THE VALUE OF HUMAN CAPITAL DURING THE SECOND INDUSTRIAL REVOLUTION - EVIDENCE FROM THE U.S. NAVY

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Abstract. This paper explores the role of human capital in officer performance in the United States Navy during the late 19th century. During this time officers, belonging either in a regular corps or an engineer corps, had fairly specialized tasks. To test the effects of different skills on the performance of these specialized jobs for each group, we compile educational data from original naval academy registers for the graduating classes of 1858 to 1905, and merge these with career performance data extracted from official navy registers for the years 1859 to 1907. Results suggest that those with greater technical skill earned higher wages early on; this wage premium however diminished later in their careers. From this evidence we argue that naval technical progress was more skill-*depreciating* than skill-*biased* during this period.

- *Keywords*: naval history, human capital, skill premium
- *JEL Codes*: J24, N31, N41, N71, O33

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This paper explores the role of ability and technical skill in officer performance in the United States Navy during the latter half of the nineteenth century. This period is a critical juncture in our economic history, for many modern skill-intensive technologies can trace their roots to the turn of the 20th century (see for example Mokyr 1990, 2002; O'Rourke et al 2008). Understanding the Industrial Revolution and economic growth in history requires us to understand the interactions between human capital and technological change. In order to link the past with the present, theories of industrialization and "unified growth" make assumptions concerning the effects of the current technological system (A) on human capital h (so that $h = f(A)$) as well as the effects of human capital on subsequent technological change (so that $\frac{\dot{A}}{A} = g(h)$) (Galor 2009; Galor and Weil 2000; Galor and Moav 2000). Without careful empirical study, we can only speculate over these relationships, and ascribe functional forms to f and g in an ad hoc manner.

Yet our knowledge of this period is limited; individual-level data collected consistently over time are typically not available for any period prior to the second half of the *twentieth* century.[1] Arguably then, this is a great arena to explore the historic role of technical skill, for navies are both excellent indicators and creators of a nation's economic and technological capabilities.

Navies have always been one of the vanguards of technological progress (O'Brien 2001). But technical "progress" during the latter 19th century posed particular challenges for the Navy. Innovations in propulsion, hull construction, and ordnance had the potential to erode the relevance of the skills of officers educated and trained under a former technological paradigm. As is true today, officers of the 19th century

[1]The earliest example of a study linking individual schooling and experience data of which we are aware comes from the Iowa State Census of 1915, skillfully exploited by Goldin and Katz 2000. Aldrich 1970 has a very interesting study that tracks the earnings of West Point graduates during the ante-bellum period, but not their educational profiles.

derived their professional worth in part from their education of particular naval "systems." The general-purpose nature of naval technology meant that changes could radically depreciate the specialized human capital of these officers. The technological skepticism that naval officers have historically expressed was plausibly a by-product of this depreciation (McBride 2000).

But was such skepticism justified? The analysis of the naval profession during the latter 19th century affords us a unique opportunity to gauge the effects of dramatic and uncertain technological changes in a specific labor market. During this time officers, belonging either in a regular corps or an engineer corp, had fairly specialized tasks. So we ask a number of questions. Did specialized technical skills correlate with naval career success? Did officers with specialized engineering training and skill fare better than officers with more general training? And did success deteriorate over time?

We analyze the relationship between skill and performance by compiling data on naval officers documented in the U.S. Navy registries. These registry books, arranged in annual volumes, chart the rank, station and pay of every serving naval officer over time. We match this data with the scores these officers earned in different subjects as students at the Naval Academy (compiled in the Naval Academy registers) as well as data tracking the characteristics and stations of the fighting ships to which each officer is ultimately assigned each year. The final merged dataset provides us one of the earliest examples of detailed individual measures of education, experience and work performance of which we are aware. Furthermore, while studied and discussed extensively by naval historians, this data has hitherto never been codified, and thus has never been systematically studied.

We proxy for officer job performance by alternatively using measures of individual earned wage profiles and durations of naval service. Our empirical exercises uncover a number of results concerning the effects of skill on officer careers. First, those with engineering skill tend to leave the service earlier than those without. This is true either when we measure skill *extensively* (comparing engineer officers with regular line officers) or *intensively* (comparing line officers with varying engineering ability). On the other hand, technically skilled individuals (again measured either extensively or intensively) earn higher wages early on, but these premia diminish as time goes on. Taken together, naval technical progress appears to be more technical-skill *depreciating* rather than technical-skill *augmenting*. The more technically skilled officers earned a lower premium for their skills over time, and they tended to leave the service with greater speed.

Finally, we analyze the effects of skill on different types of work *experience*. We find evidence that technically skilled officers worked more often on shore, and less at sea. This implies that the more technically gifted officers worked more as technocrats in bureau jobs rather than actual practitioners "in the field." One lesson from this may be that capital-skill complementarities, characteristic of the second Industrial Revolution in general and certainly of the Navy, need not mean that these factors worked closely or directly together.

The next section of the paper discusses the historic background in more detail. We then describe the data we have collected and some of the empirical tests we have performed, and present our econometric results.

1. Background

1.1. **A Navy in Transition.** Like most industries of the time, the 19th century navy underwent dramatic, sometimes wrenching, science-based technological changes that affected nearly facet of the industry. Developments in steam propulsion, metallurgy, and naval ordnance transformed the very nature of naval professional life. The question of whether or not "skilled" workers benefitted more from such changes is however ultimately an empirical one, for upon cursory inspection the answer does not immediately surface.

On the one hand, technical skill in engineering would appear to matter greatly in the U.S. postbellum navy. The maintenance of blockades during the Civil War seems to owe much of its effectiveness to naval engineers (Davis and Engerman 2006). The growing reliance on steam power for the propulsion of naval vessels was evident even before the war - in November 1860 Congress announced its plans to convert seven of the navy's sailing ships to steam power, at a cost of $3,064,000 (Sweetman 1984). Furthermore England, the paragon of all things naval, was rapidly transforming its navy into one propelled predominantly by steam (Bennett 1896). These and other factors would seem to indicate that technical progress in the U.S. navy would be *skill-biased* - that is, it would raise the wages of officers skilled in engineering relative to their unskilled counterparts as the U.S. modernized its fleet.[2]

Yet there were a number of factors that appear to work against the exponents of technical progress. By the end of its civil war, the United States had one of the most powerful and technologically advanced navies in the world. In 1865 the northern states maintained 671 modern war vessels, including 559 steam-powered ships and 71 ironclads (Coletta 1987). But the naval build-up during the war subsequently led to a heated and often paralyzing debate over the future course of the navy after the war. The officer core and Congress were divided over virtually everything; questions over general naval strategy, proper building materials for ships, proper metals for gun construction, and the appropriate method of propulsion consumed naval dialectics for decades, leaving new entrants into the corps highly uncertain as to which path the navy would ultimately take.

No debate was more heated than the one over steam versus sail power. The wartime steam-powered ship buildup triggered a renewed debate between the traditionalists reared in the age of sail and the

[2]See for example Griliches 1956, Bartel and Lichtenberg 1987, and Goldin and Katz 1998 for micro estimates of the wage effects of skill-biased technological change.

disciples of newer technologies. Consequently the post-war naval profession was filled with anti-steam reactionaries.[3] This backlash within the service against both steam engines and the engineers who ran them no doubt arose partly from line officers' fears of becoming obsoleted by a new technological system. Officers in the old sailing navy controlled both the weapons and the means of propulsion; in contrast the latter 19th-century navy required officers to rely on mechanics, thus subordinating their role in core operations to a "non-aristocratic" engineer corps (McBride 2000).

Such divisiveness between engineers and line officers must have undermined to some extent the perceived value of engineers, and surely created a great deal of uncertainty over the future path of the navy. In 1869 the Navy Department directed the return of full sail power for all ships, surely heightening the insecurity faced by all naval personnel concerning their future fortunes (Coletta 1987). After this an awkward compromise resulted in new war vessels being equipped with both sail and steam rigging, provoking Rear Admiral Thorton A. Jenkins to proclaim the fleet to be a "heterogenous mass of naval incongruity miscalled a navy" (Scott 1986). This not only muddled the optimal mix of skills on which officers could rely to succeed in the navy, but it also served to further delay the navy's full transition to steam power. Until sail power was completely phased out, shipbuilders were forced to design vessels that would accommodate two incompatible propulsion systems, and officers were forced to familiarize themselves with both. Indeed, this slow transition from sail to steam was not truly completed until the end of the century. The "ABCD" ships of 1883 (the Atlanta, Boston, Chicago and Dolphin), trumpeted for their steel hulls and steam-powered propulsion systems as technological marvels and harbingers of a modernizing fleet, still incorporated traditional sail rigs. Even the USS Texas and USS Maine, commissioned in 1895 as

[3]See Morison 1966, Calvert 1967, Buhl 1974, and Albion 1980 for greater discussion.

the nation's first modern battleships, were designed to carry sails in order to complement their steam engines and extend their cruising radii (McBride 1992).

A related area of technological uncertainty was the advance in metallurgy that allowed the transition from wood to metal ships. Again, a smooth transition was thwarted by internal debate among top naval brass. Admiral David Porter and Commodore T. H. Patterson advocated the construction of many kinds of ships, but especially seagoing ironclads. On the other hand, Rear Admirals Thornton Jenkins and Louis Goldborough felt that such heavy armor would make ships ungainly, unwieldy, and prone to destruction by high speed armored rams. Better they thought to build wooden ships with single-cycle engines (Scott 1986). Adding to the damage caused by the uncertainties over technological adoption was the fact that most Civil War ships had been built of unseasoned timber, and so were prone to rapid deteriorization during the late 1860s and 1870s (Coletta 1987).

By the early 1870s the total number of ships fell to 52, with these mounting fewer than five hundred mostly obsolete guns (Coletta 1987). By 1880 there could be little doubt among members of the naval profession of the sad state of the U.S. Navy compared to her European counterparts. What was still lacking however was any consensus on the proper technological path on which to take the navy to the twentieth century. Naval technologies in general were undergoing such violent and rapid changes that few experts could advocate with any certainty what course the navy should ultimately take. This directly hindered the ability of naval constructors to design and build new warships, and thus hindered the navy's ability to properly train and educate new troops of future officers. Part of the problem was Congress, which was unwilling to spend money on guns and warships that would surely be obsoleted in a short period of time (Scott 1986). On the other hand, many other congressional leaders and their constituents held the antithetical but equally misguided viewpoint that the fleet consisted of highly durable and long-lasting vessels. John Ericsson, himself a celebrated naval engineer, proclaimed that "vessels like the monitors are good for fifty years." Such "false but soothing" advice failed to acknowledge that technological change demanded constant military modernization (Roberts 2002).

The U.S. Navy hit the nadir of its fortunes in the early 1880s. By then the continual inflow of Naval Academy graduates with very little new naval construction created the dire situation where it took Annapolis graduates as long as eight years to make ensign (Sweetman 1979).[4] Congress's rather blunt solution to this imbalance was the Personnel Act of 1882, which stipulated that the number of officers annually commissioned could be no greater than the number of vacancies that had opened up in the previous year. Those who were chosen to be commissioned were picked on the basis of class standing. Those who were not received a diploma, a severance package of $950, and an honorable discharge. Here was a stark example of what terrible consequences the lack of good overall scores in college could bring - of the 305 Academy graduates from 1882 to 1887, only 136 remained past their second year of service. Although it is impossible to know exactly who among these were directly affected by the act and who merely "were driven out of the service by the discouraging outlook,"[5] the act served as a reminder of the uncertainties inherent in a profession under wrenching transition. Of course this imbalance also affected those from earlier graduating classes - the top twelve graduates of the Class of 1868, for example, had made lieutenant by 1872, but were destined to remain lieutenants[6] until 1893.

Despite the continued debates over the future course of the navy among naval and congressional leaders, nearly every naval budget from 1884 to the turn of the century included funds for new construction. And with the resumption of naval construction came the eventual repeal of the Personnel Act in 1889. Although technological uncertainties

[4]Ensign is the lowest rank for a naval officer, ranking just ahead of midshipman.

[5]NY Times article, December 7, 1892

[6]Lieutenant is the third lowest rank for a naval officer.

in propulsion (sail versus steam), armor (wood versus iron versus steel) and ordnance (development of explosive shells and large breech-loading rifled guns) continued into the twentieth century, rival navies' continual innovations in design and engineering spurred the U.S. to do likewise.

The import of this narrative is to highlight the incertitude of naval progress during the latter 19th century. Technical skill embodied in officers could conceivably deteriorate over time in such an environment. The general-purpose nature of technology in the navy meant that changes would radically alter the relevant mix of skills useful for career success. And the uncertainty concerning such changes would conceivably bias naval education towards the status quo, limiting the ability of officers to succeed over time even further.

1.2. **Naval Education and The Pre-Amalgamated Line.** During the latter half of the 19th century nearly every new officer in the navy was a graduate of the Naval Academy. Always striving to be a mirror of the navy itself, the academy sought to design a curriculum with the express technological and personnel needs of the naval profession. With such uncertainties over the future course of the navy this mission proved to be fairly difficult. Particularly challenging was calibrating the proper mix of technical engineering courses with traditional seamanship and navigation training. Divisiveness between engineers and line officers in the service began to form during the Civil War, and this naturally colored the academy's decisions concerning its curriculum. The primary debate was over the question of whether all officers needed to be engineers as well as sailors, or whether a certain amount of specialization could take place between engineer and line officers. Proponents of the former approach included Secretary of the Navy Gideon Wells, who back in 1863 rhetorically asked "whether every officer of the line ought not to be educated to and capable of performing the duties that devolve upon engineers."[7] But line officers resented the intrusion

[7]Annual Report of the Secretary of the Navy 1863.

of engineers into their spheres of influence, preferring them to serve below deck as they traditionally did, out of sight and out of mind. Even Alfred Mahan, the celebrated champion of the big and technologically sophisticated navy, dismissed the engineer corps as "those who snored away below while line officers fought the ship" (McBride 2000). Others referred derisively to engineers as "wipers" and "greasers" (Coletta 1987).

Still, the view that technical training for all officers was of critical importance for the modernization of the fleet held firmly in the minds of many. The Department of Steam Enginery was developed by Admiral Porter, Superintendent of the academy, to attempt to make all future officers engineers as well. Blocks of academic time were set aside for engineering instruction, and during the summer cruise of 1866 the midshipmen alternated watches between the engine room and on deck. But any dispassionate survey of the program would have to deem it an utter failure from the start. The midshipmen showed very little interest in the engineering courses, and their engineering performance on cruise was so abysmal that the approach was altogether abandoned. Steam stayed in the curriculum, but the academy made no subsequent attempts at qualifying all the midshipmen as engineers (Sweetman 1979).

As a result both of this failed experiment and of the tensions among traditional officers and engineers, a heterogenous officer core emerged, where line officers and engineer officers performed mostly separate functions aboard war vessels and in the service in general. In order to accommodate this specialization among personnel, the Naval Academy developed a separate corps of cadet engineers who were instructed separately from the other midshipmen during the last two years of their studies. There were three phases during the 19th century when this was attempted. In 1868, sixteen cadets were appointed acting third assistant engineers and began a two-year engineer-oriented course of study. This program was discontinued after one year, but a new group of cadet engineers was subsequently admitted. In March 1871 Congress directed that at the discretion of the president members of the corps be given relative rank to line officers. From 1872 until 1882 the academy consistently graduated engineer officers along with line officers. The Personnel Act discontinued this separate line of training, but it was resumed with the act's repeal, and so from 1894 to 1899 the academy continued to graduate and commission engineer officers. Finally came the Amalgamation Act of 1899, whereby engineer officers were absorbed into a new "amalgamated" line. Thereafter all newly minted officers were allegedly skilled enough to perform any task aboard any vessel. This shift in organizational strategy was prompted by a study made under the auspices of Assistant Secretary of the Navy Theodore Roosevelt. This amalgamation ostensibly eliminated the independent corps of line and engineer officers, for according to Roosevelt "on the modern war vessel, every officer has to be an engineer whether he wants to or not" (McBride 2000).

2. The Evolving Value of Human Capital in the Navy

2.1. **Framework for Evaluating the Value of Human Capital.** The tumult of the technological revolutions during the second Industrial Revolution is in many ways epitomized by the U.S. Navy. Technical training was clearly important in accessing and using the new technologies, but without the continual updating of one's skills such training could face rapid depreciation over time. Given individual-level evidence for both the regular corps and the engineer corps, the 19th century navy offers us a unique industry case study to gauge the value of skills during this period. How valuable were they, and how did their value change over time?

These questions should be of particular interest to those who study the interactions between human capital and technology in history. Studies concerning this period of our economic history usually treat human capital as a binary measure; in this context, an engineer officer would be considered a "skilled" worker while a line officer would be considered an "unskilled" worker. But this approach misses some potential interactions between technology and human capital that we know to be of historic importance, at least in the context of the 19-century navy. First, it treats officers as two monolithic groups, when in fact each officer would have their own unique mix of skills which they would employ in the service. Technological change then could affect each officer differently, depending on his mix of skills. As a simple example, suppose human capital can be divided into two types, *general* human capital (h^G), and *specialized* human capital (h^S). h^G refers to general intelligence or education not specific to any one subject or type of training; h^S on the other hand refers to human capital for use in a specific production process or subject area. Human capital for individual i at time t might then be characterized as:

$$H_{i,t} = (1 - \mu g_t)\, h_i^G + (1 - \delta g_t)\, h_i^S$$

where g_t denotes technical progress in the industry, and μ, and δ are parameters which describe how technical progress affect different types of human capital. Such a description of human capital where $\mu > 0$ and/or $\delta > 0$ echoes discussions in Galor and Weil (2000) and Galor and Moav (2000), who suggest that at least a portion of human capital dissolves away with technical progress. In the context here, we suggest that officer's set of technical skills can erode with technological change, potentially at different rates. This points to the possibility of technological change as having a *general purpose* component to it, where technical progress can affect the entire economic system in such a way as to render certain skills obsolete. Indeed, the switch from sail-power to steam-power in maritime and naval activities has often been characterized in precisely this way (see Aghion and Howitt 1998, chapter 8, for a fuller theoretical discussion).

On the other hand, certain skills can become *more* valuable as technical progress occurs (in this case $\mu < 0$ and/or $\delta < 0$). The idea that general education and skills can help in coping with technological change dates back to at least Nelson and Phelps (1966) and Welch

(1970), who suggest that education can yield higher returns in an environment with more rapid technological growth. Changes in this case would appear to be skill-*biased*. More recent studies such as Krueger and Kumar (2004) suggest that only workers with general education can operate new, risky technologies, whereas workers without this general education are relatively more effective in operating old, established technologies.

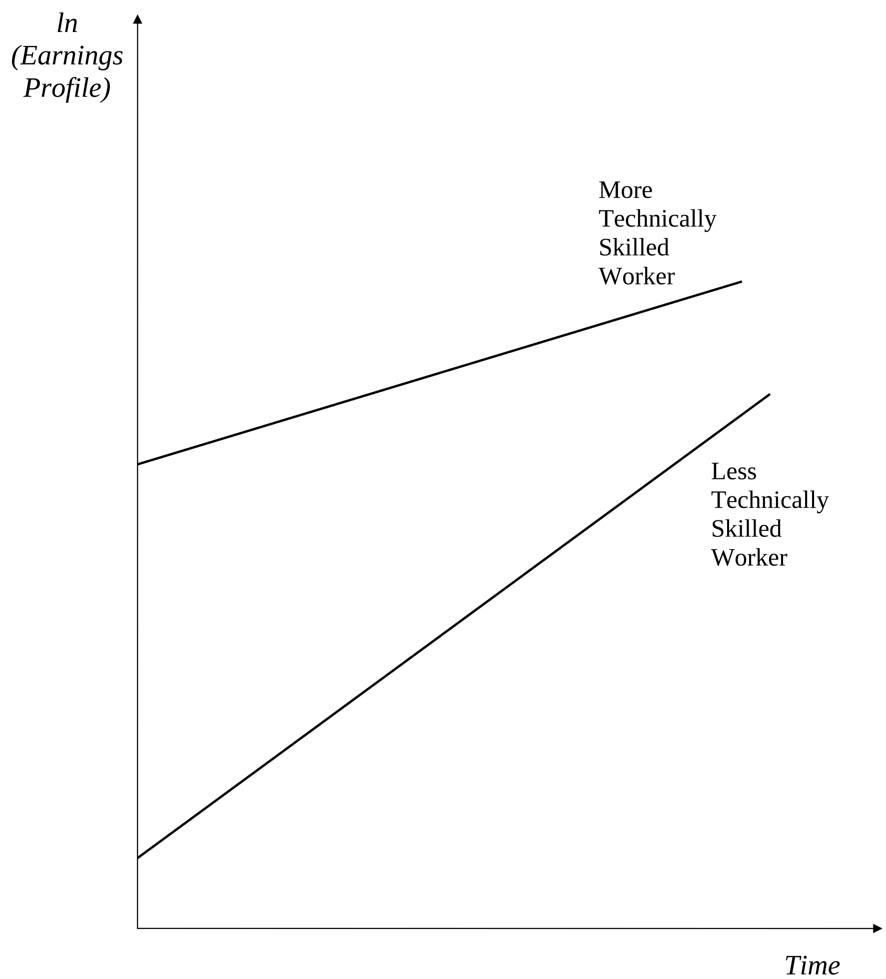
Thus whether or not technological progress is more skill-augmenting or skill-depreciating is ultimately an empirical question. Much will depend on the industry and the types of technological changes occurring within the industry. Figure 1 illustrates how the value of human capital may change over time in the context of the 19th century navy. Here the suggestion is that the more skilled worker will earn a higher wage initially than his relatively unskilled counterpart. With skill-depreciation, however, this wage differential will narrow over time.

This would suggest that technical change is more skill-depreciating than skill-augmenting; as intuitive as this possibility is, however, it need not be true in reality. Technical change in the navy during the late 19th century (switching from sail to steam technology, from wooden hulls to iron hulls to steel hulls, from many small-caliber guns to a few large-caliber guns, and so forth) could be expected to change the demand for "skilled" labor in several often countervailing ways. What kinds of skills thrived in this environment is the question to which we now turn.

2.2. **Empirical Strategy.** Our basic empirical strategy is to test the effects of education and experience on measures of career success within a stylized Mincerian framework. We have two basic proxies for "job performance" - the length of service an officer has in the Navy (*duration*),[8] and the wages an officer earns over a certain period of time (*earnings*). Each proxy in turn requires two specifications - one that includes our extensive measure of skill (engineer officer versus not),

[8]Unfortunately we are unable to track workers once they leave the Navy.

Figure 1. When Technological Progress is Both Skill-Biased and Skill-Eroding



and one that includes our intensive measures of skill (scores that line officers receive in various subjects).

For our duration analysis, we run the following specifications:

$$duration_i = \beta_0 + \beta_1 merit_i + \beta_2 engineering_i + \alpha_1 dies_i + \delta_{class} + \varepsilon_i \tag{1}$$

$$duration_i = \beta_0 + \beta_1 merit_i + \beta_2 steam_i + \beta_3 seamanship_i + \beta_4 ordnance_i + \beta_5 navigation_i + \alpha_1 dies_i + \delta_{class} + \varepsilon_i \tag{2}$$

where $duration_i$ is the number of years officer i is in the service, $merit_i$ is a measure of his general order of merit, $engineering_i$ is an indicator variable equalling one if officer i is an engineer officer, and $dies_i$ is an indicator variable equalling one if officer i dies while in service. The variables $steam_i$, $seamanship_i$, $ordnance_i$ and $navigation_i$ are all scores which line officers receive in particular subject areas as cadets in school. Equation (1) thus allows us to see how our extensive measure of education affects duration of service, while equation (2) allows us to see how intensive measures of education affect duration of service. Finally, we include dummies for each graduating class of the Naval Academy. Because the fortunes of each graduation class varied dramatically (due to appropriation differences year to year, number of vessels year to year, and so forth), this is potentially an important control to include.

For our wage analysis, we run the following:

$$ln\ (earnings)_{i,rs} = \beta_0 + \beta_1 merit_i + \beta_2 engineering_i + \alpha_1 cum.ship.exp_{i,r} + \alpha_2 cum.sea.exp_{i,r} + \delta_{class} + \varepsilon_i \tag{3}$$

$$ln\ (earnings)_{i,rs} = \beta_0 + \beta_1 merit_i + \beta_2 steam_i + \beta_3 seamanship_i + \beta_4 ordnance_i + \beta_5 navigation_i + \alpha_1 cum.ship.exp_{i,r} + \alpha_2 cum.sea.exp_{i,r} + \delta_{class} + \varepsilon_i \tag{4}$$

where *earnings* is given by the expression

$$earnings_{i,rs} = \sum_{t=r}^{s} wage_{it}$$

Here r is the chosen *starting* year and s is the chosen *final* year of officer i's wage history. The dependent variable is thus simply a summation of annual wages for a pre-chosen period of time. To capture some measure of "work experience," we include the number of years (out of a total of r years) officer i spends assigned to a naval vessel (given by $cum.ship.exp_{i,r}$), and the number of years he spends assigned to a vessel that is out at sea (as opposed to a vessel dry docked or out of commission, given by $cum.sea.exp_{i,r}$) Here we also include the same extensive and intensive measures of skill as before, as well as graduating-class dummies.

One thing to point out here is that for this exercise we can only count those officers who actually serve up to year s. If many officers leave the service before that point, a selection issue arises that biases results. To check for the robustness of results to selection issues, we alternatively produce *Heckit* estimates.[9] For example, if (3) is our equation of primary interest, the sample selection mechanism is:

$$(5) \qquad \begin{aligned} z^*_{i,s} = \gamma_0 \ + \ \gamma_1 merit_i \ + \ \gamma_2 engineering_i \ + \\ \gamma_3 sick_{i,s} \ + \ \gamma_4 leave_{i,s} \ + \ \delta_{class} \ + \ \nu_i \end{aligned}$$

where $z_{i,s}$ is an indicator variable equalling one if officer i remains in service after at least s years, $sick_{i,s}$ is an indicator variable equalling one if officer i had ever been sick or received naval hospital treatment any time up to year s of his career, and $leave_{i,s}$ is an indicator variable equalling one if officer i had ever been on a leave of absence any time up to year s of his career. The sample rule is that $earnings_{i,rs}$ is observed only when $z^*_{i,s}$ is one. Similarly, if (4) is our equation of primary interest, the sample selection mechanism is:

[9]This approach comes from the classic Heckman 1976 paper.

$$
\begin{aligned}
z^*_{i,s} = \gamma_0 \ + \ \gamma_1 merit_i \ + \ \gamma_2 steam_i \ + \ \gamma_3 seamanship_i \ + \\
\gamma_4 ordnance_i \ + \ \gamma_5 navigation_i \ + \ \gamma_6 sick_{i,s} \ + \ \gamma_7 leave_{i,s} \ + \\
\delta_{class} \ + \ \nu_i
\end{aligned} \tag{6}
$$

Ultimately these lead to OLS estimates for the conditional expectations

$$
\begin{aligned}
E\Big(ln\ (earnings)_{i,rs}\,|z_{i,s} = 1\Big) = \beta_0 \ + \ \beta_1 merit_i \ + \\
\beta_2 engineering_i \ + \ \alpha_1 cum.ship.exp_{i,r} \ + \ \alpha_2 cum.sea.exp_{i,r} \ + \\
\delta_{class} \ + \ \beta_\lambda \lambda_i \ + \ \varepsilon_i
\end{aligned} \tag{7}
$$

and

$$
\begin{aligned}
E\Big(ln\ (earnings)_{i,rs}\,|z_{i,s} = 1\Big) = \beta_0 \ + \ \beta_1 merit_i \ + \\
\beta_2 steam_i \ + \ \alpha_1 cum.ship.exp_{i,r} \ + \ \alpha_2 cum.sea.exp_{i,r} \ + \\
\delta_{class} \ + \ \beta_\lambda \lambda_i \ + \ \varepsilon_i
\end{aligned} \tag{8}
$$

where λ_i is the inverse Mills ratio generated from (5) or (6). Note that while (6) includes all subjects, (8) only includes *steam*. This is to isolate the effects of engineering skill on officer's earnings, using *all* subjects to model the sample selection mechanism.[10]

Another thing to note here is that we use a summation of wages over a period of time as one of our dependent variables, as opposed to a single wage typical of Mincerian-type regressions. The main reason for this is that pay differences among officers are primarily a function of different occupations and ranks. The "schedule" of pay among the different ranks, however, remained remarkably consistent through the period we are analyzing. Table 1 provides a portion of the schedule of

[10] As we will see in the results section, other subjects besides *steam* do not significantly affects earnings, but can significantly affect the length of one's service, making them ideal for inclusion in (6).

the annual wages paid to line officers and engineer officers during the late-19th century.[11]

This pay depended on the rank of the officer, the length of time he has been at that rank, and his duty (broadly classified as "at sea," "on shore duty" and "on leave or waiting orders"). In order to construct earnings profiles, we match each officer's rank and duty station to the appropriate wage, constructing a time series of annual wages particular to each officer. To create a career earnings measure that varies among the officers, we aggregate these wages across time, ultimately capturing year to year variation in jobs, ranks, experience, and responsibilities (e.g. command). If the officer serves on a vessel during a particular year, we cross reference information on the ship to which he was assigned - if the ship is dry-docked, in ordnance, or otherwise incapable of being launched for sea service, we allocate shore duty pay for the officer.

Finally, by changing r and s, we can gauge *changes* in the relationship between human capital and earnings over the course of one's career. If changes in the navy are skill-augmenting, we can expect a stronger relationship between education and earnings as those earnings are measured further into the future. On the other hand, if changes tend to depreciate existing skills, we can expect a weaker relationship between education and earnings measured over greater lengths of time.

3. Data

We use data on naval officers compiled by the Navy Register and housed in the National Archives. Arranged by year, each volume contains the names of officers, their rank, and their duty or station. This information was compiled by the navy at the beginning of each year

[11]Other more nontraditional positions not reported in the table include the various ranks for marines, paymasters, naval constructors, and even professors (these were typically instructors at the Naval Academy). These positions also had specific pay schedules that varied according to rank and length of tenure.

Table 1. Summary Statistics from Naval Academy and U.S. Navy Registers

Number of academy graduates (1858 – 1905)	2,376
Number of cadet engineers (1868 – 1899)	252
Average graduating class size	49.2
1860s	55.1
1870s	49.5
1880s	50.1
1890s	44.9

Annual Wages for Selected Naval Officers and Personnel, 1899 U.S. Dollars

	at sea	on shore duty	on leave or waiting orders
Rear Admiral	6000	5000	4000
Captain	4500	3500	2800
Commander	3500	3000	2300
Lieutenant Commander			
first 4 years	2800	2400	2000
after 4 years	3000	2600	2200
Lieutenant			
first 5 years	2400	2000	1600
after 5 years	2600	2200	1800
Lieutenant, junior grade (Master)			
first 5 years	1800	1500	1200
after 5 years	2000	1700	1400
Ensign			
first 5 years	1200	1000	800
after 5 years	1400	1200	1000
Cadet	500	500	500
Chief Engineer			
first 5 years	2800	2400	2000
second 5 years	3200	2800	2400
third 5 years	3500	3200	2600
fourth 5 years	3700	3600	2800
Passed Assistant Engineer			
first 5 years	2000	1800	1500
second 5 years	2200	2000	1700
third 5 years	2450	2250	1900
fourth 5 years	2700	2350	1950
Assistant Engineer			
first 5 years	1700	1400	1000
after 5 years	1900	1600	1200

(typically January or February). For regular officers, ranks range from admiral[12] to cadet or midshipman. For engineer officers, ranks range from chief engineer to cadet engineer. Figure 2 illustrates the number of officers we track through these registers, arranged by class year.

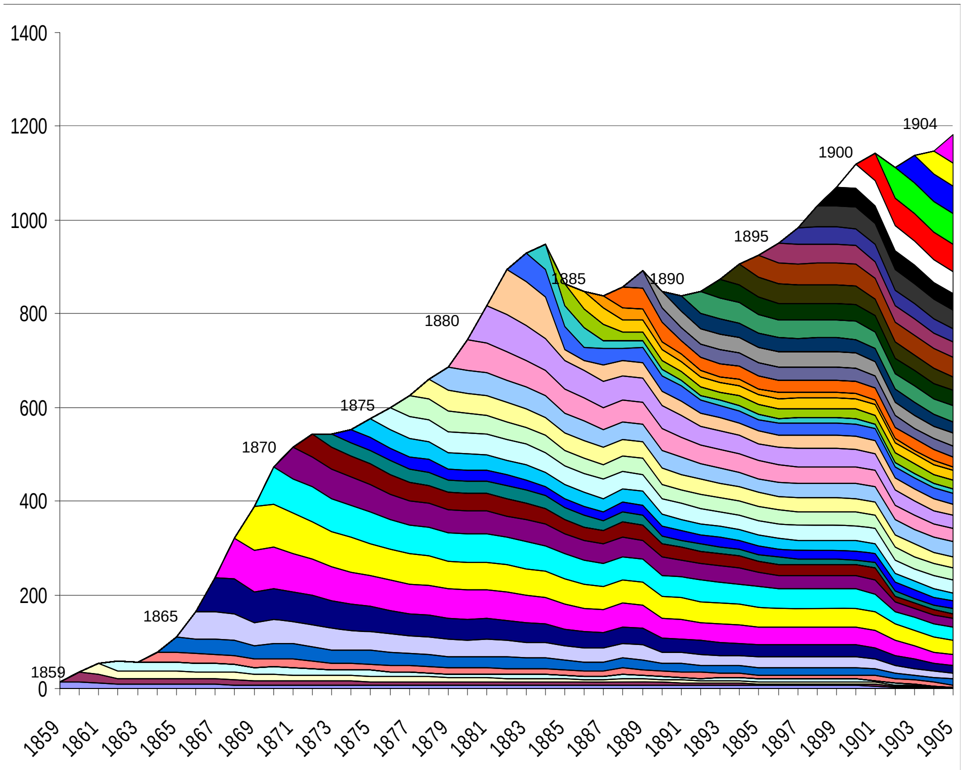
Each navy register also maintains a list of active naval vessels, their present duty or station, and basic ship characteristics such as rate, number of guns and displacement. For each officer serving aboard a particular vessel we cross reference these ship characteristics. This allows us to determine on what kinds of vessels the officer served, and if he was in fact out to sea as opposed to serving on a docked or uncommissioned vessel.

In order to construct earnings profiles for each officer, we combine both sets of data. Specifically, we match each officer's rank and duty station to the appropriate wage, constructing a time series of annual wages particular to each officer. If the officer served on a vessel during a particular year, we cross reference information on the ship to which he was assigned - if the ship is dry-docked, in ordinary, or otherwise incapable of being launched for sea service, we allocate shore duty pay for the officer.

Figure 3 illustrates the *average* earnings for certain graduating classes over time, both for regular officers and engineering officers. As is clear from the figure, the economic fortunes of each officer were highly sensitive to which graduating class he belonged. A graduate of the class of 1870 for example faced a crippling decline in commissioned war vessels, and so found his chances of promotion limited. A graduate of the class of 1890 on the other hand was fortunate to have a career during what now we can call a "naval renaissance." Further, each class faced a different curriculum from the Naval Academy, and so each class differed somewhat in education and training. Because of this dramatic heterogeneity, we include graduating class dummies for all our econometric specifications. Inclusion of class dummies allows us to compare

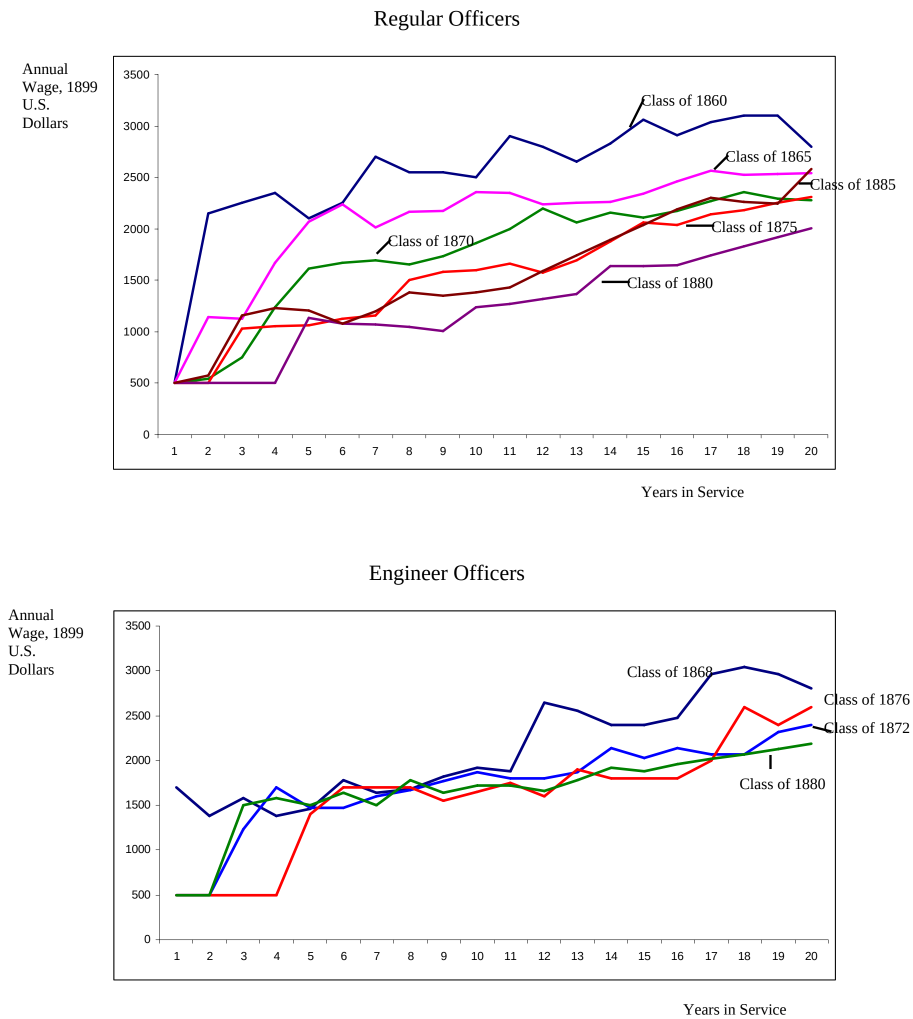
[12] George Dewey of the class of 1858 is the only member in our data to make the rank of admiral.

FIGURE 2. Number of Officers in Data by Class Year



the effects of education on career success for officers within the same graduating class, so that we can better isolate the effects of various educational measures on performance.

FIGURE 3. Class-Average Earning Profiles for Selected Graduating Classes



We match merge this data on officer performance to the Naval Academy records of each officer. These records, housed in the Naval Academy archives, document each midshipman's overall order of merit rank for his particular class, as well as orders of merit according to a variety of specific subjects. For overall order of merit, we compile both freshman-year merit scores (arguably a measure of more general ability as freshman classes tended to be less navy-specific and more generally academic, with classes like basic math and science, English and composition) and final-year (the end of four years) merit scores. Engineer cadets were ranked along with regular cadets during their freshman year (since both groups took the same classes during their first year); during their final year however engineer cadets were ranked as a separate group. For each officer i the score is defined as

$$merit_i = 1 - \frac{classrank}{classsize}$$

so that scores are scaled from zero (bottom of the class) to one (top of the class).

One issue we face in compiling specific subject information is the lack of exact comparability across all subjects and graduating classes. For example, four-year scores on History and Composition, Grammar, Rhetoric and Drawing only exist for the classes 1871 and 1872. Fencing was apparently deemed an unnecessary skill for effective naval service and eliminated as a required course after 1875. Further, courses were often changed around and renamed (for example, a "navigation" course could be labeled "practical navigation," or "navigation and surveying," or even "astronomy and navigation"). We choose four primary subjects to include in our specifications, both for their high comparability across class years and for their potential relevance for effective naval service. As made explicit in regressions (2) and (4), these are "steam," "seamanship," "navigation" and "ordnance and gunnery."

The final data set maintains the educational profile of every graduating officer from the academy from 1858 to 1905, and information concerning their service in the navy from 1859 to 1907.[13] This is the earliest example of matched education-work experience data at the individual level of which we are aware, and provides us a glimpse into an industry undergoing rapid and uncertain technological change during the latter 19th century.

Finally, we include controls for human capital while on the job. These are given by cumulative ship experience and cumulative blue water (or sea) experience. If an officer spends a year aboard ships navigating aborad in international waters, his cumulative *sea* experience rises. On the other hand, if he serves aboard a dry-docked vessel, or on a vessel that is part of the "brown water" navy (a coastal vessel), he increases his cumulative *ship* experience without increasing his sea experience. In this way we can control for different types of naval experience that may or may not be important to one's earnings potential.

4. Results

We first test the length of one's service in the navy, independent of earnings, by regressing the number of years of service on measures of skill and ability. This requires right-censored regressions, as we have navy register information only up to 1907, while many officers in our dataset serve in the navy well beyond that point.[14]

Tables 2 and 3 present our first set of results. We see in Table 2, which includes all personnel, that line officers with greater engineering skill leave early, while those with navigation and seamanship skill stay longer. This makes sense, since engineering skill was likely to be far more transferable to other industries than seamanship or navigation.

[13] 1858 is the earliest class for which we could find information; our decision to end at 1907 is essentially arbitrary.

[14] For the graduates of the class of 1904, for example, the dependent variable can take values of 1 or 2 (the uncensored cases) or 3 (the censored case). Thus censored points will be class-dependent. The officer graduating in 1904 who lasts for at three years is thus *top coded*.

Table 2. Right-Censored Regression Estimates of Effects of Skill and Ability on Duration of Naval Career (All Personnel)

	1	2	3	4
Overall Relative Merit	8.2*** (1.2)	7.4*** (1.6)	--	--
First Year Relative Merit	--	0.3 (1.6)	--	1.6 (1.7)
Relative Steam	--	--	-3.5* (1.9)	-4.1** (2.0)
Relative Seamanship	--	--	4.7** (1.9)	4.7** (2.0)
Relative Navigation	--	--	8.3*** (2.1)	8.1*** (2.3)
Relative Ordnance	--	--	2.9 (2.4)	1.8 (2.5)
Engineer (dummy)	-0.4 (1.2)	-0.29 (1.4)	--	--
Dies in service (dummy)	-8.6*** (1.1)	-9.9*** (1.2)	-8.6*** (1.3)	-9.9*** (1.4)
pseudo R – squared	0.03	0.03	0.04	0.04
Number of Obs.	2361	2179	1765	1665
Number of Right Censored Obs.	1095	1070	892	886

Dependent variable is number of years of naval officer's career (up to 1907).
Constant and class dummies not reported.
Standard errors in parentheses. Significance at 1%, 5%, and 10% indicated by ***, **, and *, respectively.

Table 3. Right-Censored Regression Estimates of Effects of Skill and Ability on Duration of Naval Career (All Personnel Who Serve at Least Three Years)

	1	2	3	4
Overall Relative Merit	1.9 (1.4)	1.4 (1.8)	--	--
First Year Relative Merit	--	-0.7 (1.8)	--	-1.3 (2.1)
Relative Steam	--	--	-4.9** (2.4)	-5.8** (2.6)
Relative Seamanship	--	--	3.4 (2.3)	4.1* (2.4)
Relative Navigation	--	--	5.2** (2.5)	5.8** (2.7)
Relative Ordnance	--	--	-0.3 (2.8)	-0.9 (2.9)
Engineer (dummy)	-2.7** (1.3)	-3.7** (1.6)	--	--
Dies in service (dummy)	-10.9*** (1.2)	-11.6*** (1.2)	-11.3*** (1.4)	-12.1*** (1.5)
pseudo R – squared	0.02	0.02	0.03	0.03
Number of Obs.	1901	1761	1359	1289
Number of Right Censored Obs.	986	961	783	777

Dependent variable is number of years of naval officer's career (up to 1907).
Constant and class dummies not reported.
Standard errors in parentheses. Significance at 1%, 5%, and 10% indicated by ***, **, and *, respectively.

We also see that overall merit has a strong negative effect on duration of service.

One complication here however is that the Personnel Act of 1882 forced the navy to discharge many midshipmen throughout the 1880s; further, as we mention in the previous section, this decision was made *primarily* on the basis of overall merit. This creates a great many number of small observations for the dependent variable and overestimates the effects of "Overall Relative Merit." In order to deal with this, we rerun the same specification, but limit our observations only to those who serve at least for three years. These classes would not have been directly affected by the Personnel Act.[15] Results are reported in Table 3. Coefficients for Overall Relative Merit fall to insignificance. Thus it appears that overall standing at the Naval Academy helps an officer survive his first few years in the Navy, but does not appear to matter much thereafter. Also, now we observe a statistically significant negative effect on duration for both extensive intensive measures of engineering skill. The more technically gifted officers tended to leave the service a good few years ahead of the rest.

Next, we regress the logged earnings officers received over a certain interval of their careers on individual measures of education obtained at the Naval Academy and ship experience from past naval service. These are regressions (3) and (4). We consider year r the first year of their earnings history, and year s the last year of this history. Specifically, Table 4 has $r = 3$ and $s = 7$, so that we are estimating the effects of education and the first *two* years of experience on *five* years worth of earnings. Table 5 sets $r = 3$ and $s = 12$, so that we are estimating the effects of education and the first two years of experience on *ten* years worth of earnings.

Note that for these results we only include officers who lasted at least s years in the service (so that we always measure s years worth of earnings for each officer). This however creates a selection bias, so we

[15]When we do this we lose around 400 observations.

Table 4. OLS and Heckit Estimates of Effects of Education and Experience on Earnings (r=3, s=7)

	1	2	3	4	5	6	7	8
Overall Relative Merit	0.08*** (0.012)	--	--	0.06** (0.03)	0.08*** (0.01)	--	--	0.07*** (0.02)
First Year Relative Merit	--	0.07*** (0.011)	--	--	--	0.08*** (0.012)	--	--
Relative Steam	--	--	0.05*** (0.02)	0.04** (0.02)	--	--	0.096*** (0.01)	0.045** (0.02)
Relative Seamanship	--	--	0.015 (0.02)	0.002 (0.02)	--	--	--	--
Relative Navigation	--	--	0.03 (0.02)	0.01 (0.02)	--	--	--	--
Relative Ordnance	--	--	0.014 (0.02)	-0.004 (0.02)	--	--	--	--
Cum. Ship Exp.	-0.09*** (0.01)	-0.09*** (0.01)	-0.075*** (0.01)	-0.088*** (0.015)	-0.085*** (0.01)	-0.092*** (0.01)	-0.088*** (0.01)	-0.085*** (0.01)
Cum. Sea Exp.	-0.005 (0.007)	-0.001 (0.007)	0.0002 (0.006)	-0.0003 (0.007)	-0.005 (0.007)	-0.001 (0.007)	0.0008 (0.008)	0.0009 (0.008)
Engineer (dummy)	0.27*** (0.02)	0.3*** (0.02)	--	--	0.26*** (0.01)	0.29*** (0.01)	--	--
Mills	--	--	--	--	0.027 (0.048)	0.055 (0.048)	0.048 (0.052)	0.069 (0.049)
Number of Obs.	1385	1276	964	964	2361	2191	1759	1759
Number of Censored Obs.	--	--	--	--	976	915	795	795
R – squared	0.82	0.82	0.86	0.87	--	--	--	--
OLS Estimates	Yes	Yes	Yes	Yes	No	No	No	No
Heckit Estimates	No	No	No	No	Yes	Yes	Yes	Yes

Dependent variable is the logged sum of annual earnings from year 3 to year 7 of naval officer's career.
OLS estimates include only observations on those officers who serve for at least 7 years.
Constant and class dummies not reported. Standard errors in parentheses. Significance at 1%, 5%, and 10% indicated by ***, **, and *, respectively.

Figure 4. OLS and Heckit Estimates of Effects of Overall Merit Scores on 5-Year Earnings for Varying Values of r and s.

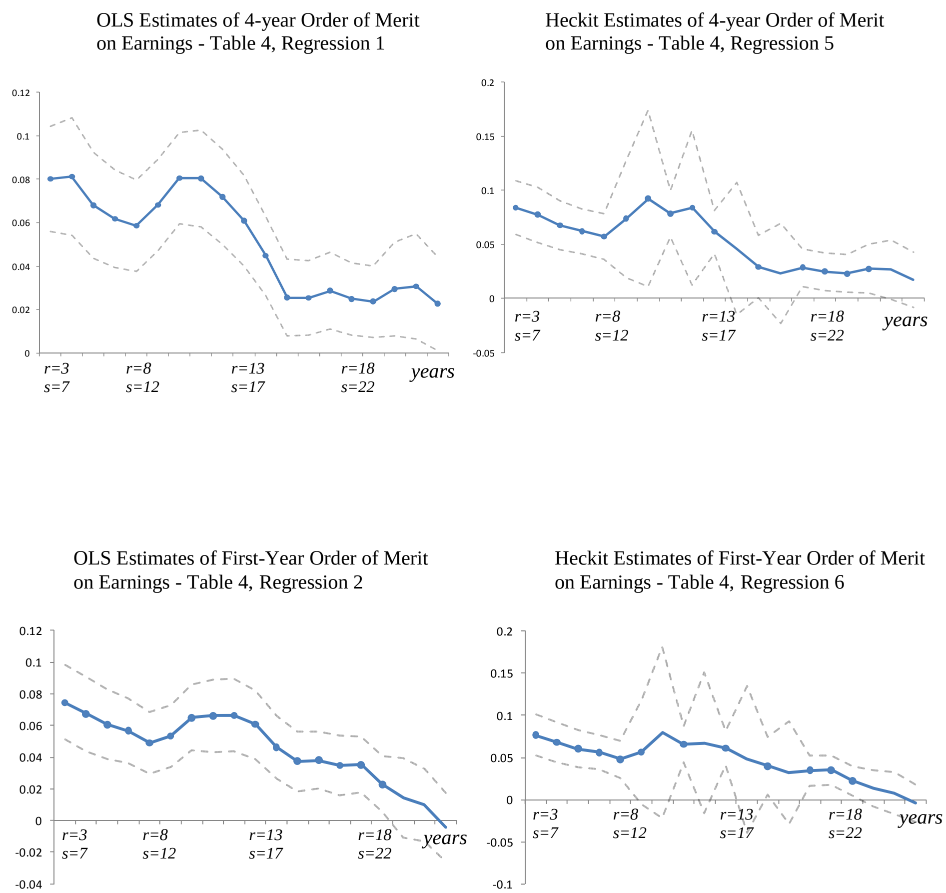


Figure 5. OLS and Heckit Estimates of Effects of Engineering Skill on 5-Year Earnings for Varying Values of r and s.

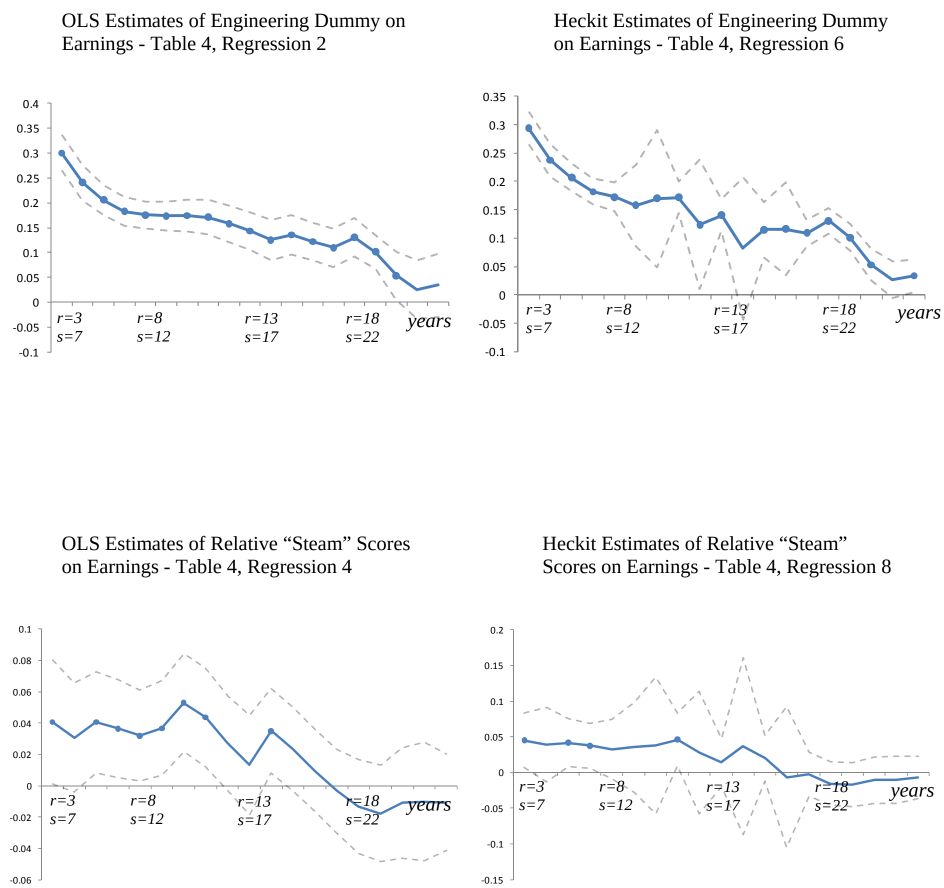


TABLE 5. OLS and Heckit Estimates of Effects of Education and Experience on Earnings (r=3, s=12)

	1	2	3	4	5	6	7	8
Overall Relative Merit	0.07*** (0.01)	--	--	0.06*** (0.02)	0.08*** (0.01)	--	--	0.06*** (0.02)
First Year Relative Merit	--	0.06*** (0.01)	--	--	--	0.06*** (0.01)	--	--
Relative Steam	--	--	0.05*** (0.014)	0.037** (0.016)	--	--	0.08*** (0.01)	0.037** (0.016)
Relative Seamanship	--	--	0.01 (0.01)	-0.000 (0.006)	--	--	--	--
Relative Navigation	--	--	0.02 (0.02)	0.01 (0.02)	--	--	--	--
Relative Ordnance	--	--	0.006 (0.02)	-0.01 (0.02)	--	--	--	--
Cum. Ship Exp.	-0.03*** (0.01)	-0.03*** (0.01)	-0.028** (0.012)	-0.027** (0.012)	-0.01 (0.01)	-0.015 (0.01)	-0.025** (0.01)	-0.022** (0.01)
Cum. Sea Exp.	-0.008 (0.006)	-0.004 (0.01)	-0.001 (0.006)	-0.001 (0.006)	-0.007 (0.007)	-0.002 (0.006)	0.0003 (0.007)	0.0001 (0.007)
Engineer (dummy)	0.22*** (0.02)	0.28*** (0.02)	--	--	0.21*** (0.014)	0.26*** (0.017)	--	--
Mills	--	--	--	--	0.100** (0.04)	0.113*** (0.04)	0.043 (0.035)	0.051 (0.034)
Number of Obs.	1015	927	711	711	2361	2191	1759	1759
Number of Censored Obs.	--	--	--	--	1346	1264	1048	1048
R – squared	0.88	0.88	0.85	0.85	--	--	--	--
OLS Estimates	Yes	Yes	Yes	Yes	No	No	No	No
Heckit Estimates	No	No	No	No	Yes	Yes	Yes	Yes

Dependent variable is the logged sum of annual earnings from year 3 to year 12 of naval officer's career.
OLS estimates include only observations on those officers who serve for at least 12 years.
Constant and class dummies not reported. Standard errors in parentheses. Significance at 1%, 5%, and 10% indicated by ***, **, and *, respectively.

Figure 6. OLS and Heckit Estimates of Effects of Overall Merit Scores on 10-Year Earnings for Varying Values of r and s.

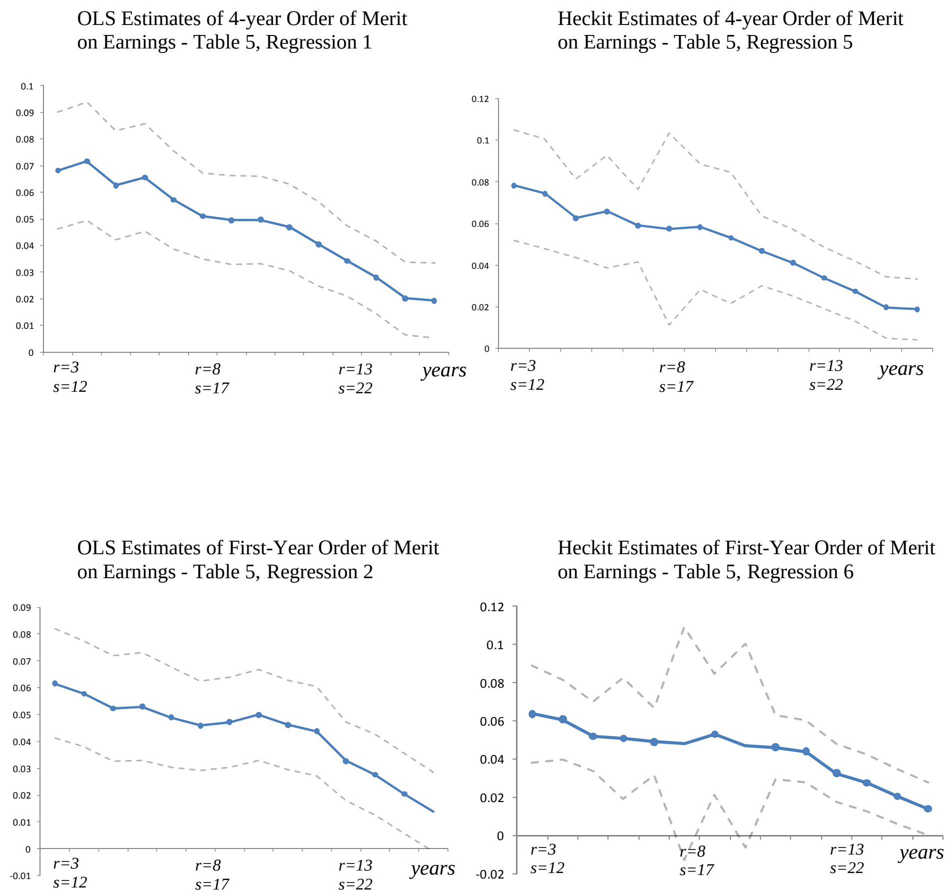
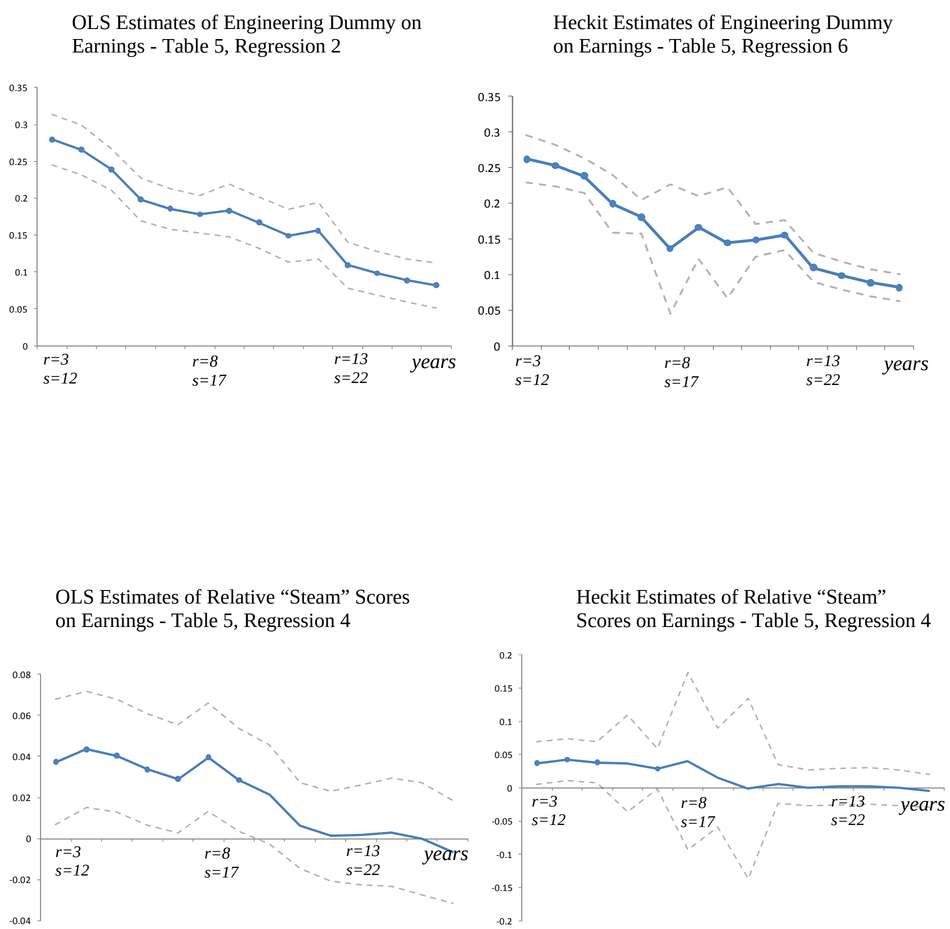


Figure 7. OLS and Heckit Estimates of Effects of Engineering Skill on 10-Year Earnings for Varying Values of r and s.



alternatively produce Heckit estimates (shown in (7) and (8)). Both tables include both OLS and Heckit estimates.

Our proxy for general education, Overall Relative Merit, consistently shows up as positive and significant. We can see from our 5-year measures that someone who graduates from the top of his class is predicted to earn roughly 6% to 8% more over a 5 year stretch of time compared to someone who graduates at the bottom of his class. First year relative merit, arguably a better gauge of innate general intelligence, seems to echo this.

We also include subject specific ability measures. Engineering ability, as captured by steam scores, seem to pay a premium early in one's career. Strikingly, someone graduating at the top of their class in engineering makes somewhere between 4 to 10% more than someone at the bottom of the class over a 5-year period (depending on the specification), controlling for other things. That is comparable to the earnings effects from the overall order of merit![16] Interestingly, steam is the only specific subject that generates a measurable premia for line officers.[17]

We can also see that engineer officers were paid a sizable premium; they received around 25 to 30% more over 5 years relative to line officers. Note that historical studies of skill-premia do not typically control for innate ability. We can do that here, for we include first-year relative merit scores, which compare all the officers together. That deals with another selection issue - the possibility that engineer officers were just smarter than regular line officers. That is why specifications 2 and 6 (which test this *extensive* measure of skill) include the first-year order of merit as an additional explanatory variable.

[16] Not included are other subject areas, such as Physical Science, Political Science and Foreign Languages. None of these came in as statistically significant or altered any of the other results.

[17] We also try each specific subject one by one; the other subjects do not show any significance.

Informative as these OLS estimates are, they limit the analysis only to those who serve a certain number of years in order to directly compare officers with varying degrees of skill. This however misses those officers who leave the service before these end points. Early "retirement" from the navy may happen for a variety of reasons, including dismissal, resignation, desertion, or death.[18] Further, many leave the service before truly serving; these midshipmen typically do their two years aboard naval vessels or serve in other stations, and then leave before getting promoted to ensign. To ignore these officers is to invite potential selection bias. So, specifications 5-8 redo specifications 1-4, but use equations (5) or (6) to employ the two-step *Heckit* estimation. None of our findings are tremendously affected by doing this.

This gives us a sense of the magnitude of skill premia, both for more general skills and engineering skills (intensively and extensively measured). However, this gives us only a snapshot: to gauge the extent of skill-*depreciation*, we need to look at how these relationships change over the course the officers' careers. To do this we simply increase r and s by yearly increments, and re-run all specifications. What we find is that *all* skill-premia decline over the course of one's career. Figures 4 through 7 display these results (for both 5 years and 10 years worth of earnings).

Arguably "general" skills tend to hold up better than engineering skill. For example, Figure 4 depicts how the estimated earnings effects on 4-year order of merit and first-year order of merit evolve over the course of one's career - these we can consider more general skills. Figure 5 on the other hand depicts how earnings effects on the extensive skill measure (engineering officer or not) and the intensive skill measure (steam scores for regular cadets) of engineering skill evolve over one's

[18]While the navy registers do distinguish between those who "resign" and those who are "dismissed," it is difficult to get an accurate feel for who precisely left the service voluntarily, and who were truly forced out. Because of this uncertainly, we treat both situations as cases of early retirement due to issues of compatibility. We do however control for cases where the officer dies within the allocated time.

career - these we can consider more specific technical skills. Over the course of 25 years, the 5-year earnings premium from 4-year merit scores fall from 8% to 2%. Engineers, on the other hand, go from enjoying a huge 30% premium to roughly a 2-3% premium over a similar period of time. And line officers who score at the top of their class in engineering earn roughly a 5% premium at the start of their careers but end up earning a *negative* return after twenty years or so (although this finding is not statistically significant). Also note that from peak to trough, most estimates are *statistically* different (that is, the bottom errors at the peaks are typically higher than the top errors at the trough). The point here is simply that those with engineering ability tend to lose their superior earnings power more rapidly than those with general ability, suggesting perhaps that changes in the Navy eroded the relevance of some of those technical skills.

Finally, we regress a variety of "experience" measures on relative merit and an engineer officer dummy. These experience measures are meant to capture the extent to which officers served aboard war vessels during their careers. Results are posted in Table 6. The first set of results use the number of years aboard any ship as the dependent variable; the bottom set of results use the number of years aboard *active* vessels (those out to sea) as the dependent variable.

Whichever way we measure "ship experience," ability appears robustly *negative*.[19] It appears then that those with less general ability served aboard vessels with greater propensity, and served on more active and larger vessels with even greater propensity. Indeed, the effect appears to strengthen for those who serve longer. Contrary to what many would perhaps expect, the navy did not match those with high levels of human capital to naval ships. Those with the best general human capital instead tended to work in various office positions on shore - these included the different bureaus (steam engineering, ordnance, navigation, and so forth), hydrographic offices, torpedo stations and

[19]Performance in specific subjects had no statistically significant effects on experience.

Table 6. OLS Estimates of Effects of Skill and Ability on Measures of Ship Experience (5, 10, and 20 years)

	1	**2**	**3**
Overall Relative Merit	-0.29***	-0.68***	-1.32***
	(0.1)	(0.21)	(0.48)
First Year Relative Merit	-0.28***	-0.86***	-0.83*
	(0.1)	(0.2)	(0.44)
Engineer (dummy)	-0.35***	-0.9***	-1.99***
	(0.1)	(0.17)	(0.65)
R - squared	0.42	0.47	0.37
Number of Obs.	1421	1031	524

Dependent variables are number of years officers spend aboard naval vessels out of the first (**1**) five, (**2**) ten, and (**3**) twenty years of officers' careers.
Constant and class dummies not reported.
Standard errors in parentheses. Significance at 1%, 5%, and 10% indicated by ***, **, and *, respectively.

	1	**2**	**3**
Overall Relative Merit	-0.21	-0.2	-0.73
	(0.14)	(0.23)	(0.47)
First Year Relative Merit	-0.33***	-0.45**	0.12
	(0.13)	(0.22)	(0.44)
Engineer (dummy)	0.16	0.21	-1.1*
	(0.11)	(0.18)	(0.57)
R - squared	0.26	0.20	0.19
Number of Obs.	1421	1031	524

Dependent variables are number of years officers spend aboard naval vessels that are in active duty out of the first (**1**) five, (**2**) ten, and (**3**) twenty years of officers' careers. Constant and class dummies not reported. Standard errors in parentheses. Significance at 1%, 5%, and 10% indicated by ***, **, and *, respectively.

Table 7. LOGIT Estimates of Effects of Ability and Experience on Obtaining Command

	1	**2**	**3**	**4**
Overall Relative Merit	0.71***	-0.21	0.85	1.3
	(0.24)	(0.63)	(0.59)	(0.9)
First Year Relative Merit	-0.41*	-0.37	-1.2**	-0.61
	(0.24)	(0.58)	(0.54)	(0.9)
Years spent on vessels	--	0.29***	0.11*	0.1*
		(0.11)	(0.055)	(0.6)
pseudo R - squared	0.16	0.14	0.15	0.22
Number of Obs.	2182	668	479	182

Dependent variable equals 1 if the officer had obtained command of a vessel:
1 – ever in his career
2 – during the first 10 years of his career, provided he was in the service during that period
3 – during the first 20 years of his career, provided he was in the service during that period
4 – during the first 30 years of his career, provided he was in the service during that period

"Years spent on vessels" equals the number of years aboard naval ships:
2 – out of 10 years
3 – out of 20 years
4 – out of 30 years

Constant and class dummies not reported.
Standard errors in parentheses. Significance at 1%, 5%, and 10% indicated by ***, **, and *, respectively.

naval yards, and even the Naval Academy and War College. General ability meant that officers could get promoted to managerial office roles fairly quickly, away from naval vessels and sea duty. Perhaps it was the officer managing a bureau on shore that would need a great deal of general skill to cope with the various technological and organizational changes the navy was experiencing.

This idea is further explored by looking at those officers who end up commanding a vessel. To do this we run a LOGIT specification, where the dependent variable equals one if the officer ends up in command of a ship during a certain period of his career, and zero if not. We report results in Table 7.

When we look at *all* officers (the first specification), overall relative merit seems to positively predict the obtainment of command; however, this is only because general skill allows one to stay in the navy longer, and this obviously would increase one's chance of getting command. When we look at just those officers who are in the service for comparable periods of time (the second to fourth specifications), relative merit falls to insignificance. Furthermore, first year relative merit often comes in weakly negative, suggesting that those of lesser general aptitude obtained command with greater propensity! The best predictor of whether one will ultimately command a ship is simply the degree of experience one has with ships, and, as it happens, those with a great deal of ship experience tended to have lower merit scores.

5. Conclusion

This paper suggests that the rate of return on education deteriorated over time for U.S. naval officers during the 19th century. Using archival data, we empirically document that the value of the marginal product of "skilled" workers converged to the value of the marginal product of lesser-skilled workers over time, suggesting that human capital depreciated over time. This is somewhat surprising: the 2nd Industrial

Revolution is considered to be a more skill-biased one, and naval technological change was considered to be particularly skill-biased. But the nature and structure of the industry was such that the rewards to one's education petered out, inducing some to leave the industry. This was probably exacerbated by the GPT nature of changes in the Navy (although we can not isolate that effect from other factors). This should perhaps serve as a cautionary tale, both to managers of skilled individuals, and to the skilled individuals themselves. Industries with lots of technological transition may dampen the value of the marginal product of skilled workers; skilled workers may find themselves relatively worse off over time, and the industry may ultimately see an exodus of these skilled individuals as they search for better opportunities elsewhere.

The lessons drawn from this industry-specific study may help us understand how technological change interacted with human capital more generally in the late 19th century. The second Industrial Revolution, where many innovations occurred in industries such as chemicals, electricity, and steel, created a new class of technician, and perhaps undermined skills accumulated for older outmoded techniques. Our understanding of this period is however limited by lack of individual-level data. With the compilation of this archival, industry-specific data, we have attempted to fill this gap in the literature. Our results from analyzing this data suggest that technical skill paid a sizable premium early on but less so as technical changes eroded the relevance of such skill. The question of whether this was true of other industries remains to be explored.

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