

Technical Human Capital
and Job Mobility in an
Era of Rapid Technological Innovation

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Abstract

We analyze the job matching process for skilled labor using an extensive panel dataset of naval officer careers during the Second Industrial Revolution. We find strong separation effects for officers with accumulated skills in technology-focused work and/or those with formal training as engineers. In particular, technology-based human capital increases the probability of a job switch quite substantially, even after controlling for wage differences and seniority. In addition to providing tests of matching-models, our results have important implications for policy makers evaluating incentives for retaining technologically trained human capital. This is applicable to help understand effects of wage differences in labor markets experiencing rapid technological change. Estimates also indicate that a *ceteris paribus* increase in the distribution of external wage offers increases the probability of job separation. Controlling for seniority and the effects from accumulated human capital, a 1% increase in the wage gap of internal wage offers relative to wages in external labor markets decreases the hazard for job separations by 0.8%.

Keywords: human capital; job mobility; technological change; military personnel; U.S. economic history.

JEL Classifications: J6, J45, J62, N31.

1 Introduction

In times of rapid innovation, if new technology is skill-enhancing, firms and economies alike must develop and improve human capital to keep pace. Workers need training and experience in the use of new technology, and firms must develop retention mechanisms for newly trained and highly skilled workers. If retention mechanisms do not keep pace, quality workers may walk, and competitors may regain the edge.

This paper adds to the body of empirical research on job turnover by disentangling the effects of heterogeneous human capital accumulation on job separation probabilities. In particular, we focus on the most highly skilled workers in an economy experiencing rapid technological change and rapid economic growth—the United States during the Second Industrial Revolution. Navies in general experienced large leaps in productivity at the end of the nineteenth century, and are indicative of a leading economic sector (Harley 1993). The United States Navy was certainly at the forefront of this boom, experimenting with and using much of the new technology. Naval officers were needed with commensurate levels of technical human capital.

Using longitudinal data on Naval officer careers with exceptional detail on training, experience and skills accumulated over time, we examine how the accumulation of technical human capital affects job separations. All naval officers during this era graduated from the Naval Academy in Annapolis, and we can track entire careers, measuring both initial levels of human capital as well as human capital accumulated over time within the Navy. Officer exits were essentially one-sided decisions during the time encapsulated by this data, so we worry little about the endogeneity of the firm’s decision¹. This gives us an exceptionally clean measure for how alternative incentives directly impact worker decisions about turnover. After controlling for wage changes, seniority and the accumulation of numerous types of firm-specific and general human capital, workers with more years of technical job

¹A handful of officers resign due to “disability” or for being un-promotable. A few egregious cases of misconduct force others from the service, but the net impact of these observations on results is negligible.

experience exhibit much higher rates of job separation. Among the sub-set of workers trained specifically as engineers, an additional eight years of high-tech work experience doubles the hazard for a job separation.

A significant portion of labor market research analyzes the effects of training and subsequent wage-growth on the long-term stability of the firm-worker relationship. Employers may prefer a stable workforce, especially when they make substantial investments through hiring or in the cost of training. For navies, this includes the development of human capital for officers to attend school (e.g. academies, college, etc.), but it also involves the acquisition of firm-specific training within the fleet after they become officers (i.e. post-commissioning). Of course naval officers serve on ships, but they also serve on land in shipyards (building and repairing ships), as diplomats, staff officers and bureaucrats, or more generally as engineers and/or project managers.

After the American Civil War and during the Second Industrial Revolution, two simultaneous factors facilitated officer separations (i.e. exits and/or retirements). Promotions stagnated, which meant that officers who acquired firm-specific training did not receive a compensating wage increase. At the same time, wages for skilled labor in the broader labor market increased, indicating a rising premium for technical skill. These two facts implicitly increased the opportunity cost of remaining in the Navy. Furthermore, without promotions or Congressionally approved wage increases, officers' stagnating wages could not keep pace with inflation. Conditions were ripe for the most highly trained and skilled officers to abandon military careers for more lucrative opportunities in the private sector.

In addition to the seminal work of Becker (1962, 1964) that concerns job training, our empirical framework leans heavily on theoretical models of job matching that stem from Burdett (1978), Johnson (1978) and Jovanovic (1979a, 1979b). Burdett (1978) argues that wages are correlated with age, and that the *ceteris paribus* probability of a job separation should not change with seniority. Jovanovic (1979a), indicates that even with wages held

constant, a positive relationship can exist between seniority and the likelihood of separation, but the strength of this effect weakens over time and should eventually reverse sign.

Empirically, the evidence on turnover in the labor economics literature appears mixed but generally supports a decline in the hazard with tenure. Topel and Ward (1992) indicate how worker turnover is especially common early in a career as workers engage in repeated search until they find the optimal long-run match. Especially for those who have found their “long-run match”, Farber’s (1999) summary supports this, noting the clear decline in job separations as workers remain longer with the same job. More recently, some have even argued that these long term employer-employee relationships may be on the decline (Farber, 2007).

The findings on turnover presented in our paper support the hypothesis of an important role played by specific types of human capital on turnover decisions. This implies a theoretical lineage to the merging of job-search theory with firm-specific human capital as originated in Jovanovic (1979b). Our results, however, focus on the role of both firm-specific and more general human capital that a worker can adapt to any high-tech industry. Similar to the highly skilled workers of the second industrial revolution, we live today in an era of rapid technological change. If similar market conditions hold, then our results suggest that workers with the most adaptable skills (skills which are usually unobserved to the researcher) are the characters that drive the decline in long-term single-firm employment. Theoretical models of mobility presumably should provide similar empirical results for earlier periods of history. Assuming similar conditions of mobility and the fulfillment of other core assumptions of the market, our results implicitly should not be at odds with what we would expect from rational job seekers in any era².

The rest of the paper provides historical background in section 2 and a description of the data in section 3. Section 4 presents the empirical model and section 5 discusses results and

²A few examples exist that use data prior to the mid-twentieth century (see Reynolds (1951), Ginzberg (1951) and Parnes (1954)), but no studies exist that have updated these early empirical studies using recently developed methodology.

sensitivity checks. Section 6 provides a brief conclusion and areas to extend research.

2 Background

As discussed in Blank and Stigler (1957) and more recently and extensively in Edelstein (2009), formal technical training arose in response to the burgeoning need for skilled labor to manage and facilitate production using the new technologies of the industrial revolution. Regardless of the original source of technological innovation, by the end of the nineteenth century the Navy and the overall economy had an un-satiated need for technologically advanced workers. While college educated metallurgical and chemical engineers were needed in their respectively growing industries, other sectors of the economy needed workers with the technological understanding of education in the applied sciences. While the technically educated participated in the process of innovation and patenting (Usselman, 1999), prior to the development of business degrees during the twentieth century, engineering and applied science programs were important funnels for business management and the bureaucracy of industrial organizations.

Historically, military academies began training future officers for skilled work earlier than most private and public institutions, especially given the need to formalize education in mathematics (for projectile trajectories as well as surveying), chemistry (for explosives and ordnance), metallurgy (for weapons, vehicle and systems production), steam (for propulsion), and the general skills necessary for bureaucratic administration. Not surprisingly, the first institutions devoted to the development of technical human capital in Europe during the latter part of the 18th century were heavily weighted with future military officers and funded for both the promotion of domestic industry and the defense of sovereign interests (Edelstein 2009). The same focus, not surprisingly spilled-over to the United States, where the nation's first engineering school was established at West Point in 1802 in the form of the United States Military Academy. Other private and public schools followed with similar

curricula, including the United States Naval Academy in 1845³.

In spite of the growing commitment by institutions of higher learning for technical training, Blank and Stigler (1957) estimate that by 1870 only 10% of the approximately 8000 engineers and chemists in the U.S. economy had formal educations in engineering or chemistry. Even though formal education in engineering and chemistry was on the rise, by 1900 approximately 4% of the population was enrolled in college but a mere 3.3% of those who attended continued-on to acquire a degree in engineering. (By the 1950s, these numbers had risen to 25% and 8.9% respectively. The labor market for engineers and chemists grew from 0.18% of the labor force in 1900 to 1.1% in 1950.) This growth situated graduates of the Naval Academy in a particularly advantageous position for finding jobs in the external labor markets of their era. Their specific type of human capital was certainly in demand.

As discussed in O'Brien (2001), navies historically have served as laboratories and vanguards of technological progress, and the postbellum era in the United States was certainly no exception. The United States emerged from the Civil War with the most technologically advanced navy in the world. The decline of wood hulled ships was most clearly demonstrated during the Civil War with the clash of iron clads *Merrimac* and *Monitor*, and this continued shortly thereafter with the development and construction of steel-hulled ships and advances in steam powered propulsion. These advances in naval technology coincided with economy-wide technological advances in steel manufacturing, chemicals and electricity during the second industrial revolution (Mokyr 1990). At the same time, the corps of officers in the Navy not only had the experience to work with this technology, but their experience and education gave them a head start towards understanding the physics, mechanics and chemistry that was accelerating nationwide industrial growth. Their accumulated technical human capital propitiously positioned them to take advantage of changes in the economy.

One often thinks of a naval officer as a master of seamanship, navigation and gunnery.

³Although the Naval Academy was not specifically an “engineering” school at its outset, its curriculum included numerous “technical” courses in mathematics, chemistry, ordnance and navigation. Separate engineering-focused tracks in the curriculum followed nearly three decades after its inception.

Beyond this, 19th century naval officers had opportunities to develop skills as liaisons to iron and steel foundries, ship building yards and supply and ordnance bureaus, as well as potentially serving as lighthouse inspectors, lawyers, engineers and bureaucrats. This training enabled them to develop skills in the art of diplomacy and negotiation, mathematics, chemistry, electricity, telecommunications and numerous other fundamental tools useful in private industry. Their military jobs undoubtedly enhanced their general human capital as well, and made them attractive candidates for jobs in other rapidly expanding private sectors. This is supported by words from the Navy Chief of the Bureau of Construction and Repair in 1913, who blamed the loss of human capital principally on the private sector's preference for the technically proficient (McBride 2000).⁴ Just as officers today have the option to exit after the fulfillment of initial service obligations (usually 5 years), historically officers could freely take their human capital elsewhere.

The loss of valuable human capital for the Navy grew particularly intense during the 1880s and again during the early 1900s. With national priorities turned in other directions such as reconstruction and westward expansion, the Navy suffered through a period of stagnation. Ship development declined, and antiquated internal methods of promotion and job selection inhibited the efficient use and turnover of human capital. Externally, the volatile and often recessed economy during the 1870s may have prevented the accelerated exit of many officers during this time. Internally however, the situation appeared even worse. Officer in-fighting, arising from ineffective and myopic senior leadership, damaged morale and stymied innovation, not only for those best equipped to develop uses for new technologies including engineers and constructors, but also for young line officers with more experience with these new technologies (Bennett 1896).

By the 1890s, the once proud United States Navy had fallen behind most European and

⁴This is also supported by our cursory examination of U.S. census records for those few ex-officers we can track after they leave the service. Self-reported professions include such skilled jobs as banker, "capitalist" (presumably this meant he was an independent businessman), lawyer, moulder, and civil, consulting or mechanical engineer.

even many South American fleets in terms of numbers, tonnage and technology (Coletta 1987). Certainly many officers viewed patriotism and duty as the predominant forces which kept them in Naval service in the face of such relative decline, but it would be naive of us to think that reservation wages did not exist for many if not most officers. For the right price, options always existed for them to take their talents elsewhere, especially if the Navy could not or would not use those talents appropriately or pay them accordingly.

2.1 Training

In 1864, Secretary of the Navy Gideon Welles argued that all Naval Academy students should study engineering, formally introducing the technologies of the industrial revolution to the development of officer human capital (McBride 2000). This call formally signaled the inevitable need for the Navy to switch training of human capital away from old-guard wood and sail technologies to a new era of steel, steam, grease, oil and ultimately electricity. Still, it would take decades to complete the transformation of the Navy's human capital through an evolutionary process that involved everything from executive orders, to acts of Congress and even rulings by the United States Supreme Court. We can not detail this rich history here; instead we highlight the general tone of the discussion that provided a backdrop for both pecuniary and non-pecuniary options of Naval personnel. Secretary Welles' declaration indicates the prescience of at least some leaders to the changes ahead for the military and the country. Although investment in the enhancement of skilled human capital had begun, the mechanisms for efficiently retaining these investments remained deficient. Congress controlled military budgets and appropriated painfully rare pay increases. Promotions were infrequently granted and bonuses were non-existent.

Until 1899, naval officers were tracked into two separate lines with separate duties, training, education and cultures. Line officers represented the traditional role of sailors as masters of navigation, sailing, seamanship and warfare. Engineers on the other hand typically worked behind the scenes or below the deck in engine rooms with little fanfare or glory. Their jobs

involved engineering, naval construction, serving as paymasters, or other miscellany with an officer's commission. Thus prior to 1899, the corps of naval officers could be simplistically split into those who understood and embraced new technology and those who did not. Aside from differing jobs, staff officers possessed different titles and ranks, but earned similar pay based on a system of "relative rank". In spite of the ostensible equality fostered by this system, engineers received promotions less frequently and thus did not receive wage increases commensurate with line officers (Bennett 1896, Glaser and Rahman 2011).

During the latter 19th century, naval engineers rarely possessed college educations and generally arose from humble socioeconomic roots. Their limited social pedigree combined with less glorious military service during the Civil War positioned them as second-class citizens within the ranks of the corps of Naval officers. For decades, older line officers treated them with condescension and derision with numerous recorded instances of engineers suffering not only prejudice, but outright shifts in the system of staff officer ranks that reduced their status and eroded their attempts at achieving a more equitable and meritocratic position. General Order No. 120, dated in 1869 effectively reduced the ranks of nearly every engineer in the Navy by at least one rank (Bennett 1896). Pay remained the same, but the move was humiliating to many and reflected the overall obtuse attitude of senior line officers to the plights of engineers and the technological changes occurring in world around them.

The haughty attitude towards fellow staff officers mirrored attitudes towards technology in general, and not only adversely affected engineers and naval constructors, but also discouraged younger line officers with enhanced training in the sciences at the Naval Academy from inventing, innovating or exploring new ideas. Shifts in technology such as from sail to steam were perceived as antithetic to the culture and lifestyle of a line officer as, first and foremost, sailing masters of the sea. Line officers did not understand, and therefore could not control, these emerging technologies. New engineering technologies, understood only by staff and younger line officers, could only receive the stamp of approval from senior leadership by

performing well at sea or at war, but tests under such real conditions occurred very rarely (McBride 2000). This attitude coincided with a period when the Navy struggled to find a viable role for itself while the nation focused on reconstruction and continental expansion (Coletta 1987). This era of budgetary stagnation left the United States with a Navy that ranked in number of ships, personnel and technological power well below most European and even some South American countries by the mid-1880s.

In 1899, engineers and constructors combined with line officers to form an amalgamated lines (McBride 2000). This step formally recognized the importance of officers having multiple skill sets.⁵ While all naval officers potentially had incentive to work elsewhere, we can gauge whether more technically-oriented staff officers had even greater incentive than line officers, given their human capital differences.

2.2 Career Stagnation

Over the same time-frame, both line and staff officers languished for years with limited opportunities for promotion and fewer tours at sea. In the reconstruction era, a glut of officers competed for limited positions on ships in a fleet that had declined in number. This influenced earnings, since serving at sea (or at an international station) resulted in a wage bump for the officer. With few promotions available, officers' best means to increase earnings were by either serving at sea or exiting for a higher paying job in the private sector.

The Navy accelerated the construction of new ships during the late 1880s and early 1890s, and many of these new ships implemented some of the best cutting-edge technologies. The traditional role of line officers diminished relative to engineers and constructors, but the duties and workload of all increased as internal labor supply forces, even from the new technologically proficient officers graduating from the Naval Academy, could not keep up with the demand required to man all of the new ships. Thus ships were undermanned and

⁵Engineers were required to pass examinations in seamanship. Line officers, in contrast to this were not immediately required to study "engineering" per-se. In spite of this, a perusal of the academic rigor and required courses at the Naval Academy during the postbellum period indicates the enhanced rigor of the core curriculum for all cadets in mathematics and the sciences.

personnel overworked, at least relative to the peers who served in the preceding decades.

While the very best officers could find themselves on a career fast-track (Glaser and Rahman 2011), the bulk of officers remained stuck in an archaic system of promotion partly weighted by within-class rank but heavily weighted on seniority. Without a system to periodically clear out deadwood personnel, morale sank⁶. President Roosevelt, who at one time served as Assistant Secretary of the Navy, claimed that the promotion system within the Navy “sacrifices the good of the service to individual mediocrity” (Coletta 1987). With common frequency, officers stagnated at the rank of Lieutenant for 15 or 20 years without promotion⁷. Table 1 highlights the distribution of officers ranks by years of service.

Table 1: Density Across Rank (conditional on years served)

| rank | years of service | | | | |
|-------------------------------|------------------|--------|--------|--------|--------|
| | 10 yrs | 15 yrs | 20 yrs | 25 yrs | 30 yrs |
| O-1 (ensign) | 29.67 | - | - | - | - |
| O-2 (lieutenant junior grade) | 22.78 | 22.25 | - | - | - |
| O-3 (lieutenant) | 47.56 | 72.11 | 87.55 | 48.35 | 3.17 |
| O-4 (lieutenant commander) | - | 5.49 | 12.08 | 50.63 | 55.28 |
| O-5 (commander) | - | 0.14 | 0.38 | 1.01 | 41.55 |
| # officers | 900 | 692 | 530 | 395 | 285 |

Frequencies reported for line officers serving from 1866 to 1905.

Not until President Taft’s administration did the navy begin to alleviate the problem of stagnating promotions. Even as late as 1913, the Chief of the Bureau of Construction and Repair (an engineering-focused naval bureaucracy) complained that the seniority based system not only limited the technologically proficient officers from advancing through promotion (and thereby achieving higher wages), but it forced them sometimes to languish for as

⁶Unlike today, officers were not forced from service after failing to receive promotions within a designated period of time.

⁷In contrast to this, officers in the modern Navy typically spend 5 to 6 years at the rank of Lieutenant before either receiving a promotion to Lieutenant Commander or being forced into retirement.

many as 15 years within a single rank (Coletta 1987). With fewer options for wage increases through internal advancement, the external labor market certainly provided options worth consideration.

The extent to which naval officers switched into technical jobs in the private sector remains opaque, with no specific records that track retirees. We have some knowledge, however, of the market for West Point graduates during the first half of the nineteenth century. In 1802, the United States Military Academy at West Point was established as the first school of engineering in the United States. A West Point education at this time included a curriculum on canal, bridge and fortress construction, not to mention chemistry (necessary to understand explosives) and mathematics. It also seems that the private sector had an appetite for the engineer training provided at West Point, with 12 to 15% of graduates from 1802-1850 ultimately moving into careers in civil engineering in the private sector (Edelstein 2009). Parallel statistics are not available for Annapolis graduates, but in this study we attempt to tease-out which factors caused officers to separate. We focus on wages, seniority and specific types of accumulated human capital.

3 Data

We compile data from publicly available naval officer career records stored in the National Archives and in the historical archives of the United States Naval Academy library. Published annually, the *Navy Register* contains data on the job assignments, rank and duty station of every officer for every year of their career, and also the deployment status of ship on which officers served. These also include tables which outline how rank, station and job assignment affect annual pay. This allows us to determine whether officers served on a ships in international waters, in domestic waters, or held any one of several dozen shore positions. To build career-length measures of human capital, we use this information to construct measures of year-specific and cumulative human capital. In any given year of his career, we know

how many years each officer served on ships in international waters, in domestic waters, or in some other capacity. We also have information of each officer’s time in school at the Naval Academy. This includes specific measures of academic performance, including their overall ranking within class. This gives us a standardized measure of academic ability. Importantly and even after separations over time, the distribution of Academy order of merit (relative ranking) among officers does not change. That is, we have no evidence that indicates officers with relatively higher or lower initial levels of human capital separate earlier or later than others. While all officers at the Naval Academy received some sort of technical education during this time, approximately thirteen to sixteen percent of officers at any point in time received formal degrees as “engineers” or “naval constructors”. We account for these specialized technical degrees with dummy variables. Summary statistics of these and other measures of accumulated human capital appear in table 2.

Unconditional statistics from initial glances at the data also indicate several interesting and contrasting trends on the accumulation of human capital post-commissioning. Firstly, the average officer serves one out of every five years on vessels in domestic waters, regardless of time served. Other measures of human capital accumulated as a percentage of time served, however, change over the length of careers. These include time served on vessels in international waters, service with command, or service in a technical job. The percentage of service time on vessels in international waters decreases, while percentage of service with command slightly increases. We also control for the physical constitution of officer’s with measures of sickness and cumulative sickness over a career⁸.

⁸For brevity, we do not include illness descriptive statistics in Table 2, but will provide them upon request. While not a substantial portion of the sample, the percentages are still large enough to include in regressions.

Table 2: Descriptive Statistics (conditional on years served)

| rank | years of service | | | | |
|--|------------------------|------------------------|------------------------|------------------------|------------------------|
| | 10 yrs | 15 yrs | 20 yrs | 25 yrs | 30 yrs |
| experience in “technical” jobs mean years (std. dev) % of years served | 0.634 (1.321) 0.063 | 1.321 (1.895) 0.088 | 2.215 (2.542) 0.111 | 2.927 (2.882) 0.117 | 3.897 (3.066) 0.096 |
| engineer or constructor percent of total (std. dev) | 0.158 (0.365) | 0.134 (0.341) | 0.140 (0.348) | 0.134 (0.341) | 0.082 (0.275) |
| ship experience (domestic) mean years (std. dev) % of years served | 1.849 (1.499) 0.185 | 2.815 (2.059) 0.188 | 3.810 (2.564) 0.191 | 4.697 (2.827) 0.188 | 5.633 (3.000) 0.188 |
| ship experience (international) mean year (std. dev) % of years served | 4.285 (1.700) 0.429 | 5.782 (2.129) 0.385 | 7.139 (2.392) 0.357 | 8.905 (2.655) 0.356 | 10.58 (2.844) 0.353 |
| command experience mean years (std. dev) % of years served | 0.063 (0.315) 0.006 | 0.128 (0.521) 0.009 | 0.244 (0.723) 0.012 | 0.426 (1.025) 0.017 | 0.996 (1.543) 0.033 |
| Academy order of merit percentile mean (std. dev) | 0.518 (0.282) | 0.525 (0.282) | 0.535 (0.281) | 0.531 (0.290) | 0.525 (0.288) |
| # observations | 1104 | 829 | 606 | 455 | 281 |

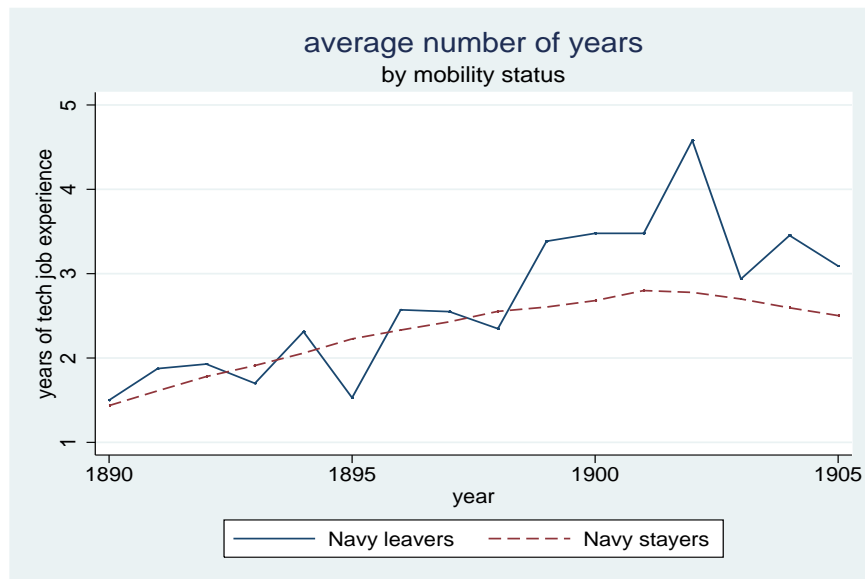
Technical jobs include assignments at one of the technically-oriented bureaus (e.g. Bureau of Construction and Repair or the Bureau of Steam), in shipyards (for the construction and maintenance of ships), in privately operated iron or steel foundries (to oversee steel production), as lighthouse inspectors, in jobs at the Naval Observatory or additional schooling at one of a handful of top Universities in Paris (the engineering capital of the world at the time), the United Kingdom or the United States. Notably for the average officer, technical experience as a percentage of service time nearly doubles between the 10th and 20th years of careers. What particularly interests us, however, is the technical experience of officers who leave relative to the officers who stay. Table 3 highlights these differences with statistics for sub-samples of those who leave and those who stay in the Navy. Exiting officers have a half-year more of technical experience than the officers who stay, while formally trained engineers comprise a slightly larger portion of the exiting group than not.

Table 3: Years of Technical Job Experience
by mobility category

| | 1871-1889 | | 1890-1905 | | 1871-1905 | |
|---------------------------------|-----------|---------|-----------|---------|-----------|---------|
| | stayers | leavers | stayers | leavers | stayers | leavers |
| experience in tech jobs (years) | | | | | | |
| mean years | 0.556 | 0.593 | 2.342 | 2.933 | 1.668 | 2.085 |
| (std. dev years) | (1.030) | (0.290) | (2.765) | (2.901) | (2.420) | (2.651) |
| engineer or constructor | | | | | | |
| fraction | 0.093 | 0.119 | 0.159 | 0.186 | 0.135 | 0.169 |
| (std. dev) | (1.030) | (0.324) | (0.365) | (0.390) | (0.341) | (0.375) |
| # observations in group | 6128 | 177 | 10474 | 344 | 17167 | 544 |

From 1890 until 1905, the result appears even more striking. During this period, exiting officers exhibit an average of one more year of technical experience than those who stay. Figure 1 especially highlights how this gap expands after the amalgamation of engineers and line officers in 1899. Rather than simply affecting one group, however, these mass exits appear for both groups. Both prior engineers and non-engineers who exited after 1898 had acquired one more year of technical job experience than those who remained⁹.

Figure 1: Technical Experience of Naval officers



⁹These sub-group sample statistics for 1898-1905 are not shown in the table but are available upon request.

3.1 The earnings gap

We define relative earnings for each officer, i , during year τ as the percentage difference

$$e_{i\tau} = \left[\frac{w_{i\tau} - w_\tau}{w_\tau} \right] * 100 . \quad (1)$$

Each individual i 's τ -specific pay, $w_{i\tau}$, is constructed by combining information on his rank, years within rank and type of job (sea, international shore, domestic shore or awaiting orders) with annual pay tables published in the *Navy Register* mentioned above. We use three alternative measures for w_τ , the average wage from external labor markets during the year t , drawing on historical wage statistics published in Long (1960) and Rees (1961)¹⁰.

Since we hope to determine effects in markets principally for skilled labor, we include two measures of wages for the external labor market as closely aligned to Naval officers' human capital as we could identify. We focus on data summarized in Rees (1961) which draws from information originally outlined in Douglas (1930). In particular, we choose the Douglas estimates for the specific labor market of skilled unionized workers, foundry workers and machinists. Growth rates in the Douglas data appears generally consistent with engineer wages in the late 1890s and early 1900s imputed by Blank and Stigler (1957).

For a second set of estimates, we turn to an earlier stretch of skilled labor earnings data that spans the years from 1866-1890. This data originally appeared in the Aldrich report (subsequently summarized in Long 1960), which was compiled by the Labor Department in 1893 for then Senator Aldrich to develop and construct measures of wages and prices. In particular, the Aldrich report summarized actual payroll data of over 5000 employees in 13 manufacturing industries from 1860-1890. We focus on the Long (1960) summary of annual weighted averages from 5 skilled occupations (blacksmiths, carpenters, engineers, machinists and painters). These were compiled for firms located in the Northeastern and Mid-Atlantic states¹¹.

¹⁰We analyze several other alternative measures of relative earnings from these same sources and generate results similar to information reported in the paper. For brevity we do not included these additional results.

¹¹Most naval bases existed in these regions, and we suggest that localized relative earnings are what would matter most to worker considering a job switch.

The Douglas data covers the early careers of the most technologically educated graduates from the Naval Academy. The Aldrich data covers the early careers of an earlier set of graduates. Both periods of data (1871-1905) are combined by Brown and Browne (1968), who adjust the overall manufacturing wages reported in Long (1960) and Rees (1961) to generate a lengthier time series of wages. We include estimates using the Brown and Browne (1968) measure of overall manufacturing wages as a sensitivity check in results presented in tables 6 and 7¹².

Figure 2: e_τ across time

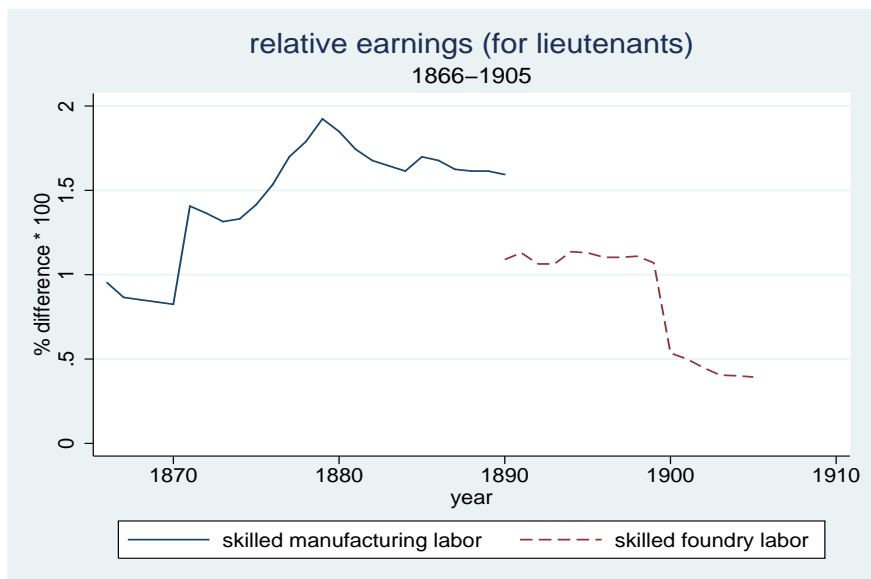


Figure 2 depicts different measures of relative earnings, using a Navy Lieutenant serving in a shore duty position as a reference category. It is worth noting several historical factors that affected relative earnings. First, the U.S. economy underwent a severe depression from 1873-1879, a time during which baseline officer wages did not change. This results in the corresponding run-up in the relative wage prior to 1880. Although less severe, recessions also hit in 1893 and 1896, indicated by the second spike in the relative wage towards the end of the 19th century. In contrast to economy-wide price deflation during several spans of time,

¹²Estimates using Brown and Browne data appear in columns labeled for the years 1871 – 1905.

naval officers earnings schedules remained relatively stable, shifting upwards on occasion but never moving downwards.

Figure 3 supplements this story with year-over-year earnings growth rates for each subset of data and demonstrates the volatility of earnings in careers outside of the Navy. In general, skilled wages follow similar, but not perfectly correlated patterns of wage growth over time. Not surprisingly given the discussion of data on unionized workers in Wolman (1932), shocks are particularly less severe in the Douglas data.

Figure 3: changes in w_r across time



4 Econometric Model

The job mobility literature contains a number of theoretical and empirical studies which highlight the job switching process, including a useful and extensive meta-discussion in Gibbons and Waldman (1999). Additional work from Bernhardt (1995) and McCue (1996) on promotions proved especially helpful for ideas in the development of our empirical framework. Particularly, we build our empirical model from the work of Topel and Ward (1992). This allows us to connect separation decisions of naval officers with factors that define the

distributions of external and internal job offers during the late 19th and early 20th centuries. Underlying this is the notion that officers search for the optimal wealth enhancing career path as elucidated in Mortensen (1988).

4.1 Framing the separation decision

Following Topel and Ward (1992), we begin with the primal assumption that workers base mobility decisions on the maximization of the net present value of lifetime wealth. Wage offers from the private sector generate from a known distribution and vary as careers progress due to the nature of work experience. The distribution of *private*-sector offers is given as

$$Prob(w^p < z) = G(z) . \tag{2}$$

Additionally, the *occurrence* of private sector job offers follow a Poisson distribution with parameter π .

Within the postbellum Navy, wage changes for individual officers occur through one of three different mechanisms. First, promotion guarantees an increase in wages. A deterministic mechanism for promotions does not exist on record, with only anecdotal discussions that relate it to seniority and merit. One might expect that Academic order of merit plays an important role; historically the Navy ranked officers according to their overall Academy class standing, and tended to advance those with the highest “ranks” first. It is also possible that promotions were related to the type and amount of fleet experience as demonstrated in table 2.¹³ Without a promotion, officers faced stochastic year-to-year changes in wages due to job assignments on ships, or on international shores (e.g. embassy work), or due to instructions to await further orders without a current assignment. The distribution of internal *navy* wage offers (job assignments), w^n , depends on current wages, w , naval experience, and the overall years since an officer was commissioned, t . Furthermore even without a promotion, an officer received a guaranteed wage increase when he stagnated *within* the same rank for 5, 10, 15

¹³The appendix includes estimates from ordered logit specifications to indicate which factors affected promotions.

or 20 years. These 5 year (pentennial) interval wage changes are known to the officer and controlled through the variable s . Hence the distribution of internal offers is defined by:

$$Prob(w^n < y; w, s, t) = F(y; w, s, t) . \quad (3)$$

As Mortensen (1988) details, a higher current wage increases the entire distribution of internal offers such that stochastically $F_w(\cdot) < 0$. Additionally if internal wage growth is non-increasing (concave) with tenure, then stochastically $F_t(\cdot) \geq 0$. Finally, the automatic pay raises due to officers who stagnate within rank would indicate $F_s(\cdot) < 0$ during the pentennial years. As with external offers, the distribution of offers for internal wages also follows a Poisson process.

Assuming a discrete choice between extending his career in the Navy or separating, the offer distributions given by (2) and (3) jointly capture the characteristics of the current career outcome of the officer, given his set of alternatives¹⁴. With both sides of the search market defined, the value function, $v(w, s, t)$, represents the expected present discounted value of lifetime wealth for officers paid a wage of w at time t . Given this and an external private wage offer w^p , a separation occurs when $v(w, s, t) < v(w^p, s, 0)$. In other words, an exit occurs when the outside job in which the officer has no experience ($t = 0$) has greater expected wealth than the current naval job with t years of experience. This decision rule captures reservation offers, $r(w, s, t)$, satisfying $v(r(w, s, t), s, 0) = v(w, s, t)$. Any private sector offer, w^p , exceeding the reservation wage leads to separation. The probability of receiving a new offer is π , so the hazard of a separation from the Navy at t , conditional on the officer not leaving before t is given by

$$h(w, s, t) = \pi Prob(w^p > r(w, s, t)) = \pi [1 - G(r(w, s, t))] . \quad (4)$$

¹⁴A competing risks model may also be employed for officers making transitions to unemployment or into another paying job. We may explore this in a later draft if we can find supporting data.

For discussion, assume $r(\cdot)$ is differentiable and let $g(z) = G_z(z)$ give the density of wage offers. A change in the current wage affects the hazard by

$$h_w(w, s, t) = -\pi g(r)r_w(w, s, t) . \quad (5)$$

A larger current wage increases the net present value of the current job and bumps-up the reservation wage. This also implies that $h_w(w, s, t) < 0$. In other words, increasing the current internal wage should decrease the conditional probability of separations.

Secondly, the effect of service time on the hazard appears as

$$h_t(w, s, t) = -\pi g(r)r_t(w, s, t) . \quad (6)$$

Given the assumption of concave wage-profiles over time from on-the-job training, then $r_t < 0$ for $t > 0$. All else equal, this implies that switching jobs becomes optimal over time, as private sector jobs offer larger growth in expected wages. Officers may even choose to accept a wage cut with the separation simply because the potential for wage growth on the new job over time leads to higher lifetime wealth (see Bernhardt 1995 for related discussion). This indicates a result in which $h_t(w, s, t) > 0$. As discussed by Jovanovic (1979a), however, separation probabilities can first increase, but then should decrease later in a career (i.e. $h_t(w, s, t) < 0$). Finally, we assume that the Navy's guaranteed wage increases due to within-rank stagnation (lack of promotion) implies an increase in the reservation wage in the year prior to the potential raise. This implies a positive effect on the reservation wage, $r_s(w, s, t) > 0$, and therefore $h_s(w, s, t) < 0$ for every fifth year without a promotion.

4.2 Empirical methodology

Estimation of the dynamic process in (4) follows from method for estimating hazards originally outlined in Gloeckler (1978), Kalbfleisch and Prentice (1980) and Heckman and Singer (1984). Kiefer (1988) provides a useful and systematic summary as well. Results are not sensitive to the inclusion of controls for class specific unobserved heterogeneity¹⁵.

¹⁵ See outline of methods developed in Meyer (1990) and McCall (1994).

The hazard following from (4) is defined by the conditional probability that an officer separates for a private sector job during year $t + 1$ of his career, given that his career lasts t years. During the postbellum period (and unlike today), the Navy did *not* have a defined mechanism to force officers from service until they were 62 years old, or physically unable to perform. For the most part, separation decisions were one-sided. Assuming covariates remain constant on the intervals between time periods denoted by t and $t + 1$, the baseline specification of the log-likelihood function used to estimate the model for N officers is given by:

$$\log L(\gamma, \beta) = \sum_{i=1}^N [\delta_i \log [1 - \exp \{-\exp [\mathbf{x}_i(T_i)' \beta_x + \gamma(T_i)]\}]] - \sum_{t=1}^{T_i - \delta_i} \exp [\mathbf{x}_i(t)' \beta_x + \gamma(t)] . \quad (7)$$

The log-likelihood here is a discrete time model with incompletely observed continuous hazards for censored ($\delta = 0$) and uncensored ($\delta = 1$) careers. Estimates of (7) begin with year 6 of an officer's career and end after 35 years¹⁶. Step-function intervals define the experience spline for years $[6, 10)$, $[11, 15)$, ..., $[31, 35)$. The job tenure spline generates from estimates of γ ¹⁷. Control variables at time period t are defined by the vector $\mathbf{x}(t)$ and include: the percentage difference in wages between an officer and aggregate measures from the overall economy, cumulative experience at sea or in command, dummy variables taking into account the length of time officer's stagnate within a rank, a dummy variable capturing status as an engineer, cumulative experience in technical jobs, and variables that control for an officer's physical constitution.

¹⁶ By Congressional stipulations at the time, officers could not continue working beyond sixty-two years of age or with forty years of service. Due to the limited number of observations remaining in the data beyond the thirty-fifth year and the impending forced retirements for this handful, we limit the career time-frame to thirty-five years.

¹⁷ We choose five year intervals for tractability and for presentation, but the results presented throughout the paper are not sensitive to the choice of 5 year intervals. The general shape of the baseline hazard remains the same.

5 Results

Results generate from the specification outlined in equation (4) and estimated through (7). Table 4 includes the hazard estimates for officers whose careers last at least 5 years after graduation from the Naval Academy between 1866 and 1900. Earning gaps are estimated from the average wage of skilled and unionized workers employed in foundries and machine shops between 1890-1905¹⁸. Using a different time period for data of wages, table 5 includes estimates on a subset of officers who had careers only on the time-frame from 1866 and 1885. Earning gaps in this table are generated based on the average wages of workers in skilled occupations¹⁹.

In tables 4 and 5, column (1) includes baseline estimates without controls for specific forms of human capital accumulation, while columns (2) and (3) control for changes in technical and non-technical human capital. Estimates in column (4) include an interaction term to test whether technical experience affects exit rates of formally trained engineers differently from regular line officers. To control for unobserved shocks to the demand for officers within the Navy and any other non-wage related shocks to the overall labor market, we estimate models with fixed effects for the actual years (1871 – 1905). These appear in column (5).

5.1 Technical training and technical job experience

To begin our discussion, we focus on the results for Academy-trained engineers in table 4. Following from the specification given column (3), training as an engineer increases the hazard by about 33%. The results estimated on the earlier sample (shown in table 5) indicate a strikingly similar result. The accumulation of technical experience, however, only appears to matter after 1890. After 1890, each additional year of technical experience increases the hazard by 4.5 percent. In column (4) we control for the interaction of technical experience

¹⁸These are based on the work of Douglas (1930) and outlined in Rees (1961)

¹⁹The are based on the Aldrich report and outlined in Long (1960)

with status and general training as an engineer. After 1890, line officers still exit at faster rates with each additional year of technical experience increasing the hazard by 3.3 percent. In this specification, the engineer effect disappears, or becomes slightly negative. Despite this, it is the accumulation of technical experience appears to matter to the engineer. Each year an engineer builds his resume with time in a technical job increases his hazard by 11.9 percent. The effect of these variable interactions does not appear to matter prior to 1890 (as indicated by the null result in column (4) of table 5), but training as an engineer still appears accelerate the rate of separation by 34%.

We also consider the role played by specific types of technical experience. Recall that the measure of “technical” experience includes assignments at the Bureau of Construction and Repair, the Bureau of Ordnance or the Bureau of Steam, working on ship repair in Navy shipyards, overseeing the production of steel in foundries, inspecting lighthouses, working at the Naval Observatory in Washington D.C. or acquiring additional schooling. Table 6 includes results subdivided on these specific dimensions. Prior to 1890, the only specific training that appears to matter is additional school. Since this entails as much as 4 additional of advanced study, the affect is exceptional. We will never know if the Navy made a wise investment by sending young officers to Paris and London for advanced technical training, but at the very least their hazard quadrupled relative to other officers of the time.

The most notable effects appear from 1890 until 1905, with the strongest impact on all types of non-bureaucratic technical experience. From earlier discussions, it was established that each year of technical experience during this frame of time increases the hazard 3.3%. Time served as a bureaucrat, particularly at the Bureau of Steam, appears to decrease the hazard. Additional schooling bumps it by 24%, while time served in lighthouse inspection bumps it by 8.7%. The biggest jump appears for those who serve in ship construction, where each year served doubles the hazard.

Bureau-specific experience, rather than have general transferability to the private sector

appears to only decrease the chance of a job switch. This would certainly be consistent with the story in Jovanovic (1979b) on the role played by firm-specific human capital. Other types of technical, however, drive the hazard in a different direction, also consistent with how outside firms perceive the transferability of skill in newer, high-tech sectors of the economy.

5.1.1 Time Varying Coefficients

Table 7 includes the estimates from specifications in which we allow coefficients to vary across careers. We use these to identify if technical human capital has a varying effects on the hazard. For example, do officers who have four years of accumulated technical experience behave similarly during their tenth and fifteenth years? When does technical experience matter the most, or is the effect constant at all points during a career? To isolate these effects, we alter the model defined in (7) such that controls and associated coefficients for technical human capital can vary over a career. At each point in time, t , for the variables $tech = \{engineer, cumulative\ technical\ experience\}$, the specification includes:

$$\eta_{tech}(t) tech = [\eta_1 + \eta_2 I(t > 10) + \eta_3 I(t > 15) + \eta_4 I(t > 20) + \eta_5 I(t > 25) + \eta_6 I(t > 30)] tech . \quad (8)$$

The functions $I(\cdot)$ represent indicator variables used to isolate timing effects for t years after the start of a career. Results reported in table 7 include estimates of the individual coefficients in the vectors η_{tech} and the cumulative effects of these coefficients on the hazard at different points in time. It is these cumulative odds-ratios that matter, so we include p-values of joint significance tests for $exp(\eta_{tech}(t)) = 1$.

Our results from this broad specification not only highlight the importance of specific types of training, but the fickle manner in which labor adjusts job search patterns to technological training over the course of a career. After 1890, rapid technological changes occurred in steel, electricity and chemical production which likely increased demand for workers with

technologically advanced human capital. The Navy is a fertile training ground for labor, and the highest skill workers appear to leave at substantially higher rates during prime years of their careers. The loss of these young officers with the most advanced training on the most advanced technologies of the time most certainly would have been felt. One wonders how this loss impacted the Navy in the coming decades as it fought and prepared to fight two World Wars.

Among the set of estimates for η , we find several noteworthy results. First, the accumulation of technical human capital prior to 1890 has no effect on job separations. Engineers at this time appear more likely to separate during earlier career years (until year 15), but the results are not statistically significant. After 1890, however, officers with more technical experience exit with noticeable rapidity especially prior to year 16 during which the hazard appears to jump by 26 to 32%. These effects decline after 15 years. Older officers with technical experience in older technologies (i.e. those more than 25 years into their careers), appear more likely to stay. This effect appears even though the model controls for job seniority and other effects.

5.2 Job Seniority

A general control for seniority appears through the splines of each specification. We do not extend the analysis past 35 years, since officers were forced to retire due to age beyond this point. Our a-priori expectation suggests a concave hazard in experience with it decreasing during the latter portion of a career. Our results do not contradict this theoretical prediction, although we would have expected the decline to occur earlier. The hazard increases across most 5 year intervals within each specification up until year 30, after which it decreases on the margin. Despite non-pecuniary benefits of military seniority, the wage stagnation that accompanied such seniority appears to matter for most of a career²⁰. Rather than appearing in the early part of a career, as suggested by the theoretical matching literature,

²⁰ See Melese et al. (1992) and Hartley and Sandler (2007) for more discussion on the non-pecuniary benefits for military personnel.

the concavity of the experience-separation that drives the search for a better match occurs rather late. If anything, the result more closely approximates findings in Topel and Ward (1992), where data supports positive returns to the search for a job as experience increases. Another possible reason consistent with Jovanovic (1979b) is that search costs decrease for officers as their careers advance²¹. Quite possibly in the military it may also take longer for the quality of the match to reveal itself.

We report p-values on the hypothesis that each time interval statistically does not increase relative to base years 6 – 10. An examination of the results in column (3) of table 4 indicates that separation rates relative to years 6 – 10 are only 5.6% greater for years 11 – 15. This measure rises to 27% greater for years 16 – 20, and more than twice as large for years 21 – 25, and over three times as large for years 26 – 30. It begins to decline after year 30 as the remaining workers settle-down and wait for a forced retirement.

Table 5 covers a shorter time frame, but the results remain generally consistent with the early years highlighted in Table 4²².

5.3 Earnings gap

We depict shocks to earnings and relative earnings in our data for lieutenants in figures 2 and 3²³. As indicated in equation (5), higher wages in the current job decrease the hazard. Our results not only support this hypothesis, but the outcome remains remarkably robust across all specifications. Every 1% increase in officer wages (relative to skilled foundry labor) decreases the probability of exiting by about 0.8% or 0.9%. This result is similar for wage changes relative to skilled labor using the Aldrich data (table 5). While these are theoretically consistent and statistically significant, the net effect on the hazard is essentially small.

²¹ Without more information on time-use, we cannot measure exactly why search costs may have declined over time. Still, we can speculate that possible reasons include the presence of labor market networks established over time through contacts on the job, or perhaps a reduction in the time demands of daily job responsibilities. Anecdotal information may help support this.

²² Although we do not report the estimates that concern job seniority in the other tables presented in this paper (tables 5-8), the reader should know that similar shapes and statistical significance are robust across specifications. These results are available upon request.

²³ Relative wages follow similar patterns for other ranks, albeit on smaller or larger scales depending on the duties and ranks of the officers.

Simply to determine if this measure of wages impacts our results from previous sections, we include sensitivity analysis on the core model specification using alternative measures of external wages. Each measure is drawn from the same source used to construct foundry wages for union workers from 1890 until 1905 (Rees, 1975)²⁴. These sensitivity checks appear in table 8. Column **1**) repeats the results from table 4 already discussed, and are included as a baseline for comparison. Column **(2)** uses the NBER estimate for foundry and machine shop wages . These are non-unionized skilled workers for which Rees reports wages from 1890 to 1905. Column **(3)** includes estimates based on the earnings of skilled workers from electrical machinery industries. These results date from 1896 to 1905. We estimate full specifications and control variables, but report only the estimated odds-ratios that relate to technical human capital. Regardless of the measure of relative earnings, the impact of accumulated technical human capital remains unchanged. The wage coefficients change a little, becoming slightly smaller with both the NBER measure and the measure for electrical workers. Both specifications estimate that a one percent increase in the relative earnings of officers decreases the hazard by 0.4 to 0.5 percent. An already small effect is essentially cut in half. Still, the sign on these coefficients remains consistent with theoretical matching models, and they are also statistically significant.

Even though the wage effect is small, it appears that the Navy could have easily used the right mix of incentives to retain the most highly trained officers. Rather than losing workers who understood the new technology best, a five percent raise in relative pay would have gone a long way to retaining the best. They seemed to understand the concept of compensating wages for dangerous and boring duty at sea, since those who served at sea and abroad earned higher pay. Unfortunately, they could not also adjust incentives to the market realities of new technology. One wonders if similar issues plague modern firms as well suffering from rapid turnover.

²⁴ Each measure discussed below is based on the wages reported in Table 13 of Rees (1975).

5.4 Career malaise

Aside from changes in earnings arising from different job assignments, officers could receive pay increases through two avenues: promotion to a higher rank or, ironically, by stagnating within the same rank for too long. That is in the absence of a promotion, a 10% pay-step increase occurs each time an officer achieves within-rank milestones of 5, 10, 15 or 20 years of service. We expect that 5 year bumps in earnings should influence decisions similarly to increases in w , in that officers pentennially increase their reservation wage in the absence of a promotion. This indicates a shift in the distribution of offers such that $h_s < 0$. When not in a pentennial year, officers expect zero growth from internal wage offers and thus $h_s \geq 0$.

We estimate the stagnation effect on the reservation wage with a dummy variable for whether the officer is serving in his pentennial year within rank. For skilled foundry labor specifications reported in table 4, results indicate that service during the pentennial year decreases the hazard by 36%. For the specification estimated using Aldrich skilled labor data, service during the pentennial year decreases the hazard by 22%. Both sets of data indicate that an impending pay increase bumps-up the reservation wage and decreases separation probabilities.

5.5 Other measures of human capital accumulation

Finally we analyze the human capital effects on retention and separation decisions. Overall Academy ranking appears to decrease the hazard, but we cannot produce statistically discernable effects on hazards.²⁵

In latter-year specifications covering years after 1890, each year that officers serve on domestic ships increases separation probabilities by about 5%. This result reverses for models covering later years. This result reverses for earlier years, domestic waters decreases the

²⁵ This finding is consistent with the career duration analysis in Glaser and Rahman (2011) - overall merit is a poor predictor of whether or not an officer will decide to stay in the Navy.

hazard by approximately 6% per year of experience. From 1866 until 1890, the Navy confined most of its operations to domestic shores, so it should not surprise us that the only means of enhancing job-specific human capital during this era decreases mobility. International experience at sea also has a negative effect on separations, decreasing the hazard by 1 to 2%, but this result is not statistically significant for any period. Each year of command for officers after 1890 increases the hazard 9%. Prior to 1890, command experience appears to reduce the hazard by one-quarter.

6 Conclusion

We model the job mobility decision in a survival framework, and use an empirical setup similar to Topel and Ward (1992). Estimating a dynamic model of job mobility, we find that changes in relative earnings effect the probability of separation. We also show how job tenure, while controlling for wage effects and the accumulation of human capital has a concave effect on the probability of a career switch, a result consistent with Jovanovic (1979). All of the results in the paper are quite robust to alternative specifications.

The most important and interesting conclusions relate to the impact of the accumulation of technical human capital. Our results indicate that the accumulation of this very specific type of human capital increases job-separation probabilities by a substantial margin. For officers with general training as engineers, each additional year experience in “high-tech” jobs increases the probability of separating by approximately 12 percent. When we consider the effects on even smaller levels of minutiae, we see that officers with skills particular to steel, metallurgy and electricity appear to have the greatest incentives leave for non-military jobs.

Factors affecting worker mobility decisions over a century ago remain relevant today. In the past and present, the military often leads in the development and implementation of the newest technologies. Skilled workers (i.e. officers) trained to work with new technologies

continuously face the decision of whether they should take their human capital and leave for jobs in the private sector²⁶. Even today, government budget analysts grapple with issues that balance the desire for controlled spending with the need to efficiently provide incentives for retaining the best personnel. In fiscal year 2011, the defense budget approached \$800 billion with personnel accounting for approximately 2/3 of this cost. Perhaps ideal for the government would be the case where individuals choose long military careers motivated chiefly by fervent patriotic zeal and other non-pecuniary factors. Our results, however, provide supporting evidence that even military personnel for whom non-pecuniary factors (e.g. patriotism) may play a large role, relative earnings do indeed affect career-mobility decisions, and their human capital is valued elsewhere.

²⁶Empirical evidence of job mobility for military personnel remains scant, with only a few dynamic models such as Gotz and McCall (1984), Mattock and Arkes (2007) and Glaser (2010) analyzing the job mobility decision of officers.

Table 4: Separation hazards, 1890-1905

Naval Academy graduates from classes 1866-1900

| variable | (1) | (2) | (3) | (4) | (5) |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|
| tech job experience | - | 1.038 (0.039) | 1.045 (0.020) | 1.033 (0.052) | 1.039 (0.023) |
| engineer | - | 1.187 (0.162) | 1.331 (0.048) | 0.930 (0.388) | 1.224 (0.110) |
| engineer × technical experience | - | - | - | 1.086 (0.005) | - |
| % difference earnings (skilled union manufacturing) | 0.992 (0.001) | 0.991 (<0.000) | 0.991 (<0.000) | 0.991 (<0.000) | 0.990 (<0.000) |
| 11-15 years experience | 1.097 (0.367) | 1.072 (0.401) | 1.056 (0.425) | 1.032 (0.457) | 1.218 (0.250) |
| 16-20 years experience | 1.402 (0.126) | 1.322 (0.172) | 1.269 (0.238) | 1.212 (0.288) | 1.590 (0.090) |
| 21-25 years experience | 3.328 (<0.000) | 3.108 (<0.000) | 2.882 (0.001) | 2.674 (0.003) | 3.811 (<0.000) |
| 26-30 years experience | 5.094 (<0.000) | 4.712 (<0.000) | 4.264 (0.002) | 3.981 (0.003) | 5.435 (<0.000) |
| 31-35 years experience | 5.463 (<0.000) | 4.850 (0.001) | 3.780 (0.021) | 3.590 (0.025) | 5.192 (0.004) |
| <u>rank stagnation effects</u> | | | | | |
| in rank: 5, 10, 15 or 20 years | 0.563 (0.007) | 0.570 (0.008) | 0.573 (0.006) | 0.576 (0.008) | 0.540 (0.001) |
| <u>other human capital</u> | | | | | |
| overall USNA class percentile | - | - | 1.159 (0.263) | 1.156 (0.268) | 1.149 (0.273) |
| ship experience (domestic) | - | - | 1.049 (0.025) | 1.053 (0.018) | 1.040 (0.053) |
| ship experience (international) | - | - | 0.980 (0.267) | 0.986 (0.385) | 0.964 (0.120) |
| command experience | - | - | 1.087 (0.026) | 1.092 (0.018) | 1.092 (0.026) |
| <u>illness</u> | | | | | |
| cumulative years of sick leave | 1.384 (0.002) | 1.421 (0.001) | 1.437 (<0.000) | 1.439 (<0.000) | 1.429 (<0.000) |
| sick | 8.793 (<0.000) | 8.680 (<0.000) | 8.667 (<0.000) | 8.842 (<0.000) | 8.865 (<0.000) |
| year effects | no | no | no | no | yes |
| log likelihood | -349 | -346 | -340 | -339 | -302 |
| observations:officers:separations | 10002:1013:313 | | | | |

Odds-ratios reported with one-sided p-values shown in parentheses.
Standard errors estimated on clusters by USNA graduating class.

Table 5: Separation hazards, 1871-1890
 Naval Academy graduates from classes 1866-1885

| variable | (1) | (2) | (3) | (4) | (5) |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|
| tech job experience | - | 1.011 (0.387) | 0.997 (0.470) | 0.996 (0.468) | 0.999 (0.488) |
| engineer | - | 1.441 (0.031) | 1.346 (0.068) | 1.342 (0.090) | 1.466 (0.016) |
| engineer × technical experience | - | - | - | 1.003 (0.487) | - |
| % difference earnings (skilled manufacturing labor) | 0.993 (<0.000) | 0.993 (<0.000) | 0.993 (<0.000) | 0.993 (<0.000) | 0.992 (<0.000) |
| 11-15 years experience | 1.551 (0.043) | 1.536 (0.042) | 1.666 (0.014) | 1.666 (0.014) | 1.730 (0.018) |
| 16-20 years experience | 2.043 (0.001) | 2.078 (0.001) | 2.589 (0.001) | 2.589 (0.001) | 2.895 (0.008) |
| 21-24 years experience | 1.818 (0.030) | 1.837 (0.035) | 2.598 (0.021) | 2.598 (0.021) | 3.223 (0.035) |
| <u>rank stagnation effects</u> | | | | | |
| in rank: 5, 10, 15 or 20 years | 0.769 (0.108) | 0.771 (0.110) | 0.779 (0.114) | 0.780 (0.119) | 0.753 (0.034) |
| <u>other human capital</u> | | | | | |
| overall USNA class percentile | - | - | 0.684 (0.076) | 0.684 (0.076) | 0.708 (0.099) |
| ship experience (domestic) | - | - | 0.943 (0.114) | 0.943 (0.114) | 0.957 (0.178) |
| ship experience (international) | - | - | 0.986 (0.348) | 0.986 (0.347) | 1.007 (0.421) |
| command experience | - | - | 0.733 (0.011) | 0.733 (0.011) | 0.739 (0.008) |
| <u>illness</u> | | | | | |
| cumulative years of sick leave | 1.386 (<0.000) | 1.394 (<0.000) | 1.384 (<0.000) | 1.384 (<0.000) | 1.368 (0.002) |
| sick | 9.334 (<0.000) | 9.392 (<0.000) | 9.476 (<0.000) | 9.477 (<0.000) | 8.449 (<0.000) |
| year effects | no | no | no | no | yes |
| log likelihood | -362 | -361 | -358 | -358 | -333 |
| observations:officers:separations | 7362:766:209 | | | | |

Odds-ratios reported with one-sided p-values shown in parentheses.
 Standard errors estimated on clusters by USNA graduating class.

Table 6: *Any* Technical Experience or *Specific* Technical Experience?

| | 1871-1890 | | 1890-1905 | | 1871-1905 | |
|--------------------------------------|-----------|----------|-----------|----------|-----------|----------|
| | any | specific | any | specific | any | specific |
| experience in all tech jobs | | | | | | |
| coefficient | -0.003 | - | 0.044*** | - | 0.019 | - |
| (std. error) | (0.042) | | (0.021) | | (0.022) | |
| [odds ratio] | [0.997] | | [1.045] | | [1.019] | |
| experience in navy yards | | | | | | |
| coefficient | - | -0.033 | - | 0.036 | - | 0.009 |
| (std. error) | | (0.026) | | (0.040) | | (0.032) |
| [odds ratio] | | [0.968] | | [1.036] | | [1.009] |
| experience at the naval observatory | | | | | | |
| coefficient | - | -0.178 | - | -0.009 | - | -0.038 |
| (std. error) | | (0.256) | | (0.056) | | (0.048) |
| [odds ratio] | | [0.837] | | [0.991] | | [0.963] |
| experience at the bureau of steam | | | | | | |
| coefficient | - | 0.036 | - | -0.083* | - | -0.074* |
| (std. error) | | (0.067) | | (0.051) | | (0.046) |
| [odds ratio] | | [1.034] | | [0.920] | | [0.928] |
| experience at any other tech bureau | | | | | | |
| coefficient | - | -0.073 | - | 0.009 | - | -0.028 |
| (std. error) | | (0.134) | | (0.052) | | (0.055) |
| [odds ratio] | | [0.930] | | [1.009] | | [0.972] |
| additional university studies | | | | | | |
| coefficient | - | 0.402*** | - | 0.208** | - | 0.154** |
| (std. error) | | (0.113) | | (0.094) | | (0.074) |
| [odds ratio] | | [1.494] | | [1.231] | | [1.166] |
| experience in ship construction | | | | | | |
| coefficient | - | - | - | 0.703*** | - | 0.587*** |
| (std. dev years) | | | | (0.225) | | (0.205) |
| [odds ratio] | | | | [2.020] | | [1.799] |
| experience as a lighthouse inspector | | | | | | |
| coefficient | - | 0.167 | - | 0.084** | - | 0.065* |
| (std. dev years) | | (0.194) | | (0.046) | | (0.046) |
| [odds ratio] | | [1.182] | | [1.087] | | [1.067] |

All models specified with same control variables as those shown in from column (3) of tables 4 and 5. One-sided statistical significance indicated with *** if $p \leq 0.01$, ** if $p \leq 0.05$ and * if $p \leq 0.10$.

Table 7: Technical human capital and time-varying coefficients

| | $5 < t < 11$ | $11 \leq t < 16$ | $16 \leq t < 21$ | $21 \leq t < 26$ | $26 \leq t < 31$ | $t \geq 31$ |
|----------------------------|------------------|------------------|-----------------------|-------------------|------------------|------------------|
| <i>covariate</i> | $J = 1$ | $J = 2$ | $J = 3$ | $J = 4$ | $J = 5$ | $J = 6$ |
| 1871-1890 | | | | | | |
| <i>engineer</i> | | | | | | |
| η_j | 0.398 | -0.149 | -1.010 | - | - | - |
| $exp(\sum_j^J \eta_j)$ | 1.488 (0.283) | 1.283 (0.376) | 0.467 (0.059) | | | |
| <i>tech job experience</i> | | | | | | |
| η_j | 0.171 | -0.284 | 0.115 | - | - | - |
| $exp(\sum_j^J \eta_j)$ | 1.187 (0.249) | 0.894 (0.288) | 1.003 (0.945) | | | |
| 1890-1905 | | | | | | |
| <i>engineer</i> | | | | | | |
| η_j | 0.287 | -0.144 | -1.309 | 1.697 | -0.821 | 1.054 |
| $exp(\sum_j^J \eta_j)$ | 1.332 (0.475) | 1.154 (0.736) | 0.312 (<0.000) | 1.7012 (0.264) | 0.748 (0.499) | 2.148 (0.138) |
| <i>tech job experience</i> | | | | | | |
| η_j | 0.229 | 0.048 | -0.119 | -0.113 | -0.130 | 0.135 |
| $exp(\sum_j^J \eta_j)$ | 1.257 (0.016) | 1.319 (0.007) | 1.171 (0.053) | 1.046 (0.148) | 0.918 (0.009) | 1.051 (0.241) |

Columns represent the covariate effects during the span of years denoted by t . Specifications include all previously identified control variables (not shown) except year effects. Parentheses show p-values from hypothesis test $H_o : exp(\sum_j^J \eta_j) = 1$.

Table 8: Sensitivity to alternative measures of external wages, 1890-1905

| variable | Douglas' Foundry Wage (1890-1905) | NBER's Foundry Wage (1890-1905) | Electrical Machinery Wage (1896-1905) | B & B Manufacturing Wage (1871-1905) |
|-----------------------------------|--------------------------------------|------------------------------------|--|---|
| tech job experience | 1.045 (0.020) | 1.045 (0.022) | 1.048 (0.014) | 1.020 (0.186) |
| engineer | 1.330 (0.048) | 1.347 (0.043) | 1.478 (0.021) | 1.312 (0.013) |
| % difference earnings | 0.991 (<0.000) | 0.995 (<0.000) | 0.996 (0.001) | 0.998 (<0.000) |
| overall USNA class percentile | 1.159 (0.263) | 1.151 (0.268) | 1.282 (0.102) | 0.930 (0.344) |
| log likelihood | -340 | -343 | -213 | -699 |
| observations:officers:separations | 10220:1013:339 | | 6519:926:236 | 16824:1213:510 |

Odds-ratios reported with one-sided p-values estimated on USNA class clusters in parentheses.
Includes all Naval officer careers lasting at least 5 years for USNA graduates from classes 1866-1900.
Results estimated but not reported for all control variables.

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