Public Versus Private Initiative in Arctic Exploration:

The Effects of Incentives and Organizational Structure

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Abstract

From 1818 to 1909, 35 government and 57 privately-funded expeditions sought to locate and navigate a Northwest Passage, discover the North Pole, and make other significant discoveries in arctic regions. Most major arctic discoveries were made by private expeditions. Most tragedies were publicly funded. By other measures as well, publicly-funded expeditions performed poorly. On average, 5.9 (8.9%) of their crew members died per outing, compared to 0.9 (6.0%) for private expeditions. Among expeditions based on ships, those that were publicly funded used an average of 1.63 ships and lost 0.53 of them. Private ship-based expeditions, in contrast, used 1.15 ships and lost 0.24 of them. Of public expeditions that lasted longer than one year, 47% were debilitated by scurvy, compared to 13% for private expeditions. Although public expeditions made some significant discoveries, they did so at substantially higher cost (as measured by crew size or vessel tonnage) than private discoveries.

Multivariate tests indicate that these differences are not due to differences in the exploratory objectives sought, country of origin, the number of previous expeditions on which the leader served, or the decade in which the expedition occurred. Rather, they are due to systematic differences in the ways public and private expeditions were organized. Historical accounts indicate that, compared to private expeditions, public expeditions: (1) employed leaders that were relatively unmotivated and unprepared for arctic exploration; (2) separated the initiation and implementation functions of executive leadership; and (3) adapted slowly to new information about clothing, diet, shelter, modes of arctic travel, organizational structure, and optimal party size. These shortcomings resulted from, and contributed to, poorly aligned incentives among key contributors.

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I. Introduction

Politicians and researchers continue to debate the relative merits of public and private enterprise. Proponents of schemes to privatize government-owned businesses argue that private companies run more efficiently. The evidence, however, is mixed. Boardman and Vining (1989) report that government-owned companies are less profitable than private firms, and Megginson, Nash, and Van Randenborgh (1994) report that newly privatized companies have significant performance improvements. Kole and Mulherin (1997), in contrast, find that large blockholdings by the U.S. government do not correspond to poor corporate performance. Similarly, Caves and Christensen (1980) conclude that publicly-owned Canadian railroads do not perform worse than their private counterparts. Dewenter and Malatesta (1999) find that government-run companies tend to improve performance *before* they are privatized, but not afterwards.

Eckel, Eckel, and Singal (1997) point out that attempts to compare the performances of public and private enterprises encounter problems from differences in accounting, market environments, regulations, and objectives. In this paper I propose an alternative way to investigate the relative efficiencies of public and private enterprise: by examining historical data on arctic exploration in the 19th century.

Much like space exploration in the 20th century, arctic exploration in the 19th century dominated popular culture in Europe and the United States. There are many parallels between exploration of outer space in recent decades and of arctic regions in the last century. Both involved competitive races for major geographic prizes: the first manned orbit and lunar landing in one, and the Northwest Passage and North Pole in the other. In both cases, returning explorers became symbols of national pride. Disasters and deaths triggered widespread mourning and calls for cutbacks in exploration activity.

In one important area, however, the analogy between 19th and 20th century exploration breaks down. The twentieth century space race involved primarily the bureaucracies of two national governments. Nineteenth century polar expeditions, in contrast, were conceived, initiated, and funded by both national governments and private organizations. The public and private expeditions shared a common goal: geographic discovery without loss of life or ship. Initiators of both expedition types were rewarded for discovery through public adulation, awards, promotions, cash prizes, book sales, lecture fees, and larger budgets. They also were penalized for failure, through lost funding opportunities, smaller budgets, and fewer personal rewards. In extreme cases, failure also meant death from accidents, exposure, scurvy, or starvation.

Because goals, prospective rewards, and penalties were in most cases similar, it is possible to make meaningful comparisons between the successes of public and private arctic expeditions. I find that, compared to private expeditions, government-sponsored expeditions tended to be large and well-funded. By most measures, however, the government expeditions fared poorly. They made fewer major discoveries, introduced fewer technological innovations, were subject to higher rates of scurvy, lost more ships, and had more explorers die.[1]

In section II below, I present case histories of several famous arctic expeditions that illustrate these conclusions. To provide a more systematic analysis, sections III through VI compare the characteristics of 35 public and 57 private arctic expeditions from 1818 - 1909. My conclusions, although drawn from multivariate tests that control for various expedition characteristics, are illustrated by several univariate comparisons: an average of 5.9 crew members died on public expeditions, compared to 0.9 on private expeditions. Public ship-based expeditions lost 0.53 ships, on average, compared to 0.24 ships for private expeditions. Debilitating scurvy struck 47% of all public expeditions lasting longer than one year, compared to 13% for private expeditions. Private expeditions not only took most of the major arctic prizes, but they also made arctic discoveries using significantly fewer crew members and vessel tonnage.

In sections VII and VIII, I examine the reasons for public expeditions' poor performance. The evidence does not support arguments that public expeditions assumed great risk or focused on objectives with lower expected returns than private expeditions. It is not explained by any benefits of a public goods nature that might have accrued from public expeditions. Rather, compared to their private counterparts, public expeditions: (1) had poorly motivated and prepared leaders; (2) separated the initiation and implementation functions of executive leadership; and (3) were slow to exploit new information about

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[1] To be sure, most leaders of government-funded expeditions performed courageously -- U.S. Army Captain Adolphus W. Greely, for example, personally cared for his dwindling number of starving men in the winter of 1884, and British Navy Lt. John Franklin literally ate his boots to stay alive in 1821. Many made notable discoveries. Fridtjof Nansen, for example, relied on government funding to implement his plan to *purposefully* get his ship stuck in the polar ice, thereby floating most of the way to reach farther north in 1895 than any previous explorer. Also, some privately funded expeditions were fiascos -- Evelyn Baldwin, for example, so alienated his crew that his 1901 attempt at the North Pole achieved nothing, despite lavish financial support from industrialist William Ziegler. Overall, however, public expeditions represent few of the major arctic discoveries and many of the fiascos.

clothing, diet, shelter, modes of arctic travel, organizational structure, and optimal party size. These shortcomings resulted from, and contributed to, poorly aligned incentives among key contributors.

II. Arctic Exploration During the Heroic Age: 1818 - 1909

II.A. Major arctic prizes

Nineteenth century arctic exploration focused on two major goals: to discover and navigate the Northwest Passage, and to reach ("discover") the North Pole. A third goal, to discover the fate of the lost Franklin expedition of 1845, rose to prominence in the 1850's.[2] Each of these prizes promised riches "beyond his wildest dreams" to the person who achieved it (Berton 1988, p. 21). The British government, for example, posted a £15,000 award for the discovery of a Northwest Passage. Successful explorers also anticipated, and typically received, knighthoods, political positions, and/or honorary treatment around the world, not to mention a lucrative income from books and lecture tours.

In terms of accomplishing these major quests, private explorers fared much better than those who relied primarily upon public funds. Running a shoestring budget, Roald Amundsen first navigated the Northwest Passage from 1903-06 after sailing from Norway in the middle of the night to prevent a creditor from confiscating his ship. Robert Peary, backed by a council of such wealthy investors as J.P. Morgan, laid the first credible claim to the North Pole in 1909.[3] And despite enormous public expenditures by the British government from 1847 to 1855 to locate John Franklin's missing crew, Franklin's fate was determined almost exclusively through private efforts: John Rae first discovered relics and remains of some crew during 1853-54, and Francis M'Clintock in 1858 discovered the sole written record ever found from the ill-fated expedition. Later (private) expeditions by Charles Francis Hall and Frederick Schwatka discovered additional relics and interviewed Inuit Natives to help complete the narrative.

[2] A fourth major arctic goal was the crossing of Greenland, accomplished by Fridtjof Nansen during 1888-89. Nansen's primary competitors were Robert Peary and A.E. Nordenskiold, who failed in previous attempts to cross Greenland. Because it did not involve a long-running competition between public and private expeditions, the crossing of Greenland may not rise to the level of the three major arctic quests. I include it in some empirical tests below, but the results are not sensitive to how this goal is categorized.

[3] Frederick Cook's claim to have reached the North Pole in 1908 was thoroughly discredited by 1911. Peary's claim also has been criticized, although historians agree that he reached much further north than any predecessor; unlike later North Pole explorers, he also *returned* without air or other assistance (e.g., see Rawlins 1972; Herbert 1989). Richard Byrd's claim to have flown to the North Pole in 1926 also is disputed (e.g. see Fisher 1992, pp. 192-200). The first undisputed claim to the North Pole is by Roald Amundsen, who flew by dirigible in 1926. The Cook, Byrd, and Amundsen expeditions all were privately funded.

The sole portion of a major arctic prize that can be credited to a publicly-sponsored expedition is the initial verification that a Northwest Passage exists. Traveling east around Alaska in 1850, British Navy Captain Robert McClure's ship was beset in ice near the northern shore of Banks Island. In 1853, with four out of 66 crew members dead and the rest near death by starvation, McClure was saved by a sledging crew from a British naval expedition that entered the Canadian archipelago from the Atlantic Ocean. McClure abandoned ship and returned to England via the Atlantic Ocean with his rescuers, but in doing so generally is credited with having discovered the first Northwest Passage.[4,5]

II.B. Major arctic tragedies

Although publicly-sponsored expeditions achieved few of the major discoveries, they comprise the major tragedies of arctic exploration. The most famous tragedy is the 1845 Franklin expedition. Franklin's ships left London with orders to circumnavigate the earth via a Northwest Passage. After last being sighted by Baffin Bay whalers in 1845, however, Franklin's ships were never seen again. Subsequent reports from John Rae and Francis M'Clintock indicate that the ships were trapped in ice and destroyed, and that crew members died trying to walk south to safety. "They fell down and died as they walked along," reported an old Inuit woman to M'Clintock (Courtauld 1958, p. 290). Evidence of cannibalism indicates that most crew members starved to death.

A second famous tragedy resulted from a U.S. Government-sponsored expedition during 1881-84 led by Adolphus Greely, an officer in the Army Signal Corps. Greely's men were deposited on a northern shore of Ellesmere Island, from where sledging parties established a record for a furthest north. But when no relief ship appeared by 1883, Greely, following orders given him at the start of the expedition, abandoned his base and traveled south on foot, hoping to be picked up by a rescue ship. Nineteen of

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[4]Another publicly-funded expedition, the one led by Franklin in 1845, also may have found a Northwest Passage. Franklin's ships sailed through and eventually got stuck in ice in a portion of the Canadian archipelago that now is called Franklin Strait. It is possible that, before their death, the crew traveled by foot over the last remaining unexplored stretch of a Northwest Passage via Rae Strait and Queen Maud Gulf.

[5]Although I focus on arctic exploration, the experiences of many antarctic explorers of this period are similar. For example, Roald Amundsen’s private expedition to the South Pole was so finely managed that, traveling over entirely new terrain, he and his men actually gained weight during their excursion to the Pole. Robert Falcon Scott, in contrast, displayed less adaptability to antarctic conditions. Although Scott's last expedition was financed largely by private sources, Scott maintained the rigid naval conventions that characterized his previous and nearly-disastrous antarctic expedition in 1901-03, for which he was selected by the British Navy. Scott and four crew members died after getting beat to the South Pole by Amundsen (see, e.g., Huntford 1999).

Greely's crew of 25 died before rescuers found the six starving survivors huddled under a fallen canvas tent near the southern part of Ellesmere Island.

Among privately-funded expeditions, the greatest tragedy involved an attempt by Navy Lieutenant George Washington De Long from 1879-81 to reach the North Pole by travelling north of Siberia. (The expedition was "... indorsed (sic) by special act of Congress", which "authorized the Secretary of the Navy to take charge of the expedition and to appoint De Long to its command" (Miller 1930, pp. 187, 189). It was staffed by Navy personnel and conducted under Navy discipline. But since a majority of financial support came from James Gordon Bennett, the publisher of the New York *Herald*, I classify this as a private expedition.) His ship trapped and damaged by ice, De Long and his crew headed south to Siberia in three small boats. When a storm overtook them, one boat disappeared, a second reached safety, and a third reached shore only to have most of its members die of starvation. In all, 20 of the 33 crew members died, including De Long.

III. Data

As the De Long tragedy illustrates, privately-funded expeditions were not uniformly successful. Likewise, many significant discoveries were made by expeditions that used government funds. To examine more systematically the determinants of expedition success and failure, I use data on 92 different arctic explorations from 1818 through 1909. Appendix 2 lists these 92 expeditions. I begin my analysis in 1818, when the British Navy first exploited renewed interest in arctic discovery to forestall calls for military downsizing. The sample period ends in the year Robert Peary claimed to reach the North Pole. After 1909, technological changes -- especially in air travel and wireless communications -- and the increasing diversity among explorers' goals make difficult any direct comparisons between public and private expeditions. Viljhammer Stefansson's expeditions starting in 1913, for example, sought new arctic lands and a mythical tribe of "Blond Eskimos." In 1926, Roald Amundsen and (possibly) Richard Byrd each reached the North Pole by air (see Clarke 1964; Fisher 1992, pp. 192-201).[6]

[6] Anecdotal evidence from the years after 1909, however, is consistent with the evidence reported in this paper. An expedition sponsored by the Canadian government and led by Viljhammer Stefansson from 1913 - 18, for example, was marked by poor organization and conflicting incentives among the leaders and scientists on the trip. The expedition lost both its ship and the lives of 11 of 25 members (see McKinlay 1999). The last great arctic tragedy, involving the Italia dirigible in 1928, was sponsored by Mussolini's Italian government. Eight of the 16 crew died and the airship was lost (see Fisher 1992, pp. 202-9).

The expeditions listed in Appendix 2 were identified from Holland (1994a) and Berton (1988). Data on the expedition's initiator, the leader's prior experience, primary sources of funding, ships and vessel tonnages, crew sizes, deaths, incidence of scurvy, and other outcomes were collected from a variety of additional sources listed in the references and Appendix 1. The information from these sources sometimes is inconsistent. For example, two different sources may report slightly different crew sizes or vessel tonnages. When conflicts arise, I use the information provided in Holland (1994a), if available, then Berton (1988), then the source that by date or author identity seems closest to the expedition in question.

During the 1818-1909 period, hundreds of voyages were taken to arctic regions. Most, however, were commercial whaling and sealing ventures, or trips to resupply the Hudson Bay Trading Company's outposts in northern Canada. I focus instead on expeditions made primarily -- in many cases exclusively -- for geographic discovery, focusing primarily on the Northwest Passage, Greenland, and North Pole. I exclude expeditions seeking the Northeast Passage (across the Russian arctic) or exploring the Bering Sea and Alaska.

Some expeditions, particularly during the Franklin search period of 1847-1859, involved coordinated efforts from more than one ship. As an example, Horatio Thomas Austin commanded four ships during a 1850-51 effort to find Franklin. In general, I list such efforts as single expeditions. In isolated cases I treat ships that were dispatched together as separate expeditions. The most notable example of this involves Robert McClure in 1850-54. McClure's *Investigator* originally was supposed to be part of a larger search coordinated by Richard Collinson aboard the companion ship *Enterprise*. Through a combination of miscommunication and deception, however, McClure effectively established separate command, and his is treated as a separate expedition in this study. While such treatment involves judgment calls on my part, the major empirical results reported below do not change if I treat these cases as parts of their original expeditions.

Data on vessel tonnages are reported only occasionally in most popular accounts of arctic travel. When popular or first-hand accounts do not provide vessel tonnage data, I rely on Hartman's (1983) *Guiness Book of Ships and Shipping*, Kemp's (1976) *Oxford Companion to Ships and the Sea*, and various issues of *Lloyd's Register of Shipping* (1850, 1851, 1875, 1900, 1905).[7] I can find no

[7] Most reported figures are based on *displacement* tonnage, a measurement of vessel weight. Some figures for private expeditions reflect *register* tons, a measure of carrying capacity volume. The two measures are correlated measures of ship size, as indicated by a strong correlation (0.8) between reported tonnage and crew size in my sample. There is some evidence, however, that, on average, a displacement ton is a smaller unit than a register ton (e.g., Johnson 1913, p. 105;

information on the tonnage weights for 10 vessels. For tests reported in this paper, I estimated tonnages for these 10 vessels using a technique described by Maddala (1977, p. 204). Using data from all expeditions with complete records, I first estimated an ordinary least squares regression using tonnage as the dependent variable and crew size and expedition year as independent variables. Coefficients estimated from this regression were then used to fit values for vessel tonnage for the 10 cases. The results reported here are not sensitive to this procedure, and tests in which these 10 expeditions are excluded yield similar conclusions.

Table 1 reports the distribution of the expeditions by nationality and the decades in which they began. A majority (49) were British, 24 American, and 19 from continental Europe, including Austria, Denmark, Germany, Italy, Norway, Russia, and Sweden. Until an American expedition led by Lt. Edwin DeHaven in 1850, all expeditions were British. The decade of the 1850's has the largest number of expeditions, due to the intensive search for the lost Franklin expedition. Many expeditions also occur in the latter decades, reflecting increased interest in arctic exploration from the United States and continental Europe.

Panel B of Table 1 shows how the goals of arctic exploration changed over time. From 1818 through 1846, 14 of 16 expeditions sought the Northwest Passage. Expedition leaders' stated goals changed after Franklin's disappearance in 1845. Of the 28 expeditions from 1847 through 1864, 27 ostensibly were to search for Franklin. There is little doubt, however, that in many cases the Franklin search was a thinly veiled excuse for further discovery, most often to seek the Northwest Passage. Following the discovery of a passage in 1854 and of Franklin's demise by 1859, the Franklin search wound down and the focus of arctic exploration shifted to the North Pole. Thirty-four of the 48 expeditions between 1868 and 1909 sought the Pole. During this period, 11 expeditions had other primary motives, most involving Greenland. These include Fridtjof Nansen's 1888-89 first crossing of Greenland, and Robert Peary's 1891-92 and 1893-95 expeditions to northern Greenland (largely to determine Greenland's northernmost reach).

Many expeditions relied on combinations of public and private support. As shown in Panel C of Table 1, however, 35 relied primarily (i.e., more than 50%) upon government funding, while 57 were

Gould 1928, pp. 10-11, 34; Dunnage 1925, pp. 85-6). The tests reported here treat all tonnage measures as equivalent. None of the results are sensitive, however, to reasonable alternative assumptions about which vessels are measured using which method, and how to convert from one method to the other. The results also are not sensitive to assumptions about which vessel tonnages may have been affected by a 1854 change in the definition of register tonnage.

supported primarily from private funds. Government-supported expeditions generally are more common in the first half of the sample period, and privately-supported expeditions are more common in the latter half. In most decades, however, public and private expeditions competed directly with each other.

Finally, Panel D of Table 1 reports on the primary mode of transportation used in the expeditions. Sixty-three were primarily ship-based, in which ships were navigated in search of the Northwest Passage, Franklin, or the North Pole. Of the remaining 29, 25 relied primarily on overland or ice travel, and four relied primarily on helium balloons in attempts to reach the North Pole. The distinction between land and ship-based expeditions sometimes is ambiguous. Many overland expeditions were supplied by ships, and most ship-based expeditions deployed teams that traveled over land and ice. I classify those for which the ship was used as most crew members' primary home as ship-based. If the ship deposited the explorers and returned to civilization, I classify the expedition as land-based. As reported in Panel D, the mix of ship-based versus other travel modes is roughly constant over time.

IV. Characteristics of public versus private expeditions

Anecdotal evidence suggests that public expeditions were much better financed than private expeditions. This is consistent with the evidence reported in Table 2. Sixty-three of the 92 expeditions -- 30 public and 33 private -- were based on ships. Of these, publicly-funded expeditions employed an average of 1.63 ships, private expeditions an average of 1.15 ships. The difference in means is statistically significant at the 1% level using both parametric and Wilcoxon rank sum test statistics. Public expeditions not only employed more ships, they also used larger ships. The mean tonnage per vessel on public expeditions is 365.8, compared to 260.6 for vessels on private expeditions. The mean tonnage of all vessels used, per expedition, is 596.2 tons for public expeditions and 276.9 tons for private expeditions. This difference is statistically significant at the 1% level.

Public expeditions also employed more people. The average crew size for all 35 public expeditions, including both land and ship-based trips, is 69.7. For private expeditions, it is 16.0. (Crew data are not available for two private expeditions: an 1871 North Pole excursion by Benjamin Leigh Smith and a 1900 German North Pole expedition led by Oskar Bauendalh.) Thus, public expeditions used more and larger ships, and employed substantially more people, than private expeditions. This indicates that the typical public expedition was much more costly than the typical private expedition.

Also reported in Table 2, leaders of public expeditions had been on 1.8 previous arctic or antarctic exploratory expeditions, on average. Their private counterparts previously had been on 1.5 previous polar expeditions. This difference in experience, however, is not statistically significant.

V. Univariate comparisons of expedition outcomes

Unlike profit-seeking businesses, arctic explorations have no single measure -- i.e., wealth creation -- by which to judge success or failure. Instead, I focus on four alternative groups of measures: crew member deaths, loss of ship, incidence of scurvy, and the efficiency with which new discoveries were made.

V.A. Crew member deaths and death rates

My first measures are the number and percentage of crew member deaths. None of the arctic explorers in my sample displayed anything short of a fervent desire to return home alive. Even for expedition leaders who returned alive, the death of any crew member was treated as both a tragedy and a failure of the expedition. Deaths reflected poorly on the expedition leader, possibly tarnishing his image and decreasing his ability to transform arctic fame into wealth or promotion. Deaths increased the public's perception of the risk of future expeditions, thus making more difficult one's ability to raise money from either public or private sources.[8]

Panel A of Table 3 reports on the average numbers and percentages of deaths for public and private expeditions. On average, 5.9 crew members died on public expeditions, compared to 0.9 on private expeditions. The difference is statistically significant at the 1 percent level using the Wilcoxon measure, but because of the large variance due to the 1845 Franklin disaster, the parametric test statistic is not significant. Omitting the Franklin expedition, the mean number of deaths on public expeditions falls to 2.3, but the t-statistic for the difference in means increases to 1.84.

[8]The adverse impact of crew members' deaths is reflected in newspaper editorials of the time. For example, responding to Sherard Osborn's 1868 proposal for a British North Pole expedition, *The Times* of London argued, "We must protest in the name of common sense and humanity ... We trust that not a single life may be adventured in another attempt to reach the North Pole" (Berton 1988, p. 412).

One reason public expeditions had more deaths is that they deployed more crew. Still, the death rate as a percentage of crew size is larger for public expeditions, 8.93% versus 6.04% on private expeditions. The difference is statistically significant at the 10% level using the Wilcoxon signed rank test statistic.

V.B. Ships and vessel tonnage lost

Other than losing crew members, the greatest single representation of failure among sea-going expeditions was the loss of ship. The ship was the expedition's link to civilization and safety. Losing it doomed crew members to an extended period of privation and uncertainty over their fate. Even among leaders who survived, shipwrecks could end careers. In the British Navy, for example, the loss of ship triggered an automatic court-martial of the captain (Struzik 1991, p. 97). In my sample, only three leaders returned to lead a subsequent expedition after losing a ship. Even in these cases, shipwrecks appear to have had adverse reputational effects.[9]

By this measure also, public expeditions fared poorly. As reported in Panel B of Table 3, among the 30 ship-based public expeditions, the mean number of ships lost is 0.53. The mean for the 33 ship-based private expeditions is 0.24. Thus, approximately one ship was lost for every two public expeditions or every four private expeditions. These means are significantly different at the 10% level using the parametric t-statistic, but not using the Wilcoxon rank-sum test statistic.

One reason public expeditions lost more ships is that they deployed more of them. Public expeditions lost 33.8% of their ships deployed, compared to 22.7% for private expeditions. This difference, however, is not statistically significant.

Panel B also reports on the vessel tonnage represented by the lost ships. The mean loss for public expeditions is 197.9 tons, compared to 59.7 tons for private expeditions. The difference is statistically significant at the 5% level using the parametric t-test, and at the 10% level using the Wilcoxon test. Public expeditions also lost a greater fraction of their vessel tonnage employed, 34.9% versus 22.3% for private expeditions. This difference, however, is not statistically significant.[10]

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[9] Edward Parry shifted his attention away from the Northwest Passage and attempted only one more expedition after losing the *Fury* in 1824, and John Ross had to finance his final 1850 expedition largely on his own after losing the *Victory* in 1830. Only Walter Wellman, who lost the *Ragnvald* in 1894, continued to pursue an extended arctic career after his shipwreck.

[10]In addition to the 63 ship-based expeditions, I have data on the ships used by 11 of the land-based or balloon expeditions. Ten of these are private and one public. Including data from these 11 expeditions, the differences in means and associated test statistics for each of the measures in Panel B become larger. For example, the mean number of ships

V.C. Scurvy

Scurvy -- a debilitating and ultimately fatal disease attributable to a vitamin C deficiency -- contributed to many expeditions' problems. The cause of scurvy was not established until the 20th century. Until then, avoiding it was a central goal of nearly all expeditions. In addition to contributing to crew members' deaths, scurvy's debilitating symptoms severely limited their exploring capabilities. Arctic explorers tried various methods to avoid it, including brisk exercise, diversionary entertainment, lemon juice, and fresh meat. (Of these, only the latter two are anti-scorbutics.)

Scurvy's effects (e.g., swollen joints, bleeding gums, loose teeth) typically became apparent only after several months. Even if scurvy was incipient on expeditions lasting less than one year, its presence usually was undetected. I therefore examine the incidence of scurvy for the 68 of the 92 expeditions that lasted longer than one year. Of these, 19 definitely or probably were affected by advanced forms of scurvy. Twenty others were free of it. The remaining 29 expeditions most likely did not have significant scurvy problems. Panel C of Table 3 reports on two measures of the incidence of scurvy. The first excludes the 29 cases about which I am uncertain, and the second presumes that these expeditions did not have advanced scurvy problems.

Based on the first measure, 14 of 17 (82.4%) of public expeditions had significant scurvy problems. Only five of 22 (22.7%) public expeditions had such problems. Using the second measure, 14 of 30 (46.7%) public expeditions, and five of 38 (13.2%) private expeditions had scurvy. Both differences in proportions are statistically significant at the 1% level.

V.D. Achievements

Panel D reports on three measures of expedition achievement. The first reflects the major arctic prizes: discovery and navigation of the Northwest Passage, discovery of the lost Franklin expedition, and discovery of the North Pole. I include the initial crossing of Greenland as a fourth major prize.[11] Of the 35

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lost per public expedition is 0.52, and per private expedition is 0.19. This difference in means is statistically significant at the 5% level using either the parametric or Wilcoxon test statistic.

[11]As noted in footnote 3, the initial crossing of Greenland may not rise to the level of a "major arctic prize." Hence, an argument can be made to exclude it from this list. Demoting it to my second measure of achievement ("major geographic discoveries"), however, has little effect on the results reported here.

public expeditions in the sample, only one, or 2.9% (Robert McClure in 1850-54) achieved one of these prizes. Five of the 56 private expeditions accomplished one of the prizes: Rae in 1853-54 and M'Clintock in 1857-59 each claiming a share of the resolution to the puzzle of the missing Franklin expedition, Nansen crossing Greenland in 1888-89, Amundsen navigating the Northwest Passage from 1903-06, and Peary making it to the North Pole (or thereabouts) in 1908-09. However, the success rate for private expeditions of 8.8% is not significantly higher than that for public expeditions.

A second measure of achievement recognizes other major geographic discoveries in addition to the major arctic prizes. I define such additional major discoveries as consisting of: (i) major island groups (e.g., Weyprecht's discovery of Franz Josef Land during 1872-74), (ii) the establishment of a new farthest north (e.g., Parry in 1827), and (iii) three additional expeditions that I judge as meriting the distinction of a “major discovery”. These three are John Ross' discovery of the north magnetic pole during 1829-33, Parry's 1819-20 push into the Canadian archipelago that was not duplicated for over 30 years, and Nordenskiold's 1868 trip in which he took a ship farther north than any previous explorer. Using this criterion, public and private expeditions had similar records of achievement. A total of 7 of 35 (20%) public expeditions, and 11 of 57 (19.3%) private expeditions recorded such major discoveries. The difference in proportions is not statistically significant.

A third measure of achievement includes the major discoveries plus a number of lesser-known but significant accomplishments. I include 14 additional expeditions in this set. Examples include Franklin's 1825-27 charting of 1,000 new miles of the Canadian arctic coast, George Back's 1833-35 discovery and navigation of the Back River, William Kennedy's record-setting sledge trip during 1851-52, and Elisha Kent Kane's 1853-55 push into Smith Sound and the Kane Basin. As reported in Panel D of Table 3, 12 of 35 (34.3%) public expeditions recorded such achievements. Of the 57 private expeditions, 20 (35.1%) recorded achievements of similar importance.[12]

V.E. Achievement efficiency

Although the rates of achievement do not differ significantly between public and private expeditions, the efficiencies with which the achievements were made do. This is because public expeditions tended to

[12]My classification of significant accomplishments admittedly is subjective. Any reasonable reclassification of the expeditions -- for example, excluding Back's navigation of the Back River or including Peary's 1891-92 trek to northern Greenland -- does not alter substantially the results in Panels D and E of Table 3.

be much larger and more costly than private expeditions. Panel E reports on three measures of achievement efficiency. The first is

$$\text{Efficiency measure \#1} = (1 + \text{Major arctic prize})/\text{Crew size}, \qquad (1)$$

where "Major arctic prize" equals one for expeditions achieving a major arctic prize, and zero otherwise. Also,

$$\text{Efficiency measure \#2} = (1 + \text{Major geographic discovery})/\text{Crew size}$$

$$\text{Efficiency measure \#3} = (1 + \text{Lesser but significant accomplishment})/\text{Crew size}.$$

These measures use crew size as a proxy for expedition cost. Each has a potential range of 0 to 2. Large expeditions that achieved little have low efficiency measures, whereas small expeditions that made achievements have high measures.

The mean value of the first efficiency measure for private expeditions is 0.139, compared to 0.024 for public expeditions. For the second efficiency measure, the mean value for private expeditions is 0.147 compared to 0.030 for public expeditions, and for the third efficiency measure, the mean value for private expeditions is 0.170, compared to 0.034. The differences are statistically significant at the 1% level for all three measures.

The finding that private expeditions made discoveries at significantly lower cost than public expeditions is not sensitive to the specific efficiency measure. For example, the results are qualitatively similar if I use vessel tonnage, crew member deaths, or ships lost as proxies for an expedition's cost. The results also are similar if I assign different values to "achievement." For example, if "Major arctic prize" in equation (1) is assigned a value of 2, or 10 (instead of one), for expeditions achieving a major arctic prize, private expeditions' efficiency measures remain significantly higher than those for public expeditions.

Thus, as shown in Panel D, private expeditions recorded most of the major prizes of arctic exploration. When the definition of arctic achievement is expanded to include major geographic discoveries or other lesser-known but important discoveries, public and private expeditions achieved successes at roughly equal rates. As shown in Panel E, however, private expeditions made discoveries of all types at significantly lower cost than public expeditions.

VI. Determinants of expedition failure and success

VI.A. Determinants of crew member deaths and death rates

The univariate comparisons reported in section V do not control for numerous factors that conceivably contribute to expedition success or failure. In this section I report on multivariate tests that seek to control for the time period, nation of origin, goals, and other expedition characteristics. Table 4 reports on the determinants of crew member deaths and death rates. The number of deaths is highly skewed, so my first measure is the natural log of one plus the number of crew members who died. At least one death occurred on 39 of the 90 expeditions on which I have sufficient data. On the other 51 expeditions, all crew members survived. Because of the large number of cases for which the number of deaths is zero, I use a Tobit censored regression model.

The independent variables include the following:

- PRIVATE is a dummy variable set equal to one for expeditions that were initiated and funded primarily through private sources.
- BRITAIN and USA are dummy variables indicating whether the expedition was from Great Britain or the United States, respectively. Expeditions from continental Europe are reflected in the constant term.
- NORTHWEST PASSAGE, FRANKLIN SEARCH, and NORTH POLE are dummy variables indicating the expedition's main objective. The 11 expeditions in the sample that had other primary objectives (e.g., Greenland) are reflected in the constant term.
- Finally, I include dummy variables representing the decade in which the expedition began. Separate dummies are defined for expeditions in the 1820's, 1830's, 1840's, continuing to the 1900's. The four expeditions initiated in 1818 and 1819 are reflected in the constant term.

The results are reported as Model 1 in Table 4. The coefficient for PRIVATE is -1.43 with a t-statistic of -3.37, and is statistically significant at the 1% level. Thus, private expeditions experienced significantly fewer deaths than public expeditions, even after controlling for the nation of origin, objective, and time period.

None of the other reported coefficients are significantly different from zero. The coefficients for BRITAIN and USA indicate that the number of deaths is not significantly related to nationality of origin. The number of deaths also is not significantly related to whether the expedition's objective was the Northwest Passage, the search for Franklin, or the North Pole. Although not reported in the table, the coefficient for the 1840's dummy variable is positive and significant at the 5% level, reflecting largely the influence of the 1845 Franklin tragedy.[13]

Model 2 in Panel A includes four additional regressors that characterize the expedition's mode of travel, leader's experience, and crew size:

- LAND is a dummy variable set equal to one for each of the 24 expeditions that relied primarily upon land-based exploration.
- BALLOON is set equal to one for each of the four (two each by Salomon Andree and Walter Wellman) that sought to reach the North Pole by helium balloon. If land-based or balloon exploration attempts pose fundamentally different risk than ship-based travel, these variables could be related to the number of deaths.
- EXPERIENCE is equal to the number of previous polar expeditions on which the expedition leader served.
- CREW is the number of crew members. The number of deaths quite plausibly is related to the number of people that embark on the expedition.

As reported in Model 2, the coefficient for LAND is -1.07 with a t-statistic of –1.91, indicating that land-based expeditions had fewer deaths than ship-based ones. The other three additional variables are not significantly related to the number of deaths. The coefficient for PRIVATE is reduced to -1.12, but remains statistically significant at the 5% level. (As reported in Section III, crew sizes are relatively large for public expeditions. Because of this, the inclusion of CREW decreases the coefficient and t-statistic for PRIVATE in all of the model specifications examined.)

One additional factor that may have affected crew member deaths is the size of the expedition's supporting budget. Expedition leaders allocated scarce budgets among many items, including food, equipment, support staff, and travel. In doing so, they traded off safety against expedition amenities and the probability of success. It is reasonable to expect that leaders with less constrained budgets were able

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[13]Although its 129 deaths far exceed that of any other expedition, the results reported here are not sensitive to the inclusion to the 1845 Franklin tragedy. When this expedition is excluded, the coefficient for PRIVATE (and t-statistic) becomes -1.26 (-3.08) in Model 1, -1.03 (-2.20) in Model 2, and -0.87 (-2.08) in Model 3 of Table 4. The results also are not sensitive to the inclusion of alternate control variables. For example, the coefficient for a measure of capital intensity (equal to vessel tonnage divided by crew size) is not statistically significant, and its inclusion does not substantially affect the coefficient for PRIVATE.

to purchase more amenities, success, and safety. Thus, well-funded expeditions should have relatively few deaths.

I do not have budget information on any but a small number of expeditions. One proxy for expedition funding on which data are available, however, is the crew size. Extra crew required extra food, clothing, space, and supplies, so budget-constrained expeditions were unlikely to have large crews. Model 3 in Table 4 reports the results of a Tobit regression model in which observations are weighted by CREW. To the extent that CREW correlates with the expedition budget, the weighted model controls for the additional safety afforded well-funded expeditions. The procedure weights relatively heavily any crew deaths from well-funded expeditions.

The coefficient for PRIVATE in Model 3 is similar to that in Model 2. Coefficients for USA and Franklin search expeditions, however, become significant at the 10% level, while that for land-based expeditions becomes statistically insignificant. In addition, coefficients for the 1840's, 1850's, 1870's and 1880's, while unreported, become positive and statistically significant at the 5% level. In effect, the weighted regression emphasizes the deaths from several large (and presumably well-funded) expeditions in the middle part of the 19th century. Controlling for the overall high numbers of deaths during the 1840 – 1889 period, expeditions from the USA had large numbers of deaths, and those searching for Franklin had relatively few deaths.

Models 4 - 6 of Table 4 report on three Tobit regressions in which the dependent variable is the death rate, defined as the fraction of the crew members who died while on the expedition. This measure places less emphasis on the Franklin tragedy than the log of the number of deaths. It places greater emphasis on smaller expeditions in which at least one crew member died. For example, the 100% death rate for the 129-man (public) Franklin expedition in 1845 has the same value for the dependent variable as the 100% death rate for the 3-man (private) Andree expedition in 1897.[14]

As reported in Model 4, the death rate is negatively and significantly related to PRIVATE. The coefficient of –0.23 implies that, holding other factors constant, private expeditions had a 23% lower death

[14]Salomon Andree attempted to float to the North Pole in a helium balloon. All three crew members, including Andree, disappeared and were never seen alive again after their balloon left Spitsbergen. The mystery was solved in 1930 when Andree's remains and journal were discovered on White Island near Spitsbergen. The crew survived the balloon's crash, but died during their attempt to reach civilization.

rate than public expeditions. The coefficient for the Northwest Passage dummy variable is positive and significant at the 5% level (as is the 1840's decade dummy variable), reflecting in part the Franklin tragedy.

The coefficients for these variables decline slightly in Model 5, in which the EXPERIENCE, BALLOON, LAND, and CREW variables are included. None of the added variables is significantly related to the crew member death rate.

Model 6 reports the results in which the observations are weighted by the size of CREW, thereby placing greater emphasis on larger, better-funded expedition death rates. The coefficient of -0.14 indicates that, controlling for the other regressors, crew members on privately-funded expeditions had a 14-percentage point higher likelihood of staying alive than those on publicly-funded expeditions.

It would appear that crew members on U.S. expeditions had a 19% higher probability of death than crew members on European expeditions (since non-British European expeditions are reflected in the constant term), and those involved with the Franklin search had a 73% lower probability of death than those with "other" objectives (which are reflected in the constant term). Both of these results, however, depend upon the inclusion of decade fixed effects. The coefficients for the 1840's and 1850's dummy variables are 1.01 and 0.93, respectively, and both are statistically significant at the 1% level. The 1840's coefficient reflects in part the Franklin disaster, and most expeditions during the 1850's were British searches for Franklin. Omitting the decade fixed effects, both the USA and FRANKLIN SEARCH coefficients are statistically insignificant. Hence, the results in Model 6 indicate that, among expeditions *after* the 1850's, crew members on U.S. expeditions faced high likelihood of death and those searching for Franklin faced a low likelihood of death.

Overall, the results in Table 4 indicate that both the numbers and rates of crew member deaths are significantly lower for private than for public expeditions. Expeditions during the 1840's and 1850's had unusually high death numbers and rates, although the 1840's results reflect in part the 1845 Franklin tragedy. For expeditions outside these two decades, expeditions originating in the U.S. had greater numbers of deaths and death rates.

VI.B. Ships and vessel tonnage lost

Table 5 reports on multivariate tests of the determinants of lost vessel tonnage. Of the 63 expeditions based from ships, 20 lost at least one ship. The sizes of the ships lost vary from 66 to 1082 tons, and the distribution of lost vessel tonnage is skewed. In models 1 - 3 the dependent variable is defined as the natural log of one plus the lost vessel tonnage.

Including all nine decade dummy variables causes multicollinearity problems that prevent the computation of standard errors. I therefore replace the decade dummy variables with a single dummy variable set equal to one for pre-1860 expeditions. The results from Model 1 indicate that lost vessel tonnage is not significantly related to the PRE-1860 dummy, the nation of origin, or the expedition objective. It is negatively related, however, to whether the expedition was primarily privately funded: the coefficient for PRIVATE is -5.41 with a t-statistic of -2.25.

Model 2 includes the EXPERIENCE variable and TONNAGE, which is the total tonnage of all ships deployed on the expedition. TONNAGE reflects both the expedition size and the tonnage that potentially could have been lost. (The LAND and BALLOON variables are omitted because all 63 expeditions included in this regression are ship-based.) In Model 3, observations are weighted by TONNAGE, which serves as a proxy for the expedition's cost. The effect is to weight more heavily any vessel tonnage lost by relatively expensive, and presumably better equipped, expeditions. (The results are virtually unaffected when CREW is used in place of TONNAGE to measure the expedition size or to weight the observations.) The results from Models 2 and 3 are virtually identical to those from Model 1: only PRIVATE is significantly related to the vessel tonnage lost.

The dependent variable in models 4 - 6 of Table 5 is the ratio of vessel tonnage lost to that deployed on the expedition. As before, Models 4 and 5 are unweighted, and in Model 6 observations are weighted by vessel tonnage. (Results using the fraction of ships lost, without regard to the ships' sizes, are similar to those reported.) The coefficient for PRIVATE is negative in all three regressions, but its t-statistics are lower than in Models 1 - 3, ranging from -1.57 to -1.75. Only in Model 6 is the coefficient statistically significant at the 10% level. The results therefore are consistent with the univariate comparisons: controlling for the nation of origin, objectives, timing, and size, public expeditions lost more and larger ships than private expeditions. Public expeditions also lost a higher fraction of ships and vessel tonnage deployed, although the PRIVATE coefficient is only marginally significant at conventional levels using a two-tailed hypothesis test.

VI.C. Scurvy

Table 6 reports on logistic regressions that examine the determinants of crew health on the 68 expeditions in the sample that lasted longer than one year. In each regression, the dependent variable is set equal to one if the expedition had scurvy problems, and zero otherwise. Models 1 and 2 include only the 39 expeditions for which the presence or absence of scurvy is known. Models 3 and 4 report results for these 39 expeditions plus the 29 additional expeditions for which I infer that scurvy was not a problem. When all nine decade dummy variables are included, multicollinearity among the independent variables prevents computation of standard errors, so I include only the single dummy variable (PRE-1860) to control for the timing of the expedition. For similar reasons, I exclude the USA, NORTHWEST PASSAGE, and NORTH POLE dummies.

In Models 1 and 3, the incidence of scurvy is negatively related to PRIVATE, and the coefficient is statistically significant in Model 1. The coefficient for the PRE-1860 dummy is positive and statistically significant at the 5% level, indicating that scurvy was more prevalent on public than private expeditions and on expeditions before 1860.

PRIVATE and CREW are highly collinear (the correlation coefficient is –0.77 for the 39 expeditions used to estimate Models 1 and 2), and their simultaneous inclusion makes the coefficient and t-statistic for PRIVATE highly sensitive to changes in model specification. For example, Models 2 and 4 include CREW and EXPERIENCE as explanatory variables. In both models the PRIVATE coefficient is statistically insignificant. However, in (unreported) tests I also included an interaction term involving PRIVATE and PRE-1860 in Models 2 and 4; the PRIVATE coefficient becomes negative and significant at the 1% level in these tests. Thus, while scurvy was more prevalent on public expeditions, it is difficult to establish whether this is because of the source of funding *per se* or because public expeditions deployed relatively large crews.

VI.D. Expedition achievement efficiency

Table 7 reports the results of ordinary least squares regressions that investigate the causes of achievement efficiency. The dependent variable in the first regression is the first efficiency measure as defined in equation (1) in section V.E. The second and third efficiency measures are the dependent variables in the second and third regressions. For all three efficiency measures, the coefficients for PRIVATE are positive and statistically significant at the 1% level, indicating that private expeditions achieved arctic discoveries at significantly lower cost than public expeditions. The positive coefficient for

LAND indicates that land-based expeditions also were relatively efficient. Expeditions from the United States, holding other factors constant, were relatively inefficient. Overall, achievement efficiency is not significantly related to the expedition's main objective, the time period, or the number of the leader's previous polar experiences.

VII. Reasons private expeditions were more successful

Both univariate comparisons and multivariate tests indicate that, despite greater funding, public expeditions achieved fewer major arctic prizes, suffered greater losses, and performed more poorly than private expeditions. Case histories indicate that the performance differences are not mere coincidence. Rather, they result from the ways the expeditions were organized. In particular, compared to private expeditions, many public expeditions (i) had unmotivated and unprepared leaders, (ii) had poor leadership structures, and (iii) were slow to adapt to new information. These characteristics resulted from and contributed to poorly aligned incentives among expedition organizers, leaders, crew members, and outfitters.

VII.A. Leaders' preparation and motives

One reason that many private expeditions were successful is that their leaders were prepared and motivated for arctic exploration. Roald Amundsen, for example, spent several years training for cold weather travel. To avoid possible conflicts from a divided leadership, he spent years earning a skipper's license so he would not have to rely upon a hired ship's captain for his 1903-06 expedition. Similarly, such explorers as John Rae, Thomas Simpson, and William Kennedy were seasoned wilderness travellers before they attempted to engage in new exploration. Robert Peary spent most of his adult life scheming about and putting into practice his plans for arctic exploration.

Even relatively unprepared private leaders had strong desires for arctic exploration. Elisha Kent Kane's writing reflects an almost religious attitude toward high latitudes. Charles Francis Hall was so driven to explore that he sold his business, abandoned his wife and family, and spent ten of his last 13 years in the arctic.

Many leaders of government expeditions, in contrast, had little direct knowledge of, or interest in, arctic exploration. George Nares, leader of a 1875-76 British Naval North Pole expedition, considered the arctic a "wretched place." He went north not because of any particular interest in the job, but rather, because he had been appointed and he sought promotion (Berton 1986, p. 420). Edward Belcher, leader of a 1852-54 search for Franklin, was so distraught over the prospect of a second arctic winter that he abandoned four undamaged ships that were stuck in ice and fled back home to England. One of his abandoned ships was discovered by whalers the following year, floating unharmed in Baffin Bay.

As another example, Berton (1988, p. 65) notes that Franklin was chosen for his initial arctic leadership position in 1819 in part "because he came from a well-placed family. . . . He had no canoeing experience, no hunting experience, no back-packing experience. . . .", all qualities that would have proved useful for his land-based journey, on which 11 of 25 crew members died.

VII.B. Leadership structure

One reason that many public expedition leaders demonstrated little preparedness or passion is that most of them were appointed to their jobs. Fama and Jensen (1983) argue that managers in successful modern corporations initiate *and* implement plans of action. In my sample, however, the persons initiating and organizing public expeditions actually led them only 26.5% of the time. For private expeditions, in contrast, the percentage is 78.2%. (This difference in proportions is statistically significant at the 1% level.) Thus, I infer that public expeditions performed poorly partly because the people who lobbied for and initiated them frequently did not also implement them.[15]

Because they did not actually go on the trips, the organizers of public expeditions faced few of the negative consequences of poor planning or erroneous theories. The man behind the 1845 Franklin expedition, Sir John Barrow, for example, directed Franklin to pursue a sailing course that, we now know, is covered mostly by land and ice. If that course proved impassible, Barrow directed Franklin to sail north into the fictitious "Open Polar Sea," which Barrow thought was unencumbered by ice. Since Barrow initiated but did not actually undertake arctic expeditions, he had less direct knowledge of the arctic than

[15]To examine the importance of separating the initiation and leadership functions, I conducted all tests reported in Tables 4-7 after replacing PRIVATE with a dummy variable (INITIATE) that equals one if the expedition was initiated by the leader. The empirical results are similar to those reported, although in some cases the t-statistics are insignificant. When both PRIVATE and INITIATE are included, the coefficients for PRIVATE generally have higher t-statistics than those for INITIATE. When I replace PRIVATE with a variable that equals one if the expedition was privately funded *or* initiated by the leader, the results also are similar to those reported.

did private whalers who advised him that the "Open Polar Sea" was a myth. He also bore relatively few of the costs of his misguided directions.

The problem of separating the initiation and implementation functions also is illustrated by the Greely disaster of 1881-84. When relief ships did not reach his quarters at Fort Conger in northern Ellesmere Island, Greely abandoned the safety of Fort Conger and moved his men south, seeking to meet a relief ship before the onset of winter. The subsequent deaths of most of his crew prompted criticism, most notably from Robert Peary, who noted that Fort Conger was well-stocked with supplies and located in an area rich with game. Greely, of course, was just following orders.

VII.C. Adaptation and learning

The official logs, unofficial exposes, and popular descriptions that followed most expeditions provided valuable information to subsequent explorers about the techniques that facilitated survival and success at high latitudes. Poor preparation and ineffective leadership impeded many public expeditions' abilities to uncover and exploit this information. As a result, private expeditions generally were much quicker to adopt and use new information.[16]

1. Clothing. British arctic explorers in the early 19th century wore tight-fitting woolen uniforms. Late in the century, British and American public expeditions led by Nares (1875-76) and Greely (1881-84) still were outfitted with woolen clothing. Tight wool clothes cause people to sweat during the day and are stiff and cold when first put on. Amundsen noted that, "in woolen things you have to jump and dance about like a madman before you can get warm" (Berton 1988, p. 540).

Private explorers, including William Kennedy (1851-52), Elisha Kent Kane (1853-55), and Robert Peary (in the 1890's), were more likely to adopt Native clothing. Inuit parkas consisted of loose-fitting doubled layers of sealskin or other hide, one fur side facing in and another facing out, with attached hoods that protected against heat loss from the neck and face. The loose hide clothing provided an insulating layer of air and prevented body perspiration from condensing against the skin. Beginning at least with Charles Hall in 1860 and continuing with Robert Peary through 1909, many private explorers adopted an

[16] These examples are consistent with Hart, Shleifer, and Vishny's (1997) model, in which private enterprise is more efficient than government particularly in activities for which quality innovations are important and there are few incentives to reduce quality by cutting costs.

Inuit practice of shedding their outer clothing and sleeping in snow houses under communal hide blankets. Sleeping next to each other enabled them to, in John Rae's words, "communicate the heat from one body to another" (Berton 1988, p. 417).

2. Shelter. Rae, Kennedy, Amundsen, and Peary all learned from Inuit Natives to use snow for shelter. A skilled traveller, Rae claimed, could construct a snow house large enough for five men within one hour. The snow house could be used again on the return journey, and was warmer than the canvass tents most explorers carried. As Rae noted, "When you use snow as a shelter your breath instead of condensing on your bedding gets condensed on the walls of the snow house, and therefore your bedding is relieved from nearly the whole of this" (Berton 1988, p. 415).

All of the expeditions in my sample that used snow houses extensively were privately organized and funded. The others relied on canvass tents and cloth sleeping bags, which would freeze stiff with condensed water vapor. Sledging crew members used their own body heat to thaw themselves into frozen sleeping bags at night. An additional problem was that the tents and sleeping bags were heavy. Berton (1988, p. 418), estimates that on the Nares expedition each man on a sledging team pulled basic gear totalling 80 pounds, twice the basic weight hauled by Rae a generation earlier. Greely (1886, p. 306) reports that his crew hauled one sledge that weighed 217 pounds per man, much of it basic gear. Fittingly, they called the sledge "Nares."

3. Modes of overland travel. By the 1850's Rae and Kennedy had demonstrated the efficacy of dogsled travel over polar ice and snow. Isaac Hayes converted to the use of dogsleds following a harrowing experience during the Elisha Kent Kane expedition of 1853-55. Hayes and several others were easily overtaken while attempting to escape from a group of hostile Natives who were using dogsleds. Hayes used dogs on his subsequent 1860-61 expedition. Other explorers used skis and snowshoes to facilitate overland travel. Skis enabled Nansen to successfully cross Greenland in 1888-89. Amundsen learned dogsled handling techniques during layovers on his 1903-06 navigation of the Northwest Passage, a skill that would enable him to breeze to victory in the 1911 race to the South Pole.

A disproportionate number of public expeditions, in contrast, never used dogsleds, skis, or snowshoes, or used them ineffectually. John Rae persuaded a reluctant friend to take snowshoes with him during the (public) 1875 Nares expedition. "When the snowshoes were brought on board, there 'was a shout of laughter and derision from the gallant but very inexperienced officers.'" Nares' sledge crews wore themselves out plowing through hip-deep snow, while Rae's friend had "many a long and pleasant walk."

Without his snowshoes, "I should not have gone half a mile from the ship without much discomfort and labour" (quotes from Berton 1988, p. 415).

Even when private explorers did not use dogs and hauled their own sledges, they had greater success with their sledge designs. The sledges used by British Naval expeditions were so large and cumbersome that they required pulling by ten to twelve men. The sledges got stuck in heavy snow and did not travel easily over ice hummocks. Rae, in contrast, designed a light sledge with three runners that sank less than 3/4 inch in snow and did not nose-dive into the snow when descending hummocks (Berton 1988, pp. 415-6). Nansen devised a thin sledge for his 1888-89 Greenland expedition that tracked easily behind his skis and snowshoes (Maxtone-Graham 1988, pp. 107-26). Amundsen learned to coat sledge runners with thin layers of ice, decreasing friction with surface snow and ice (Huntford 1999, p. 293).[17]

4. Party size. Early in the 19th century, numerous observers suggested that small parties were better able than large parties to move quickly and support themselves in the arctic. Perhaps because they were poorly funded, private explorers immediately put this idea to work. Governments, in contrast, continued to mount large expeditions up until 1875.

One advantage of smaller party size was illustrated by John Ross from 1829-33. Rebuffed when he proposed an expedition to the British Admiralty, Ross organized his own private venture using funds donated by Felix Booth, a wealthy distiller of gin. Ross' ship was crushed by ice, but his party was able to survive for four years before being rescued partly because it was small enough to live off the land and receive support from nearby Inuit natives. (Ross also benefited from provisions left by Parry's 1824-25 expedition.) Despite this experience, the British government outfitted the 1845 Franklin expedition with 129 (originally 134) men. Berton (1988, pp. 336-9) argues that one reason Inuit Natives did not help Franklin's starving crew is that there simply were too many of them to feed.

By 1850, Peter Dease, Thomas Simpson, and John Rae had demonstrated the superior overland capabilities of small parties. Dease and Simpson nearly completed the Canadian coastline map during 1837-39 with a party of six. Rae covered 1060 overland miles in 1851 traveling with only 2 other men. Smaller parties also fared well on ship-based expeditions. In 1852, William Kennedy left most of his 16 crew on board and used dogsleds to cover 1265 overland miles in 95 days, outdistancing the later

[17] Explaining the British Navy's adherence to man-hauled sledges, Robert F. Scott told the International Geographic Congress in 1899 that using dogs "is a very cruel system." Nansen replied, "[B]ut it is also cruel to overload a human being with work" (Imbert 1992, p. 80).

achievements of Francis M'Clintock, the so-called "Father of (man-hauled) arctic sledging." Later explorers, including Frederick Schwatka in 1878 and Robert Peary in 1892, intentionally mimicked these expeditions by choosing traveling parties of two to five men.

Government-sponsored expeditions, in contrast, deployed large crews up through the 1875 Nares expedition, which used 122 men. Crew sizes decrease over my sample period, but the differences between public and private expeditions are statistically significant even controlling for the time period. For example, in an ordinary least squares regression using crew size as the dependent variable, the coefficients for PRIVATE and a time trend term both are negative and statistically significant.

5. Diet and crew health. As reported in section V.C, more public than private expeditions had scurvy problems (although the results in VI.C suggest that this difference may be attributable to crew size in a multivariate test). As examples, private expeditions by Peter Dease and Thomas Simpson (1837-39), John Rae (1846-47), and Charles Francis Hall (1860-62) were free of scurvy. At roughly the same times, the government-sponsored expeditions of George Back (1836-37), James Clark Ross (1848-49), and Henry Kellett (1852-54) faced debilitating scurvy problems.

The key difference was that private expeditions relied heavily upon fresh meat, which is rich in vitamin C. Many public expeditions relied on salt meat, which has little vitamin C. Some used lemon juice as a source of vitamin C, but typically in insufficient quantities to prevent scurvy.

Once again, the problem was not a lack of information about the importance of fresh meat or vegetables. Scurvy, and ways to prevent it, had been known for centuries. The East India Company, for example, had used lemon juice to prevent scurvy on its ships since 1601 (see Gurney 1997, p. 40). John Ross testified about the importance of fresh meat after his 1829-33 expedition. A meddlesome explorer named Richard King had criticized the British government for its expeditions' inadequate diets *before* the 1845 Franklin disaster. Rather, the problem was that organizers of public expeditions were slow to recognize and use this information. It was only in 1877, under excoriating public pressure following the scurvy-ridden Nares expedition, that the British government organized a public inquiry into the causes of scurvy (Berton 1988, p. 430).

6. The Open Polar Sea. Some 19th Century geographers promoted a theory that a temperate, ice-free ocean lay beyond the ice that stopped previous expeditions. This view influenced many private expedition leaders, including Elisha Kent Kane in 1853, Isaac Hayes in 1860, and Karl Koldeway in 1869. But public expedition organizers seemed particularly wedded to this flawed theory, possibly because it

helped justify their designs for large and expensive ship-based expeditions. As far back as 1817, William Scoresby, a renown whaler, advised the British Admiralty that the Open Polar Sea was a myth. The Admiralty nevertheless continued to espouse the theory and send large ships into the arctic ice pack.

The Open Polar Sea was not a uniquely British delusion. Austrian geographer August Petermann theorized that the warm Gulf Stream opened the seas between Greenland and Siberia: "I have no doubt that a sturdy steamship could, in the appropriate season, complete the trip from the Thames to the North Pole and back - or to some land around the Bering Strait - in two or three months" (Holland 1994b, p. 52). Petermann's ideas influenced a 1872 Austrian government expedition led by Karl Weyprecht, which lost its ship near Franz Josef Land.

7. Organizational structure. By its nature, exploration requires frequent adjustment by many crew members to new information and changing circumstances. Fama and Jensen (1983) argue that partnerships and other non-hierarchical organizations are well-suited to such situations. Private expedition leaders appear to have adopted non-hierarchical organizations more frequently than public expedition leaders. Rae, Kennedy, Nansen, and Amundsen, for example, all solicited and used information from their crew, delegated some decision authority to their men, and participated in menial tasks. This is in contrast to the strict hierarchical structures maintained on many government expeditions, including those by Collinson, Belcher, Greely, and Nares.

VII.D. The pervasive influence of weak incentives

As this discussion illustrates, many of the public expeditions' problems lay with the poorly aligned incentives of key decision makers. Expedition leaders were appointed by senior officials who were motivated by political objectives in addition to expedition success, and who did not suffer severe consequences for expedition failures. Many leaders themselves were motivated by the promise of promotion, which accompanied but did not require success as explorers.

Poor incentives could affect not only an expedition's leadership, but also its provisions and the selection of its crew. As a result, even skilled leaders were rendered ineffective by governmental control of important decisions. For example, after two small but successful private expeditions, Charles Francis Hall obtained U.S. government support for a large-scale expedition in 1871. Hall's first choice of a scientific leader was overridden by government officials, who instead appointed a young German named Emil Bessels (see Loomis 1971, pp. 251-5). Bessels' resistance to Hall's leadership helped undermine the effectiveness of the expedition. (The choice of Bessels may also have led directly to Hall's death during the expedition. Hall's body was exhumed in Greenland in 1968, and forensic evidence suggests that he was murdered. Bessels is the prime suspect.)

Conflicting incentives impeded the flow of information to expedition leaders. The official accounts of many British Naval expeditions, for example, downplayed the incidence and risk of scurvy, partly as a means to safeguard public support for the expeditions. Thus, even though George Nares prepared for his 1875-76 expedition by reading the logs of prior British Naval expeditions, he was unprepared for the devastation that scurvy would wreck upon his crew: "I am certain that what is reported in the official papers [of previous British Naval expeditions] as being an attack of debility was most decidedly the same as our attack by a more advanced form of scurvy..." (Berton 1988, p. 431).

Nares also fell victim to a haphazard approach to outfitting his ships. Expedition organizers -- Nares' bosses -- ignored evidence about the usefulness of snowshoes, snow houses, light traveling sledges, and native clothing. The procurement official charged with ordering "lime juice" did exactly that, unaware that the British Navy used "lime juice" to refer to *lemon* juice. Lime juice, it turns out, has only one-fourth the vitamin C of lemon juice, and thus contributed to Nares' scurvy problems (Berton 1988, pp. 418-9).

VIII. Other possible explanations

It is possible that public expeditions lost many crew members and ships because they assumed greater risks. If so, public expeditions should have achieved a disproportionate share of arctic discoveries as well as a large share of the tragedies. The evidence in Panel D of Table 3, however, indicates that public expeditions achieved arctic discoveries at no greater rate than private expeditions. Thus, it is unlikely that public expeditions' losses result from greater risk-bearing.

Many public expeditions came early in my sample period, raising the possibility that they generated information that subsequently was exploited by private explorers. The multivariate tests reported in section V include dummy variables that control somewhat for time variation in the expeditions' outcomes. I also conducted sensitivity tests to explore the importance of the time period in determining the expeditions' outcomes. In one such test, I truncated the sample to eliminate all of the early expeditions (e.g., those before 1850, or 1860), reasoning that the early expeditions were most likely to generate knowledge upon which subsequent expeditions built. In another, I truncated both early and later expeditions (e.g., including only those between 1850 and 1890), reasoning that unusual factors may have influenced both early (primarily public) and later (primarily private) expeditions. In yet another, I focus only on expeditions meeting certain criteria (e.g., those searching for Franklin's lost crew). The results from these sensitivity tests are consistent with the overall results: private expeditions outperform public ones, and also suffer fewer losses (although in some subsamples the differences are not statistically significant). These results indicate that public expeditions' poor performance extends throughout the 1818-1909 sample period.

Another possibility is that governments funded expeditions with low expected returns, leaving high-return expeditions to private initiative. This could explain private expeditions' success at the major arctic prizes and their efficiency at arctic discoveries in general. However, there is nothing in the histories of these expeditions to support this conjecture. The British Admiralty did not intentionally look for Franklin in all the wrong places during its 1847-54 searches. North Pole expeditions led by Hall in 1871, Nares in 1875, and Greely in 1881, funded by the U.S. and British governments, were designed to take advantage of previous discoveries by the private expeditions led by Kane (1853-55), Hayes (1860-61), and Hall (in the 1860's). That is, the Nares and Greely expeditions, as well as Hall's last expedition, attracted public support largely because they had *high*, not low, expected returns.

It also is possible that public expeditions appear inefficient at arctic discovery because I mismeasure their costs. For example, there were few alternative uses for British warships following the defeat of Napolean in the early 19th century, suggesting that their opportunity costs were low. As reported in Panel E of Table 3, private expeditions were approximately five times more efficient at arctic discoveries than public expeditions. (The efficiency measure for "major arctic prizes" is 5.8 times that for public expeditions. For "major geographic claims," the difference is 4.9-fold, and for "lesser but significant accomplishments, the difference is 5-fold.) Thus, the true efficiency indices would be roughly equal if the opportunity costs of public expedition crew members were only 20% of that for private expedition crew. Such a large discrepancy in opportunity costs is unlikely, however. It is even less likely that the opportunity cost of the resources necessary to outfit crew members (e.g., food, clothing, gear) was substantially lower for public expeditions. Thus, it is very unlikely that public expeditions only appear to have been inefficient because I have mismeasured their costs.

The conjecture that public expeditions achieved little because they had low expected returns or overstated costs also is inconsistent with their large losses in lives and ships. Even if the expeditions were not expected to make significant discoveries, or had lower costs per crew member, it is unlikely that they optimally lost more lives and ships. Indeed, the losses of lives and ships undermined careers and public support for future arctic expenditures (as argued in section IV).

To summarize, the public expeditions' poor performance cannot be attributed to greater risk taking or to public investment in expeditions with high external benefits or low expected returns. Public expeditions' notable inefficiency in expedition achievement is not likely due to mismeasurement of their costs. Rather, the conclusion that is consistent with all the evidence presented here -- regarding deaths, ship losses, scurvy, and expedition achievement efficiency -- is that public expeditions performed poorly because they were poorly organized and executed relative to private expeditions.

VIII. Conclusions

In this paper I use historical data on arctic exploration to examine the relative efficiencies of public and private initiative, support, and control. Anecdotal evidence indicates that privately-funded expeditions achieved most of the major arctic prizes, while publicly-funded expeditions constitute the greatest tragedies. This conclusion is broadly supported by more systematic evidence from 35 public and 57 private arctic expeditions from 1818 through 1909. In particular, I find that:

• Public expeditions were relatively well funded and large, deploying an average of 69.7 crew members per expedition, compared to 16.0 for private expeditions. Among those based on ships, public expeditions deployed 1.63 ships representing 596 vessel tons, on average, compared to 1.15 ships and 277 vessel tons for private expeditions.

• Public expeditions experienced more deaths and a higher rate of deaths than private expeditions. On average, 5.9 men died on public expeditions, an average death rate of 8.9%, compared to 0.9 men, or a 6.0% rate, for private expeditions. The differences in deaths and death rates are statistically significant in multivariate tests that control for the expedition's size, timing, nation of origin, objectives, and leader's experience.

• Public expeditions lost and destroyed more and larger ships than private expeditions. On average, public expeditions lost 0.53 ships per expedition, representing 198 tons, compared to 0.24 ships representing 60 tons for private expeditions. The difference is partly but not wholly because public expeditions deployed more and larger ships.

• Nearly one-half (47%) of all public expeditions lasting longer than one year had significant health problems as indicated by advanced symptoms of scurvy, compared to 13% for private expeditions. In multivariate tests, however, the incidence of scurvy is not consistently related to an expedition's source of funding when crew size is included as a regressor.

• Private expeditions achieved most of the major arctic prizes, including the initial navigation of the Northwest Passage and the first claim to the North Pole. Public and private expeditions achieved a broader set of less significant arctic geographic discoveries at roughly equal rates, although private expeditions achieved their discoveries at significantly lower cost (as measured by crew size or vessel tonnage).

I also find evidence that death rates were relatively high for expeditions seeking the Northwest Passage (due in part to the 1845 Franklin tragedy), that scurvy was a problem particularly before 1860, and that U.S. expeditions were relatively inefficient in achieving arctic discoveries. Overall, however, the most persistent influence on success and failure is whether the expedition was privately or publicly funded. A closer analysis of the expeditions' characteristics suggests that there is nothing magical about the source of funding. Rather, publicly funded expeditions tended to have three specific handicaps: they deployed poorly motivated and prepared leaders, they separated the initiation and implementation functions of leadership, and they adapted slowly to important innovations regarding clothing, diet, shelter, modes of arctic travel, organizational structure, and optimal party size. These handicaps resulted from, and contributed to, the poorly aligned incentives of expedition organizers, leaders, crew members, and suppliers. That is, men died and ships were lost not because of the public nature of the funding *per se*, but rather, because of the perverse incentives, slow adaptation, and ineffective organizational structures that frequently accompanied public funding.

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Appendix 2: Arctic expeditions 1818-1909

(Abbreviation legend below)

Leader	Years	Nationality	Objective	Funding
Ross, John R.N.	1818	GB	nwp	gov
Buchan, David	1818	GB	np	gov
Parry, William Edward	1819-20	GB	nwp	gov
Franklin, John	1819-22	GB	nwp	gov
Parry, William Edward	1821-23	GB	nwp	gov
Lyon, George Francis	1824	GB	nwp	gov
Parry, William Edward	1824-25	GB	nwp	gov
Franklin, John	1825-27	GB	nwp	gov
Beechey, Frederick William	1825-28	GB	nwp	gov
Parry, William Edward	1827	GB	np	gov
Ross, John R.N.	1829-33	GB	nwp	pvt
Back, George	1833-5	GB	nwp	pvt
Back, George	1836-7	GB	nwp	gov
Dease, Peter and Thomas Simpson	1837-39	GB	nwp	pvt
Franklin, John	1845-47	GB	nwp	gov
Rae, John	1846-7	GB	nwp	pvt
Richardson, John	1847-49	GB	fs	gov
Ross, James Clark	1848-49	GB	fs	gov
Kellett, Henry	1848-50	GB	fs	gov
Shedden, Robert	1849	GB	fs	pvt
Saunders, James	1849-50	GB	fs	gov
Pullen, Wm John Samuel	1849-50	GB	fs	gov
Forsyth, Charles Codrington	1850	GB	fs	pvt
Austin, Horatio Thomas	1850-51	GB	fs	gov
Penny, William	1850-51	GB	fs	gov
Ross, John R.N.	1850-51	GB	fs	pvt
De Haven, Edwin J.	1850-51	USA	fs	pvt
Rae, John	1850-51	GB	fs	pvt
Collinson, Richard	1850-55	GB	fs	gov
McClure, Robert	1850-54	GB	fs	gov
Kennedy, William	1851-52	GB	fs	pvt
Inglefield, Edward A.	1852	GB	fs	pvt
Belcher, Edward	1852-54	GB	fs	gov
Kellet, Henry	1852-54	GB	fs	gov
Pullen, Wm John Samuel	1852-54	GB	fs	gov
Maguire, Robert	1852-54	GB	fs	gov
Inglefield, Edward A.	1853	GB	fs	gov
Rae, John	1853-54	GB	fs	pvt
Kane, Elisha Kent	1853-55	USA	fs	pvt
Anderson, James	1855	GB	fs	pvt
M'Clintock, Francis	1857-59	GB	fs	pvt
Hayes, Isaac	1860-61	USA	np	pvt
Hall, Charles Francis	1860-62	USA	fs	pvt
Hall, Charles Francis	1864-69	USA	fs	pvt
Nordenskiold, Adolf Erik	1868	SWE	np	pvt
Koldewey, Karl	1868	GER	np	pvt
Koldewey, Karl	1869-70	GER	np	pvt

Appendix 2, continued:

Nordenskiold, Adolf Erik	1870	SWE	oth	pvt
Smith, Benjamin Leigh	1871	GB	np	pvt
Weyprecht, Karl	1871	AUS	np	pvt
Hall, Charles Francis	1871-73	USA	np	gov
Smith, Benjamin Leigh	1872	GB	np	pvt
Nordenskiold, Adolf Erik	1872-73	SWE	np	gov
Weyprecht, Karl	1872-74	AUS	np	gov
Smith, Benjamin Leigh	1873	GB	np	pvt
Young, Allen	1875	GB	nwp	pvt
Nares, George	1875-76	GB	np	gov
Young, Allen	1876	GB	oth	pvt
Schwatka, Frederick	1878-80	USA	fs	pvt
De Long, George Washington	1879-81	USA	np	pvt
Smith, Benjamin Leigh	1880	GB	np	pvt
Berry, Robert Mallory	1881-82	USA	np	gov
Smith, Benjamin Leigh	1881-82	GB	np	pvt
Greely, Adolphus	1881-84	USA	np	gov
Hovgaard, Andreas Peter	1882-83	DEN	np	pvt
Peary, Robert	1886	USA	oth	pvt
Gilder, William Henry	1886-87	USA	np	pvt
Nansen, Fridtjof	1888-89	NOR	oth	pvt
Peary, Robert	1891-92	USA	oth	pvt
Peary, Robert	1893-95	USA	oth	pvt
Nansen, Fridtjof/Otto Sverdrup	1893-96	NOR	np	gov
Wellman, Walter	1894	USA	np	pvt
Andree, Salomon August	1896	SWE	np	pvt
Andree, Salomon August	1897	SWE	np	pvt
Sverdrup, Otto	1898-02	NOR	oth	pvt
Wellman, Walter	1898-99	USA	np	pvt
Peary, Robert	1898-02	USA	np	pvt
Di Savoia, Luigi Amedeo, Duke of Abruzzi	1899-00	ITA	np	pvt
Bauendalh, Oskar	1900-01	GER	np	pvt
Toll', Eduard Vasil'yevich	1900-03	RUS	oth	gov
Baldwin, Evelyn	1901-02	USA	np	pvt
Mylius-Erichsen, Ludvig	1902-04	DEN	oth	pvt
Fiala, Anthony	1903-05	USA	np	pvt
Amundsen, Roald	1903-06	NOR	nwp	pvt
Peary, Robert	1905-06	USA	np	pvt
Harrison, Alfred Henry	1905-07	GB	oth	pvt
Wellman, Walter	1906-07	USA	np	pvt
Mylius-Erichsen, Ludvig	1906-08	DEN	oth	gov
Leffingwell, Ernest de Koven	1906-08	GB*	np	pvt
Cook, Frederick	1907-09	USA	np	pvt
Peary, Robert	1908-09	USA	np	pvt
Wellman, Walter	1909	USA	np	pvt

*Joint GB-USA expedition

Nationality: AUS-Austria, DEN-Denmark, GER-Germany, GB-Great Britain, ITA-Italy,
NOR-Norway, RUS-Russia, SWE-Sweden, USA-United States
Objective: nwp - Northwest Passage, np-North Pole, fs-Franklin search, oth-other (mainly Greenland)
Funding: gov - government, pvt - private sources

Table 1
Description of the sample of arctic explorations, 1818-1909

Breakdown of the sample of 92 arctic expeditions from 1818 - 1909 by nationality, objectives, primary source of funding, and primary mode of travel. "Continental Europe" includes expeditions from Austria, Germany, Denmark, Italy, Norway, Russia, and Sweden. The data are collected from sources listed in the references and Appendix 1.

Decade beginning:	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	**Total**
Panel A: Nationality of origin											
Great Britain	4	7	3	8	17	0	6	2	0	2	**49**
United States	0	0	0	0	2	3	3	4	5	7	**24**
Continental Europe	0	0	0	0	0	3	4	2	5	5	**19**
Panel B: Primary exploration objective											
Northwest Passage	3	6	3	2	0	0	1	0	0	1	**16**
Search for Franklin	0	0	0	6	19	2	1	0	0	0	**28**
North Pole	1	1	0	0	0	4	9	6	7	9	**37**
Other	0	0	0	0	0	0	2	2	3	4	**11**
Panel C: Primary source of funding											
Public	4	6	1	6	9	0	4	2	1	2	**35**
Private	0	1	2	2	10	6	9	6	9	12	**57**
Panel D: Primary mode of travel											
Ship	3	6	1	5	16	4	11	4	4	9	**63**
Land	1	1	2	3	3	2	2	4	4	3	**25**
Balloon	0	0	0	0	0	0	0	0	2	2	**4**
Total expeditions	**4**	**7**	**3**	**8**	**19**	**6**	**13**	**8**	**10**	**14**	**92**

Table 2
Expedition characteristics

Comparisons of expedition characteristics: the number of ships deployed, total gross tonnage of the vessels deployed, numbers of crew, and the number of previous polar expeditions on which the leader served. Data are collected from sources listed in the references and Appendix 1. The far right-hand column reports the t-statistic for the difference in means between public and private expeditions, and (in parentheses) the Wilcoxon signed-rank z-statistic.

		All Expeditions	Publicly-funded Expeditions	Privately-funded Expeditions	Difference in means: t-statistic (Wilcoxon z-statistic)
Number of ships	mean	1.38	1.63	1.15	3.31[c]
(for ship-based expeditions)	median	1	2	1	(3.25)[c]
	observations	63	30	33	
Vessel tonnage employed	mean	440.9	596.2	276.9	3.97[c]
(for ship-based expeditions)	median	400	528	225	(4.35)[c]
	observations	63	30	33	
Crew size	mean	36.9	69.7	16.0	6.92[c]
	median	24	61	16	(6.51)[c]
	observations	90	35	55	
Leader's previous polar	mean	1.6	1.8	1.5	0.85
expedition experiences	median	1	1	1	(1.02)
	observations	92	35	57	

[c]indicates statistical significance at the 1% level using a two-tailed test.

Table 3
Expedition outcomes

Comparisons of the outcomes of 92 arctic expeditions, 1818-1909. Panel A reports on the number and percentage of crew members who died for 90 expeditions with available data. Panel B reports the number and percent of ships and vessel tonnage lost for 63 ship-based expeditions. Panel C reports on the incidence of scurvy for expeditions lasting longer than one year. Panel D reports on three successively broader measures of geographic accomplishment (each of which subsumes the previous measure). And Panel E reports on three measures of achievement efficiency, in which accomplishments are weighted by the inverse of crew size. Data are collected from sources listed in the references and Appendix 1. The far right-hand column reports the t-statistic for the difference in means between public and private expeditions, and (in parentheses) the Wilcoxon signed-rank z-statistic.

		All Expeditions	Publicly-funded Expeditions	Privately-funded Expeditions	t-statistic (Wilcoxon z-statistic)
Panel A: Crew member deaths					
Number of deaths	mean	2.84	5.89	0.91	1.35
	median	0	1	0	(3.28)[c]
Percent of crew who died	mean	7.16	8.93	6.04	0.67
	median	0	2.08	0	(1.84)[a]
Number of observations		90	35	55	
Panel B: Ships and vessel tonnage lost (ship-based expeditions only)					
Number of ships lost	mean	0.38	0.53	0.24	1.90[a]
	median	0	0	0	(1.59)
Percent of ships lost	mean	28.0	33.8	22.7	1.02
	median	0	0	0	(1.15)
Vessel tonnage lost	mean	125.5	197.9	59.7	2.32[b]
	median	0	0	0	(1.67)[a]
Percent of vessel tonnage lost	mean	28.3	34.9	22.3	1.15
	median	0	0	0	(1.18)
Number of observations		63	30	33	

Table 3 continued on following page

Table 3 - Continued
Expedition outcomes

		All Expeditions	Publicly-funded Expeditions	Privately-funded Expeditions	t-statistic (Wilcoxon z-statistic)
Panel C: Incidence of scurvy (for expeditions lasting more than one year)					
Scurvy status is known	mean (% of cases)	48.7	82.4	22.7	4.51[c]
	median	0	1	0	(3.94)[c]
Number of observations		39	17	22	
Scurvy status is known or inferred	mean (% of cases)	27.9	46.7	13.2	3.10[c]
	median	0	0	0	(3.33)[c]
Number of observations		68	30	38	
Panel D: Expedition accomplishments					
Major arctic prize	mean (% of cases)	6.5	2.9	8.8	1.24
	median	0	0	0	(1.11)
Major geographic claims	mean (% of cases)	19.6	20.0	19.3	-0.08
	median	0	0	0	(-0.08)
Lesser but significant accomplishments	mean (% of cases)	34.8	34.3	35.1	0.08
	median	0	0	0	(0.08)
Number of observations		92	35	57	
Panel E: Expedition accomplishment efficiency					
Major arctic prize	mean	0.094	0.024	0.139	6.27[c]
	median	0.043	0.017	0.071	(6.58)[c]
Major geographic claims	mean	0.102	0.030	0.147	6.05[c]
	median	0.050	0.019	0.083	(6.30)[c]
Lesser but significant accomplishments	mean	0.117	0.034	0.170	5.82[c]
	median	0.071	0.020	0.100	(6.08)[c]
Number of observations		90	35	55	

[a,b,c] indicate statistical significance at the 10%, 5%, and 1% level. respectively, using a two-tailed test.

Table 4

Determinants of crew member deaths and death rates

Tobit regression results using data from 90 arctic expeditions from 1818-1909. The dependent variable in Models 1-3 is the natural log of one plus the number of deaths. In Models 4-6 it is the percent of crew members who died on the expedition. Observations in Models 3 and 6 are weighted by the size of CREW, a proxy for the expedition budget. PRIVATE is a dummy variable equal to one for privately-funded expeditions. BRITAIN and USA reflect the country of origin, and NORTHWEST PASSAGE, FRANKLIN SEARCH, and NORTH POLE reflect the expedition objectives. LAND and BALLOON reflect the primary mode of travel. EXPERIENCE is the number of previous polar expeditions on which the leader served, and CREW is the number of crew members deployed on the expedition. Data are collected from sources listed in the references and Appendix 1. t-statistics are in parentheses.

	Dependent variable:					
	Ln (1 + # deaths)			Percent of crew members who died		
	Model 1	Model 2	Model 3 (weighted)	Model 4	Model 5	Model 6 (weighted)
PRIVATE	-1.43	-1.12	-1.02	-0.23	-0.21	-0.14
	(-3.37)[c]	(-2.27)[b]	(-2.36)[b]	(-2.40)[b]	(-1.96)[a]	(-1.92)[a]
BRITAIN	-0.29	-0.27	0.42	-0.17	-0.13	-0.03
	(-0.40)	(-0.36)	(0.62)	(-1.02)	(-0.76)	(-0.26)
USA	0.55	0.88	1.14	0.06	0.14	0.19
	(1.01)	(1.49)	(1.83)[a]	(0.51)	(1.08)	(1.85)[a]
NORTHWEST PASSAGE	1.49	1.30	0.79	0.45	0.40	0.21
	(1.52)	(1.35)	(0.76)	(2.01)[b]	(1.81)[a]	(1.07)
FRANKLIN SEARCH	-0.41	-0.31	-2.20	-0.05	-0.10	-0.73
	(-0.37)	(-0.29)	(-1.89)[a]	(-0.21)	(-0.40)	(-3.36)[c]
NORTH POLE	-0.12	-0.57	-0.79	0.05	-0.07	-0.12
	(-0.19)	(-0.85)	(-1.06)	(0.39)	(-0.46)	(-0.94)
LAND		-1.07	-0.33		-0.15	0.02
		(-1.91)[a]	(-0.60)		(-1.20)	(0.19)
BALLOON		-0.24	-0.24		0.27	0.18
		(-0.25)	(-0.12)		(1.35)	(0.62)
EXPERIENCE		-0.02	0.01		-0.00	-0.00
		(-0.17)	(0.10)		(-0.15)	(-0.38)
CREW (x 10^2)		0.35	0.42		0.01	0.03
		(0.55)	(1.17)		(0.09)	(0.51)
Decade fixed effects	YES	YES	YES	YES	YES	YES
χ^2	22.9	29.1	55.8	20.1	24.1	75.8
p-value	0.09	0.07	0.00	0.17	0.19	0.00
Pseudo R^2	0.11	0.14	0.21	0.22	0.26	0.85

[a,b,c] indicate statistical significance at the 10%, 5%, and 1% level. respectively, using a two-tailed test.

Table 5
Determinants of vessel tonnage lost or destroyed

Tobit regression results using data from 63 ship-based arctic expeditions from 1818-1909. The dependent variable in Models 1-3 is the natural log of one plus the gross tonnage of lost or destroyed ships. In Models 4-6 it is the fraction of vessel tonnage deployed that was lost or destroyed. Observations in Models 3 and 6 are weighted by the size of TONNAGE, a proxy for the expedition budget. PRIVATE is a dummy variable equal to one for privately-funded expeditions. BRITAIN and USA reflect the country of origin, and NORTHWEST PASSAGE, FRANKLIN SEARCH, and NORTH POLE reflect the expedition objectives. EXPERIENCE is the number of previous polar expeditions on which the leader served, and TONNAGE is the gross vessel tonnage deployed. PRE-1860 is a dummy variable equal to one for pre-1860 expeditions. Data are collected from sources listed in the references and Appendix 1. t-statistics are in parentheses.

	Dependent variable:					
	Ln (1 + tonnage lost)			Percent of tonnage lost		
	Model 1	Model 2	Model 3 (weighted)	Model 4	Model 5	Model 6 (weighted)
PRIVATE	-5.41	-6.44	-8.13	-3.08	-4.11	-5.12
	(-2.25)[b]	(-2.33)[b]	(-2.54)[b]	(-1.57)	(-1.67)	(-1.75)[a]
BRITAIN	-0.25	0.00	-3.74	0.91	1.25	-0.90
	(-0.07)	(0.00)	(-0.85)	(0.42)	(0.57)	(-0.35)
USA	5.27	5.62	4.86	4.80	5.33	4.91
	(1.59)	(1.66)	(1.27)	(1.65)	(1.70)[a]	(1.51)
NORTHWEST PASSAGE	2.86	2.12	3.15	1.02	0.55	0.59
	(0.44)	(0.33)	(0.44)	(0.25)	(0.14)	(0.14)
FRANKLIN SEARCH	3.45	2.62	3.47	1.58	0.95	1.16
	(0.51)	(0.39)	(0.47)	(0.37)	(0.23)	(0.27)
NORTH POLE	1.24	0.47	-2.82	0.09	-0.45	-2.60
	(0.27)	(0.10)	(-0.67)	(0.03)	(-0.16)	(-0.95)
PRE-1860	-3.67	-3.93	-4.98	-2.58	-3.01	-3.49
	(-0.68)	(-0.74)	(-0.77)	(-0.73)	(-0.85)	(-0.84)
EXPERIENCE		-0.07	-0.03		-0.18	-0.16
		(-0.11)	(-0.04)		(-0.46)	(-0.46)
TONNAGE (x 10^2)		-0.31	-0.52		-0.24	-0.32
		(-0.78)	(-1.51)		(-0.89)	(-1.29)
χ^2	8.6	9.3	13.0	8.9	10.2	13.7
p-value	0.29	0.41	0.16	0.26	0.33	0.14
Pseudo R^2	0.05	0.05	0.16	0.09	0.10	0.14

[a, b,c] indicate statistical significance at the 10%, 5%, and 1% level. respectively, using a two-tailed test.

Table 6
Determinants of the incidence of scurvy

Logistic regression results using data from 68 arctic expeditions lasting more than one year from 1818-1909. The dependent variable in Models 1 and 2 equals one for expeditions known to have had significant scurvy problems, and zero for expeditions known not to have such problems. In Models 3 and 4, the dependent variable is set equal to zero for 29 additional expeditions for which I infer scurvy was not a major problem. PRIVATE is a dummy variable equal to one for privately-funded expeditions. BRITAIN equals one for expeditions originating in Great Britain, and NORTHWEST PASSAGE equals one for expeditions seeking the Northwest Passage. EXPERIENCE is the number of previous polar expeditions on which the leader served, and CREW is the number of crew members deployed. PRE-1860 is a dummy variable equal to one for pre-1860 expeditions. Data are collected from sources listed in the references and Appendix 1. t-statistics are in parentheses.

	Expeditions included if:			
	Scurvy status is known		Scurvy status is known or inferred	
	Model 1	Model 2	Model 3	Model 4
PRIVATE	-2.62	1.38	-1.16	-0.52
	(-2.48)[b]	(0.80)	(-1.48)	(-0.52)
BRITAIN	-0.37	-5.09	-0.94	-1.01
	(-0.625)	(-0.45)	(-0.96)	(-0.67)
NORTHWEST PASSAGE	-1.04	-0.87	0.80	0.80
	(-0.93)	(-0.59)	(1.00)	(0.96)
PRE-1860	3.83	13.21	4.03	3.76
	(2.39)[b]	(0.97)	(2.40)[b]	(2.33)[b]
EXPERIENCE		0.07		0.06
		(0.11)		(0.24)
CREW		0.19		0.02
		(1.60)		(1.66)[a]
χ^2	25.3	41.9	30.9	33.6
p-value	0.00	0.00	0.00	0.00
Pseudo R^2	0.47	0.78	0.38	0.42

a, b,c indicate statistical significance at the 10%, 5%, and 1% level. respectively, using a two-tailed test.

Table 7
Determinants of expedition achievement efficiency

Ordinary least squares regression results using data from 89 arctic expeditions from 1818-1909. The dependent variable in each regression is (1 + ACHIEVEMENT)/CREW, where CREW is the number of crew members deployed on the expedition. In the first regression, ACHIEVEMENT equals one each of five expeditions achieving a major prize in arctic discovery. In the second regression it equals one for the 18 expeditions achieving either a major prize or other major geographic claim. In the third regression, it equals one for these 18 expeditions plus 14 others achieving lesser-known but significant discoveries. PRIVATE is a dummy variable equal to one for privately-funded expeditions. BRITAIN and USA reflect the country of origin, and NORTHWEST PASSAGE, FRANKLIN SEARCH, and NORTH POLE reflect the expedition objectives. LAND equals one for land-based expeditions. PRE-1860 is a dummy variable equal to one for pre-1860 expeditions. EXPERIENCE is the number of previous polar expeditions on which the leader served. Data are collected from sources listed in the references and Appendix 1. t-statistics are in parentheses.

	Dependent variable - efficiency measure based on:		
	Major arctic prize	Major geographic claim	Lesser but significant accomplishment
PRIVATE	.074 (3.20)[c]	.072 (2.98)[c]	.080 (2.86)[c]
BRITAIN	-.034 (-0.96)	-.049 (-1.32)	-.056 (-1.30)
USA	-.068 (-2.22)[b]	-.074 (-2.32)[b]	-.076 (-2.03)[b]
NORTHWEST PASSAGE	-.012 (-0.24)	-.009 (-0.18)	.054 (0.92)
FRANKLIN SEARCH	.035 (0.74)	.035 (0.72)	0.121 (2.09)[b]
NORTH POLE	.001 (0.04)	.017 (0.47)	.030 (0.72)
LAND	.134 (5.45)[c]	.146 (5.66)[c]	.179 (5.95)[c]
PRE-1860	-.044 (-0.99)	-.036 (-0.78)	-.079 (-1.43)
EXPERIENCE	-.001 (-0.11)	.003 (0.46)	.002 (0.27)
Constant	.060 (1.61)	.059 (1.51)	.042 (0.91)
F statistic p-value	8.35 0.00	8.26 0.00	8.91 0.00
Adjusted R^2	0.43	0.42	0.44

[a, b,c] indicate statistical significance at the 10%, 5%, and 1% level. respectively, using a two-tailed test.