Mutual Optimism and Costly Conflict: The Case of Naval Battles in the Age of Sail

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Abstract

Mutual optimism theory holds that mutually optimistic beliefs about outcomes cause international conflict. Because beliefs are unobservable, this theory is difficult to test systematically. Here, I present a clean test of theory that relies exclusively on observable variables by exploiting novel features of naval battles in the age of sail, most notably an admiral's ability to avoid battle by simply sailing away. Using a formal model, I show that the outcome of mutual naval battles, where either side could avoid battle by sailing away, should not be predictable from observable capability indicators. The outcome of unilateral battles, where only one side could sail away to avoid fighting, should be predictable from these same indicators. I test these predictions against all squadron-level British naval battles from 1650 to 1833. I show that observable strength indicators are substantially less predictive in mutual battles, confirming the core key theoretical prediction.

Keywords: mutual optimism, causes of war, naval warfare, information, conflict
Short Title: Mutual Optimism and Costly Conflict

Supplementary materials providing details of the game theoretic and statistical analyses are available in an online appendix. Data and supporting materials necessary to reproduce the results in this article are available in the *JOP* Dataverse.

1 Introduction

Blainey (1973) famously argued that "wars usually begin when two nations disagree on their relative strength." Over the last forty years, this insight has become one of the most important explanations for war in the international relations literature. An early wave of scholarship focused on disagreement resulting from misperception (Betts, 1982; Levy, 1983; Jervis, 1988), but Fearon (1995) argued that states could rationally disagree about their relative strength as the result of private information. This rational optimism argument, and related informational arguments, have proven theoretically fruitful, serving as one of main avenues for theoretical development in the literature on the causes of war (Reiter, 2003; Slantchev and Tarar, 2011), but empirical testing has lagged far behind.

Scholars have long recognized the difficulties in testing informational theories of war such as mutual optimism. Beliefs serve as the core independent variable in these theories but are not directly observable. Rational theories, in particular, focus on the role of *private* information, which is inherently unavailable to outsiders, making the use of publicly available data as proxies deeply problematic (Gartzke, 1999). The study of declassified documents and archival sources after the fact can address some of these issues, but even with full access to archives, the relevant variables remain extremely difficult to measure. For example, despite nearly a century of intensive historical research, there is no consensus on whether the German leadership in 1914 believed that it would win a swift, decisive victory on the Western Front (Lieber, 2007). Further complicating the issue, an adequate test of a theory of conflict initiation requires belief measures in cases that end without war, where both the archival and secondary record tend to be much thinner.

In this paper, I offer a test that circumvents many of these difficulties and allows us to gain empirical leverage on key propositions in the optimism theory of conflict while differentiating between rational and irrational optimism. Existing empirical work focuses on conflict initiation as its dependent variable (see Bas and Schub (2017) for a review), but the the optimism theory implies a specific selection mechanism that also holds important empirical implications for conflict outcomes. These implications for outcomes can be tested without attempting to measure beliefs. In this paper, I focus on conducting such a test.

I begin by deriving empirical implications about conflict outcomes in a canonical war bargaining model. I show that the outcome of conflicts resulting from rational optimism should be unpredictable in a particular way. Unfortunately, a series of measurement issues prevent testing this prediction directly on data about wars, so I examine a specific strategic setting that circumvents these difficulties – namely the case of naval battles in the age of sail. These naval battles possess the following essential features: the effective choices for each side were to fight or sail away in an attempt to avoid battle; attempting to avoid battle did not involve prohibitively high costs in an identifiable set of cases; and the success of such attempts was stochastic.

I present a simple formal model which clarifies the assumptions and predictions in the naval context. Of these predictions, the most important holds that there should be *no* correlation between between observable capability indicators and the probability of victory in "mutual" naval battles (i.e., battles where each side chose to fight and did not attempt to avoid battle). A second hypothesis holds that there should be a strong, positive correlation between observable capability indicators and the probability of victory in "unilateral" battles (i.e., battles where one side could be forced to fight even if it wished to avoid battle). While intuitive, this second hypothesis allows me to rule out counter-explanations for a finding that there is no relationship between observable capabilities and outcomes in the mutual battles. I test these hypotheses and find strong support for the theory, showing that observable capability indicators have essentially no predictive power in explaining the outcome of mutual battles but are strongly predictive of the outcome in unilateral battles.

Beyond demonstrating that mutual optimism is a relevant cause of armed conflict, these results show that the mutual optimism theory of conflict remains a progressive research program, capable of predicting new facts. By expanding the empirical scope of the optimism theory of conflict, I also aim to address the prominent criticism that studies of interstate conflict focus on "excessive reanalysis of a small number of datasets" (Schrodt, 2014). Given the intensity with which scholars have studied the small number of interstate wars, bringing in new data suitable for studying theories of conflict holds substantial empirical promise.

2 Optimism and Conflict Initiation

Observational tests of the role of beliefs in conflict initiation face a series of severe impediments. In an effort to overcome some of these issues, a number of scholars have attempted to measure the effect of uncertainty, rather than specifically optimistic beliefs, on conflict. This approach sidesteps the necessity of specifically measuring private information. Using dyadic military parity as a proxy for higher uncertainty, Reed (2003) finds a positive association between uncertainty and war onset while Slantchev (2004) finds that higher uncertainty is associated with increased war duration. On the other hand, Bas and Schub (2014) develop a measure of uncertainty focused on the global, rather than bilateral, balance of military power and find that increased uncertainty reduces the probability of conflict. While these represent some of the best efforts to test informational theories of war, their results do not speak directly to the role played by optimism, which is theoretically and empirically distinct from uncertainty.[1]

An alternative strategy, which allows a measure of optimism specifically, is to directly measure certain forms of private information after the fact. Bas and Schub (2016) focus on secret alliances, arguing that such alliances will lead to divergent estimates of the balance of power, and show that secret alliances are associated with conflict onset. Similarly, Lai (2004) examines secret mobilization for war and finds that crises are more likely to end in war when states mobilize military resources secretly. While these are important results, it is not necessarily true that secret alliances or mobilization tend to be associated with optimism or that optimism is the mechanism linking these to war. More importantly, such tests that explore conflict onset without assessing conflict outcomes cannot address important questions about whether the underlying beliefs are reasonable. That is, these tests can not assess whether optimism is rational or irrational.

Naturally, scholars can also test parts of the mutual optimism theory by directly manipulating information in a laboratory setting. Tingley and Wang (2010) and Quek (2015), for example, attempt to test aspects of the theory using experiments. While such experiments can provide important insight, they suffer from several shortcomings. In addition to the standard concerns about external validity, experiments that directly manipulate beliefs sidestep questions about the ways that national leaders form beliefs and perceive the military balance. The nature of this process has fundamental implications for the way that we interpret the meaning of the theoretical models (Kirshner, 2000; Smith and Stam, 2004). By imposing optimism in the lab, scholars can examine whether it leads to conflict, but they cannot determine whether national officials form optimistic

[1] Optimism, unlike uncertainty, is directional. That is, under higher (rational) uncertainty, some actors will be overly optimistic but others will be overly pessimistic.

beliefs as a rational response to empirically-relevant private information.

3 Optimism and Outcomes

While the difficulties of measuring beliefs make it difficult to directly test the predictions of mutual optimism for conflict onset, the theory also has important implications for conflict outcomes. These can be tested, in principle, *without* any attempt to measure private information. Take the now standard model of ultimatum crisis bargaining with uncertainty as given in Slantchev and Tarar (2011). One state, S, makes a take-it-or-leave-it offer to a second state, D, for division of some good. If D accepts the offer, it is implemented. If D rejects the offer, a war occurs and the outcome of this conflict depends on D's type. D is either "strong" (wins with probability p_s) or "weak" (wins with probability $p_w < p_s$). D's type is private information, and S only observes the common knowledge prior probability that D is strong, q.

Following the standard results, Slantchev and Tarar show that, for sufficiently high q, S makes an offer that D always accepts. For lower values of q, S makes a "risky" offer that D accepts when weak but rejects when strong. Thus, war *only* occurs when the observable information indicated D was likely to be weak, but D was actually strong. Predicting conflict initiation in this setting, therefore, requires a measure of D's private information about its type. Given the "risky" offer, conflict occurs if and only if the private information shows D is strong.

Consider instead the issue of predicting conflict outcomes from the observable information. Within the framework of the model, q – the probability that D is strong – is common knowledge and should be observable to an outside analyst, but D's type (strong or weak) is not. Empirically, this q term might vary as the result of any of a number of measurable variables, such as military spending, CINC scores, or regime type. In equilibrium, D only fights when it is strong *regardless of how likely this appeared to be on the basis of observable factors.* Thus, if conflict is the result of optimism, changes in q (the probability D is strong) should have *no* relationship to observed outcomes. Even if q is measured perfectly, it will not be related to the outcome because *only* strong types fight. This is the selection mechanism at the core of the *rational* optimism theory. That is, apparently "weak" types only fight when they hold a private advantage of some kind that offsets their apparent weakness.

On the other hand, imagine an otherwise identical setting in which the two sides fight for some reason other than rational optimism. For the sake of argument, suppose that some mechanism (e.g., a commitment problem) operates to preclude a peaceful settlement, so that D will fight whether weak or strong. In this case, if q can be measured perfectly, it should be perfectly correlated with the outcome. Absent the offsetting selection effect implied by the rational mutual optimism mechanism, public evidence suggesting that D is more likely to be strong indicates a higher probability that D will actually be strong when conflict occurs. The same correlation will emerge if D is irrational – either in the sense that D fails to play a best response to its own beliefs or in the sense that D fails to accurately perceive its own type – here, D will fail to condition on the *actual* state of world and conflict will occur both when D is actually strong and when D is actually weak. Public information reflecting an increased probability of strength will then indicate that D is actually more likely to be strong.

In short, the mutual optimism theory holds an important, counterintuitive theoretical implication for outcomes. Rational optimism posits a specific selection mechanism that will reduce or remove the relationship between a player's apparent type (i.e., the common knowledge prior probability a player is "strong" based on observable factors) and actual type (i.e., private information about whether a player is "strong") in the set of cases where conflict takes place. Notably, testing this implication does not require any measure of private beliefs. Instead, it is sufficient to measure publicly observable strength indicators and publicly observed outcomes.[2] At first blush, this would seem to recommend a straightforward analysis – regress standard observable indicators against war outcomes and interpret a *lack* of correlation as evidence in favor of rational optimism. In fact, Caroll and Kenkel (2017) find that standard capability measures are "barely better than random guessing at predicting militarized dispute outcomes," apparently confirming this prediction.[3] Unfortunately, this finding can not be directly interpreted as support for the optimism mechanism.

First, a lack of association between observable indicators and outcomes could indicate the operation of the mutual optimism mechanism, but it might simply represent measurement error

[2]Strictly speaking, q is S's belief about D's type but it is also common knowledge, thus (theoretically) observable. The fact that this is also S's belief is an artifact of using one-sided incomplete information. Under a more empirically realistic assumption of two-sided incomplete information, S's belief would not be the same as that of an outside analyst. This can seen clearly in the model below.

[3]Caroll and Kenkel develop a dramatically improved measure of capabilities, but even this explains only 20% of the variation in dispute outcomes.

on the observables. Available measures like CINC or military spending are extraordinarily crude proxies for the underlying concepts – they might fail to predict outcomes simply because they are too noisy. This leaves a theoretical Catch-22: the only way to validate that an observable variable measures power appropriately is to show that it *can* predict outcomes, but finding that an observable variable can predict outcomes itself falsifies the prediction of the optimism theory.

In principle, there is a solution to this problem. If some subset of conflicts are identifiably *not* caused by mutual optimism, then it should be possible to validate a measure of observable capabilities on this subset. After validation, this measure could be used in a test on the remaining cases. Unfortunately, there is no clear way to empirically identify wars *not* caused by mutual optimism and an attempt to do so would pose a significant historiographical challenge. I will show below that naval battles overcome this problem by allowing the clear identification of a set of conflicts not caused by mutual optimism.

A second challenge arises from the difficulties of establishing what bargain D rejected in order to fight. That is, if D rejected a fifty-fifty split in order to fight, then this implies that D's private information about its probability of victory satisfied $p > 0.5 + c_D$, regardless of how likely this appeared in advance (the relevant unpredictability). Comparing across cases where a fifty-fifty split was offered, observable capability measures should predict nothing. On other other hand, if D rejected an eighty-twenty split in order to fight, then this implies that the probability of victory satisfied $p > 0.8 + c_D$, regardless of how likely this appeared in advance (again the relevant unpredictability). Comparing across cases where *different* bargains were rejected, the relevant baseline for rational optimism changes. Once these cases are pooled together, there will be a correlation between observable capability indicators and outcomes. While observable indicators should predict nothing among matched cases, they should also track the bargain offered. States with higher observable capabilities will be offered better bargains and will reject these when they are "strong" in the sense of *exceeding* that high baseline. States with lower observable capabilities will be offered worse bargains and will reject these only when they are "strong" in the sense of exceeding that low baseline. Thus, the selection effect will attenuate, but not eliminate, the correlation when we fail to control for the shifting baseline.

In principle, the shifting baseline problem could be resolved by measuring and precisely controlling for all of the relevant variables – that is, if the model has been specified correctly and the states play equilibrium strategies, then the bargain offered ought to depend only on the parameters of model. If these can be measured, then the equilibrium bargain can be deduced. In the model above, this essentially amounts to the ability to measure and control for the p_s and p_w terms, which is empirically and conceptually problematic. In practice, this approach requires unreasonably accurate measurement and fairly strong assumptions about the structure of the interaction. It is necessary, then, to find some other way of holding constant the alternative to conflict. I will show below that naval battles overcome this problem by allowing the clear identification of an essentially fixed alternative to conflict.

4 Mutual Optimism and Naval Battles

In the test presented here, I use specific features of naval battles in the age of sail to provide a test of the central predictions of the rational optimism theory for conflict outcomes. The essential logic of the test follows that developed in the Slantchev and Tarar model, but naval battles allow me to circumvent the difficulties sketched above. First, I show that naval battles can be cleanly divided into "unilateral" battles (where fighting would occur if *one* side wished to fight) and "mutual" battles (where fighting would occur only if *both* sides wished to fight). This allows for the validation of a capability measure against the unilateral battles, where mutual optimism was not required for conflict. Second, I show that, in the mutual battles, the next best alternative to conflict was for an admiral to simply sail away; this allows me to clearly identify the relevant baseline for judging optimism, overcoming the second problem above.

I will develop a formal model grounded specifically in the case of naval battles, but it follows the basic contours of the one above. There are two significant divergences – first, in the interest of realism, I build a model with two-sided incomplete information. Second, in the Slantchev and Tarar model, the alternative to conflict is a bargained settlement; in naval warfare, the alternative to conflict is for an admiral to sail away. There is a theoretically meaningful difference between these possibilities. By definition, a bargain must be acceptable to both parties, so it must be better for *both* sides than fighting would be. On the other hand, sailing away is a unilateral action that need not be mutually acceptable, so sailing away might allow one side to impose an outcome on the other that it is worse for it (in expectation) than fighting would be. Thus, the model here lies within the optimism tradition but outside the narrow bargaining tradition.

The core intuition is the same. Consider a case where two sides can either fight or sail away. Suppose that one side has an advantage in the observable balance of power. Given this, the observably advantaged side's opponent will only choose to fight if she holds private information that she is, in fact, stronger than the observable indicators suggest; otherwise, she would run away. Because mutual conflict requires that both the observably weaker and the the observably stronger side choose to fight, conflict will only occur in those cases where the observable balance of power does not accurately represent the true balance of power. That is, in the absence of private information *contradicting* the observable balance, the observably weaker side would always sail away. Thus, as in the simple model above, the outcome of conflicts that come from mutual optimism should not be predictable from the observables. The difference as compared to bargaining is that the outside option is fixed, so optimism occurs relative to a fixed, rather than a variable, baseline.[4]

The formal model developed below depends on several important assumptions, which I argue are satisfied in the context of naval battles in the age of sail. First, I assume that there were effectively two choices in a naval interaction: each side could either fight or withdraw (sail away). Second, I assume that we can reasonably model the utility of a given naval battle as the level of an opponents' losses less the level of one's own losses. Third, I require one out of a set of assumptions about the relative payoff for, and likelihood of, successfully fleeing when compared to fighting in the case of mutual battles. The basic predictions hold under a general condition that the probability of a given player winning a chase is not too extreme and that the cost of withdrawing is not too large relative to the cost of fighting. I will argue here that the cost of withdrawing was effectively zero in mutual battles, which is a stronger claim than actually required. Beyond supporting these assumptions, the evidence presented here also supports the equilibrium strategies of the model,

[4] Fey and Ramsay (2007) study a related class of models and identify an important divergence between bargaining models and models where unilateral actions prevent conflict. In the class of models they study, Fey and Ramsay allow either party to take an action that certainly avoids war and imposes an outcome on the opponent that may be worse than war (i.e., imposes an outcome that the opponent would not accept through bargaining – see Slantchev and Tarar (2011)). Under this unilateral peace assumption, Fey and Ramsay find that war *never* occurs through mutual optimism. They point out that, given its awareness of the opponent's strategic selection process, even the apparently stronger side should not be willing to fight (because the opponent's failure to impose unilateral peace implies that it is stronger than the observables indicate). Because one side should only be willing to fight when the other is not, the possibility of conflict unravels. An essential assumption here is that one side can impose peace with *certainty*, despite the opponent's desire to prevent this action. While this might apply to some substantive peace-imposing actions, it certainly does not apply to running away. That is, a side can always attempt to run away, but the opponent might be able to chase after and catch the fleeing party. For this reason, conflict does occur in the model developed below unlike the Fey and Ramsay model.

discussed below. That is, naval doctrine corresponds to the basic “fight only if you believe you are stronger than your opponent” strategy that forms the model’s equilibrium. Finally, I assume that an identifiable set of naval battles were unilateral (i.e., only one side had the effective choice about whether or not to fight and could impose conflict on its opponent) and describe the difference below.

The first assumption amounts to the claim that for any beliefs, either fighting or fleeing was superior to any other option. Of course, an admiral could simply surrender, but this was undoubtedly inferior to attempting flight if he had any reasonable chance of success. Even if a fleet was trapped, surrender was worse than anything other than total defeat. On a few occasions, fleets that were dramatically outnumbered and had no realistic chance of escape did surrender without firing a shot (Ralfe, 2010, p. 112), but these are rare exceptions and incorporating this possibility into the model would not change the conclusions. In theory, it might also have been possible for the two sides to make some sort of explicit bargain – a weaker fleet might offer to surrender a few of its ships to a stronger fleet in return for being allowed to sail away with the remainder – but any such bargain would have been inherently unenforceable (i.e., nothing would prevent the stronger side from simply attacking immediately after the transaction). Thus, modeling a fight or flight choice is reasonable.

The second assumption concerns the players’ utilities. I assume that an admiral’s utility for a given battle was determined by the capture or destruction of his opponent’s ships. From a broader strategic perspective, the goal was not capture or destruction *per se*. Rather, leaders hoped to achieve either global or local “command of the sea,” but classical naval theorists agreed that the capture or destruction of the enemy’s ships in battle was the way to achieve this goal (Vego, 2016, pp. 81-82). The utility function in the model can be derived in one of two ways: either by assuming that admirals received higher utility from winning larger battles or that their utility was proportional to the *absolute* margin of victory. These assumptions contrast with alternative ones positing either that the relative margin of victory was the source of utility or that there was a constant payoff to winning. The shortcomings of these alternatives are fairly clear. The most celebrated (and rewarded) naval victories rarely involved capturing or destroying an overwhelming proportion of the opponent’s force. Even at Trafalgar, Nelson sunk or captured only about half of his opponents, while on the “Glorious” First of June, Howe sunk or captured only a quarter of his. Under a relative margin of victory concept, we would assume that the payoffs to these battles were lower than those for a single-ship encounter where a captain took his lone adversary. To the contrary, admirals who won larger battles or by larger margins could anticipate significant rewards, perhaps even a knighthood, viscountcy, or earldom. Moreover, national authorities explicitly attempted to create an incentive structure that was roughly linear in the absolute margin of victory. Nearly all navies of the period paid prize or bounty money for captured (and any many cases sunk) enemy ships; generally, this money was proportional either to the number of men or guns on a ship or to its resale value, all of which are strongly correlated with combat strength. The amount of money involved for an admiral could be quite substantial, perhaps many years pay (Pope, 1987, pp. 231-235).

Modeling a margin of victory differs somewhat from the dichotomous (complete victory or complete defeat) outcomes posited by simple war models, such as the one given above. It is, however, easily analogized to the set of richer war models that allow intermediate outcomes – that is, a larger margin of victory in the naval context is equivalent to getting more of the disputed good in a standard bargaining model. Some intermediate margin of victory in a naval battle is, for example, equivalent to terminating a war (for whatever reason) after conquering some, but not all, of a disputed piece of territory.

The third required assumption concerns the cost of battle, the likelihood of successfully fleeing, and the payoff to fleeing. I will begin with the cost of battle – it is not strictly necessary to assume a cost but assuming some non-zero cost relaxes the necessary assumption on the payoff to withdrawing, and battles certainly were costly for the admirals who chose them, not least because of the substantial personal risk of death. From 1650 to 1805, 37 admirals in the British, French, Dutch, and Spanish services died as the result of wounds received in battle, including such notable cases as Nelson's death in his great victory at Trafalgar (*The Naval Chronicle for 1806*, 1806, p. 408-412). Thus, battle was costly for those who chose it.

This leaves the issue of avoiding battle by sailing away. Here, the relevant assumption is that, absent countervailing strategic factors described below, an admiral's decision to sail away from battle came at a low cost. Here, there is an important difference between land and naval warfare. In land warfare, withdrawing to avoid battle often (although not always) involves the sacrifice of valuable territory or resources. For example, Clausewitz, while famously declaring that "no battle can take place unless by mutual consent" maintains that in modern land warfare the defender cannot decline battle without "giving up his position, and the role with which that position was connected [which] is half a victory for the offensive side" (von Clausewitz, 1873, p. 140). That is, in conventional land warfare, retreat is generally costly.

Classical naval theorists emphasize that naval warfare is different. At its core, the difference arises from the fact that "you cannot conquer sea because it is not susceptible to ownership" (Corbett, 2004, p. 89). Because sea space is of no inherent value (although it might become valuable through some external strategic calculus), Corbett, a pre-eminent British theorist, argues that the primary question facing an inferior force is "not how to sell your life dearly, but how to maintain the fleet actively on the defensive so as to deny the enemy the decision he sought" (Corbett, 2004, p. 166). This focus on avoiding action differs from the case on land, where the inferior side's optimal strategy involves "the holding of positions and forcing [the] superior enemy to exhaust his strength in attacking them" (Corbett, 2004, p. 213). The essential difference here, while necessarily stylized, is that weaker sides will often want to fight on land – because fleeing gives up objects of valuable and sacrifices prepared positions (thereby further reducing the odds of victory) – but rarely want to fight at sea. Thus, at sea, a weaker fleet will focus on "avoiding decisive action by strategical or tactical activity" (Corbett, 2004, p. 213).[5]

Period naval doctrine emphasizes this calculus. The English "Fighting Instructions" first issued in 1650, ordered subordinate commanders of the fleet "not to engage if the enemy's ships exceed them in number except [if] it shall appear to them on the place that they have the advantage" (Corbett, 1905, p. 88); the same language carries over into subsequent iterations (Corbett, 1905, pp. 122, 153). Informal incentives were roughly the same. In the mid-eighteenth century, for example, Captain Savage Mostyn received a letter (evidently "written in fun") criticizing his decision his decision to avoid a battle while outnumbered (Motooka, 2013, pp. 7-8). Mostyn demanded a court martial to clear his name, and the court found that Mosytn was "so far from deserving any blame, that the Court are unanimously of [the] opinion, that he did his duty as an experienced good officer,

[5]Within the context of the war initiation literature, many land battles can be understood as resulting from a commitment problem. Prepared positions confer a dramatic advantage on the defender. A common rule of thumb among military strategists holds that an attacker needs a 3:1 margin of local superiority in order to break through prepared defenses (Mearsheimer, 1989). By abandoning its prepared position through retreat, a defender sacrifices this advantage, generating a very large (effectively threefold) and nearly instantaneous shift in the balance of power, rendering any implicit or explicit conflict-avoiding bargain infeasible (Powell, 2006). If the seized position is itself the principal object of the dispute, circumstances are even more severe. In this case, the result of retreat is effectively a ninefold shift in the balance of power in that the (initial) attacker will have the opportunity to fortify the position, obtaining the 3:1 advantage for itself.

and as a man of courage and conduct" (*Minutes of A Court-Martial Held on Board His Majesty's Ship Lennox in Portsmouth Harbor*, 1745, pp. 24-25). Similarly, Admiral William Cornwallis was unanimously voted the the thanks of Parliament for successfully maneuvering his outnumbered squadron to avoid battle with the French under difficult circumstances in 1795 (Clowes, 1899, pp. 257-260).

For other navies in the period, the incentive structures were similar. No national government wished to throw away its naval strength in an ill-chosen battle. Nicholas Tracy writes that the French Navy, "developed a strategic modus operandi which largely sought to avoid battle unless the odds were very much in their favor" (Tracy, 1996, p. 25). The French Admiral Grivel, argued that the side with "the fewest ships must always avoid doubtful engagements; it must run only those risks necessary for carrying out its missions, avoid action by maneuvering, or at worst, if forced to engage, assure itself of favorable conditions" (Mahan, 2003, p. 289). Peter the Great, of Russia, "ordered his commanders to avoid battle unless they had a one-third superiority of force" (Mitchell, 1974, p. 28), while Glete (2004, p. 78) notes that Danish admirals were generally "instructed to avoid combat unless they were superior in strength ... [because] the Danish-Norwegian monarchy could not afford a serious defeat at sea." Of the period in general, Sam Willis writes: "It was rare indeed for two ships or fleets to meet and both be intent on action, and usually the aggressive party in some way had to force action on his enemy" (Willis, 2008, p. 27).

This leaves only the final assumption to discuss – that success in a chase was stochastic and that the odds of successful pursuit were not too skewed. Because all navies used roughly the same technology during the period studied, differences in speed between fleets were never too great. Even successful chases often lasted several days and covered hundreds of miles (Willis, 2008, p. 38), so that changing circumstances made the outcomes difficult to predict in advance. Even a rare fleet much slower than its opponent could always hope for a shift in the weather to save it, such that, as Willis (2008, p. 37) writes, "the escaping or chasing ship, however outclassed, therefore always had a chance of success." This possibility of successfully fleeing over open water separates naval warfare in the age of sail from the earlier galley period during which range limitations made fleeing nearly impossible. Similar range limitations limit the applicability to coal-powered steamships, while the eventual development of naval aviation made it impossible for ships to flee from aircraft. Moreover, given the importance of weather to outcomes, the stochastic component of chase in the age of sail is larger than in early or later periods. For this reason, I focus specifically here on the age of sail, rather than naval warfare writ large.

While flight was generally costless and likely, though not certain, to succeed, a variety of identifiable cases occur in which flight was either impossible or very costly. First, and most obviously, flight was sometimes physically impossible because a fleet was physically trapped – most notably when it confronted a lee shore or was at anchor. Such circumstances give rise to what I label a "unilateral" battle in that the side that was trapped could be forced to fight by its opponent, not out of optimism, but merely because it had no alternative. Similar circumstances arose when admirals received explicit orders to fight whatever the odds in pursuit of some broader strategic objective. Finally, admirals could not simply flee when the naval squadron was escorting a valuable convoy that would be lost to the enemy in the event of flight. In theses cases, the naval squadron was generally expected to sacrifice itself in order to allow the convoy time to escape. For example, the Articles of War governing the Royal Navy imposed criminal penalties, up to and including execution, on "the officers and seamen of all ships appointed for convoy and guard of merchant ships ... [for] refusing or neglecting to fight in their defense" (Delafons, 1805, p. 353). In the empirical analysis below, the existence of these unilateral battles will be crucial to the results.

4.1 A Formal Model of Naval Battle

The model developed here includes two actors, each of whom has some strength, s_i. Public information is represented as common priors about these strengths. I assume that the public information about each side can be modeled as some continuous probability density function f_i with expectation $E(s_i)$ and support on $[0, \infty)$. I further assume that each player pays a cost of battle c_i if fighting occurs and a cost of retreat r_i if it chooses to withdraw.

As discussed, I argue that an admiral's utility for a naval outcome is best approximated by the number and strength of enemy ships sunk or taken less his own losses. In modeling the relationship between outcomes and capabilities, I use the standard ratio form contest success function (Skaperdas, 1996) and assume that a side captures each "unit" of its opponents capability (one can think of this as one ship though the assumption is more general) with probability $\frac{s_i}{s_i+s_{-i}}$. Under complete information, Player 1's expected utility for a given battle would be the expected capability remaining to him $s_1 - \frac{s_2}{s_1+s_2} * s_1$, less the expected capability remaining to his opponent, $s_2 - \frac{s_1}{s_1+s_2} * s_2$, less the cost of fighting. That is, $s_1 - \frac{s_2}{s_1+s_2} * s_1 - (s_2 - \frac{s_1}{s_1+s_2} * s_2) - c = s_1 - s_2 - c_1$.

Given these assumptions about the beliefs and payoffs, I turn to the structure of the game. I present two variants, and the difference between these is the essence of the results. In the first variant, I model "mutual" battles and assume that each side simultaneously chooses to fight or withdraw. If both sides choose to fight, then a battle occurs with certainty. If both sides choose to withdraw, then no battle occurs. If, however, one side chooses to fight while the other side chooses to withdraw, then a chase occurs and Player 1 wins the chase with probability w, which roughly captures the relative speed of the two fleets (i.e., if Player 1 pursues, then battle occurs as the result of a chase with probability w, while if Player 1 flees then battle occurs with probability $1 - w$). Given this, we can solve for the equilibrium of the game. The solution concept adopted here is Bayesian Nash equilibrium.[6] The second variant models "unilateral" battles. Here, I assume that only one side has the option to avoid conflict because the other side is physically trapped, under orders, or escorting a convoy. In this case, because there is only one actor making a choice, the model is purely decision theoretic.

An equilibrium for this game will take the form of a pair of thresholds t_1, t_2 such that each player fights if and only if his strength is greater than the appropriate threshold (or a single threshold in the unilateral variant). At the threshold, each player will be indifferent between fighting and withdrawing. These are derived mathematically in the supplemental information and presented in the propositions below.

Proposition 1: In the unique Bayesian Nash equilibrium of the game where either player may withdraw, Player 1 fights if $s_1 > c_1 + E(s_2) - r_1/w$ and withdraws otherwise. Player 2 fights if $s_2 > E(s_1) + c_2 - r_2/(1 - w)$ and withdraws otherwise.

Proposition 2: When only Player 1 has the option to withdraw, Player 1 fights if $s_1 > c_1 + E(s_2) - r_1$ and withdraws otherwise.

The features of this equilibrium are straightforward and unsurprising: each player sets a higher threshold when it expects its opponent to be stronger or when the cost of battle is higher, and sets a lower threshold when the cost of retreat is higher. Given small costs of battle and retreat (as argued on a historical basis above), the optimal strategy can be roughly stated as: fight only if you

[6]The simultaneous, one-shot moves here may strike readers as unrealistic, but because I have assumed no particular distributional form to the prior beliefs, these could easily be the posterior beliefs generated by earlier interaction; that is, the model here can be thought of as the terminal move of some longer game.

believe you are stronger than your opponent is, or, equivalently, fight only if you believe you are more likely than not to win. As noted, this captures the essential period naval doctrine described above.

4.2 Implications of the Equilibrium

Consider now the issue of predicting battle outcomes from observables. Here, it is necessary to make some further assumptions about the distribution of s_1 and s_2. Ideally, it would be possible to use historical information to fully characterize f_1 and f_2. In practice, this places far too high a demand on the historical record. Instead, it is only reasonable to believe that we can measure, or at least approximate, $E(s_1)$ and $E(s_2)$, that is the expected strength of the two fleets. The equilibrium strategies stated in the propositions above rely *only* on these expectations and not other features of the two distributions. Consequently, I will represent the distributions f_1 and f_2 beyond their expectations using the principle of maximum entropy (Shore and Johnson, 1980). Technical details are presented in the appendix.

As a second matter, I will proceed under the substantive assumptions $c_1 > r_1/w$ and $c_2 > r_2/(1-w)$, which are justified above – that is the substantive assumption that the costs of fleeing are not too high relative to the costs of fighting and that attempts to flee succeed with a probability that is not too skewed. The consequences of deviating from these assumptions are discussed in the formal appendix. In brief, the three remarks below always follow from these assumptions, but could be justified on somewhat weaker grounds as well.

The first result concerns the outcome of unilateral and chase battles:

Remark 1: In a unilateral battle (where only one player has the option to withdraw) or a chase battle (where one player flees but is caught), the margin of victory for the choosing/chasing party should be greater than zero regardless of the observable balance of power.

The intuition here is relatively straightforward. In a unilateral battle, only the choosing player has the ability to condition on the observables. Unless retreat is prohibitively costly, the choosing player will choose to fight only if he is likely to win. Similarly, in a chase battle, the decision by the fleeing player to withdraw implies that her information indicates victory is unlikely while the decision by the pursuing player to fight implies his information indicates victory is likely. Given reasonable beliefs, this means the chaser will be more likely to win.

Remark 2: The expected outcome of a mutual battle is independent of the observable strengths $E(s_1)$ and $E(s_2)$.

This is the core prediction, differing substantially from the unilateral case. In the unilateral case, the "chooser" must believe he is stronger than the other side and will fight only when advantaged. In the mutual case, however, *both* sides must believe they are stronger than their opponent. If both sides rationally hold such beliefs, then they must be in possession of "offsetting" private information. That is, if one side holds an observable power advantage, then the opponent will *only* fight conditional on an offsetting unobservable advantage. The end result of this selection process is that the outcome should not be predictable from the observables.

Remark 3: The margin of victory in a unilateral or chase battle is increasing in the observable balance of power

Unilateral and chase battles do not feature the same offsetting strategic selection as mutual battles. Consequently, the observed balance of power will correlate with outcomes in these cases. That is, when an observably stronger side chooses to fight, this does not imply any divergence between the observable indicators and unobservable sources of strength, so there should be a strong correlation between the observed balance of power and the actual balance of power. The stronger the chooser seems to be, the more likely it is to be strong.

5 Research Design

The formal model generates a number of testable propositions, so the primary challenge for research design is to operationalize the relevant variables and deal with rival explanations. I begin with a discussion of the operationalization of the balance of power, the margin of victory, and the availability of flight.

When measuring the balance of power, it is important to note that it is *not* necessary to measure either side's beliefs. Each side's beliefs about the balance of power would include both its own private information and the publicly-observable information about its opponent. Here, my goal is only to measure the publicly-observable information about each of the two sides. While a variety of variables capture this information, by far the most important is the number of guns (i.e., cannons) mounted on a fleet's ships. Guns were the actual mechanism for fighting in the age of sail and the most-discussed capability indicator among tactical writers. Unfortunately, for some early battles, information on the total number of guns is not available. In these cases, we can count either the total number of ships on each side, or the total number of ships of the line (a superior indicator accounting for the differential capability represented by different ships).[7]

It is also necessary to identify the appropriate functional form for translating the number of guns or ships on each side into a measure of the balance of power. In the formal model, I have assumed that the relationship follows a ratio-form contest success function, measuring each side's share of total capabilities present in the encounter (i.e., $\frac{s_1}{s_1+s_2}$). Consequently, I use this functional form in the empirical specifications. In order to adjust for the fact that different navies may have had a different level of gun-for-gun effectiveness, I also estimate models of the form $\frac{s_1}{s_1+\gamma * s_2}$ where the γ term is estimated from the data.

The historical measurement of strengths (in ships or guns) also requires a few choices about what to count. First, I include only ships of the line and frigates (or equivalents) in the measurement of strength. This excludes minor vessels, such as yachts or brigs. Because of their small size, such vessels made little contribution to effective fighting capability. Largely as a consequence of this, available sources do not systematically record the presence of these small vessels. Even between a ship of the line and a frigate the power imbalance was large, so I code data on the two classes separately.

Second, I must measure the margin of victory. Here, I measure the number of ships sunk or captured by each side. Some care must be taken in defining this measure. I code only ships captured or sunk in the battle or its *immediate* aftermath as a direct consequences of battle damage. I also code a second outcome variable based on the naval historiography of each battle that subjectively assesses each battle on a five point scale. While less precise and objective than ship losses, this variable captures some additional nuance and provides a useful robustness check.

Third, I turn to the issue of coding battles as mutual or unilateral. Here, I select coding rules that maximize clarity and transparency. Rather than attempting to subjectively measure any given admiral's views on fleeing in a particular situation, I code a battle as unilateral only if it falls into

[7] In the specifications below, I use guns whenever they are available then ships of the line if guns are not available and finally the count of ships if neither of the other variables is available).

one of three categories: a fleet escorting a convoy, a physically trapped fleet, or a fleet under *explicit* orders from a higher authority to fight in pursuit of some strategic objective. While it would be entirely reasonable to classify additional battles as unilateral on the basis of evidence that the admiral felt compelled to fight for whatever reason, there are no clear cases of this form in the data, and I err on the side of clear coding rules.

Finally, it is necessary to define the universe of cases. In principle, the model applies to any naval engagement within the age of sail. In practice, it is not possible to identify all such engagements, so I limit the analysis to cases in which each side had *at least* four ships. I further limit to those battles involving the Royal Navy, also for reasons of source availability. It is possible to systematically identify all, or at least very nearly all, such cases. Using secondary sources, I identify all battles involving the British navy in the period from 1650-1833 with at least four ships on each side.[8] While, in principle, the temporal scope could be extended somewhat earlier than 1650 or to battles not involving the British navy, either such change raises significant issues about data quality, so I limit my data collection to this set. As a practical matter, this captures a substantial majority of all naval battles in the period, given Britain's naval position at the time. I code the data on each battle mostly from secondary sources, making sparing use of primary sources and consulting multiple sources for each battle.

We can now turn to the key hypotheses to be tested from the quantitative evidence. The three hypotheses derive directly from the remarks in the formal model above:

1. The margin of victory for the "chaser" in a chase battle or the "chooser" in a unilateral battle should be greater than zero (Remark 1).

2. The margin of victory in a unilateral or chase battle should increase in the observable balanced of power (Remark 3).

3. The margin of victory in a mutual battle should be unrelated to the observable balance of power (Remark 2).

Strictly speaking, the model implies slightly different predictions for unilateral and chase battles.

[8]Battles of the British Navy are identified based on the lists provided in Rodger (2004) and Willis (2008) as well as all battles described in the appropriate volumes of William Laird Clowes's *The Royal Navy: A History from the Earliest Times to the Present*. Battles included in those lists but excluded from the analysis are described in the appendix along with the reasons for exclusion.

That is, the margin of victory should increase linearly in the balance of power for unilateral battles but might, for certain parameterizations, increase non-linearly in chase battles. The effect of the expected strengths is, however, nearly the same for plausible parameterizations. Consequently, I will pool chase and unilateral battles in the analysis.

I turn now to threats to inference. There are a large number of alternative explanations as to why wars or battles occur; some of these lead to the same predictions as some of the hypotheses above, but to my knowledge none of these generate the same prediction as hypothesis three, which can only arise theoretically if players condition in a very particular way on the combination of private and observable information. To generate the same prediction would require assuming that players operate under some heuristic effectively equivalent to that suggested by the optimism mechanism. Thus, the central threats to inference here come from alternative reasons that we might see a lack of correlation of the form specified by hypothesis three. The most likely challenge comes from measurement issues. Straightforwardly, if there is sufficient measurement error in the measure of capabilities then I would not find a relationship between capabilities and outcomes. This is why hypothesis two so important, although it does not directly test the optimism mechanism. If poor measurement leads to evidence that supports hypothesis three then it should also lead to evidence that falsifies hypothesis two. Measurement error on the availability of flight has the more traditional consequence of biasing against a finding. If I miscode the availability of flight, this should tend to introduce a correlation between observables and outcomes in the consensual cases and attenuate the correlation in the unilateral cases.

Finally, there is the issue of the nuisance parameters: c, r, and w. As argued above, there are fairly strong historical reasons to believe that these did not vary much, which would preclude any need to control for them, as they can bias the test only by covarying with expected capabilities. If, however, these parameters did meaningfully vary and did so in a way that was correlated with expected capability, then this would **always** bias against hypothesis three, as the expected margin of victory would now depend on the expected strengths via their covariance with c, r, and w, whatever that might be.

6 Data Description

Before proceeding to the tests, I will briefly introduce the data. I have coded data for all British naval battles from 1650 to 1833 involving at least four ships on each side. This produces 95 battles, which I summarize by type in Table 1 by type.

Table 1: Distribution of Battle Types

Mutual	36
Chase	21
Unilateral – Convoy Escort	18
Unilateral – Trapped	19
Unilateral – Ordered to Fight	2

For the strength variable, I rely on the number of guns, the number of ships of the line, and the number of ships. The number of guns measure is available for 81 cases (i.e., the vast majority). The number of ships of the line is the most precise measure available in 6 cases. The number of ships is the most precise measure available in the remaining 8 cases. I use the most precise of the available measures (in the order just listed).

Turning to the outcome measures, I code two separate variables. First, I characterize battles on a five point scale on the basis of the naval historiography of the battles. This coding is meant to encompass the broader strategic context of the battle. I present the historiographical codings in Table 2. Second, I code the quantitative outcome measures: the underlying variable here is the number of ships lost by each side (though this is subjected to various normalizations in the subsequent analysis). Coded at the disputant level, the number of ships lost ranges from 0 to 22 with a mean of 2.3 and a standard deviation of 4.5 .

Table 2: Distribution of Outcome Codings

Decisive British Defeat	4
British Defeat	15
Inconclusive	23
British Victory	27
Decisive British Victory	26

7 Hypothesis Tests

7.1 Testing H1 and H2

From an empirical perspective, H1 is the most straightforward. Here, I simply predict that in chase battles or unilateral battles, the outcome will favor the chooser/chaser even without conditioning on the observed strengths. Thus, this test assesses the ability of "choosing" admirals to form rational beliefs about outcomes. In the test, I pool the chase and unilateral battles. I conduct three t-tests on three different versions of the outcome measure, expressing the outcome from the perspective of the chooser/chaser. First, I use the historiographical outcomes transformed such that decisive defeat for the chooser/chaser is -2 and decisive victory for the chooser/chaser is 2 (and an inconclusive battle is coded as 0). Second, I use the net losses imposed – that is, the total number of ships lost by the opponent minus the total number of ships lost by the chooser/chaser. Finally, I normalize the losses imposed, dividing the net losses by the opponent's total number of ships. I show these in Table 3.

Table 3: Testing H1

Dependent Variable	Observed Value	95% CI of Observed Value
Historiographical Coding	1.1	0.9 - 1.4
Net Losses Imposed	5.2	3.7 - 6.6
Normalized Net Losses Imposed	0.44	0.33 - 0.55

The results here strongly support H1. All are positive, statistically significant, and substantively large. The first result indicates that, when one side has the unilateral option to avoid battle, the expected result roughly corresponds to victory for that side on the historiographical scale when it chooses to fight. The second result indicates that the side with the unilateral option expects to capture or sink five more ships than its opponent does. The third result indicates that, on average, the side with the unilateral option to avoid battle captures or sinks just under half (44%) of its opponents ships. These results indicate that choosers/chasers act in a way consistent with reasonable beliefs about the balance of power. That is, if their source of optimism was unrelated to the actual balance of power, then we would not expect to see choosers/chasers select their battles in such a way as to generally win. The fact that the choosers tend to win, then, suggests that admirals are able to accurately assess the strength of their adversaries in a generally reasonable way.

7.2 Testing H2

H2 predicts that, in chase and unilateral battles, the margin of victory will increase linearly in the observable balance of power. As discussed above, the predicted effect is linear for unilateral battles but slightly non-linear for chase battles. Given that the theorized deviation from linearity is small, I pool the two sets of battles and test for a linear relationship.

In principle, each battle presents two observations: that is, the ships taken by side 1 as well as the ships taken by side 2. Both conceptually and practically, these are correlated quantities, but they are not mechanically related to one another (i.e., it is possible that both sides will experience very large losses, but, as a general rule, large losses for one side imply small losses for the other). As such, the equation to estimate where i indexes battles and j indicates sides within battles is:

$$\frac{OpponentLosses_{ij}}{OpponentShips_{ij}} = \beta_0 + \beta_1 * \frac{\gamma_j * Guns_{ij}}{\gamma_j * Guns_{ij} + \gamma_{j'} * OpponentGuns_{ij}} + \beta_j + \epsilon_{ij}$$

Notably, the γ parameters here allow the gun-for-gun effectiveness of different navies to vary, which may be substantively important. To identify these, I impose the restriction $\gamma_{British} = 1$ and pool all other navies to estimate $\gamma_{Non-British}$, which then indicates the relative effectiveness of all other navies. Under an assumption of equal effectiveness (i.e., $\gamma_{British} = \gamma_{Non-British}$), it is possible to estimate the model via simple OLS. The model is, however, non-linear in the γ parameters, so when this parameter is freed, it is necessary to conduct the estimation via non-linear least squares. To account for the non-independence of the ϵ_{i1} and ϵ_{i2} terms within a given battle, I compute the standard errors by bootstrapping at the battle-level in all specifications.

Table 4 shows the results for this test. In model 1, I assume equal effectiveness and estimate only the intercept and the coefficient on the balance of power. In model 2, I allow the effectiveness parameter to vary between the British navy and other navies, while also estimating separate intercepts for the two groups to control for differences in doctrine or propensity to fight.

The primary coefficient of interest here is β_1, indicating the relationship between the balance

Table 4: Unilateral and Chase Battles

	Dependent variable: Opponent Losses/Opponent Ships	
	Model 1	Model 2
Balance of Power	1.46	1.20
(β_1)	$(1.17, 1.83)$	$(0.92, 1.80)$
Non-British Capability Multiplier		0.84
($\gamma_{NotBritish}$)		$(0.36, 2.91)$
Non-British Dummy		-0.44
($\beta_{NotBritish}$)		$(-0.91, -0.32)$
British Dummy		-0.30
($\beta_{British}$)		$(-0.86, -0.00)$
Intercept	-0.50	
	$(-0.68, -0.38)$	
Number of Battles	59	59
R^2	0.36	0.46

Note:
Models estimated via least squares with errors bootstrapped by battle.
95% confidence intervals from 5,000 bootstrap samples shown in parentheses.

of power and outcomes. In both models, this variable is highly significant and substantively large in magnitude. The strongest version of the theory implies that the coefficient on the balance of power should be exactly one, while the intercept should be exactly zero (thus, predicting no ships taken for a side with no capabilities and all ships taken for a side with all capabilities). The coefficients estimated here, especially in Model 1, diverge from this expectation. These estimates imply a somewhat "steeper" relationship between capabilities and outcomes, possibly reflecting an underlying non-linearity. In Model 3, the control for heterogenous gun-for-gun effectiveness suggests that non-British navies were about 84% as effective on a gun-for-gun basis as the British, but this estimate is very noisy. Finally, I note that, as measured by the R^2 values, the fit of the models here is quite high – that is, the balance of power explains a substantial proportion of variance in ship losses. The second model, for example, explains nearly half of the variance in outcomes.

Next, I turn to a series of tests at the battle level, rather than the disputant level. This allows the use of the historiographical outcome codings, rather than ship losses, as a robustness check. Here, I use as the primary independent variable the British share of the balance of power in order to predict outcomes for the British in a battle. As outcome indicators, I use the historiographical codings (expressed as a five point scale), net losses (i.e., opponent losses - British losses), and normalized net losses (the net losses for the British opponent normalized by their number of ships). I estimate all of these models via OLS with robust standard errors and present them in Table 5

Table 5: Battle-Level Outcomes and Balance of Power in Unilateral/Chase Battles

	Dependent variable:		
	Historiographical Outcome	Net Losses	Net Losses / Non-British Ships
British Share of Power	4.48 (1.08)	16.92 (5.06)	2.00 (0.23)
Constant	−0.72 (0.64)	−5.19 (2.92)	−0.73 (0.14)
Number of Battles	59	59	59
R^2	0.25	0.14	0.39

Note:
All models estimated via OLS with robust standard errors in parentheses.

Again, the balance of power variable is substantively large and statistically significant across specifications, providing strong evidence in favor of H2. That is, using the more flexible outcome measures, the essential conclusion still holds – changes in the observable balance of power are strongly associated with changes in the observed outcome.

7.3 Testing H3

The third hypothesis suggests that there should be no relationship between observable indicators of strength and observed outcomes in mutual battles. The strongest version of this suggests that in mutual battles, we should precisely estimate an intercept and slope of zero. A weaker variant suggests that the slope on observed capabilities should be significantly smaller for mutual than unilateral battles. Moreover, the predictive fit of the model on mutual battles should be poor.

As a first test of H3, I repeat the first specification from Table 4 on the sample of mutual battles only. I present this specification in Table 6. If H3 is correct, then it is not possible to identify the γ parameter. Consequently I do not attempt to estimate this from data in the mutual sample.

The results in Table 6 provide support for H3. Perhaps most importantly, the R^2 indicates that

Table 6: Outcomes and Balance of Power in Mutual Battles

	DV: OpponentLosses/OpponentShips
Balance of Power	-0.09
(β_1)	$(-0.67, 0.32)$
Non-British Capability Multiplier	1.00
($\gamma_{NotBritish}$)	(assumed)
Intercept	0.09
	$(-0.12, 0.39)$
Number of Battles	36
R^2	0.003
Note:	*p<0.05; **p<0.01; ***p<0.001

Models estimated via least squares with errors bootstrapped by battle.
95% confidence intervals from 5,000 bootstrap samples shown in parentheses.

the balance of power explains essentially none of the variance in the outcomes of mutual battles. As hypothesized, the slope on the balance of power is very close to zero.

Next, I combine the mutual and unilateral samples in Table 7 and include an interaction term between the balance of power and the mutuality of the battle. This has two advantages. First, this allows us to determine if the relationship between capabilities and outcomes is significantly attenuated in mutual battles (i.e., a negative and significant coefficient on the interaction term). Second, by pooling the samples, it is again possible to identify and estimate the γ parameter, so the second column once again allows differential gun-for-gun effectiveness.

The results provide strong support for H3. In both models, the interaction between the balance of power and the mutuality of the battle is negative and significant. Further, in both models, the estimated relationship between the balance of power and outcomes in mutual battles is very small. That is, whatever relationship exists between the balance of power and outcomes is substantively negligible in mutual battles.

I present these results graphically in Figure 1, which plots each data point. The mutual battles are in red while the unilateral battles are in blue. On the x-axis, I plot the share of the balance of power held by each side in each battle, while the y-axis plots the number of losses imposed by that side as a proportion of its opponent's ships (i.e., the primary IV and DV from the regression

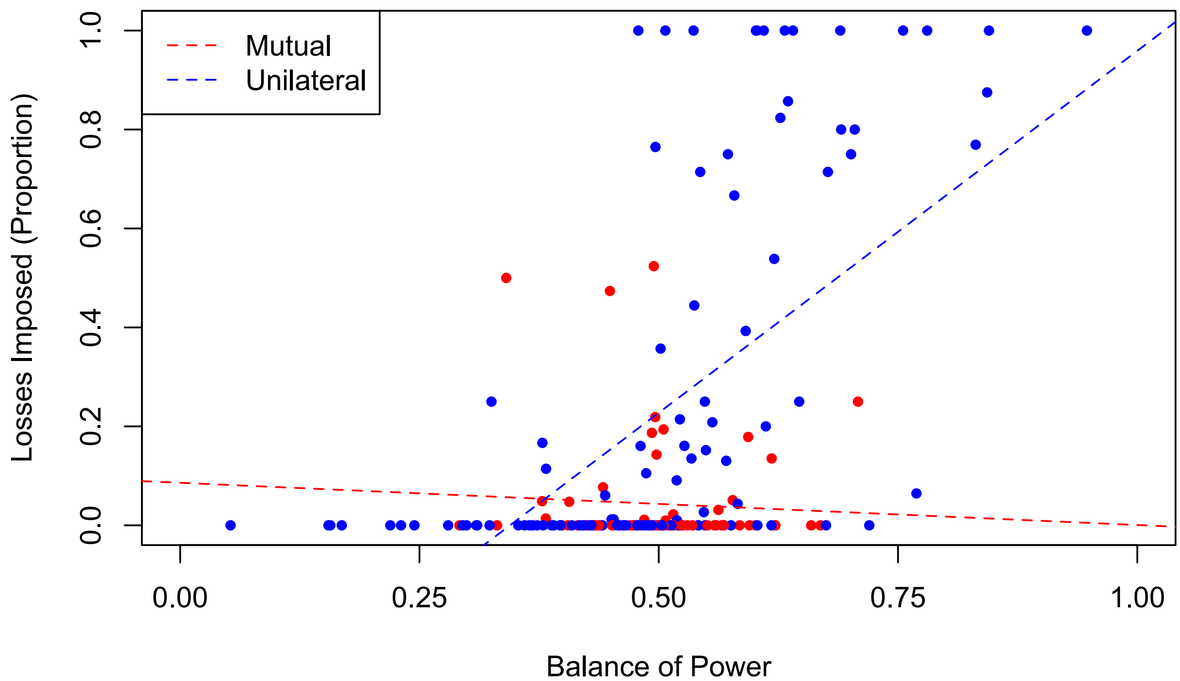
Table 7: Relationship Between Outcomes and Capabilities

	Dependent variable: OpponentLosses/OpponentShips	
	Model 1	Model 2
Balance of Power	1.46	1.23
(β_1)	$(1.16, 1.84)$	$(0.99, 1.52)$
Balance of Power * Mutual	-1.55	-1.25
	$(-2.24, -1.03)$	$(-1.83, -0.82)$
Mutual Battle	0.59	0.44
	$(0.34, 0.94)$	$(0.23, 0.74)$
Non-British Capability Multiplier		0.73
($\gamma_{NotBritish}$)		$(0.53, 0.90)$
Non-British Dummy		-0.42
($\beta_{NotBritish}$)		$(-0.56, -0.31)$
British Dummy		-0.36
($\beta_{British}$)		$(-0.52, -0.22)$
Intercept	-0.50	
	$(-0.68, -0.38)$	
Number of Battles	95	95
R^2	0.40	0.48

Note:
All models estimated via least squares with errors bootstrapped at the battle level
95% confidence intervals from 5,000 bootstrap samples shown in parentheses.

specifications). I overlay the regression lines for mutual battles (blue) and unilateral battles (red) on the plot.

Figure 1: Capabilities vs. Outcomes in Mutual and Unilateral Battles



The figure clearly shows the basic finding. For unilateral battles, there is a strong and positive relationship between observed capabilities and the outcome, while there is essentially no relationship in the mutual battles. The figure does, however, point to potential non-linearity issues with the OLS model. In order to address these, I calculate the non-parametric Spearman rank correlation coefficient between capabilities and outcomes to test simply for an increasing relationship. The Spearman correlation in mutual battles is a negligible -0.04 as compared to the strong, positive Spearman correlation in unilateral/chase battles of 0.62. In short, these results confirm what is visually apparent – effectively no relationship between capabilities and outcomes in mutual battles but a strong, positive relationship in unilateral battles.

Readers may also note that the range of the data differs between mutual and unilateral battles. Unilateral battles occur across nearly the entire possible range of the balance of power variable, but no admiral holding a balance of power share of less than 0.29 ever chose to fight in a mutual setting. While not explicitly a prediction of the theory, this is broadly consistent with rational optimism as it is hard to imagine what private information an admiral could hold in order to overcome a highly skewed observable balance of power. As an empirical matter, however, it is possible that this difference in the range of the data could result in different findings for mutual and unilateral battles. In order to address this, I re-estimate Model 1 of Table 7 after dropping all of the unilateral battles whose values on the balance of power measure lie outside the range for mutual battles. The results are found in Table 2 in the appendix and show that the findings here are robust to this change. Thus, the difference in the range of the data for the two battle types does not drive the results here.

After this analysis, I repeat the specifications from Table 5, including the interaction for mutual battles. Once again, the hypothesis holds that we should observe a negative and significant coefficient on the interaction, which is roughly equal in magnitude to the coefficient on the balance of power measure. I present these results in Table 8.

Table 8: Battle Level Outcomes in the Full Sample

	Dependent variable:		
	Historiographical Outcome	Net Losses	Net Losses / Non-British Ships
British Share of Power	4.48	16.92	2.00
	(1.08)	(5.06)	(0.23)
Mutual Battle	1.60	1.60	0.90
	(1.40)	(1.40)	(0.28)
British Share*Mutual Battle	−3.62	−3.62	−2.24
	(2.67)	(2.67)	(0.53)
Constant	−0.72	−0.72	−0.73
	(0.64)	(0.64)	(0.14)
Observations	95	95	95
R^2	0.21	0.21	0.47

Note:
All models estimated via OLS with robust standard errors in parentheses

Table 8 again provides support for H3. Across all three models, the interaction term (British Share*Mutual Battle) takes on the expected negative sign. In the first two models, the interaction is not significant, but it is highly significant when using normalized losses as the dependent variable. This is unsurprising given that normalized losses provide a more precise measure.

8 Discussion and Conclusions

Overall, the results here provide strong evidence for the theory of rational mutual optimism in the context of naval battles. The first core result shows that, when only one of two sides has the option to avoid fighting, that side tends to win. From the informational perspective, this result suggests that admirals are able to accurately perceive and condition on the observable balance of power. That is, if admirals formed substantially inaccurate beliefs about their probability of victory in battle, then we would not see the choosing side generally win. The second key finding shows that, while capabilities predict outcomes in unilateral battles, they do not predict outcomes in mutual battles. This implies, consistent with the mutual optimism hypothesis, that observably disadvantaged admirals are choosing to fight *only* when they hold unobservable advantages to offset this disadvantage. In short, mutual naval battles occur only when two sides both hold reasonable beliefs implying they are likely to win.

While the findings provide strong evidence for a counterintuitive prediction associated with the mutual optimism theory, readers may worry about the generalizability of these results to interstate war. In particular, the naval battles studied here occurred during wars and were, by definition, smaller than those wars. While this is inherently true, the naval battles studied here involved choices of great consequence about costly conflict made by senior political and military leaders. These were not mere skirmishes: at least a third of them involved more than one thousand casualties. The Battle of Trafalgar alone, for example, led to at least 4,500 fatalities, a higher number than 40% of the wars in the COW Interstate War dataset. Further, it is no exaggeration to say that the fate of nations hung in the balance at a number of these engagements: the tactically minor French victory at the Battle of the Chesapeake led directly to Cornwallis's surrender and American independence; the dramatic victory at Trafalgar served as a key turning point in the Napoleonic Wars; and the two battles of Copenhagen marked the permanent end of Danish-Norwegian naval power. The admirals involved were among the most senior leaders of their nations; in fact, one admiral represented in the data is James, Duke of York, later King James II of England.

At a theoretical level, battles present the same puzzle as wars – they are are *ex post* inefficient. The same, of course, is true of a variety of other forms of costly conflict. For example, labor strikes and jury trials have often been analogized to war given the similarity of the strategic setting. While all of these strategic settings are broadly similar, battles have a uniquely tight connection to war because they involve essentially the same officials, largely the same costs, and many of the same uncertainties. Wars are undoubtedly more complex than battles, but the study of battle holds untapped empirical promise for testing our theoretical models. Scholars have long recognized the limitations of studying only interstate wars or crises because these are so rare (e.g., 95 wars in the COW dataset, coincidentally the same sample size as the battles here). In response to this paucity of data, scholars have often turned instead to MIDs, but here too the data has been extensively exploited and perhaps substantially overexploited (Schrodt, 2014). Battles provide a source of new, unexploited data with great promise for studying theories about costly conflict. While there are, undoubtedly, differences between the causes of battles and the causes of wars, the ability to derive new implications from our theories and test them on new data is essential to scientific progress. As argued above, theories of information and commitment apply to battles, so this holds new and exciting opportunities.

The rational optimism theory of conflict has broadly the same predictions about outcomes for wars and naval battles. Applying the outcome unpredictability insight to diplomatic interactions and war is somewhat more complex than the naval case, though. In our theories of diplomacy and war, the bargain available for avoiding war should depend on the observable balance of power. That is, an observably advantaged state should be offered a deal that reflects its observable strength. Conflict will occur either when the state has even larger unobservable advantages that lead it to reject the deal and fight or when its adversary has unobservable advantages that lead it to make an offer smaller than the observables would suggest, which is then rejected. In either case, there will be an attenuation in the relationship between observable capability indicators and outcomes when states actually select into conflict, but there is no reason to suppose that the bias will be sufficiently large to erase the relationship. This suggests a fundamental limit on our ability to predict outcomes, but it is difficult to say what that limit is.

While the difficulty of assessing this limit in a principled way makes a test on wars difficult, the basic theoretical implication is no less important. According to the rational optimism theory, leaders should expect the unexpected when they start wars. The very fact that a conflict begins suggests some divergence between beliefs and reality. Notably, however, the contemporary literature on the causes of war is deliberately multi-causal, suggesting that informational issues are but one of several mechanisms. Like unilateral naval battles, wars resulting from commitment problems or indivisiblity *should* be (relatively) predictable. The overall level of uncertainty in war outcomes thus provides important information about the relative frequency of these mechanisms.

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