Steaming in the Dark? Rules, Rivals, and the British Navy, 1860-1913

Richard J. Stoll, Rice University

Abstract: The empirical literature on arms races has often failed to find strong evidence of the existence of arms races among "obvious" dyads. In this article it is argued that if we assume that decision makers use simple rules and concentrate on the weapons stock of their rivals, we can produce highly accurate models. These premises are tested by examining the size of the British navy from 1860 to 1913. The results offer support for this line of argument.

From the late 1400s to the end of World War II, Great Britain was an important, often dominant, naval power. In this vast swath of history, it was often faced with challenges, repeatedly involving itself in what we now call arms races. The purpose of this article is to develop a quantitative depiction of the size of the British navy during one critical period of time: 1860 to 1913. Thus, this study belongs within the arms race literature, although it is an attempt to understand only one side in a set of shifting arms race dyads. And although my goal is to examine one country in one time period, the study will suggest an approach that can be applied to the examination of other arms competitions.

I begin by noting how this article will differ from the "classic" quantitative arms race study. Then, the major naval, technical, and tactical challenges facing the British during the time period will be described. Finally, I proceed to examine an hypothesis about British naval behavior during that period in order to gain a better understanding of it.

The Arms Race Literature: A Brief Overview

One might argue that the scientific study of international relations began with the study of arms races. Lewis Richardson ([1919] 1960) used a pair of equations to study the dynamics of arms races, and applied the equations to the study of the military expenditures of the great powers before World War I in an attempt to learn why that war started. Richardson's work was generally unknown until an article by Anatol Rapoport (1957) introduced it to social scientists. It is an understatement to state that subsequently Richardson's work had an impact on international relations; a recent review of the arms race literature (Anderton 1989, 349) claims that there are over 100 published studies that use Richardson-process models to study arms races. Of course, there are other ways to study arms races; Huntington's ([1958] 1971) classic article uses no mathematics or statistical methodology. But it is fair to say that Lewis Richardson's work has served as the dominant paradigm for both theoretical and empirical work on arms races among those who adopt the scientific approach to the study of international relations. There appear to be at least three reasons for the popularity of this type of study:

1. The subject is an important one. Regardless of the possible links from arms races to war, arms races consume a lot of scarce resources that could better be applied to other societal needs if the behavior that leads to arms acquisition could be understood and controlled
2. Important aspects of arms races are quantitative in nature, or can be represented quantitatively. In particular, consider the widespread use of military expenditures to measure military capability.
3. The form of the Richardson equations is very similar to that of estimation equations for a variety of econometric techniques. These techniques are the staple of empirical work in the social sciences, including the quantitative study of international relations.

Military expenditures appear to be a seductively simple solution to the problem of what to count when measuring military capability, and how to aggregate when more than one item and/or multiple characteristics are enumerated. But there are strong reasons to reduce our reliance on monetary measures of military capability. An example from recent American history illustrates the difficulties with an expenditure measure of military capability. The Central Intelligence Agency develops estimates of Soviet military expenditures. Needless to say, until recently the only certainty in the business of such estimation was that the official Soviet figure was incorrect. In the middle 1970s, there was considerable pressure from conservatives for the CIA to reevaluate upward its estimates of expenditures. George Bush (then the Director of the CIA) organized the so-called Team B, a group of conservatives who were given access to the same basic information that the CIA used to draw up its estimates. Team B concluded that the CIA had greatly underestimated Soviet expenditures. Shortly afterwards, the CIA revised its estimates of Soviet spending upwards by 100% (Lee 1977). But the curious part of the story is that the revision of expenditure estimates was not accompanied by any revision of the size of Soviet forces. That is, the CIA did not discover any more missiles, tanks, or personnel in the Soviet armed forces. The agency decided that the Soviet Union was only half as efficient as previously thought; therefore, to produce a military of such size and extent, the Soviets must have spent twice as much. In effect, the CIA decided that the accounting procedures they used to turn counts of Soviet military hardware and personnel into dollar figures were off by 100%. But, while the expenditure figures were greatly altered, the actual military capability of the Soviet Union (the forces it possessed) vis-a-vis the United States did not change. This may be an extreme case, but it does suggest that the "convenience" of summarizing military capability as expenditures may not be worth the cost.¹

Perhaps problems with military expenditures as a measure of military

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¹ Even when the military expenditure figures themselves are not in dispute, other problems remain. For example, during the 1970s the U.S. greatly increased its strategic nuclear capabilities by MIRVing its missile forces (placing multiple warheads on the same missile). This was relatively inexpensive, so the increase in capability was not reflected in the budget. Another example occurred in the late 1970s when the computer software of U.S. JCBMs was improved, which led to increased accuracy of warheads. This significant increase in capability was achieved at little discernible cost, so was not accurately reflected in the change in the level of U.S. military expenditures. An additional problem is not with the expenditure figures themselves, but with the use of total military expenditures (certainly the most frequently used indicator). It is not always the case that an arms race between countries extends to all the military services. For example, it is commonly (but not universally) assumed that Great Britain and Germany engaged in a naval arms race prior to World War I (see below). However, although no one would assert that this arms race extended to the armies of the two countries, the total military expenditures of the two countries (a substantial portion of which was devoted to the army) are often used to track the arms race.

capability account for one of the curiosities of arms race studies: the failure to find systematic evidence to support the existence of several "obvious" arms races.

Most historians feel strongly that the British and the Germans engaged in a naval arms race prior to World War I. But in their study of great power interaction from 1870 to 1914, Choucri and North (1975) find no evidence of this arms race. Rather, they conclude that the naval expenditures of both Britain and Germany are driven primarily by internal factors (Choucri and North 1975, 214-18). As for the nuclear arms race, as Ward notes when reviewing a large group of empirical studies in the Richardson tradition, "there is rarely any evidence to suggest that the United States and the USSR are involved in what analytically and empirically can be termed an escalatory arms race" (Ward 1984, 297-98).

Of course, some studies do find an arms race. For example, Lambelet (1974, 1975, 1976) conducted a series of studies with strong findings on the previously mentioned Anglo-German dreadnought race just prior to World War I. Note that, unlike many researchers, Lambelet uses weapons stocks and aggregate measures of weapons characteristics in his work. Ward (1984) himself finds strong links between the expenditures and weapons stocks of the United States and the Soviet Union. Ostrom and Marra (1986) also provide a multiequation model that fits United States defense expenditures from 1967 to 1984, and they find that these expenditures are linked to Soviet behavior.

Collectively, those studies that do have strong findings on these arms races suggest several conclusions about arms races: (1) Government behavior is influenced as much or more by counts of weapons and/or the level of military capability possessed by a rival, than by the military expenditures of the rival; and (2) government behavior can be modeled successfully by treating decisions as if they were made using simple decisions rules and/or pursuing simple goals.

These two premises-the use of weapons counts and simple decision rules -will form the basis of this investigation of the size of the British navy from 1860 to 1913. As will be demonstrated below, this is an especially interesting period to study, because the navy environment faced by the British underwent a number of dramatic and important changes. If a simple model can successfully account for British behavior throughout these changes, this would provide a strong indication that the two underlying assumptions can be used to account for a variety of different behaviors.

The British Naval Setting, 1860-1913

As noted above, Britain was a major naval power from the mid-1400s on. In 1815, after years of struggle, Napoleon was defeated and the British navy was the dominant navy. But by 1860, the British began to face a number of significant changes in the naval environment. These changes involved the identity of their major rivals, the technology associated with naval power, and the tactical problems of using new weaponry at maximum effectiveness.

British Rivals

For almost 30 years after the battle of Trafalgar in 1805, British naval dominance was so great that it is not much of an exaggeration to say that it had no serious rivals. In all but a few of those years, the British possessed more major warships than the combined total of the rest of the major powers of the world-even while they remained locked in a global struggle against

Napoleon and the French. But after that time, although Britain still maintained superiority over the other naval powers, it became more concerned about the navies of others. This concern was reinforced as the technology of naval vessels underwent significant change around 1860.

The British were particularly concerned about the largest possible naval opponents, and began to justify plans for the size of their navy by the so-called two-power standard. The two-power standard set as a goal that the British navy be as large (or perhaps a bit larger) than the next two largest navies in the world. For most of the last half of the 19th century, the two largest navies were the French and the Russian, whose combined size provided a clear standard for the British to follow. Toward the end of the century, the situation became much more confused, with several other navies appearing to pose a threat to the British, and (in some eyes at least) the threat from the French and the Russians decreasing.²

All of this confusion was clarified early in the 20th century with the rise of the German navy. Coincident with the rise of the German threat, the British established better relations with a variety of other powers (an alliance with Japan in 1902, with France in 1904, and with Russia in 1907). As a result- and once again, interacting with a change in naval technology -the British based the size of their navy on that of a single power, Germany.³

Naval Technology

From the mid-17th to the mid-19th centuries, naval technology was basically static. Ships became larger, and mounted more guns, but the "ship of the line"⁴ of the 1850s would have been familiar to sailors of the 1650s. For example, Nelson's flagship at Trafalgar in 1805, the HMS Victory, was forty years old at the time of the battle (Lavery 1983, 101), but was not obsolete or inferior to other, newer ships of the line. But by 1860, technological developments occurred that led to radical changes in what constituted a capital ship. From about 1860 to 1880, a variety of ideas was tried, many of which were later shown to be dead ends (for example, for a time the ram was thought to be a crucial weapon for a ship to possess).

In about 1860 three developments began to have a profound effect on naval construction, leading to the demise of the wooden sailing ship of the line. One was the exploding shell, which replaced the solid shot that had been the standard ammunition for naval vessels. This development made wooden hulled ships vulnerable, and led logically to the second development, armor, first simply to cover the wooden hull of a ship (hence the term "ironclad"), and then as a

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² Until about the turn of the century, there was much public information about each great power's naval construction program. This information was made available in a variety of ways with which we are quite familiar: information leaked to newspapers, debates in the national legislatures, and statements by government officials. After 1900, the amount of information that was released diminished, as governments sought to prevent rivals from obtaining advance information.

³ An additional complication for British naval planning in the early 20th century was the rise of the American navy. Viewed strictly in terms of its size, one could have argued that the two-power standard should have remained in effect-with the United States and Germany replacing France and Russia. But as a result of financial considerations and the growing friendship between Britain and the U.S., the German fleet alone became the standard of comparison for the size of the British fleet. I am grateful to one of the reviewers for emphasizing this point. See Marder 1940, 442-55.

⁴ The designation "ship of the line" meant that a ship was powerful enough, and protected enough to sail in a line with others of its kind and to fight it out with the most powerful ships of an opponent. This is equivalent to the designation "capital ship," and in the era under study here, "battleship." All three terms will be used interchangeably in this article.

replacement for wood in construction. A third development was the introduction of steam power first as a supplement to, then as a replacement for, sails.

By the 1880s, observers could look back and see how all three were inevitable, but for 20 or so years a variety of different schemes was used as the basis for naval design. The British navy was, for the most part, conservative in its designs, preferring to let other navies innovate, and then to use its greatly superior resources (including the ability to build ships more quickly than other navies) when other experiments were shown to be successful. To illustrate the conservatism of the British navy, of the 37 ships of the line begun, converted, or purchased by the British navy from 1860 to 1874, 33 were rigged for sails (calculated from information in Parkes 1956). After that point, steam had proved itself to the British navy sufficiently, and no new ships of the line were built with sails. In addition, a number of existing ships were refit by removing their masts and rigging.

By about 1880, the technology stabilized enough so that a "standard" ship of the line-henceforth known as the battleship-emerged. The typical first-class battleship⁵ displaced between 15,000 and 17,000 tons, had a maximum speed about 16 knots, and was armed with four 12-inch guns (in twin turrets, one in the bow and one in the stern), and a secondary armament of mixed calibers (for example, four 9.2-inch and ten 6-inch guns).

This standard lasted about a quarter of a century. In contrast to the period between 1860 and 1880, there were few large changes from battleship to battleship during that period. Displacement went up, armored protection increased, and there were some changes in armament, but naval construction had settled into a comfortable rut.

This came to an end in 1906 with the completion of the HMS *Dreadnought*. This one ship effectively rendered all the first-class battleships in the world obsolete (some 103 in 1906, including 45 British [Modelski and Thompson 1988, 76]). The Dreadnought had a displacement of 18,000 tons, making it somewhat larger than contemporary battleships. As well, it had somewhat better armor protection. But two characteristics marked its revolutionary impact. It was the first large ship to be powered with turbine engines, giving it a top speed of 21 knots. In fact, it was able to cruise at the maximum speed of earlier battleships.⁶ In contrast to the four 12-inch guns of other battleships, the Dreadnought was armed with ten 12-inch guns, arranged so that eight could fire a broadside (in contrast to four in earlier battleships), and six could fire forward (in contrast to two in earlier battleships). As well, because all the guns were of the same caliber (as opposed to the mixture of sizes in pre-Dreadnoughts) and connected to a central gun director, it was easier to correct the fall of shots that missed a target, allowing the Dreadnought to fire more accurately. Thus, the Dreadnought had the speed to close with any battleship afloat, and the accuracy and firepower to sink it, giving its commander the ultimate in tactical flexibility.

Naval Tactics

After the defeat of Napoleon, debate on tactical issues was dormant. Technology was static, and in any case, the absence of a serious rival to the British suggested there was little

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⁵ Size and armament distinguished first-class battleships from those of lower classes (second, third, and fourth). But only first-class battleships were ships of the line- that is, assumed to be capable of fighting against the most powerful ships of the opposition.

⁶ On its first crossing of the Atlantic, the Dreadnought maintained an average speed equivalent to the maximum speed of any other battleship.

urgency in questioning the successful practices of the past. But by the beginning of the era studied here, the changing conditions outlined above sparked what has been called "a golden age of tactical thought, without parallel before or since" (Hughes 1986, 55).

Naval tacticians had to cope with a bewildering array of problems. With respect to weaponry, ranges drastically increased. Obviously, this meant that engagements would start much earlier. But more importantly, increased ranges (and mounting guns in turrets for much wider arcs of fire) allowed groups of ships to concentrate fire on one opposing ship; this type of concentration was not possible with basically immobile short-range cannon on the sailing ship of the line. A related concern was the ability of armor to protect ships against shellfire. Would armor render ships invulnerable to shellfire, or would the increase in gun size and effectiveness render protection meaningless? Obviously, the nature of the gun/armor relationship would have a heavy impact on how battles would be fought.

Steam propulsion gave both more speed and more flexibility in maneuver; tactical options were no longer limited by wind speed and direction. This suggested that the ship with the higher speed would give its captain the option of how to fight the battle; that is, at what range and with enough of a speed advantage-direction vis-a-vis the opponent.

Finally, additional weapons entered the naval inventory: the torpedo and the mine. They had several common characteristics. First, they attacked beneath the waterline of a ship, an area that was typically only weakly protected. Thus, a single such hit might well sink the largest vessel. Second, both weapons systems could be (and often were) delivered by small ships. This raised the prospect in the minds of many that large ships were obsolete, and that a significant naval force-one that could easily threaten British naval superiority-could be bought for relatively little money.⁷ The British worried both about whether this argument was correct, and what could be done to minimize the effects of these sinister weapons.

A final concern during the entire period was the proper tactical formation to be used prior to and during a battle. There were competing demands between ease of steaming in noncombat situations, the ease of deployment into battle formation, and the proper order to take in battle to maximize the chances of destroying the enemy.

All of these issues spawned a large amount of literature discussing the pros and cons of various approaches. The primary outlet for these musings was a series of naval journals, with one or two appearing in each country possessing a significant navy. One factor complicating the analysis was the lack of a significant body of empirical data, that is, actual navy combat between modern ships.⁸ The Battle of Lissa (1866) was widely discussed, but one of its major "lessons"-the high utility of ramming as a naval maneuver-was a tactical dead end. In addition, a number of naval battles were associated with wars off the western coast of South America between 1877 and 1879, engagements during the Sino-Japanese War in 1894, and of course the combat of the Russo-Japanese War of 1904-05. But this was simply an insufficient empirical foundation on which to build sound tactics or confidently to design a first class navy.

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⁷ There are many obvious parallels between these weapons and the modern air-to-surface and surface-to-surface cruise missile, such as the Exocet, used with great success by the Argentine forces against the British in the Falklands/ Malvinas War. Like the cruise missile, torpedoes and mines were regarded as a cheap means to create a significant threat to large naval ships. Another parallel is that both cruise missiles and torpedoes and mines can be delivered from a variety of relatively inexpensive weapons platforms.

⁸ The lack of actual combat to aid in the analysis of the impact of naval technology is another parallel between that era and the current era. Aside from a few skirmishes, there has been no serious naval combat between ships armed with modern electronics and weapons systems.

Sailing in the Dark?

Taken together, the shifting rivals, the changing technology, and the debate about naval tactics created a very uncertain environment for British naval decision makers. But they could hardly sit back and wait for clarity to emerge. They (along with the British government and its people) believed that the loss of naval supremacy would be tantamount to national surrender. Thus, important decisions had to be made, and if these decisions were incorrect, disaster would result. British decision makers were therefore faced with the worst of all possible circumstances: the necessity to make decisions that could have the most major consequences, but to make these decisions in an environment that changed drastically from time to time, rendering previous guideposts obsolete.

The major questions posed by this article are what behavior did the British undertake with regard to the size of their navy, and what inferences can be drawn from this behavior to British decision making? To approach these questions, I conceive of the British government not as a rational entity, but rather as a limitedly rational, goal-seeking system striving to operate within a complex environment. With this framework, I expect that the British government will use simple decision rules with short-term feedback to guide its naval program (Cyert and March 1963).

The two-power standard proclaimed by the British fits this perspective nicely. It is certainly simple. And given the large amount of information available on the naval programs of the powers, British decision makers could count on obtaining short-term feedback on the naval balance. Finally, because it took the British less time to construct a capital ship than its rivals (typically about three years per ship), and because Great Britain had a large shipbuilding capacity, if conditions changed, they could use the short-term feedback to step up their construction plans before the balance of naval power was significantly altered.

This perspective suggests two other expectations for British behavior in the period. First, as long as the short-term feedback indicated that the British navy was in good shape, the simple decision rule should have a major influence on the size of the British navy. Second, consider the British situation when the focus of British naval concern shifted from France and Russia to Germany. In addition to the shift to a new rival, and the continued pace of technological change, one additional factor enters into British calculations; the speed of German naval construction approached that of British, so part of the cushion of British safety disappeared. Taken together, this new set of circumstances suggests that the new standard or goal for British naval construction would be higher than the earlier one (i.e., greater than equality). But before these questions can be addressed, it is necessary to operationalize the key concepts, and describe the research design to be used.

Operationalization and Research Design

Although the task of turning the concepts of interest in this study into operationalized measures is not as daunting as in other studies, there still remain the usual ambiguities and arbitrary (but not capricious) choices that must be made. Similar comments can be made about the research design to be used to test hypotheses about the decision-making process that led to the size of the British fleet during the period under study.

Operationalization

Number of Battleships as a Measure of Naval Power

The focus of the article is the number of British capital ships during the period from 1860 to 1913. A variety of alternative measures of naval power could be used to tap the strength of the British navy during that period. As noted above, expenditures, although widely used, have serious deficiencies. However, a decision to concentrate on the actual manifestation of naval power (i.e., the ships themselves) still leaves a number of choices. One could count the total number of warships in the fleet, something that was embodied in the Reagan Administration's naval standard for its buildup of a 600-ship navy. Or one could derive a measure of naval power by forming some aggregate of ship characteristics, for example, the total tonnage of ocean-going warships.⁹ But it is quite clear from the basic histories of the period under study (Marder 1940, 1961; Woodward 1935) that both British decision makers and interested onlookers (members of Parliament, media) placed a heavy emphasis on the capital ship. This is not to say that other aspects of the naval balance were ignored; there were frequent references to the number of cruisers the British navy must have to protect worldwide commerce, to the quality of ships, to other weapons, systems (the torpedo being the most obvious example), and to total navy expenditures. But time and time again, the focus of debate and concern was the ship of the line. For example, in 1904 a special Admiralty committee chaired by Prince Louis of Battenberg was appointed to study the question of the two-power standard, and how it should be implemented. The committee's conclusions were expressed in terms of numbers of battleships (Marder 1961, 124). This is consistent with a variety of statements made through the era by persons commenting on the naval balance. Thus, for this investigation the currency of capital ships-the total number possessed by a navy in each year-will be used.

As noted above, changes in naval technology during the period from 1860 to 1913 produced different types of ships that were granted the status of capital ship. There is a certain amount of confusion on just what is, and what is not, a capital ship at a particular time. In a mammoth effort, Modelski and Thompson (1988) have tackled this question, not just for the era discussed here, but for the entire period from 1494 to 1993. This article borrows from their effort, relying on their counts of ships. For the period from 1860 to 1879 they rely on the work of Chesneau and Kolesnik (1979) to identify capital ships of the world's most important navies.¹⁰ As Modelski and Thompson (1988) note, by 1880 there was a clear consensus on what qualified as a first-class battleship, so they shift their rules for counting capital ships at this point. Finally, beginning in 1906, "regular" first-class battleships began to be superseded by the Dreadnought (here used to designate all battleships of this type, rather than the single ship of that name). But while the Dreadnought (i.e., the ship of that name) created a significant stir when it was completed in 1906, it took a few years for its total impact-to cause all pre-Dreadnought

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⁹ Such measures are quite common in the study of strategic nuclear weapons; for example, total throw weight or megatonnage.

¹⁰ With regard to the British navy, Chesneau and Kolesnik (1979) are in agreement with Parkes (1956), whose focus is exclusively on British battleships from 1860 to 1946. Unfortunately, Parkes' extensive efforts deal only occasionally with the rivals to the British navy, so there is no convenient check on non-British figures for the early part of the period under study.

battleships to become obsolete-to occur. For purposes of this study, the count of capital ships shifts from first-class battleships to Dreadnoughts in 1910.¹¹

It is of course unfortunate that the standard for the dependent variable for this study changes twice (once in 1880 and again in 1910). But it is clear that these changes do reflect the changing standards for evaluating what is a capital ship. The analysis problems introduced by these shifts are secondary to the necessity that the dependent variable provide an accurate reflection of what was considered to be the key measure of naval strength.

Research Design

To undertake this study, it is first necessary to have an explicit formulation and a formal hypothesis of the power standard. From the earlier discussion of the British navy, it should be clear that for the first part of the period under study, the two-power standard would dictate that the size of the British navy should be set by the size of the French plus the Russian navies. And later in the period, the power standard would dictate that the size of the British navy be set by the size of the German navy.

However, several points are not so clear. First, with regard to the French and Russians, was equality the goal, or did the British decision makers seek to have a slight margin above equality? The standard histories of the era are simply not clear on that point, but tend toward the view that a margin of superiority was desired. Second, when the British shifted their attention to Germany, exactly what was the British goal? Most histories suggest that the British desired more than equality- perhaps considerably more-but an exact standard is not clear (note that this is consistent with the theoretical rationale offered above). Finally, in what year did the British shift the focus of their naval effort from the French and Russians to the Germans? In actual fact, the sequence was probably a bit more complicated. There was a brief period in the middle 1890s where it seemed that all of the other major naval powers of the world had some basis for a grievance against Britain, and therefore might be viewed as potential opponents. Gradually, however, states were eliminated from this "enemies list," and even the traditional foes France and Russia were viewed with less alarm. Ultimately, only Germany was considered a threat.

For purposes of this article, several simplifying assumptions were made. First, the period when the British opponent(s) were unclear is ignored; the analysis will assume that for the first part of the period under study the British sized their navy to that of France and Russia, and that this pair of opponents was then replaced by the German navy (i.e., no transition period, and no overlap of opponents).

Given these assumptions, two variables can be constructed to reflect the goals pursued by the British navy during this period. One variable represents the period in which the British sought the two-power standard over the French and Russians. The variable is simply the total number of capital ships of the French and Russian navies for the period; this variable takes on a value of zero after the British replace their foes with the German navy. A second variable represents the period in which the British sized their navy to the German navy. It takes on the

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¹¹ There are actually two types of warship included in the Dreadnought category, battleships and battle cruisers. Both types are included in Modelski and Thompson's (1988) count. Although the size and number of the main guns on the two types is similar, the major difference is that battle cruisers possessed more speed at the expense of armor protection. The loss of three British battle cruisers at the Battle of Jutland in 1916 suggests that this tradeoff of arms for speed was not satisfactory for ships that were to fight in the battle line.

value of zero when the British are concerned about the French and Russian navies, and the number of German battleships once the British focus their attention on the Kaiser's navy. But in what year should we assume that the British shifted from the French and Russian navies to the German navy? Because the analysis will be conducted on the number of British battleships, it should be noted that throughout the period, it took about 3 years from the time a capital ship was started until it was ready for service (calculated from data in Parkes 1956). Thus, if British attention shifted from France and Russia to Germany in one year, then the impact of this shift would not materialize in the size of the fleet until 3 years later. In an appendix devoted to the two-power standard, Woodward (1935, 459) notes that the German naval program was mentioned in the introduction of the British naval estimates for the first time in 1900. If the German navy was first a consideration in estimates of 1900, this should be reflected in the size of the British fleet in 1903. That is the year that will be used to switch between the two variables representing the different British standards for sizing their navy.

Results

Table 1 shows quite clearly that the size of the British fleet is well predicted. The coefficient values can be used to draw inferences as to the exact nature of the British goals. For the earlier era, when the rival was the combination of the French and Russians, the British indeed seek a slight margin of superiority (as evidenced by the coefficient value of 1.13) over the two continental powers. When the Germans become the rival in 1900, the coefficient value indicates that the British seek a much greater level of superiority—almost double that of their rival.¹²

To give a better sense of the data and of the fit, Figure 1 plots the actual number of British battleships and the predicted number of battleships through time. As the figure indicates, the definition of what was counted as a battleship changed twice during the time period. There is some variability in the size of the navy through time, but the fit between the predicted and observed numbers of battleships is strong.

Alternative Explanations

Despite the strong fit of the equation and the close correspondence of the coefficients to historically postulated values, it is important to consider alternative hypotheses for the findings. Because there are a number of alternatives available, only a few of the more prominent possibilities will be considered.

One alternative hypothesis is that the level of capital ships in the major European navies was driven by the response of each to changing naval technology. Innovations occur, and each navy responds as best it can by building new ships to take advantage of the innovation. Of course, experience may show that some of these innovations are dead ends, and such a conclusion would dictate a new round of ship building. But the basic pattern we should observe is an acceleration of ship building shortly after an innovation occurs, followed by a slow down once enough new ships have taken their place in the fleet. Further, the impact of technological

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¹² Technically, the dependent variable is a count, rather than a continuous variable. As a check on the possible invalidity of findings due to the use of an inappropriate technique, ordinary least squares (OLS), I ran a Poisson regression predicting the number of British battleships from the two-power standard variables. The results were very similar to those from OLS.

change should be similar across all navies, so that the size of the growth and de-acceleration should be similar.¹³ If this explanation is correct, then the observed covariation between the size of the British and other navies in Table 1 is spurious, and due to the common factor of technological change.

In Table 2, the change in number of capital ships, and the percent change in ships is shown for all four navies for each half decade.¹⁴ As can be seen, although there are some similarities in the growth of navies (directions are usually the same for all four names, as well as some of the relative magnitudes), the patterns do not appear to be similar enough to offer strong support for the technological imperative hypothesis. This is particularly apparent when growth in the French and Russian navies is compared; growth rates for the two navies are often very different during the same time period. It is clear that the regression coefficient of Table 1 for the French-Russian aggregate is not representative of the two individual navies.

Statistical Artifact

A second explanation for the findings is not substantive, but statistical. The strong results of Table 1 are due to the combination of the tendency for the number of capital ships to rise through time, punctuated by sharp drops as the definition of what type of ship is to be counted changes at several points in the time series. The combination of trend and outliers drives the coefficients and the fit of the model.

One way to test this explanation is to convert all ship measures to changes in the number of capital ships, rather than to use the number of capital ships as was done in the analysis reported in Table 1. In addition, dummy variables are added for two of the different capital ship eras (the first from 1860 to 1879, and the Dreadnought era from 1910 to 1913), and the first year of each time period (1860, 1880, and 1910) is dropped to reduce the impact of outliers. Table 3 displays the results of the analysis.

As would be expected, the overall fit of the model drops when changes are used instead of levels. But the fit is still good. In addition, the dummy variables for the different capital ship eras do not play a large role in the fit. Finally, the coefficient values for the combination of the French and Russian navies, and the German navy are close to those for the level variables in Table 1. These results do not support the hypothesis that the original results are statistical artifacts.¹⁵

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¹³ One could argue that the "technological imperative" will have different impacts on different navies. But if this is so, then it is difficult to see how this could account for the strong fit and the coefficient values in Table 1. Because the purpose of this exercise is to explore alternative explanations for the results in that table, I will stick with the assumption of a similar pattern of growth and de-acceleration across all four navies.

¹⁴ Deviations from the half-decade time period were made whenever the operationalization of a capital ship changed in the data.

¹⁵ Another way to check for the impact of the change in operationalization of the capital ship is to divide the data set into the time period of the first operationalization (1860-1879), and the time period of the second and third operationalizations (1880-1913; note that capital ships are operationalized as Dreadnoughts for only the final 4 years, which is too small for a separate analysis). For the first time period, the number of British battleships is regressed on the sum of the French and Russian fleets; for the second time period, the size of the British fleet is regressed on the same two-power standard variable (which has a value of zero after 1902), the size of the German navy (which has a value of zero before 1902), and a dummy variable for the Dreadnought era. As well, the first year of 1880 is dropped from the second regression because the values are very low and may be considered outliers.

A final alternative hypothesis that deserves consideration is that of an internally driven process. That is, although the British publicly proclaimed that they were building a navy to meet foreign threats, the real process was internally driven. In most arms race studies, internal and external explanations are both represented in the same equation, and their relative strength is compared. A similar strategy is adopted here. Both the level and change in level in British capital ships will be examined, and the appropriate lagged dependent variable is added to the equation.¹⁶

The results of these two analyses are encouraging. The overall fit of both equations does not represent an improvement over the earlier equations that did not include the lagged dependent variable. A comparison of the t ratios and significance levels of the coefficients in these equations shows that the lagged dependent variables in both equations have much smaller impacts than the coefficients for the rival navies. Finally, the coefficients for the rival navy variables are very close to the values they had when the lagged dependent variables were not included (see Tables 1 and 3). Collectively, the analyses including the lagged dependent variables offer support for the earlier conclusion that British capital ship construction during the time period was primarily driven by naval rivalry, rather than by internal momentum.¹⁷

Discussion

The results of the analysis strongly support the proposition that the British used simple decision rules and relied on short-term feedback to size their navy during an era of high uncertainty. This is one of those happy occasions where the historical interpretation matches well with theoretical literature, and produces a strong statistical fit as well. Of course, one could say that we knew the results all along. But this is not always true; some have denied the existence of a relationship between the size of the British and German navies (Choucri and North 1975). And given the myriad of conflicting assertions that competes for being the "obvious" explanation, it seems prudent to expose these matters to closer scrutiny.

But the important point is that British behavior is well predicted by simple decision rules. For an extended period, in an extremely important area of policy, the British government behaved as if it were using simple decision rules. One example in a limited temporal domain is not enough to generate a general theory. But it is suggestive, and similar frameworks might

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The results of these two regressions have extremely good fits (adjusted R^2 s are .95), with coefficient values for the capital ship variables highly significant, and with values close to those reported in Table 1.

¹⁶ An autoregressive disturbance in the presence of a lagged dependent variable creates problems for statistical estimation. Because of that, the two stage estimator developed by Hatanaka was used in the two analyses described here. Note that the constant in the equation is used in conjunction with the instrumental variables, so it does not appear in the final output. See Greene 1989, 182-84, 200.

¹⁷ An alternative estimation technique is vector autoregression. Vector autoregression is most useful when faced with a system of equations, all of which involve the same set of variables (for example, variable A predicted from variables B and C, variable B predicted from variables A and C, and variable C predicted from variables A and B), but with a lagged structure that is not specifically known through theory or prior empirical analysis. However, I do not feel comfortable simply including other navies in a system of equations. This article was begun with the conviction that to model the British navy, it was necessary to take its specific environment into account. The same conviction applies to the other navies, so the result of an attempt to build a multiequation model for major navies is likely to be a series of equations that do not share the same predictor variables (although there would undoubtedly be some overlap). This is a project I would like to undertake, but not before further study of the historical record.

provide simple and powerful explanations for the arms acquisition behavior of other states in other eras.¹⁸

Conclusion

The study of arms acquisition, usually in the context of arms races, has been a very popular topic in quantitative international relations research; this is appropriate because the behavior is important, costly, and potentially dangerous. In this article I studied the acquisition of capital ships by the British navy from 1860 to 1913. This was an extremely interesting time, with changes in rivals, technology, and tactics. But, despite the high degree of uncertainty, British behavior is well predicted by simple decision rules. Although only one state and a short span of time were examined, the results suggest that a similar approach may well be useful for understanding arms acquisition in other contexts.

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¹⁸ Computer simulation may be of some value in a more detailed examination of the British navy, and of the other major navies in that time period (see footnote 17). On a yearly basis, the British updated their projections of future naval construction for other navies, and compared this to their own programs. It was possible to make adjustments to insure that their power standard goal was met. These yearly adjustments can be represented easily in a computer program, but can be awkward in an econometric model. That is the reason that the focus in this article was on the result -the number of completed ships-rather than the process- yearly micro adjustments

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Figure 1: Observed Versus Predicted Battleships, 1860-1913

NOTE: Type of battleship changes in 1880 and 1910. British naval rival and goal changes in 1903.

TABLE 1
 Predicted Number of British Capital
 Ships from Power Standard Variables, 1860-1913

<i>Variable</i>	<i>Coefficient</i>	<i>t Ratio</i>	<i>Probability</i>
Constant	2.66	1.35	.18
French and Russian capital ships	1.13	18.35	.00
German capital ships	1.97	16.92	.00
<i>N</i> = 54	Adjusted <i>R</i> square = .92		Durbin-Watson = 2.00

NOTE: See text for the definition of the variables. Due to high levels of autocorrelation, estimation was done using the iterative algorithm by Prais and Winsten (see Greene 1989, 182). Durbin-Watson statistic is that for the transformed residuals (i.e., after the correction for autocorrelation).

TABLE 2

Comparison of Change and Percent Change in Capital Ships, 1860-1913

Years	<i>Great Britain</i>		<i>Germany</i>		<i>France</i>		<i>Russia</i>	
	<i>Percent</i>		<i>Percent</i>		<i>Percent</i>		<i>Percent</i>	
	<i>Change</i>	<i>Change</i>	<i>Change</i>	<i>Change</i>	<i>Change</i>	<i>Change</i>	<i>Change</i>	<i>Change</i>
1860-1864	12	—	0	—	6	—	1	—
1864-1869	18	150.0	0	—	10	166.7	8	800.0
1869-1874	13	43.3	5	—	0	0.0	5	55.6
1874-1879	1	2.3	4	80.0	4	25.0	3	21.4
1880-1884	3	42.9	0	—	2	66.7	0	0.0
1884-1889	11	110.0	0	—	4	80.0	3	300.0
1889-1894	-2	-9.5	4	—	1	11.1	1	25.0
1894-1899	-1	-5.3	1	25.0	-2	-20.0	-1	-20.0
1899-1904	20	111.1	9	180.0	3	37.5	6	150.0
1904-1909	5	13.2	6	42.9	-2	-18.2	-7	-70.0
1910-1913	17	170.0	12	240.0	2	—	0	—

NOTE: Groupings indicate when definition of capital ship was changed (note beginning and ending years for change calculations). When total capital ships at the beginning of a period was zero, no percent change was calculated.

TABLE 3
Predicted Change in British Capital Ships
from Change in Power Standard Variables, 1860-1913

<i>Variable</i>	<i>Coefficient</i>	<i>t Ratio</i>	<i>Probability</i>
Constant	0.18	0.46	.64
Change in French and Russian capital ships	0.93	6.50	.00
Change in German capital ships	1.72	6.81	.00
Dummy: 1860-1879	0.32	0.53	.59
Dummy: 1910-1913	-1.56	-1.03	.30
<i>N</i> = 51	Adjusted <i>R</i> square = .55	Durbin-Watson = 2.00	

NOTE: See text for the definition of the variables. Due to autocorrelation, estimation was done using the iterative algorithm by Prais and Winsten (see Greene 1989, 182). Durbin-Watson statistic is that for the transformed residuals (i.e., after the correction for autocorrelation). For each of the three different capital ship definitions, the first year is dropped to avoid misleading values.

TABLE 4
Predicted Number of British Capital Ships from
Power Standard Variables and Lagged Dependent Variable, 1860-1913

<i>Variable</i>	<i>Coefficient</i>	<i>t Ratio</i>	<i>Probability</i>
British capital ships _{<i>t</i>-1}	0.15	2.20	.03
French and Russian capital ships	0.96	8.14	.00
German capital ships	1.95	7.47	.00
<i>N</i> = 48	Adjusted <i>R</i> square = .95		

NOTE: See text for the definition of the variables. Because the equation contains a lagged dependent variable, the Durbin-Watson statistic is inappropriate. For each of the three different capital ship definitions, the first year is dropped to avoid misleading values.

TABLE 5

Predicted Change in British Capital Ships from Change in Power
Standard Variables and Lagged Dependent Variable, 1860-1913

<i>Variable</i>	<i>Coefficient</i>	<i>t Ratio</i>	<i>Probability</i>
Change in British ships _{t-1}	0.15	1.28	.20
Change in French and Russian capital ships	0.95	7.51	.00
Change in German capital ships	1.64	7.41	.00
<i>N</i> = 48	Adjusted <i>R</i> square = .50		

NOTE: See text for the definition of the variables. Because the equation contains a lagged dependent variable, the Durbin-Watson statistic is inappropriate. For each of the three different capital ship definitions, the first year is dropped to avoid misleading values.