Sea Power

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Abstract

This paper analyzes the dynamics of sea power using the tools of economics and through the perspective of economic history. Specifically, we first devise a simple game theoretic approach of two rival naval powers. As naval technological advances, making vessels more powerful and more costly, this induces convergence in naval spending. It also shows how such convergence can lead to global conflict and the emergence of a single dominant player, leading to long-run cycles of naval power. We then turn to newly digitized data for over two dozen navies during one such power cycle — the late 19th and early 20th centuries. Preliminary empirical results suggest that the rising importance of inter-continental commerce during the period contributed to naval arms races around the world, and the eventual eruption of global war.

Keywords: Seapower, Conflict, State Capacity, Military Conflict, Institutions.

JEL Codes: N40, N70

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1 Introduction

Sea-power is the ability of a state to use naval force to influence the other states. This influence can come in many forms. One form is the shaping of the political and military affairs of another nation — "the sea is a strategic highroad, a medium by which one group of people can dominate the affairs of another" (Till, 2013, 14-15). Another is the shaping of global commerce — naval power can help open new trade routes, as well as improve the terms of trade with existing trade partners (Rahman, 2010; Glaser and Rahman, 2016). The importance of sea power has long been recognized by naval strategists and military historians. (Mahan, 1890; Falk, 2000; Till, 2013). But it has received little attention from economists. In this paper we ask why some states seek to acquire sea-power, while others appear to abandon such ambitions. And we ask what the economic consequences are from the competition for sea-power.

The relative neglect from economic historians of the evolution of sea-power is surprising, since it played a crucial role in the rise of Western economies from 1500 onwards, in the Great Divergence, and in the spread of globalization (Findlay and O'Rourke, 2007). The Dutch Republic, Great Britain and the United States were all, at different times, both economic powerhouses and naval leaders. As one historian notes: 'The history of the West, hence of the modern world, has been written by the sea powers; it was their market-acquisitive system that encircled and dominated the global, opening up new lands for new cash crops and commodities, sinking mines, building foundries and mills and stimulating technological change' (Padfield, 1982).

This paper provides two contributions to the literature. One, it develops a simple framework to think about the rise and fall of sea power in history. Two, it utilizes newly digitized naval data to model the dynamics of naval arms races during the late 19th and early 20th centuries.

First, we develop a simple framework to understand the conditions under which states invest in sea-power. States build military power to control economic resources: land-based trade and sea-based trade. Success in pairwise competition between states is decided by a contest success function.

We assume that that both naval and land power follow Lancaster's Power Law. This states that projected military force follow a power law in relation to military resources but that the coefficient on naval power is greater than that of land power. This is because naval battles occur on open seas, and the vessels of one power are accessible to the vessels of the other— in this case the larger power has an out-sized advantage, and factors related to greater naval reach, such as greater speed or more powerful ordnance, will confer even greater advantage to the larger power.

In equilibrium how much a state invests in naval power is determined by the cost of naval power, the value of sea-based trade, and the military investments of its rivals. Our model predicts that naval power will be less symmetrically distributed than land-power. This is accordance with modern data and with the historical evidence that we present.

The model further demonstrates how technological changes leading to larger, more powerful and more costly naval vessels can lead to a convergence of naval power. The theory also demonstrates that such changes can inevitably result in a winner-take-all global conflict that results in long-run cycles of naval leadership.

Finally, we study how the value of sea-based trade influences the incentive to invest in sea power. We find that an increase in the value of trade networks for the naval leader is associated with decreased symmetry and an increase in naval spending by the leader. On the other hand, an increase in the sensitivity of trade to naval contests is associated with increased symmetry and an increase in naval spending for all parities and can help spark a global conflict.

The other area of contribution is empirical. We focus on the period 1870–1914. This period, known as the first age of globalization (Findlay and O'Rourke (2007), or according to Robertson 2003, at least the second age of globalization), was one of dramatic technological change in naval warfare, as well as one of unprecedented flows of inter-continental trade. The framework described above generates a number of testable implications on how factors such as distance, trade and technological changes shape the types and amounts of military investments.

We document naval power measures using data from Brassey's Annuals. These are yearly accounts for all measurable naval activities around the globe. From these we have each ship's name, type and class, year built, displacement, horsepower, speed and coal capacity, hull-type, guns and number of propellers. We construct a panel dataset that measures naval power for the period 1886–1913. By estimating a series of simultaneous equations models, our initial (and highly preliminary) analysis provides empirical support for our theoretical predictions. Specifically, we suggest that rising importance of trade among the leading naval powers spurred arms races around the world and contributed to the eruption of global war.

2 Literature

The purpose of sea power is to influence political and military affairs on land (Till, 2013). The concept of sea power as a means for total dominion of international resources owes its origins to Alfred Mahan (1890). Following Mahan, the importance of sea power has been recognized by naval strategists and military historians (Corbett, 1911; Falk, 2000; Till, 2013).

There are many studies of seapower by historians and strategists have written numerous assessments of the relative strength and strategic positions of the world major sea powers. Quantitative accounts to trace the rise and fall of the major sea powers are rarer. The most systematic study is Modelski and Thompson (1988) who provide estimates for the size and strength of the world's major navies from the age of discovery onwards. They also shed light on the role seapower plays in shaping global politics.

The literature connecting naval power and trade within economics is also relatively sparse. For mercantilist writers it was a simple premise that wealth was a function of power. After the dawn of classical political economy, however, only a few writers such as Hirschman (1945) applied economic reasoning to study the relationship between trade and military power. As a consequence, economists generally neglected the role of seapower in economic history.

There is however a literature on the economic consequences of military power more generally. This originates in the insights of Lane (1958) and Boulding (1962) but has recently received renewed attention. There is a considerable formal literature on the decision to go to war (Fearon and Laitin, 1996). Economists have also recently contributed to this literature (Jackson and Morelli, 2007; Martin et al., 2008; Spolaore and Wacziarg, 2016). However, their focus has been on war in general and not on the unique characteristics of sea-based conflicts and naval power.

The same is true for the literature in economic history. Recently, scholars have examined the military revolution and the role it played in the economic rise of Europe. The intensification of conflict has been associated with the building of fiscal capacity (Dincecco and Prado, 2012; Gennaioli and Voth, 2015); an increase in urbanization (Voigtländer and Voth, 2013; Dincecco and Onorato, 2017) and the ability of Europeans to subjugate the rest of the world (Hoffman, 2015).[1] But despite its prominence in the historical and political science literature, the role of seapower has received little attention from economic historians.

One exception is Findlay and O'Rourke (2007) who emphasize the importance of military power in shaping trade routes and economic activity. They document the role that seapower played in first Dutch economic leadership in the 17th century (p 238–239) and then the subsequent rise to prominence of Britain (p 240–284). Findlay and O'Rourke (2007) also document the rise of Chinese sea power in the Song period and its demise in the Ming period. They argue that European geography was one reason for the rise of

[1] For a survey of cliometric approaches to warfare see Eloranta (2016).

European navy power which allowed Europeans to gain control of first Mediterranean and then Asian trade routes: they conclude that "combination of guns and sails (Cipolla 1965) was as we have seen an important factor in establishing European hegemony over Asia" (Findlay and O'Rourke, 2007, 360). But there have been no systematic attempts to model the decision to invest in seapower or attempts to empirically investigate what factors determine the distribution of seapower across the globe.

Seapower was crucial to Britain's rise to great power status in the 18th century. The British navy was overwhelmingly successful against rival powers during the age of sail. Britain's navy mastery enabled the British to transport small strike forces which were able to pick off French and Spanish colonial possessions and prevent France from obtaining domination of the European continent. Allen (2002) studies the internal organization of the British navy during the age of sail. He focuses on how the navy succeeded in incentivizing its captains and admirals to engage aggressively in battle.

Scholars such as Kennedy (1976) argued have that beyond its unique organization and military abilities, naval strength depended on and contributed to Britain's growing economic prosperity Following victory over France in 1815 British naval supremacy was uncontested for more than half a century. However even during this period of dominance, Britain's rivals did try to invest in new technologies that might give them an edge. The end of the age of sail is dated to 1827 and in the 1830s, the French began to innovate with ironclads.

The latter 19th century saw unprecedented change in naval technologies, and unparalleled amounts of global commerce under-girded by naval might. Historians suggest a robust naval arms race between England and Germany, leading up to the Great War. Here we ask if this can be backed up by economic logic and empirical scrutiny.

In our empirical analysis we focus on this period of rapid naval investment and geopolitical competition. In so doing we build on a small number of papers that have begun to investigate the role seapower played in the first era of globalization (1870-1914). Glaser and Rahman (2016) introduces new archival data to demonstrate that sea power had a causal effect on the direction of trade. Rahman (2010); Glaser and Rahman (2016) establish that sea power had important economic implications in the pre-World War I period but they do not seek to explain the origins of sea power.

In this paper explore the factors that predict when states invest in seapower. The simple analytical framework helps us better understand why we observe periods of high naval concentration and periods of convergence and to better explain which states are more likely to invest in seapower.

The structure of the rest of the paper is as follows. Sections 3 and 4 present the main stylized facts that our theory and empirical analysis seek to explain. In Section 5 we develop a simple theoretical framework to guide our analysis, and we link the theory to some history in section 6. Our empirical analysis is presented in Section 7.

3 The Rise and Fall of Sea Power — Some History

The Fall of Chinese Seapower

China serves as an early example of a global power, becoming a major naval force during the Song dynasty in the 12th century. China maintained its major sea power status during the Yuan and Ming dynasties. The most celebrated example of Chinese naval might is displayed by the Muslim admiral Zheng He, whose treasure ships explored the Indian Ocean in the early decades of the fifteenth century.

Modelski and Thompson (1988) note that in the early 15th century—on the eve of the Age of Discovery–China's seapower was greater than that of the leading European naval powers Venice and Portugal. Ming China possessed 3800 vessels of which 400 were large warships (250 long-distance treasure ships) and there were 2700 patrol and combat vessels used to guard the coast line and river trade routes.

However, the Ming fleet was disbanded after 1419. During the 16th century Chinese naval power was reduced to a coastal defense force and it struggled to eradicate the problem of piracy (Kung and Ma, 2014).

Thereafter, Modelski and Thompson (1988, 337) describe China "as a consistently weak, coastal-defense maritime actor". By the end of the 18th century, the Chinese navy had declined to the point that it was no match for any major western navy. But the arc of Chinese naval power is long indeed — while China is described as a minor power as recently as the 1980s (Modelski and Thompson (1988)), today China possesses a powerful and technologically advanced navy, in fact the second largest navy in the world in terms of tonnage.

The Fight for the World between the Portugese and the Dutch

Both the Portugese and the Dutch maintained merchant empires which needed complex naval systems to defend, itself requiring large infrastructures of ships and sailors (Rei, 2013). The Portugal Crown was the first to exhibit the extensive use of naval capital for global dominance (Modelski and Thompson (1988)). Starting with the efforts of Prince

Henry the Navigator, Portugal excelled in developing new ship designs and navigational techniques (Neal and Cameron, 2016). It was the first power active on the world ocean, the leader of the age of discoveries, and the developer of major oceanic ships such as the caravel and the galleon.

The Portugese and the Ottomons were in full naval competition in the Indian Ocean during the mid-1500s. The Ottomons were decisively defeated, leaving the Portugese as the dominant naval power through much of the 16th century (Stavridis 2017). But as we will argue later, the rise of new entrants was inevitable. The Dutch, and to some extent the English, did not provide the Portugese a proper challenge until the late 16th century, but when they did they did so furiously and successfully (Modelski and Thompson (1988)).

The period of expansion for the United Netherlands was the first half of the 17th century. This expansion however meant intruding into the colonial world, at the time effectively controlled by the Spanish-Portugese Empire. At first Dutch naval aggression was uncoordinated amongst the various Netherland states. But as the Dutch consolidated their efforts and extended their influence, they finally "broke the back" of the Spanish naval threat in the Battle of the Downs in 1639.

Yet the later half of the 17th century saw rising naval challenges from England and France. Due to a variety of factors, some of which we explore in the simple theory described below, the Dutch are unable to maintain global naval leadership for long.

The Rise and Fall of British Seapower

Medieval England was not a seapower. Alfred the Great invested in a navy to defend Wessex from Viking invasions. But this fleet went into decline during the 11th century. Anglo-Saxon England had no fleet capable to intercepting or defeating the invasion threats that it routinely faced.

Similarly, despite the fact that England had an extensive coastland and many natural harbors, medieval English monarchs did not invest in naval power. During the 12th and 13th centuries, "the sailor was scarcely more than a ferryman. His function was to carry armies" (Fiennes, 1918, 59). Medieval English monarchs relied on the ships of the cinque ports, particularly for transport to their French possessions, but with occasional exceptions they did not use seapower aggressively or invest in naval capacity.[2] These were private merchant vessels that the king could requisition in times of crisis. As

[2] The cinque ports were granted tax exemptions and other freedoms in return for furnishing the king with their fleet for a certain number of days a year. This tradition went back to the 11th century and was formalized in the reign of Edward I (Fiennes, 1918, 64).

Richmond notes: "So long as English kings claimed the sovereignty of portions of France, England was necessarily a land power" (Richmond, 1934, 31).

There were occasional exceptions. Edward III used a navy to gain control of the Channel during the early stages of the Hundred Years War. After the Black Death, however, the English merchant marine declined and the navy remained in disrepair throughout the 15th century. Through much of the Middle Ages, no royal or national navy existed of any kind. England seapower only arose in 16th century first during the reign of Henry VIII, and then more decisively in the second part of the century in response to the threat of invasion from Spain.

The rise of Atlantic trade dramatically increased the commercial returns to overseas trade. Initially, however, this trade was in the possession of the Portuguese and Spanish. English merchants vessels had to invest in more mobile and firepower heavy ships into order to muscle in on this trade. At first, they followed in the footsteps of the Dutch who were Europe's preeminent naval power in the mid-17th century, but they were hamstrung due to the unwillingness of Stuart monarchs such as James I to invest in seapower. However, following the English Civil War and a succession of conflicts with the Dutch, the Royal Navy, gradually became the most effective navy in the world.[3]

This effectiveness was based on the separation of the navy from the merchant marine, on the acquisition of bases such as Jamaica and Gibraltar, and on the reforms implemented by Samuel Pepys.

By the 18th century Britain's navy mastery was more or less uncontested. It enabled the British to transport small strike forces which were able to pick off French and Spanish colonial possessions and prevent France from obtaining domination of the European continent. Scholars such as Kennedy (1976) argued have that beyond its unique organization and military abilities, naval strength depended on economic strength, and that the growth of the British navy hinged on the Commercial Revolution, and that its age of supremacy rested on the Industrial Revolution (xvi).

After 1815 British naval supremacy was uncontested for more than half a century. However even during this period of dominance, Britain's rivals did try to invest in new technologies that might give them an edge. In the 1830s, the French began to innovate with ironclads.

Historians date the beginning of the end of British naval supremacy to 1884 (Kennedy, 1976). This is when the British engaged in a new program of ship building in response to French investment in new ships. Then at the end of the 19th century, Germany began to invest in a new navy while the United States established itself as the major navy power in

[3]This history is extensively documented by Kennedy (1976) and Herman (2004).

the western hemisphere. The British committed themselves to maintaining a two-power standard — that is, to maintain a number of battleships equal to the combined strength of the next two largest navies. Interestingly though, laws designed to accomplish this, such as the Naval Defence Act and the Spencer Programme, rather than deterring potential rivals, only appear to have spurred them towards further naval investments.

The Anglo-German rivalry was an important factor in the outbreak of World War I. Unique to past transitions of global naval dominance, the transition from British to American navy supremacy in the Americas, however, was accomplished peacefully. Following the peace, the British had to give up their two-power standard and acknowledge that the US was an equal naval power to themselves.

In the long-run, the economic rise of the US and German began to put pressure on Britain's position as naval leader. Despite victory in World War 2, the Royal Navy went into terminal decline after 1950.

The Rise of US Seapower

Though the newly independent United States lacked a navy, many of the Founders understood the importance of establishing a powerful navy. In 1794, in response to a new wave of Barbary piracy, the Federalists were able to persuade Congress to establish a navy.

Throughout these decades there was always a conflict between the Federalists who wished for a strong navy and those in the Jeffersonian tradition who preferred to have only defensive naval forces. During the War of 1812, the British navy swept American shipping from the seas and the United States was put under blockade by the Royal Navy.

1881 is seen as a landmark year in American naval history (Sprout and Sprout, 1939, 183). Though even before the country had much of a functioning navy, it often expressed internationalist ambitions. An 1876 report of the U.S. House Committee on Ways and Means stated, rather incredibly, "the Pacific Ocean is an American ocean ... the future great highway between ourselves and the hundreds of millions of Asiatics who look to us for commerce, civilization, and Christianity" (Findlay and O'Rourke (2007)). Large sums of money were directed into building a new navy based on steam power. Influenced by the writings of Mahan, the United States began to invest in a new fleet of battleships. By 1897, the US navy had a fleet which though smaller than that of its European rivals could "hold indisputable command of all the strategic marine approaches to the continental United States" (Sprout and Sprout, 1939, 222).

The United States demonstrated the virtues of seapower in the War with Spain (1897-

1901). Rather than mounting an invasion of Cuba, the United States relied on seapower to blockage the island and to defeat the Spanish fleet at the Battle of Santiago de Cuba. After 1901, the Roosevelt and subsequent administrations invested wholesale in naval power.

The British were forced to abandon the two-power standard after World War I. The Washington Naval Conference of 1921 saw the British acknowledge naval equality with the United States.

4 The Rise and Fall of Sea Power — Basic Facts

Several stylized facts standout from the history of seapower. First, land power is much more evenly distributed than naval power. This is evident both today and historically. Today share of the largest land power (China) makes up only around 11% of the world's total land armies. In contrast, the world's largest sea power (USA) makes up almost 35% of the world's total naval power.[4]

Second, historically seapower has also tended to be highly concentrated. Almost all states have to maintain land forces but only a subset of states invest in seapower. Throughout much of history there tends to be a single naval hegemon. Today this hegemon is the United States. Previously it was Britain. Before Britain, it was the briefly Dutch Republic and before them Spain and Portugal. Figure 1 depicts the dominance of the British navy during the age of sail (1700-1850). For much of this period the strength of the British navy measured in terms of the number of battleships and cruisers and other ships was approximately equal to the strength of the next two strongest navies combined.

Nevertheless, though naval strength has always been highly concentrated in comparison to land-based military power, the degree of concentration has varied over time, and appears to evolve cyclically. There have been episodes where the dominant naval power has been more or less unchallenged—Britain during the mid-19th century or the United States after 1989—and periods of convergence and intense attempts by followers to catchup on the leader. Figure 2 plots the degree of naval concentration among the major sea powers using data from Modelski and Thompson (1988) for the period 1500-1914. It reveals that periods of intense great power conflict such as the Napoleonic Wars (1792-1815) saw marked changes in the degree of naval concentration often resulting in the victor increasing its naval superiority over rival powers.[5]

[4] This data is available from Wikipedia. See https://tinyurl.com/dxacx57 and https://tinyurl.com/qx7nju8.

[5] Shaded areas of the graph correspond to global conflicts as defined by Modelski and Thompson (1988)

Figure 1: The Distribution of Naval Power in the Age of Sail (1780-1840). Data source: Glete (2000).

Fourth, throughout history the naval hegemon has also tended to be an economic leader. Modern economic growth began in an economy that was a major sea power (Britain) and the most successful economy of the recent times (the USA) is also the world's greatest sea power.

In the next section we introduce a simple analytical framework to better understand some of these historical facts.

5 A Simple Analytical Framework

After the Battle of Trafalgar, British naval might forced every other potential naval rival to virtually abandon the sea and relegate its sea-bound ambitions to mere coastal defense (Herman, 2004). It would appear then that during the early 19th century, naval expanse by the dominant naval player could cow weaker powers into further subservience. But a century later, such flexing of British naval muscle, through means both *de jure* and *de facto*, did little to dissuade secondary powers such as Germany from escalating its naval

— Italian and Indian Ocean Wars, 1494–1516; Dutch and Spanish Wars, 1580–1608; Wars of Louis XIV, 1688–1713; Napoleonic Wars, 1792–1815; First World War, 1914–1918. Note that the Seven Years War is not included by Modelski and Thompson (1988) due to its smaller scale and number of combatants, despite being called the first global conflict by some (Stavridis, 2017).

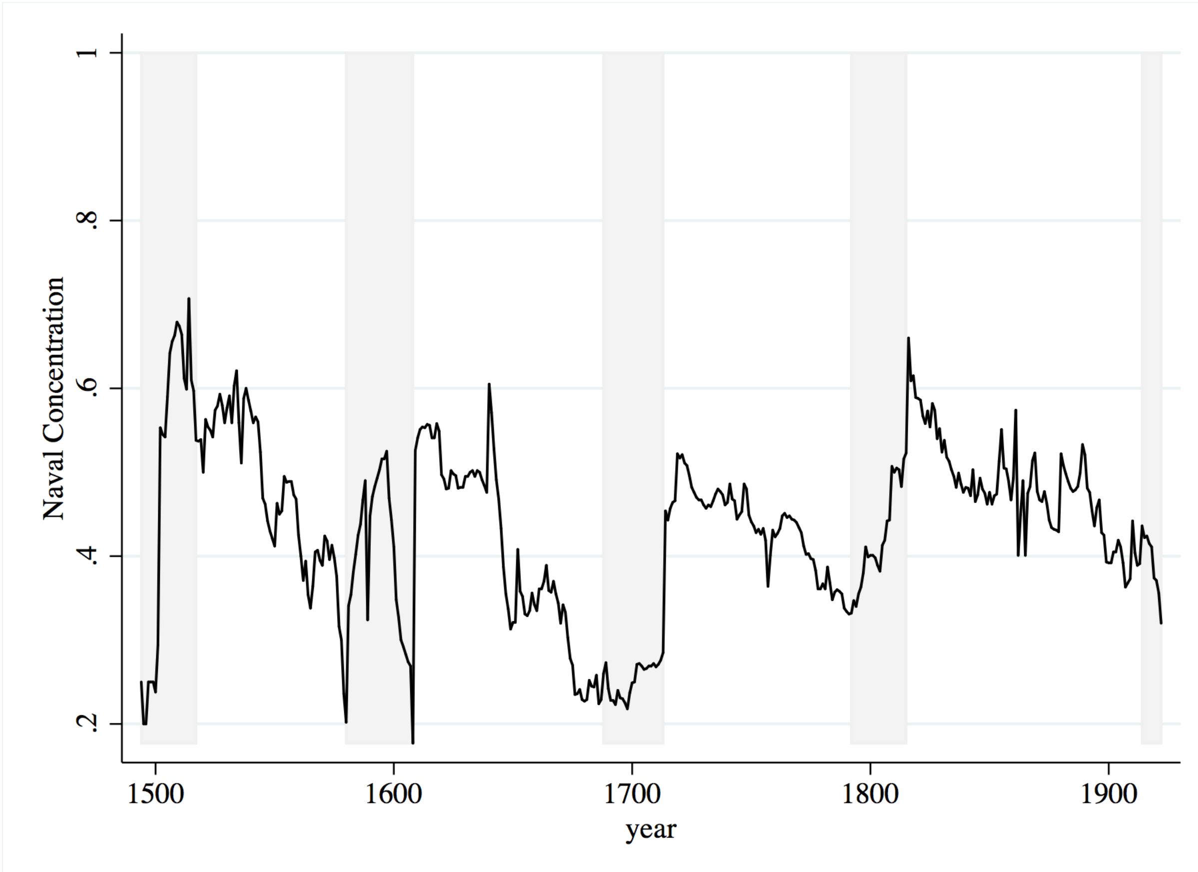


Figure 2: The Concentration of Naval Power Over Time. Data source: Modelski and Thompson (1988)

program to match British naval investments (Marder, 1961). Conflict dynamics can shift, suddenly or gradually. The rising power of the stronger group could induce the weaker power to either abandon greater power competition, or redouble their efforts. Which it might choose depends on various factors — these are the factors we shall explore in this work in the context of naval supremacy.

We now provide a simple analytical framework to account for these observations.[6] There are two antagonists. Each has to defend its land and sea trade interests by investing in its landed military and its seapower, respectively. In the event of war, victory depends on contest success functions. The key difference between land war and sea war is that the latter tends to be more advantageous to the stronger power.

The framework generates the following simple results. The degree of asymmetry in the

[6]Developing a theory to help us understand the general and timeless principles of sea power should garner sympathy from the likes of Mahan: "The old foundations of strategy so far remain, as though laid upon a rock" (Mahan, 1890)

distribution of sea [land] power is a function of relative geographic endowments and technology. An increase in the cost of sea [land] power, an increase in the decisiveness of naval [land] warfare, and an increase in the sensitivity of access to trade for the naval [land] follower will each bring about increased symmetry in naval spending. We will also generate situations where the rising importance of trade will lead to escalation of naval spending by multiple parties and threaten to trigger a global conflict.

Consider two hostile countries. Country $i \in \{1, 2\}$ has to defend its land (domestic) and trade (foreign) interests, represented by R_i and T_i respectively. To do so, it may invest in an army M_i and a navy N_i at the cost of $M_i^{\alpha} + N_i^{\beta}$, where $M \geq 0$ and $N \geq 0$, $\alpha > 1$ and $\beta > 1$.

Investing in M and N increases a country's probabilities in winning land and sea wars, which are given by the following contest success functions:

$$P_i^{Land} = \frac{M_i^{\lambda}}{M_i^{\lambda} + M_{\bar{i}}^{\lambda}} \; ; \quad P_i^{Sea} = \frac{N_i^{\theta}}{N_i^{\theta} + N_{\bar{i}}^{\theta}} \; ; \tag{1}$$

where $\lambda > 1$ and $\theta > 1$.

We will consider two types of conflict. Taking some liberty with terminology, let us name these *Corbettian* and *Mahanian*. Corbettian conflicts are on-going struggles to protect one's own commercial interests while disrupting one's rival interests. These are smaller in scale and scope, associated with commerce raiding and *guerre de course* approaches to combat. Through his publication of *Some Principles of Maritime Strategy* (1911). Sir Julian Corbett stressed the themes of limited war and strategic defense in maritime environments. To Corbett, command of the sea was relative, not absolute. One implication here is that as naval power becomes more readily exerted, smaller powers can play larger maritime roles.

In contrast, Mahanian conflicts are big struggles to gain complete command of the seas. They often erupt when a weaker power catches up and challenges the dominant naval power. To Mahan, winning decisively was all-important. Thus, when one is victorious in a Corbettian conflict, one protects one's trading and commercial interests. When one wins a Mahanian conflict, one gets *all* the trading and commercial interests.

We will first discuss a simple framework with only Corbettian conflict as the baseline. We then extend the framework to allow for Mahanian conflict as well.

5.1 Baseline Model

The expected payoff of country i is

$$V_i = (\frac{M_i^\lambda}{M_i^\lambda + M_{\bar{i}}^\lambda})^{\eta_i} \cdot R + (\frac{N_i^\theta}{N_i^\theta + N_{\bar{i}}^\theta})^{\psi_i} \cdot T - M_i^\alpha - N_i^\beta \; ; \tag{2}$$

where $0 \leq \eta_i \leq 1$ and $0 \leq \psi_i \leq 1$. Note that η_i [ψ_i] inversely measures the extent to which losing a land [sea] war would affect country i's access to R_i [T_i]. For example, if the country is an island state, we expect η to take a small value—being weak on land would not severely affect its ability to defend its homeland—and ψ to be relatively large. For a relatively landlocked country, η would be large for obvious reasons, while ψ would be relatively small because the country can still obtain access to foreign resources overland.

For ease of exposition, we assume for now that each country's investment in the army is invariable,[7] so that we can rewrite (2) as

$$V_i = \hat{R}_i + (\frac{N_i^\theta}{N_i^\theta + N_{\bar{i}}^\theta})^{\psi_i} \cdot T_i - N_i^\beta \; ; \tag{3}$$

where $\hat{R}_i = (\frac{M_i^\lambda}{M_i^\lambda + M_{\bar{i}}^\lambda})^{\eta_i} \cdot R_i - M_i^\alpha$.

Without loss of generality, suppose country 2 is more landlocked than country 1. For simplicity, suppose $\psi_2 = \psi < \psi_1 = 1$. We can derive from the FOCs that

$$(\frac{N_1}{N_2})^\beta \quad = \frac{T_1}{T_2}\frac{1}{\psi}(\frac{N_2^\theta}{N_1^\theta + N_2^\theta})^{1-\psi} \; . \tag{4}$$

From the above it is easily shown that $\frac{N_1}{N_2} > 1$ if $T_1 \geq T_2$; $\frac{dN_1/N_2}{d\alpha} < 0$; $\frac{dN_1/N_2}{d\theta} < 0$; $\frac{dN_1/N_2}{d\psi} < 0$; $\frac{dN_1/N_2}{dT_i} > 0$.

Alternatively, we can compare naval investments using the Herfindahl index. In the two-country case, the Herfindahl index is simply

$$H_N = (\frac{N_1}{N_1 + N_2})^2 + (\frac{N_2}{N_1 + N_2})^2 \; ; \tag{5}$$

where $0 \leq H_N \leq 1$ by construct and a lower value indicates more naval parity (more intense naval competition). It can be shown that $\frac{dH_N}{d\alpha} < 0$; $\frac{dH_N}{d\theta} < 0$; $\frac{dH_N}{d\psi} < 0$; $\frac{dH_N}{dT_i} > 0$.

To sum up, we have the following propositions:

[7] Though we do not attempt it in this work, we can extend the analysis to understand factors leading nations to raise R or to raise T, and to understand how military and naval resources interact with each other, something stressed in the analysis of Corbett.

Proposition 1 *An increase in the cost of seapower (β) is associated with increased symmetry in naval investments:*

$$\frac{dN_1/N_2}{d\beta} < 0 \;\; ; \;\; \frac{dH_N}{d\beta} < 0.$$

Proposition 2 *An increase in the decisiveness of naval warfare (θ is associated with increased symmetry in naval investments:*

$$\frac{dN_1/N_2}{d\theta} < 0 \;\; ; \;\; \frac{dH_N}{d\theta} < 0.$$

Proposition 3 *An increase in the sensitivity of access to trade to defeat in a sea battle is associated with increased symmetry in naval investments:*

$$\frac{dN_1/N_2}{d\psi} < 0 \;\; ; \;\; \frac{dH_N}{d\psi} < 0.$$

Proposition 4 *An increase in the value of trade networks for the naval leader is associated with decreased symmetry in naval investments:*

$$\frac{dN_1/N_2}{dTi} > 0 \;\; ; \;\; \frac{dH_N}{dT_i} > 0.$$

We have assumed that investments on the army are fixed. Note however that similar predictions would apply to army investments—we can simply replace N with M, T with R, β with α, θ with λ, ψ with η, and H_N with H_M.

Note that if both naval and land power follow Lancaster's Power Law, $\theta > \lambda$, and all else being equal, this simple framework predicts that the arms race would be more intense at sea than on land.

5.2 Extension — Possibility of Global Conflict

In an extension to the basic framework described above, we can now incorporate a more *Mahanian* element — the possibility of total war. A more general version of the expected payoffs of two naval powers i and j (i being the naval leader) can be written as follows:

$$V_i = \hat{R}_i + \phi\left(\frac{N_j}{N_i}\right) P_i \left(T_i + T_j\right) + \left(1 - \phi\left(\frac{N_j}{N_i}\right)\right) P_i T_i - N_i^{\beta}; \tag{6}$$

$$V_j = \hat{R}_j + \phi\left(\frac{N_j}{N_i}\right) P_j^{\psi_j} \left(T_i + T_j\right) + \left(1 - \phi\left(\frac{N_j}{N_i}\right)\right) P_j^{\psi_j} T_j - N_j^{\beta}; \tag{7}$$

where $0 \leq \psi_j \leq 1$ and $0 \leq \phi \leq 1$. Again, the first order condition of each equation allows us to solve for optimal values of N_i and N_j. Note that the probability of an eruption of a Mahanian conflict is given by $\phi\left(\frac{N_j}{N_i}\right)$ — the relative rise of the inferior power risks the chance of a total war when ϕ is positive.

Also note that when $\phi = 0$, we are in the Corbettian baseline case, with the closed-form solutions discussed above. Here we suggest that for a variety of reasons, ϕ can become positive, and then there is a risk of a Mahanian conflict for total domination of the seas. Further, this risk rises as the naval follower catches up to the leader. Deterrence of naval rivals was an important factor in Mahanian doctrine.

From this extended model, a number of new propositions emerge, enumerated as follows:

Proposition 5 *An increase in the cost of seapower (β) is associated with increased symmetry in naval investments for values of ϕ lower than some critical value ϕ^*:*

$$\frac{dN_1/N_2}{d\beta} < 0 \quad \forall \phi < \phi^*.$$

Proposition 6 *An increase in the decisiveness of naval warfare (θ) is associated with increased symmetry in naval investments for values of ϕ lower than some critical value ϕ^{**}:*

$$\frac{dN_1/N_2}{d\theta} < 0 \quad \forall \phi < \phi^{**}.$$

In words, factors associated with techological progress, making ships more destructive and costly, still generate naval convergence among powers as long as the likelihood of total war is not too large. If however the chance of total war is sufficiently large, smaller powers tend to back off from the technological leader when such changes occur.

Proposition 7 *An increase in the value of trade networks for the naval leader is associated with decreasing symmetry in naval investments the larger is the liklihood of total war:*

$$\frac{d^2 N_1/N_2}{dT_i d\phi} < 0 \quad \forall \phi.$$

The final proposition may have particular importance for our empirical study of the first age of globalization. It suggests that as the likelihood of total war exogenously rises, the divergence in naval power that results from an increase in the value of trade of the naval leader weakens. This occurs because increases in T_i increasingly induces the naval follower to raise naval power as the possibility of seizing T_i rises for j.

Figures 3 and 4 display results from simulations of the full-blown model. Left panel graphs are where $\phi = 0$. This is the Corbettian world of limited naval warfare to protect

Figure 3: Changes in Naval Spending Due to Changes in Trading Resources

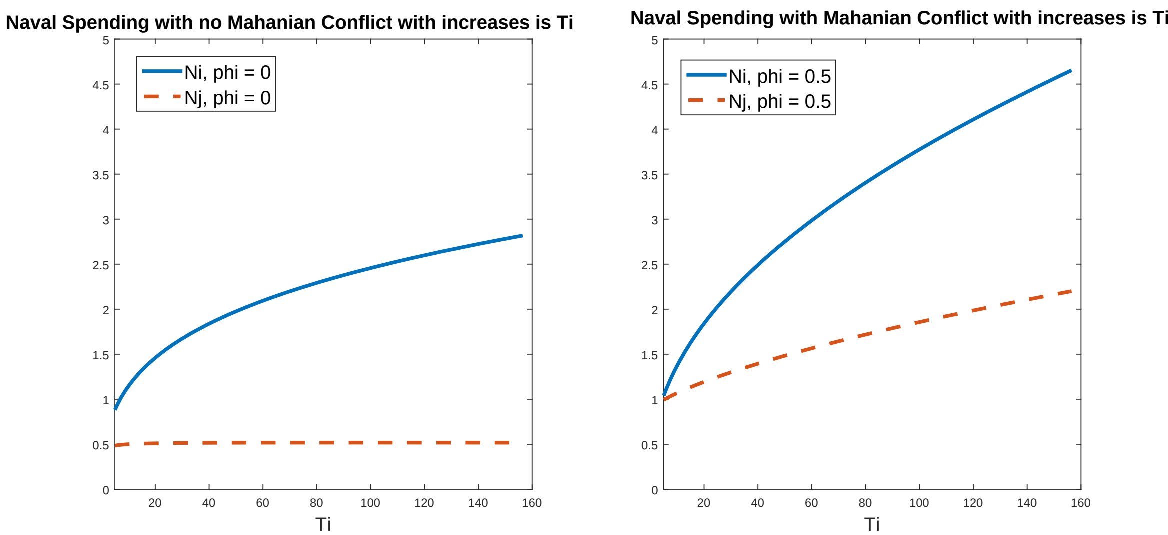
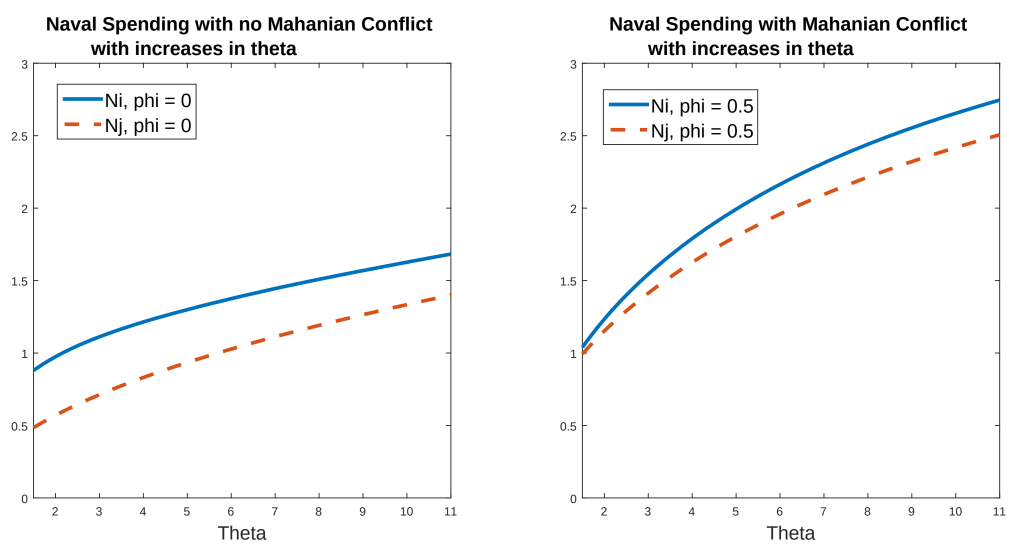


Figure 4: Changes in Naval Spending Due to Changes in Naval Technology



one's own resources and damage the other nation's resources. Right panel graphs are where $\phi = 0.5$; here there is the possibility of a Mahanian conflict for total world resources.

First, the left-side diagram of Figure 3 shows Proposition 4 — increases in T_i increases the naval leader's lead. We can also see in the right-side diagram that when ϕ is increased (positive chance of global conflict), naval spending is increased for both powers and there is convergence in naval spending. Finally, we can see that in the Mahanian world, increases in T_i still produces naval divergence, but now naval spending is much more pronounced for both powers, as suggested in Proposition 7.

The left-side diagram of Figure 4 shows Proposition 2 — when naval decisiveness in battle rises (a proxy for naval technology), there is naval convergence in the Corbettian world. But interestingly, this can reverse under a more Mahanian framework — the naval follower does not keep up with naval spending in this illustrated case where $\phi > \phi^{**}$. Thus when the probability of total conflict is large, superior naval technologies can serve as something of a deterrent for rival powers.

6 Applying the Model to History

The Age of Sail

We have data on the size of pre-steam navies from Modelski and Thompson (1988) and Glete (2000). While in this work we do not provide an econometric study of the implications from the theory for the Age of Sail, history can provide us suggestive evidence.

The model presented above suggests the possibility of naval power cycles — a global conflict can erupt and lead to a single victor. Afterwards however there may be a series of inter-bellum innovations which helped spur naval convergence. This convergence raises the probability of another global conflict. Does the history of sea power bear out these ideas? Modelski and Thompson (1988) document and discuss many such inter-bellum naval developments occurring, as they describe it, "with the major beat of the long cycle."

First, the Mercator map, first developed in 1569, was a map of the world which represented sailing courses as straight lines, greatly facilitating navigation. This heralded a new era in the evolution of navigation maps (Monmonier, 2004). This conceivably raised everyone's access to global commerce, and so raised ψ. Two centuries later, Britain's development of chronometers and the ability to calculate longitude further enhanced global commerce (Varzeliotis, 1998).

The "race-built"galleons developed by the English and used by the Spanish and English navies in opposition to Portugal during the late 16th century dramatically improved cruising speeds over traditional galleons (Kirsch, 1990). This conceivably raised θ. Also, advances in the use of sailing tactics such as the weather gage during the 16th century conferred tactical advantage to the stronger navy. The fleet holding the gage could either force battle by bearing down on the opponent, or refuse it by remaining upwind. The fleet with the lee gage could avoid battle but not force it. Thus greater naval power became more decisive with such tactical advances, raising θ.

The creation and continual refinement of ships-of-the-line from the 17th to the mid-19th centuries kept raising the decisiveness of naval combat. Since engagements among such vessels were almost invariably won by the heaviest ships carrying the most powerful guns, the natural progression was to build sailing vessels that were the largest and most powerful of their time. This of course raised the cost of production of each naval vessel, thus increase β for all naval powers.

And of course, increases in T always spurs naval spending. In some sense naval competition during the Age of Sail was over the products of the New World: "…the riches that flowed from from gold, silver, slaves, sugar, tobacco, fish, furs, manufactured goods, and the markets themselves" (Stavridis, 2017).

The Age of Steam

A number of important innovations further contributed to making ships larger, more expensive, and more decisive in naval combat during the Age of Steam. These include the development of armored battleships, explosive shells, ironclads, the Dreadnought and naval aviation. And of course this period coincides with the age of globalization, causing T to rise to unprecedented levels or all major powers.

Further increases in θ also took place. "Instead of smoothbore cannons that had to be brought to bear at extremely close range, rifled gun barrels led to great improvements in range and accuracy. The initial ideas of fire control, or the way in which guns are sighted using optimal targeting systems, were developed and implemented. And instead of hammering home a charge with a muzzle loading system (a slow and ponderous process), the use of percussion-fired projectiles emerged — with significant gains in efficiency and rate of fire" (Stavridis, 2017). All these developments contributed to an increase in the likelihood of battle success for the stronger naval player.

Applying the Model to One Leg of the "Power Cycle"

We can use this framework to study the period of intense naval competition that began in the 1880s. As illustrated in Figure 1, Britain was the unquestioned naval hegemon. This concentration of naval power was in part a function of relative technological stability during the so-called Age of Sail. Ship and naval tactics underwent only fairly minor improvements from the mid-seventeenth to the early nineteenth century (these included copper sheathing, the introduction of the carronade, and flintlock firing mechanisms). During this period of tactical and technological there was little incentive for rival powers to invest sufficiently in order to challenge Britain's hegemony.

This changed with the introduction of ironclad and steamships in the mid-19th century and then battleships in the late 19th century. Technological developments from the 1850s onwards inaugurated a period of rapid technological innovation. In terms of our model, this is captured by an increase in cost (β) and decisiveness (θ) of naval warfare. As in our framework, rival powers such as the United States, France, and German began to challenge Britain's position. Despite the British making large investments in the new technology, the distribution of naval power became more concentrated.

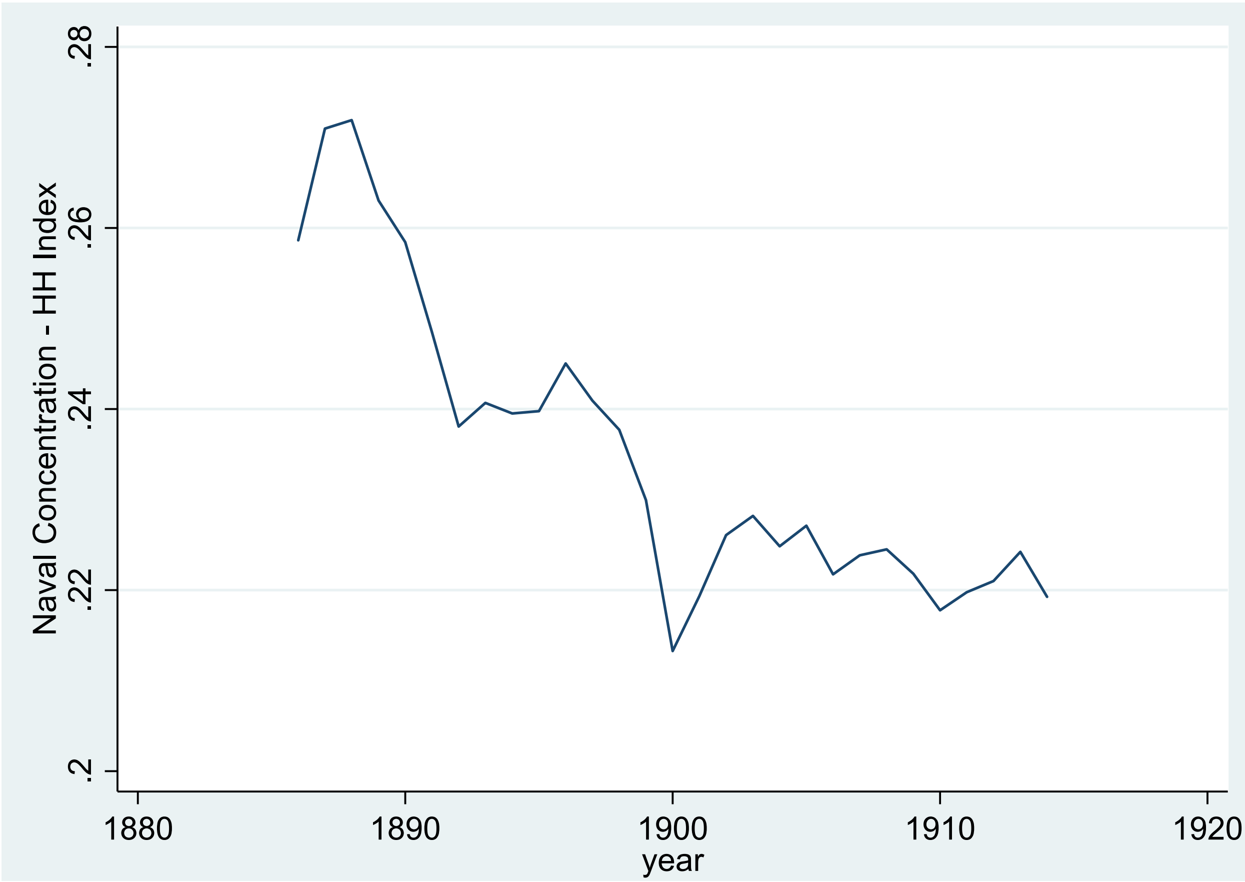
Trade routes also became more sensitive to naval power in the age of steam. Prior to the introduction of steamships, access to trade routes had dependent on wind patterns (Pascali, 2017). As overseas trade became more predictable and less subject to the elements so it became more depended on control of the sea-lanes. Britain as the maritime hegemon provided the public good of eradicating piracy in this period. In the language of our model this is an increase in ψ.

7 Data and Analysis

The model produces testable propositions regarding the country-level factors that influence sea power. We test a few of these propositions empirically for the age of steam. Specifically, we digitize naval power and expenditure measures for two dozen countries documented in Brassey's Annuals. Data include each naval vessel's name, class, displacement, horsepower, armament, ordnance capability, speed, and other characteristics. We construct a panel dataset that provides these measures across navies for the period 1886-1913. Figure 5 shows the HH index measure for the top six navies when we measure naval power as total ship displacement. Observe that the relative convergence in power we see here echoes that of Figure 2 for this leg of the power cycle.

To this data we merge data on war and conflict (from the Correlates of War database

Figure 5: Convergence in Naval Power — Total Displacement



project), trade (from Lopez-Cordova and Meissner 2008), and other economic indicators (from Mitchell 1992, 1993, 1998). We use this data to examine empirically the factors that cause nations to either raise lower spending on naval power. We use a variety of empirical tests for this, including OLS, Tobit, and Simultaneous Equations estimation. This will constitute, to our knowledge, the first fully data-driven study of a wide range of naval powers in the years leading up to the Great War.

Country i has a stock of naval capital N_i which follows a law of motion:

$$N_{it} = [(1 - \delta)\, N_{it-1}] + I_{it} \ , \tag{8}$$

where I_{it} is the investment in new naval capital by power i in year t, and δ captures the depreciation of the existing stock of naval capital. Depreciation comes in the form of aging vessels, as well as technological obsolescence.

To understand factors which lead countries to invest in naval resources, we estimate the following simultaneous equations regression using historical data from Brassey's

Annuals:

$$I_{it} = \beta_0 + \beta_1 I_{jt} + \boldsymbol{X_i'}\boldsymbol{\gamma} + \epsilon_{it} \ , \tag{9}$$

where $\boldsymbol{X}_i$ represents factors which may influence country i's decision to invest in naval resources, such as trade importance or conflicts.[8] This decision is also shaped by the naval investments of a potential rival j (given by I_j). A β_1 estimated to be less than zero would suggest that greater naval strength of country j induces lower naval spending by country i. A β_1 estimated to be greater than zero on the other hand suggests the possibility of a naval arms race.

One important covariate is the relative importance of sea-borne trade for each potential naval power. To include this we re-estimate the bilateral trade model in López-Córdova and Meissner (2008), but distinguish between sea-borne and land-based trade. That is, we estimate a bilateral trade model between country-pairs from 1870 and 1910, controlling for economic size, distance, and other country level features typical in gravity models, but split the sample between sea and land trade for each country. We use the predicted values of each as proxies for sea and land based trade for each country, labeling each respectively as "sea openness" and "land openness."[9]

To measure a nation's capacity for naval production (either GDP or a national capacity index for industrial production provided by the Correlates of War database), the total size of the navy as measured by total displacement of all commissioned vessels, and a time trend.

As a preliminary step, we first estimate a standard model of naval spending, measuring only own-country factors. That is, we first estimate

$$I_{it} = \beta_0 + \boldsymbol{X_i'}\boldsymbol{\gamma} + \epsilon_{it} \ . \tag{10}$$

Then, we estimate the full simultaneous model (equation 9).

[8] From his extensive historical work, Mahan might suggest six specific factors belong in X — geography, physical configuration, extent of territory, population, national character, and governmental institutions.

[9] Data from López-Córdova and Meissner (2008) are measured in 5-year increments. We take our 5-year trade estimates and linearly interpolate for in-between years.

Table 1: Estimating Factors Influencing Naval Spending: OLS

	Gross Tonnage of New Vessels					
	(1)	(2)	(3)	(4)	(5)	(6)
GDP	0.58***	0.09*	-	0.09*	-	-
	(0.05)	(0.05)		(0.05)		
National Capacity Index	-	-	1.7***	-	1.6***	2.2***
			(0.30)		(0.32)	(0.38)
Sea Openness	1818.9***	323.6**	370.4***	396.8***	419.7***	307.1***
	(387.8)	(159.9)	(98.7)	(156.6)	(104.6)	(129.7)
Land Openness	-324.9***	-131.3**	-41.6	-144.4**	-69.9	-147.8**
	(105.0)	(61.2)	(51.2)	(62.4)	(55.2)	(62.2)
Total Disp (Old Stock)	-	0.17***	0.17***	0.17***	0.17***	0.17***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Time Trend	-	-	-	-269.5***	-156.8***	-91.8
				(58.1)	(60.5)	(73.3)
Population	-	-	-	-	-	-0.15***
						(0.03)
Coastline	-	-	-	-	-	-0.06
						(0.13)
R-squared	0.46	0.78	0.79	0.78	0.79	0.79
F-stat	41.8	126.5	171.8	125.0	159.2	112.1
Observations	1083	1083	1337	1083	1337	1047

Table 1 reports estimates of equation 10. It provides suggestive evidence about which factors influence potential naval powers to invest in seapower. Economic size is important, measured either as GDP or the nation's capacity for industry. We also see that our measure of sea openness is a positive predictor for naval spending, while land openness is a negative predictor for naval spending.

We also observe that the amount of existing naval capital positively predicts new naval investments. This makes sense as it captures the many nations with little to no naval power. And as suggested by naval historians, naval capital need not exhibit the typical law of motion of regular capital — according to one: "[naval] appetite grows with eating" (Baer, 1994).

Finally, note that when these other controls are included, geographic factors such as the amount of coastline become statistically insignificant in predicting naval spending.

Table 2: Estimating Factors Influencing Naval Spending: Tobit

	Gross Tonnage of New Vessels					
	(1)	(2)	(3)	(4)	(5)	(6)
GDP	0.73***	0.14***	-	0.15***	-	-
	(0.03)	(0.02)		(0.02)		
National Capacity Index	-	-	2.8***	-	2.5***	2.8***
			(0.25)		(0.25)	(0.30)
Sea Openness	1640.1***	-107.7	-118.0	104.7	18.2	17.5
	(322.4)	(217.0)	(177.3)	(216.4)	(178.5)	(239.0)
Land Openness	-809.7***	-469.3***	-186.5	-545.4***	-303.0**	-387.5**
	(242.0)	(158.5)	(137.5)	(162.0)	(176.1)	(142.0)
Total Disp (Old Stock)	-	0.19***	0.18***	0.19***	0.19***	0.19***
		(0.006)	(0.005)	(0.006)	(0.005)	(0.006)
Time Trend	-	-	-	-814.3***	-601.1***	-512.2***
				(108.3)	(95.1)	(111.4)
Population	-	-	-	-	-	-0.14***
						(0.04)
Coastline	-	-	-	-	-	0.08
						(0.16)
Pseudo R-squared	0.03	0.07	0.08	0.07	0.08	0.08
Chi-square	569.5	1198.2	1507.4	1256.1	1548.2	1266.6
Observations	1083	1083	1337	1083	1337	1047
No. of censored obs.	443	443	625	443	625	428

In Table 2 re-estimate the above using Tobit estimation, as nearly half of all observations are for those nations with zero new naval spending. The results are consistent with Table 1. The estimated effect of sea openness on naval investments falls to statistical insignificance once naval capital stock is included, but the estimated effects of land openness remain negative and statistically significant.

Table 3: Estimating Factors Influencing Naval Spending: Simultaneous Equations Model — British Naval Power

	Gross Tonnage of New Vessels		Total Horsepower of Vessels	
	(1)	(2)	(3)	(4)
British Naval Investment (IV)	0.11***	0.11***	-0.02	-0.03
	(0.04)	(0.03)	(0.03)	(0.03)
National Capacity Index	4.95***	1.96***	6.77***	1.97***
	(0.22)	(0.23)	(0.38)	(0.39)
Sea Openness	150.4	254.6*	-236.3	-21.1
	(165.5)	(134.2)	(281.8)	(234.7)
Land Openness	71.9	-98.8	62.4	-212.1*
	(92.8)	(75.6)	(157.3)	(131.0)
Time Trend	-659*	-1031.7***	1425.4*	1312.0*
	(349.4)	(285.2)	(822.3)	(690.4)
Total Displacement	-	0.12***	-	0.19***
		(0.005)		(0.01)
Pseudo R-squared	0.35	0.55	0.33	0.52
Chi-square	690.1	1575.2	503.2	1170.1
Observations	992	992	992	992

Next we estimate a simultaneous equation model, where Britain is pitted against every other potential power. The left hand side variable I_{it} is country i's naval investment in year t for all countries beside Britain, while the right hand side variable I_{jt} is Britain's naval investment in year t. In essence the first stage is where British naval spending is regressed on British factors related to its sea and land borne trade, it's national capacity for production, its naval capital and a time trend. The model then estimates the effect of a potential rival's naval spending on this estimate of British naval spending.

For what follows, we measure I as either the gross tonnage of all new vessels, or as the total horsepower of all new vessels. The results suggest that British naval investments spur others to themselves invest in naval power, at least when measuring naval power as total displacement of new vessels. The British on the other hand do not appear to respond to other potential rivals at all (results not shown). Rather, they appear to be influenced by the value of their sea-based trade to invest in sea power.

The analysis here may provide us a cautionary tale. As Britain further built up its navy to protect trading interests, it also spurred potential rivals to build their navies, which then conceivably *threatened* British trade. Rather than deter other powers, the Royal Navy may have instead hastened the arms race leading to global conflict.

Table 4: Estimating Factors Influencing Naval Spending: Simultaneous Equations Model: Simultaneous Equations Model — Germany as Rival Power

	Gross Tonnage of New Vessels		Total Horsepower of Vessels	
	(1)	(2)	(3)	(4)
German naval investment (IV)	-0.08***	-0.09***	-0.04***	-0.04***
	(0.03)	(0.02)	(0.015)	(0.01)
National Capacity Index	4.94***	1.95***	6.90***	2.10***
	(0.22)	(0.22)	(0.38)	(0.39)
Sea Openness	139.1	259.9**	-55.7	137.3
	(166.6)	(134.0)	(284.7)	(236.7)
Land Openness	72.9	-97.8	73.2	-201.5
	(92.6)	(75.4)	(156.6)	(130.8)
Time Trend	826.6***	516.6***	1282.0***	742.7***
	(217.7)	(177.3)	(273.3)	(228.4)
Total Displacement	-	0.12***	-	0.19***
		(0.005)		(0.009)
Pseudo R-squared	0.40	0.61	0.33	0.54
Chi-square	693.7	1577.2	507.3	1176.6
Observations	992	992	992	992

In Table 4 Germany is pitted against every other potential power. In contrast to Britain, rival naval powers appear to be cowed by German naval expansion. This may be a function of perceived German aggression on the high seas, compared with the Royal Navy. No doubt political and institutional factors play important roles in determining if the flexing of naval might by one power frightens or emboldens a rival power.

Table 5: Estimating Factors Influencing Naval Spending: Simultaneous Equations Model: Simultaneous Equations Model: USA as Rival Power

	Gross Tonnage of New Vessels		Total Horsepower of Vessels	
	(1)	(2)	(3)	(4)
American naval investment (IV)	0.005	0.002	-0.002	-0.003
	(0.02)	(0.01)	(0.02)	(0.01)
National Capacity Index	4.07***	0.27	5.70	-0.41
	(0.27)	(0.22)	(0.46)	(0.39)
Sea Openness	-83.9	-45.5	-415.5	-351.5
	(155.6)	(108.3)	(262.6)	(291.1)
Land Openness	71.1	-109.0*	68.4	-221.0**
	(83.9)	(58.6)	(141.4)	(103.4)
Time Trend	227.3**	-106.2	630.6***	91.0
	(110.7)	(77.8)	(179.3)	(132.0)
Total Displacement	-	0.13***	-	0.22***
		(0.004)		(0.007)
Pseudo R-squared	0.26	0.64	0.22	0.58
Chi-square	337.4	1713.3	265.7	1342.7
Observations	957	957	957	957

In Table 5 we pit American naval power against all others. Potential rivals do not appear to respond to anything the U.S. Navy does, which does make some sense. The U.S. was not generally perceived as a naval leader until very late in this period when the Great White Fleet was showcased. The U.S.'s relative geographic isolation from other world powers creates a further hindrance to nay foreign response, positive or negative.

Table 6: Estimating Factors Influencing Naval Spending: Simultaneous Equations Model: Simultaneous Equations Model: Local Bilateral Contests

	(1)	(2)	(3)	(4)
Rival naval investment (IV)	0.07***	-0.006	0.04***	-0.002
	(0.02)	(0.02)	(0.01)	(0.01)
National Capacity Index	4.89***	2.17***	7.45***	2.64***
	(0.27)	(0.26)	(0.58)	(0.57)
Sea Openness	2.5	227.5	-766.6	-78.0
	(229.5)	(186.6)	(486.0)	(422.1)
Land Openness	1580.7***	130.4	3389.1***	728.1
	(251.5)	(209.5)	(489.0)	(444.2)
Time Trend	281.6	110.5	1006.8***	629.5*
	(194.4)	(155.4)	(387.5)	(330.5)
Total Displacement	-	0.14***	-	0.25***
		(0.008)		(0.02)
Pseudo R-squared	0.53	0.69	0.44	0.58
Chi-square	695.6	1430.6	477.8	896.8
Observations	636	636	636	636

Finally, in this case we create local contests, pitting countries (I_i) against the dominant regional power (I_j). Specifically, we have Latin American countries face the United States, Scandinavian countries face Germany, Western European countries face Britain, and Russia and China face Japan. The arrangement is admittedly somewhat ad hoc, but does acknowledge geographic proximity.

Baseline regressions suggest the possibility of local arms races — greater spending by the dominant power tends to increase spending by the inferior power. This makes a great deal of historic sense. German, American and Japanese naval leaders were all avid readers of Mahan, who advocated emulating the British and their efforts for total sea domination.

There are of course a number of limitations with the above highly preliminary analysis We intend to further the analysis in future drafts. For instance, we intend to weight rival naval power according to distance from one another. There are also a number of other controls we wish to include related to political and institutional factors. Nonetheless, the analysis here provides an initial and *sui generis* glimpse into how one naval power can respond to another.

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