio for the initially attacking and the initially defending coalitions. I find that the initially attacking coalition had more military capacity than the defending coalition (on average) during the Early period. Said coalition had a clear advantage in most of the inputs to the CINC index over the defending coalition. After 1914, the difference in capacity narrowed at the level of the CINC index and in each of its components. This suggests that the type of coalitions choosing to go to war has changed.

	1823-1913	1914-2003
CINC Index		
Attacker	0.113	0.153
Defender	0.074	0.145
Iron and Steel Production		
	0.126	0.142
	0.023	0.142
Energy production		
	0.130	0.129
	0.015	0.127
Military Expenditure		
	0.153	0.220
	0.085	0.181
Military Personnel		
	0.096	0.179
	0.116	0.180
Urban population		
	0.101	0.139
	0.041	0.122
Total population		
	0.070	0.108
	0.125	0.115

Table IV: Relative Military capacity between a interstate war's coalitions decomposed by components and over time.

It is ill-advised to gauge much about the type of nation going to war solely from analyzing the coalitions of nations opting to go to war. Instead, figure AI plots the average CINC ratio for the initial attackers and defenders in both disputes that ended in wars relative to those who did not. In the Early period, I find that the initial attacker tends to have a larger military capacity than the initial defender. But the difference in military capacity is smaller in conflicts that escalated to war. In contrast, the differences in military capacity are smaller in the Modern period.

I even find that the initial defender has a slight advantage (on average) in military capacity. In addition, the coalitions in disputes then to have larger military capacity than those that did not. Lastly, figure III plots these CINC ratios for each dispute by period and whether the dispute escalated to wars. It is important to note that the spread in military capacity remains less spread out among coalitions that did not end up in war relative to those that did. These statistics suggest that disputes between opponents whose military capacity differs too much are unlikely to escalate to war and this trend is more salient since 1914.

Figure III. : Correlation of military capacity between opposing factions to a dispute by whether they escalated to war and over time.

The changing trends in wars

The next basic set of trends to consider are the duration of wars and how said wars ended. In the early period, the average war lasted a little less than 11 months but and combatants spent an average of 6 months in active conflicts. In contrasts, wars fought in the Modern period lasted and average of nearly 15 months. Figure AII illustrates that the main difference in the averages was that after 1914 there were multiyear.

	1823-1913	1914-2003
Time Spent		
Overall	331.2 days	456.3 days
Fighting	185.1	327.2
Between battles	146.1	129.1
In a negotiatgion	34.1	113.3
How did wars ended?		
Following a battle	14.6 %	11.7 %
With a negotiation		
Total	65.8 %	56.9 %
Unprompted by fighting	56.1	51.0
Inconclusive	19.6	31.4

Table V: General war trends by periods.

To a significant degree, the amount of time spent fighting is more relevant than the total duration of the conflict. For example, suppose that a war lasts a year, but it consisted of only 12 battles lasting a day each. Is it relevant that the war lasted for a year or that there were 12 days of intense fighting? One can argue that the 12 days of fighting is a more relevant figure but that the full duration of the war still matters. Wars fought after 1914 spent 10.7 month fighting. This implies that the average war spends more than 4 additional month of intense fighting than in the previous period and (thus) only looking at the total duration of the conflict undermines the trends in war duration. Figure AIII plots the distribution of time spent in major battles over time[2]. This figure illustrates that the pattern presented for the overall duration of wars undermines the pattern for the time spent in these major battles.

Next, I note that the way wars end has changed. Before 1914, nearly 2 out of 3 wars ended within a week of a (formal peace) negotiation and an additional 15 percent ended preceded by some party's victory at war that did not prompt a negotiation. If one further considers the number of wars that ended preceding negotiations that were, themselves, preceded by either side's victory at a major battle, then roughly 1 in 4 wars' end were prompted by a battle's outcome. On the other hand, the share of wars that ended by a peace negotiation that is not preceded by some combatant's victory at a battle accounted for roughly 56 percent of all wars. I further point out that almost 20 percent of all wars fought in the Early period cannot be categorized as ending in these neat categories.

Wars fought after 1914 ended in a qualitatively different fashion. The share of wars that end directly precede by a battle or a negotiation that was (itself) preceded by a major battle fell by 7 pp. Meanwhile, the share of wars ending preceded by a negotiation fell by nearly 9 pp and the share of wars ending within a week of a negotiation that was not preceded by a major battle fell by more than 5 pp. Lastly, the share of wars whose end cannot be neatly categorized as above rose by nearly 12 pp. These observations implies that, since 1914, wars have gotten longer; combatants spend more time fighting; and both battles as well as negotiations are less effective at bringing an end to armed conflict.

C. On Peace negotiations

Now that general trends in battles has been discussed, I study how the frequency and efficacy of peace negotiations changed since 1914. Before 1914, 75 percent of wars had a negotiation encounter i.e., specific time when combatants sat down and held a formal peace negotiation. The average war spent a total of 34 days negotiating and 18 days in any given encounter—as shown in table VI. Wars further had 2.4 encounters conditional on spending a positive amount of time in peace negotiations and (as a result) roughly 48 percent of wars ended post-negotiation.

[2] I take the determination of whether a given battle was a major battle and not a small skirmish directly from the history and political science literature. See, for example, Min (2020).

In contrast, 77 percent of wars held after 1914 had a peace encounter and the average war in which combatants spent a positive time in formal peace negotiations had an average of 5 encounters. Figure AIV illustrates how the distribution of the number of negotiations changed over time and shows that since 1914, wars are likely to have many more encounter than during the preceding century. Combatants further spent an average of nearly 150 days negotiating and the average negotiation encounter lasted 31 days. Nevertheless, less than 29 percent of wars ended post-negotiation.

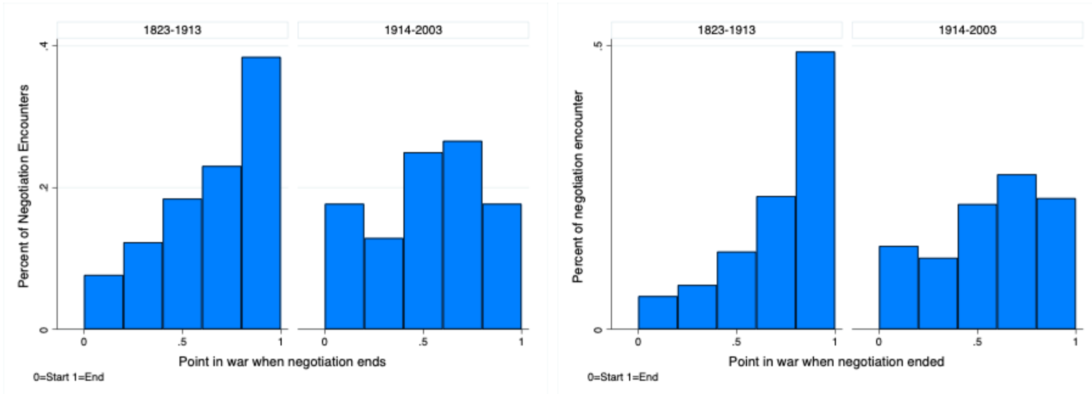
	1823-1913	1914-2003
Number of distinct encounters	2.4	5.1
Time spent negotiation	34.1 days	147.7 days
Tme spent per encpunter	18.2 days	31.1 days
Share of wars ending post-negotiation	47.9 %	28.5 %

Table VI: Summary Descriptive Statistics of Negotiations during Active Conflicts.

Next, I look at the moment in the war in which a negotiation encounter took place. For example, if an encounter took place at time 0, 1/2, or 1 means that the encounter took place at the beginning, middle, or end of the war, respectively. I first consider the distribution of the moments in the war when all negotiation encounters ended by period—on the left-hand panel of figure IV. Before 1914, the distribution of the time when negotiation encounters ended look like an inverted exponential distribution i.e., most negotiations ended near the end of the conflict and fewer ended earlier in the war.

This pattern does not persist after 1914. The mean negotiation encounter ended in point 0.71 (i.e., roughly 3/4 towards the end of the war) and the median was 0.8 before 1914. After 1914, the average encounter ended in point 0.63 (roughly 5/8 of the way towards the end of the war) and the median was 0.74. Consequently, the distribution of the point in the war when a negotiation ended shifted towards the left after 1914.

The right-hand panel shifts focus to negotiation encounters that never coincided with a pause in fighting. My model suggests that these negotiations are more likely to bring an end to a war than similar negotiations that (at least partially) coincide with a pause in fighting. Prior to 1914, the average negotiation encounter ends in point 0.8 and the median is 0.99. The average after 1914, however, is 0.66 (i.e., 2 thirds through the war) and a median of 0.75. This implies that—as predicted by the model—the distribution of the moment in the war when a negotiation encounter is shifted to the right when combatants negotiate while they fight. It should be nevertheless note that the magnitude was smaller after 1914 relative to the preceding century.



(a) All encounters. (b) Fully Coincides active fighting

Figure IV. : Distribution of the point in a war when a negotiation encounter took place.

D. Panel Regression Results

I now present the correlates between the time spent in a war/time spent fighting and the war correlates. I argue that, in absence of data on day level deaths in battle, these are the most salient dependent variables as the more time combatant spend fighting (usually) the more combatant deaths are reported as well as more death of innocent bystanders.

Using data from Lyall (2020) on combatant-battle level outcomes for battles frought from 1801 to 2011, I estimate the number of deaths per battle before and after 1914. The average combatant lost between 76 to 165 casualties per day before 1914. After 1914, the average combatant lost between 117 to 243 combatants per day and battles last for more days than in the past.

Figure AV plots the log of the deaths per day and army for the Early and Modern period. I find that the distribution of the log number of deaths looks like a right-displacement of the distribution of deaths. As a consequence, it is clear that more combatants have died (per day) more than in the previous period. And these values (crucially) disregard innocent bystanders and the material damage caused by fighting. Next, table BII shows that a day spent in a negotiation is associated with a reduction in the time spent in major battles (as those causing the casualties described above) but an increase in the overall amount of time spent fighting. Pauses in major fights (a proxy for ceasefires), for their part, are associated with an increase in both the time spent fighting and the duration of wars.

In addition, a day when a negotiation coincides with a pause in fighting is associated with an additional increase in the time spent fighting and in a negotiation. This effect appears small relative to the associated effect of negotiations and pauses in fighting and are is only statistically significant for the total duration of the conflict. The Instrumental Variable (IV) estimates provided later on argue that this effect is two orders of magnitude large when one controls for the innate endogeneity in the decision to negotiate a peace. Note that the controls added are just to keep the regression model in line to what has been done in previous studies. Lastly, I point out that the estimates of military capacity shows that changes in the capacity of the initial attacker and defender have qualitatively different effects on the duration of wars and the additional amount of time spent fighting.

E. Evolution of military capacity components.

The previous set of regressions illustrate the association between battle-specific outcomes and the remaining time spent fighting/in a war. However, it is natural to expect that the choice to hold a negotiation as well as to pause a negotiation is correlated with the regressions' error term. This is because both sides to the conflict were likely haggling over the terms of a pause in fighting or a negotiation and variables capturing those talks is difficult to consistently measure for any given war, much less for the entire section. For these reasons, I construct a set of instrumental variables attempting to correct for the endogeneity that must be expected in these regressions. In particular, I instrument for a day spent holding a negotiation, a paused fighting, and when both events take place with the log-changes in the amount of changes in some of a coalition's raw resources entering its military capacity. I only include factors that are not readily controlled by a government i.e., I exclude factors associated with a nation's recruitment of additional armed forced of expenditure in a war.

Before justifying why these random variables are valid instruments, it is important to describe how relative-military capacity as well ad the dynamics of it components evolved over the last two centuries. Figure AVI illustrates the mean and mean deviation of nations' military capacity index (CINC). The graphs show that the average nations' CINC index as well as the mean deviation of CINC index has consistently declined since 1816. There are three periods in which the decline of these two statistics were reversed: during the 1870s and during the two World Wars. These observations argue one should expect that the decline in the difference in military capacity since 1914 is to be expected from the fact that the distribution in CINC index has less variance than before.

It should be noted that these trends do not imply, however, that nations have fewer resources that are relevant for waging war after 1914. This fact is immediate from going over on how Singer (1973) constructed this index. He first calculates each nations' share of global urban population, total population, production of energy commodity, iron and steel production, military personnel, and military expenditure and takes a simple average of these 6 fractions. This normalization implies that the trends discuss above argues that the resources that are useful in war are less concentrated today than in the past.

Next, I look at the year-over-year change in the components to the CINC index averaged across countries. Note that these graphs calculate the average change in the absolute value of a factor held by a nation and not of the change in each nations share of the total amount of the resource. The graphs on the left-hand panel plots all graphs, while the right-hand panel exclude the two-most volatile series to illustrate the dynamics of the remaining series. As expected changes in military expenditure and the production of energy series are the most volatile and the former does correlate somewhat with the arrival of the World Wars. On the other hand, the change in the energy commodity production is most volatile during the early 1970s, which is perfectly in line with the oil crises in said time. I lastly find that demographic changes in the size of population and urbanization rate changes the least out of the six series considered.

I argue that the fact that a nation is at war should not influence demographic transitions and a nations industrial capacity if said nation is not involved in an all out war. An all out war refers to conflict where nations expect to require controlling the nations resources and shift said resources towards winning the conflict.

A government may, for example, increase his military personnel by mandating conscription and it thus controls how much military personnel it has under its control. But said government cannot control, in a matter of a few years, the number of able-bodied men from which to call into battled. In addition, a nation can confiscate the oil, iron, and steel that its nation produces but expanding capacity of the local production of said resources requires the discovery of raw materials within its borders. It would further require a marked expansion in workforce with the proper expertise to work in these industries. Consequently, attempts to control these endeavors is only conceivable in major conflicts of the scale of the world wars.

Table BI corroborates this hypothesis in a panel regression with fixed effect of the log-change of the different components to military capacity and several correlates on note. First, I only find a statistically significant association between the fact that a nation was at war with the growth of military personnel. This association is small and statistically insignificant for all other factors: including the change in military expenditure.

Only the World Wars were negatively and statistically significantly associated with the log-change in the factors of military capacity. In contrast, the Crimean War (one of the largest armed conflicts during the 19$^{\text{th}}$ century is not associated with any of the factors of war in a statistic or economically significant fashion. These observations suggest that one should expect little direct relation between the changes in these factors during non-all-out-wars and the duration of an armed conflict. Nevertheless, the model does suggest that the arrival rates of changes in relative military capacity should prompt combatants to make immediate concessions i.e., negotiate.

F. IV Panel Regression Results

In this subsection, I turn my attention to the panel, instrumental variable estimates. The instrumental variables are a coalitions' day-level log-change in the iron and steel as well as commodity energy production and changes in urban and total population during non-all-out-wars. The model suggests that changes in these sub-measurements of military capacity should prompt the combatants to negotiate. But they are unlikely to be associated with the unobserved factors influencing the duration of wars or the duration of wars themselves.

Table BIII presents the estimates. The panel regression without instrumenting argued that a day spent negotiating during a pause in fighting is associated with less than a week of additional fighting and that such association is not statistically significant. In contrast, the instrumental variable estimate suggest that a day spent negotiating during a pause in fighting is associated with more than 2,000 additional days of fighting. On the other hands, the same interaction is associated with more than 750 additional days of war and that the effect of holding a negotiation or pausing the fighting is (at least) two orders of magnitude larger than expected from the results in table BII.

5. Conclusion

Since Fearon (1995), many have argued that incomplete information about combatant's relative, military capacity is what drives combatants to fight rather than peacefully bargain. Such assertion is clearly violated by anyone who currently faces the US military, the British in the 19^{th} century, or the Mongols in the 12^{th}. In these cases, it is clear which combatant is most militarily capable and that the weak side's decision to fight is a deadly, fool's errand.

This paper argues, however, that a lack of certainty that one's opponent is strategic rationalizes why combatants fight. If a combatant is not strategic, they fight for reasons that defy strategic analysis. But if they are strategic, fighting allows the weaker combatant to posture and extract concessions that are untenable during peace time.

The model further provides several insights. First, due to posturing, military and bargaining power are inversely proportional. This is because incurring the costs of facing a more powerful opponent serves as a costly signal of one's intransigence. As a consequence, deterrence strategies may prevent war but does limit a combatant from diplomatically attaining a favorable end to a war.

The second insight points out that negotiating a peace while fighting has been paused is ill-advised. I find that any pause in fighting during a negotiation leads to a welfare loss provided that the combatants are strategic with a non-zero probability. Meanwhile, the empirical section suggests that holding a peace negotiation is negatively associated with a war's duration but only when said negotiation does not coincide with a pause in fighting. And, in as far as the instruments employed are convincing, the effects discussed above are large and causal in nature.

Lastly, I this model's admitted simplicity makes it an effective setting in which to study a plethora of war-related issues. Incorporating limited commitment considerations, for instance, could make it particularly sensible for studying civil wars. Moreover, non-negotiation-specific bargaining information is always and everywhere a disregarded and potentially salient feature of bargaining in general.

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Additional, empirical section figures

A1. Conflict level graphs

The following graphs present several descriptive figures pertaining wars and how said factors changed over time.

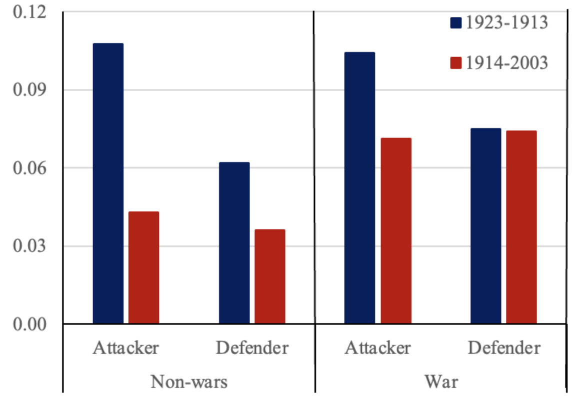


Figure AI. : Relative Military capacity between a interstate dispute's coalitions decomposed over time.

Figure AII. : Distribution of war duration over time.

A2. Aggregate changes in military capacity factors.

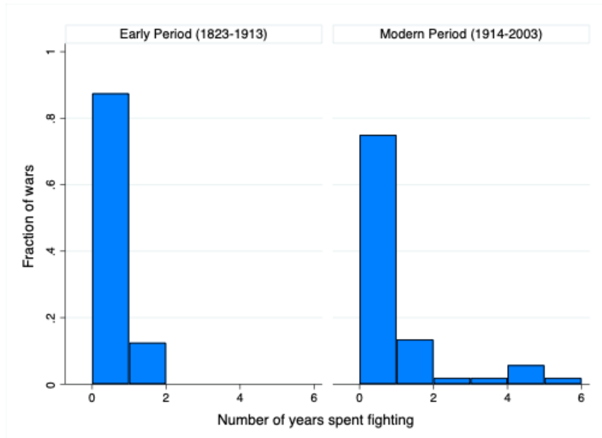


Figure AIII. : Distribution of time spent in major battles over time.

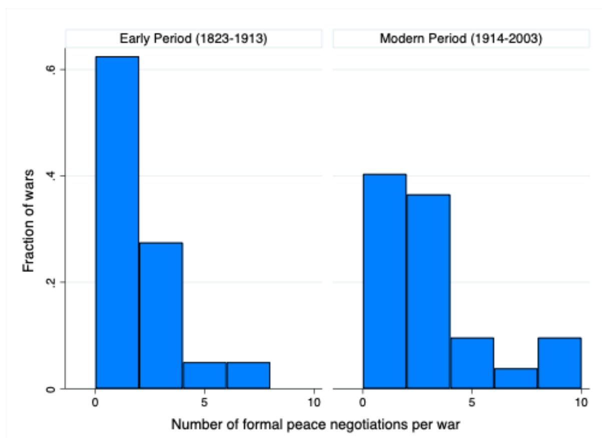


Figure AIV. : Distribution of number of formal peace negotiations per war over time.

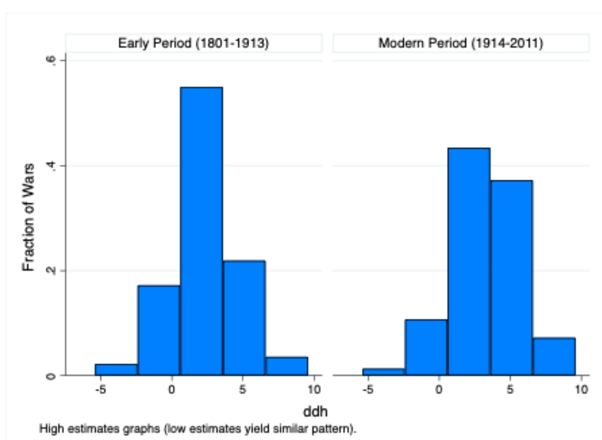
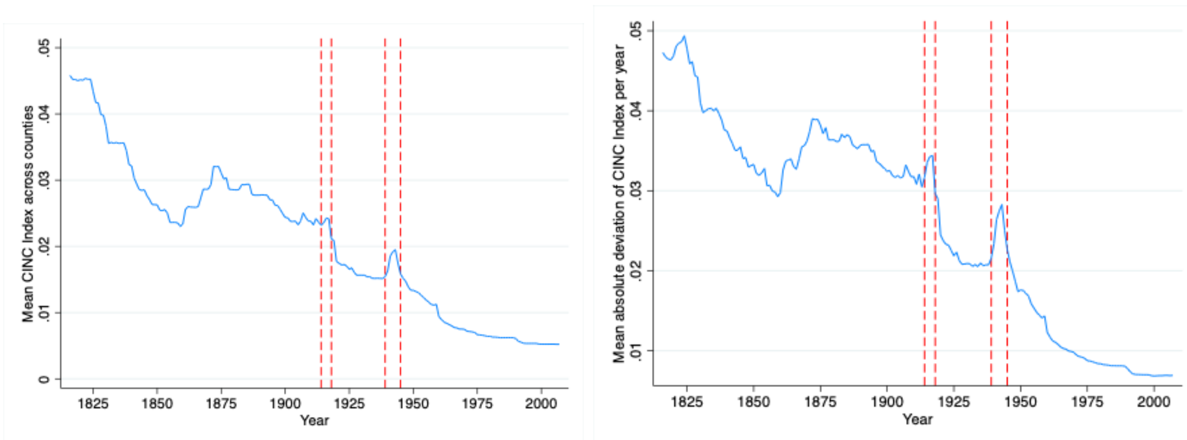


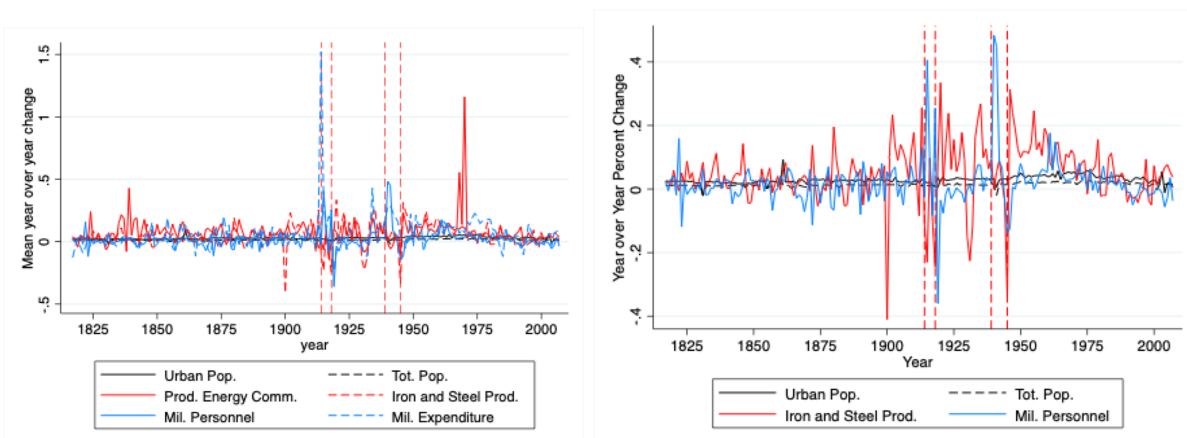
Figure AV. : Distribution the number of combatants that die (on average) per day and army.

The following graphs present key information pertaining to the evolution of factors that are key in determining a nation's military capability.



(a) Mean CINC (b) Mean Deviation of CINC

Figure AVI. : Mean and absolute mean deviation of CINC ratios across countries over time.



(a) All factors (b) Most volatile factors removed

Figure AVII. : Mean year-over-year change in factors of military capacity.

Regression tables

VARIABLES	(1) Log change PEC	(2) Log change IRST	(3) Log change Urb. Pop.	(4) Log change Tot. Pop.	(5) Log Change Mil. Per.	(6) Log change Mil Exp.
In a war last year	0.002	-0.004	0.003	0.002	0.041 ***	-0.018
	(0.015)	(0.015)	(0.004)	(0.002)	(0.012)	(0.017)
Lag 1	0.004	0.005	-0.291 ***	0.016 *	-0.129 ***	-0.076 ****
	(0.009)	(0.014)	(0.010)	(0.009)	(0.010)	(0.010)
Lag 2	0.015	-0.048 ***	0.046 ***	0.025 ***	-0.053 ***	-0.049 ***
	(0.009)	(0.013)	(0.011)	(0.010)	(0.010)	(0.010)
Lag 3	-0.03 ***	-0.012	0.099 ***	0.022 **	-0.046 ****	-0.039 ***
	(0.009)	(0.013)	(0.011)	(0.010)	(0.010)	(0.010)
Lag 4	-0.022 ***	-0.014	0.076 ***	0.010	-0.052 ***	-0.078 ***
	(0.008)	(0.013)	(0.013)	(0.010)	(0.009)	(0.010)
year	-0.001 ***	0.000 ***	0.000 ***	-0.000	0.000 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
WWI	-0.101 ***	-0.164 ***	-0.012	-0.002	0.134 ***	0.543 ***
	(0.026)	(0.035)	(0.008)	(0.003)	(0.019)	(0.031)
WWII	-0.069 ***	-0.066 ***	-0.009	-0.005 ****	0.213 ***	0.186 ***
	(0.020)	(0.024)	(0.006)	(0.002)	(0.018)	(0.024)
Crimean War	0.006	0.011	-0.011	-0.004	0.012	0.035
	(0.035)	(0.033)	(0.011)	(0.003)	(0.022)	(0.038)
Constant	1.507 ***	0.627 ***	0.305 ***	0.045 **	0.403 ****	-0.099
	(0.189)	(0.197)	(0.055)	(0.018)	(0.128)	(0.210)
Observations	11,288	5,500	10,173	12,969	11,470	9,817
R-squared	0.009	0.010	0.089	0.002	0.033	0.040
Number of ccode	203	111	169	213	190	189

This is a panel regression with fixed effects
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table BI: War-related correlates regressed on determinants of military capacity

VARIABLES	(1) Remaining time spent fighting	(2)	(3) Total remaining time in war	(4)
In negotiation	-20.067 ***	-6.247 ***	10.893 ***	1.970
	(1.872)	(1.834)	(2.085)	(2.112)
Fighting is paused	14.01 ***	10.922 ***	6.456 ***	7.69 ***
	(1.303)	(1.222)	(1.435)	(1.408)
In negotiation * Fighting is paused	4.828	0.314	10.871 ***	6.611 **
	(2.940)	(2.745)	(3.238)	(3.160)
log(day number)		-36.127 ***	-30.638 ***	-38.443 ***
		(0.700)	(0.801)	(0.806)
log(year)	-423,304.58 ***	-374,136.00 ***	-656,806.88 ***	-633,248.91 ***
	(689.808)	(1,040.851)	(1,044.033)	(1,198.496)
A party attained a military victory		-0.158		-4.115
		(5.083)		(5.853)
UN Security Council member		16.258 ***		19.444 ***
		(1.545)		(1.779)
Nuclear Power		145.233 ***		136.177 ***
		(6.851)		(7.889)
One side is a democracy		75.339 ***		80.121 ***
		(2.792)		(3.215)
log(number of allies)		-23.152 ***		-1.928
		(1.195)		(1.376)
Initiating side's CINC index		139.725 ***		4.218
		(6.473)		(7.454)
Target side's CINC index		164.309 ***		32.788 ***
		(8.913)		(10.263)
Constant	3,201,691.582 ***	2,829,952.934 ***	4,968,010.239 ***	4,789,842.799 ***
	(5,216.687)	(7,869.583)	(7,892.374)	(9,061.491)
Observations	36,849	36,849	36,849	36,849
R-squared	0.911	0.923	0.957	0.959
Number of cownum	92	92	92	92

This is a panel regression with fixed effects
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table BII: War-related correlates regressed on the subsequent number of days spent fighting.

PROOFS.

VARIABLES	(1) Remaining time spent fighting		(2) Total remaining time in war	
In negotiation	-832.724	***	-76.608	
	(108.482)		(62.173)	
Fighting is paused	-233.904	***	-404.411	***
	(80.870)		(46.348)	
In negotiation * Fighting is paused	2,011.88	***	762.709	***
	(237.876)		(136.330)	
log(day number)	-14.765	***	-36.086	***
	(4.364)		(2.501)	
log(year)	-403,192.91	***	-632,735.60	***
	(5,479.587)		(3,140.425)	
A party attained a military victory	-3.780		-75.484	***
	(25.463)		(14.593)	
UN Security Council member	15.323	**	2.692	**
	(7.646)		(4.382)	
Nuclear Power	-20.800		53.634	***
	(38.967)		(22.332)	
One side is a democracy	41.912	**	139.879	***
	(18.899)		(10.831)	
log(number of allies)	14.633	*	-22.965	***
	(8.283)		(4.747)	
Initiating side's CINC index	226.178	***	44.976	**
	(31.119)		(17.835)	
Target side's CINC index	17.017		71.666	***
	(41.525)		(23.798)	
Constant	3,049,679.36	***	4,786,059.79	***
	(41,428.826)		(23,743.420)	
Observations	36,849		36,849	
Number of wars	92		92	

This is an IV panel regression with fixed effects
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table BIII: War-related correlates regressed on the subsequent number of days spent fighting.

C1. Proof of Lemma 1.

Proof

I now establish that the payoff from cutting off communication is negative and takes the form described in lemma 1. Suppose that combatant j exercised his option to cut off communication by some time $s \geq 0$. Define strategic $i(\neq j)$'s equilibrium payoff as B_{it}. Since i cannot concede, then his equilibrium payoff simply equals to the present discounted value of when he wins the war—conditional on him winning the war before the surplus is destroyed—minus the costs incurred fighting and exercising effort, namely

$$B_{it} \equiv E_t\left[e^{-r(\tau-t)}\chi(i \text{ wins})\chi(\text{surplus not destroyed}) - \int_t^\tau e^{-r(s-t)}[\kappa_j + \kappa e_{is}]\mathrm{ds}\right] \tag{C1}$$

where $\chi(\cdot)$ is an indicator function. Next, observe that the B_{it} is a function of two independent, Poisson processes, so the Feynam-Kac theorem implies that payoffs satisfy a standard, stochastic differential equation, which is

(C2)

$$rB_{it} = -[\kappa_j + \kappa e_{it}] + \lambda[(1-e_{it}) + (1-\mu_{jt})(1-e_{jt})] \times \underbrace{[0 - B_{it}]}_{\text{Destruction}} + \xi_i \underbrace{[1 - B_{it}]}_{\text{Victory}} + \xi_j \underbrace{[0 - B_{it}]}_{\text{Defeat}} + \dot{B}_{it}.$$

Notice that if j is obstinate, $e_{jt} = 1$ and thus i only faces the risk of surplus destruction when j is strategic. Next, I define $r_t \equiv r + \xi_i + \xi - j + \lambda[(1-e_{it}) + (1-\mu_{jt})(1-e_{jt})]$ and rewrite equation C2 as

$$\kappa_j - \xi_i = -r_t B_{it} + \dot{B}_{it}.$$

If one then multiplies both sides of the equation above by $e^{-\int_s^t r_\tau \mathrm{d}\tau}$, it holds that

$$\frac{\mathrm{d}}{\mathrm{dt}}\left[B_{it}e^{-\int_s^t r_\tau \mathrm{d}\tau}\right] = [\kappa_j - \xi_i]e^{-\int_s^t r_\tau \mathrm{d}\tau}$$

Integrating both sides then implies that

$$B_{it}e^{-\int_s^t r_\tau \mathrm{d}\tau} = \psi + [\kappa_j - \xi_i]\int_s^t e^{-\int_s^\tau r_w \mathrm{d}w}\mathrm{d}\tau$$

As a boundary conditions, as $t \to \infty$, it holds that $e^{-\int_s^t r_\tau \mathrm{d}\tau} \to 0$, so

$$0 = \psi + [\kappa_j - \xi_i]\int_s^\infty e^{-\int_s^\tau r_w \mathrm{d}w}\mathrm{d}\tau$$

This last equation implies that the payoff at time t equals to

$$B_{it} = [\xi_i - \kappa_j] \int_t^{\infty} e^{-\int_t^{\tau} r_s \mathrm{d}s} \mathrm{d}\tau \leq 0.$$

Since combatants fighting while they negotiate are always free to concede immediately and net a payoff of at least $1-\rho(>0)$, strategic combatants strictly prefer keeping communication channels open. The equation above further implies that the i exercise effort if and only if $e_{it} = 1$ solves $\max_{e \in \{0,1\}} -\kappa e - B_{it}\lambda(1-e)$. But note that exercising effort implies a payoff of $-\kappa < 0$, while not exercising effort nets i a payoff proportional to $-B_{it} > 0$: thus, it is strictly optimal to exercise no effort. Next, if one combines both observations above, it holds that $r_t = \bar{r} + \bar{\xi}$, so the expression for B_{it} reduces to

(No communication payoff) $$B_{it} = \frac{\xi_i - \kappa_j}{\bar{r} + \bar{\xi}} = -B_i.$$

This concludes the proof.

□

C2. Proof of Lemma 2.

Proof

Fix some PBE, a time t, and suppose (for contradiction) that $\mu_{it} = 1$ and $\mu_{jt} < 1$ for $i \neq j$. This means that j is obstinate that j is certain that i is obstinate, but the opposite is not true. Combatant j expects to net a payoff of $1-\rho$ provided that he concedes immediately. Otherwise, he expects that j, for certain, never concedes but still faces the same costs of exerting effort, opportunity to win/lose the war, and risk of surplus destruction. This implies that his payoffs are equivalent to cutting off communication i.e., $-B_i \leq 0$. Since $\rho = 1$, then i is better off conceding immediately. This concludes the proof.

□

C3. Proof of lemma 3

Proof In this proof, I establish that if the war continues at time $t > 0$, combatants are not certain that their opponent is obstinate (i.e., $\max_i\{\mu_{it}\} < 0$), and the lines of communication remain open, then combatants concede gradually.

Fix time $t > 0$, a history $h_t = h_0$ (i.e., the surplus and lines of communication remain intact), and $\max_i\{\mu_{it}\} < 0$. I first establish that at each time $t+s$, for $s > 0$, such that $h_{t+s} = h_t$ and for each combatant i, $\mu_{it} < 1$, H_{it} is strictly increasing in s. Suppose, for contradiction, that there exists an $s \geq 0$ and a $\tau > s$ such that $\tau = \sup\{T > s : H_{it+T} = H_{it+s} \text{if } h_{t+s} = h_{t+T} = h_0\} > s$ for some buyer i. In other words, there exist some time after t after which a combatant i does not concede to his opponent j for a strictly positive interval of time conditional on no additional event occuring in the meantime, i.e., the surplus remains the same and no combatant achieves a victory of any sort. Since j is impatient, he strictly prefers to concede at any time $t+s+w$ than time $t+\tau+w$ for any $w \in (0, \tau - s)$ conditional on no event occuring in the meantime.

In turn, this implies that i strictly prefers conceding at time $t+\tau$, conditional on no event occuring from time t to $t+\tau$, than at any time $t+\tau+w$ for any $w \in (0, \tau - s)$. But this implies that if $h_{t+\tau+w} = h_0$ for $w \in (0, \tau - s)$, then $H_{it+\tau+w} = H_{it+s}$. This is a contradiction, because $w > 0$ and I (implicitly) assumed that $H_{it+\tau+w} > H_{it+s}$. Heuristically, this argument establishes that the cumulative probability that i makes a concession must be strictly increasing iff no war-related event arrives.

Next, the establish that if for each combatant i, it holds that $\mu_{it+s} < 1$ and $h_{t+s} = h_0$, then $H_{it+s} = H_{it+s^-} \equiv \lim_{\tau \nearrow s} F_{it+\tau}$. Suppose, for contradiction, that there exists some $s > 0$ such that $h_{t+s} = h_0$ and $\epsilon \equiv F_{it+s} - F_{it+s^-} = (1-\mu_{it+s})[H_{it+s} - H_{it+s^-}] > 0$. Then, for a sufficiently small dt> 0, j strictly prefers demanding ρ at time $t+s-$dt than conceding, because his payoff from conceding is $(1-\rho)$ and the payoff from making demands is greater than L_{t+s} where

$$\text{(C3)} \quad L_{t+s} \equiv \{[\rho\epsilon + (1-\rho)(1-\epsilon)]e^{-\sum_i \xi_i \mathrm{dt}} + (1 - e^{-\xi_i \mathrm{dt}})\}e^{-(r+2\lambda)\mathrm{dt}} - \frac{(\kappa + \kappa_j)\mathrm{dt}}{r + 2\lambda} + o(\mathrm{dt})$$
$$\geq [\rho\epsilon + (1-\rho)(1-\epsilon) - (\kappa + \kappa_j)\mathrm{dt}][1 - (r+2\lambda)\mathrm{dt}] + o(\mathrm{dt})$$

for $\lim_{x \searrow 0} o(x)/x = 0$. The lower bound above calculates the expected payoff from not conceding in the interval $[t+s-\mathrm{dt}, t+s]$ by assuming that the surplus is destroyed at a rate of 2λ (i.e., neither combatant exerts effort to preserve the surplus) but j still incurs the cost of exerting effort. For sufficiently small dt> 0, it holds that $L_{t+s} > 1 - \rho$ and thus j strictly prefers to not concede in the previously mentioned interval. Thus, $H_{jt+s} = H_{jt+s-\mathrm{dt}}$. This is a contradiction the the result showing that H_{it} and H_{jt} are strictly increasing functions of time and thus we conclude that $H_{it+s} = H_{it+s^-}$ for each $s \geq 0$. Since the functions H_{it} are strictly increasing function and continuous from the right, then they admit a derivative $\dot{H}_{it} \gg 0$ for each $t > 0$ such that $H_{it} < 1$. And thus $c_{it} \gg 0$ is well-defined at each time $t > 0$ such that $\max_i\{\mu_{it}\} < 1$. THis concludes the proof.

□

C4. Proof of Lemma 8

Proof In this proof, I derive the ODE that welfare solves and establish that welfare must be strictly negative. First, if one groups terms being multiplied by W_t and terms multiplied by neither W_t or $\dot{W}_t$ on the right-hand side of equation 21, said equation can be re-written as follows

(C4)

$$\begin{aligned}
rW_t &= \dot{W}_t + \sum_i \beta_{-i}(\bar{c}_{it}+\psi_t\Delta_{-i}) - \beta_i[c+\phi B_i(\mu_{it}+\mu_{-it})+\psi_t\Delta_i] - W_t\sum_i \phi\mu_{it}+\bar{c}_{it}+(\lambda+\xi_i+\Delta_{-i})\psi_t \\
&= \dot{W}_t + \sum_i \beta_{-i}(c+\mu_{it}\phi B_{-i}+\psi_t\Delta_{-i}) - \beta_i[c+\phi B_i(\mu_{it}+\mu_{-it})+\psi_t\Delta_i] - W_t\sum_i \phi\mu_{it}+\bar{c}_{it}+(\lambda+\xi_i+\Delta_{-i})\psi_t \\
&= \dot{W}_t + \sum_i \beta_{-i}\mu_{it}\phi B_{-i} - \beta_i\phi B_i(\mu_{it}+\mu_{-it}) - W_t\sum_i \phi\mu_{it}+\bar{c}_{it}+(\lambda+\xi_i+\Delta_{-i})\psi_t \\
&= \dot{W}_t + \sum_i \beta_{-i}\mu_{it}\phi B_{-i} - \beta_{-i}\phi B_{-i}(\mu_{it}+\mu_{-it}) - W_t\sum_i \phi\mu_{it}+\bar{c}_{it}+(\lambda+\xi_i+\Delta_{-i})\psi_t \\
&= \dot{W}_t - \sum_i \beta_i\phi B_i\mu_{it} - W_t\sum_i \phi\mu_{it}+\bar{c}_{it}+(\lambda+\xi_i+\Delta_{-i})\psi_t \\
&= \dot{W}_t - \sum_i \beta_i\phi B_i\mu_{it} - W_t\sum_i \phi+\psi_t(\xi_i-\lambda)+\bar{c}_{it}-\phi(1-\mu_{it})+(2\lambda+\Delta_i)\psi_t \\
&= \dot{W}_t - \sum_i \beta_i\phi B_i\mu_{it} - W_t\sum_i \phi+\psi_t(\xi_i-\lambda)+\frac{\dot{\mu}_{it}}{\mu_{it}}
\end{aligned}$$

The second line of the equation above simply re-writes the term $\bar{c}_{it}$ and the third line cancels out the terms Δ_i and c from the middle summation. The third line then cancels out the flow cost c term from the same summation, while the fourth line regroups terms. The fifth line then cancels out the term $\beta_{-i}\mu_{it}\phi B_{-i}$ from the middle summation, while the sixth and seventh line re-write the summation multiplies times the term W_t in a more analytically tractable fashion.

Next, I multiply both sides of the equation above by $e^{(r+\phi)t+(\xi_i-\lambda)\int_0^t\psi_s\mathrm{ds}}/\mu_{it}\mu_{jt}$ and re-arrange terms to get

$$\phi e^{(r+\phi)t+(\xi_i-\lambda)\int_0^t\psi_s\mathrm{ds}}\sum_i\frac{\beta_iB_i}{\mu_{-it}} = \frac{\mathrm{d}}{\mathrm{dt}}\left[\phi W_t e^{(r+\phi)t+(\xi_i-\lambda)\int_0^t\psi_s\mathrm{ds}}\sum_i\frac{\beta_iB_i}{\mu_{-it}}\right]. \tag{C5}$$

Integrating both sides of the equation above by time, it then holds that

$$\phi W_t e^{(r+\phi)t+(\xi_i-\lambda)\int_0^t\psi_s\mathrm{ds}}\sum_i\frac{\beta_iB_i}{\mu_{-it}} = \aleph + \phi\int_0^t e^{(r+\phi)s+(\xi_i-\lambda)\int_0^s\psi_s\mathrm{ds}}\sum_i\frac{\beta_iB_i}{\mu_{-is}}\mathrm{ds} \tag{C6}$$

where $\aleph$ is a constant. Next, at time T, I claim that W_t becomes constant—i.e., $\dot{W}_t = 0$—and it is clear that no concession arrives since both combatants are known to be obstinate, hence equation 21 implies that

(C7)

$$rW_T = \overbrace{\phi\sum_i[-(B_{-i}\beta_{-i}+B_i\beta_i)-W_T]}^{\text{Communication loss}} - \overbrace{\sum_i\beta_i[c+\psi_T\kappa_{-i}]}^{\text{Costs}} + \overbrace{\sum_i\lambda\psi_T[0-W_t]}^{\text{Destruction}} + \overbrace{\psi_T\sum_i\xi_i[\beta_i-W_T]}^{\text{Military outcome}}$$

It is then without loss of generality to assume that at times $t \geq T, \psi_t = \psi_T$ i.e., the optimal policy should be fixed yielding that

$$W_T = -\min\left\{\frac{2\big[c+\phi\sum_i \beta_i B_i\big]}{r+2\phi}, \frac{2\big[c+\phi\sum_i \beta_i B_i\big]+\sum_i \Delta_i}{\bar{r}+2\phi+\bar{\xi}}\right\}$$

Plugging this observation into equation 13, it holds that

$$\aleph \leq \phi W_T e^{(r+\phi)T+(\xi_i-\lambda)\int_0^t \psi_s \mathrm{ds}} \sum_i \beta_i B_i - \phi \int_0^T e^{(r+\phi)s+(\xi_i-\lambda)\int_0^s \psi_s \mathrm{ds}} \sum_i \frac{\beta_i B_i}{\mu_{-is}} \mathrm{ds}$$

and if one plugs this observation back into equation 13, it further implies that

$$W_t \leq W_T e^{(r+\phi)(T-t)+(\xi_i-\lambda)\int_t^T \psi_s \mathrm{ds}} \frac{\sum_i \beta_i B_i}{\sum_i \frac{\beta_i B_i}{\mu_{-it}}} - \int_t^T e^{(r+\phi)(s-t)+(\xi_i-\lambda)\int_t^s \psi_s \mathrm{ds}} \frac{\sum_i \frac{\beta_i B_i}{\mu_{-is}}}{\sum_i \frac{\beta_i B_i}{\mu_{-it}}} \mathrm{ds} \tag{C8}$$

It is consequently clear that for each $t \geq 0$ such that $h_t = h_0, W_t < 0$. This concludes the proof.
$\square$