Research Report

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Civilian Cyber Workers in the U.S. Department of Defense

Demographics, Retention, and Responsiveness to Training Opportunities

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About This Report

In the 2016 National Defense Authorization Act, Congress recognized the need to recruit and retain a civilian workforce with specific expertise in cybersecurity and granted the Secretary of Defense the authority to create the Cyber Excepted Service (CES) personnel system. This personnel system provides the U.S. Department of Defense (DoD) greater flexibility in hiring and in adjusting compensation to remain competitive in the labor market for civilian cyber talent. To provide analytic support in making use of this greater flexibility for the CES workforce, the DoD Chief Information Officer asked the RAND Corporation's National Defense Research Institute to conduct a study of labor demand, labor supply, retention, and the use of training and education for the CES workforce. In this report, we provide summary statistics on DoD civilian cyber retention, promotion, and pay in addition to estimates of the effect of various options for training programs on CES retention using RAND's dynamic retention model capability.

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Summary

In the 2016 National Defense Authorization Act, Congress recognized the need to recruit and retain a civilian workforce with specific expertise in cybersecurity and granted the Secretary of Defense the authority to create the Cyber Excepted Service (CES) personnel system. This personnel system provides the U.S. Department of Defense (DoD) greater flexibility in hiring and in adjusting compensation to remain competitive in the labor market for civilian cyber talent. To provide analytic support in making use of this greater flexibility for the CES workforce, the DoD Chief Information Officer asked the RAND Corporation's National Defense Research Institute to conduct a study of labor demand, labor supply, retention, and the use of training and education for the CES workforce. The results on labor demand and labor supply are summarized in two previous RAND reports (Knapp, Beaghley, Schwindt, et al., 2021a; Knapp, Beaghley, Smith, et al., 2021b). In this report, we provide summary statistics on DoD civilian cyber retention, promotion, and pay in addition to estimates of the effect of various options for training programs on CES retention using RAND's dynamic retention model (DRM) capability.

There are countervailing theoretical effects of training on retention. Training might be a retention lever if it improves the job and pay opportunities within the civil service, making staying more attractive than leaving, or if DoD requires a service obligation with any training that it funds. On the other hand, if training and certification programs offered as part of DoD employment also improve the external job market opportunities for employees, these programs could hurt retention. For programs that require a service obligation, retention could improve during the service obligation but drop once the employee is free to leave. To assess the retention effects of training for the CES workforce, we extend the DRM to four cyber occupations, listed in the next section. Once we estimated the parameters of the models, we then used the estimated parameters to simulate the retention effects of alternative hypothetical training scenarios. The scenarios vary five aspects of training: training length, when training occurs during an individual's career, the required service obligation following training completion, the effect of training on DoD pay, and the effect of training on external pay.

Cyber Worker Demographics, Retention, Pay, and Promotion

The DoD Chief Information Officer requested information on the retention, pay, and promotion of DoD civilian cyber workers over time. We used administrative data on DoD civilians and data from the American Community Survey on salaries for workers in computer occupations to provide descriptive statistics on the demographics, retention, promotion, and pay for cyber employees at DoD from fiscal year (FY) 2014 to FY 2018. Our descriptive statistics

are provided separately for each of the following cyber occupational series identified by the DoD Chief Information Officer as the focus of our effort:

854: Computer Engineering Series
855: Electronics Engineering Series
1550: Computer Science Series
2210: Information Technology Management Series.

We also examine differences between employees on different pay plans: primarily, grade-step pay structures (i.e., the general schedule [GS] and similar pay systems, including government grade [GG]) and pay-banded pay schedules (in which each position is assigned a range or band of pay, and limited structure is imposed on where salaries are set within a band).[1] Differences across occupational series and/or pay plans should not be taken to be causal, as we generally do not control for characteristics (observed or unobserved) of employees in different occupation series that might be associated with differences in retention, promotion, or pay. In that vein, our analysis should not be taken as an assessment of the adequacy of retention rates, promotion rates, or pay for civilian cyber workers at DoD but instead as simply an assessment of differences in these variables across occupational series and pay plans.

We find that demographics vary across cyber occupations and are generally different from the rest of DoD. Series 854, 855, and 1550 employees are better educated, less likely to be veterans, and more likely to be in pay-banded pay systems than the rest of DoD. Series 2210 employees are better educated, more likely to be veterans, and equally likely to be in pay-banded systems than the rest of DoD.

Among the cyber occupational series we considered, we find that cyber employees tend to have higher retention than the rest of DoD. Ninety-four percent of FY 2018 employees in series 854, 855, and 1550 and 92 percent of FY 2018 employees in series 2210 remained in service at the end of FY 2019, compared with 91 percent of FY 2018 non-cyber employees. This should not be interpreted as a statement about the adequacy of retention rates for cyber workers; if there are significant returns to experience in cyber occupational series, then even higher retention rates than we currently see might be desirable. We find no difference in retention between pay-banded and GS/GG cyber employees, except in series 2210, in which pay-banded employees have higher retention than GS/GG employees.

GS/GG cyber employees, except in series 2210, have higher promotion rates than non-cyber employees, but the pattern is less clear for pay-banded employees. Both GS/GG employees and pay-banded employees in series 2210 have lower promotion rates than non-cyber employees: In FY 2018, 12 percent of GS/GG 2210 employees at DoD were promoted, compared with 17 percent of non-cyber GS/GG employees, while 5 percent of pay-banded 2210 employees were promoted, compared with 8 percent of pay-banded non-cyber employees. GS/GG employees in

[1] Assignment to a pay-banded pay system typically depends on where in DoD the employee works.

series 854, 855, and 1550 had higher promotion rates (21 percent, 32 percent, and 31 percent, respectively) than non-cyber GS/GG employees in FY 2018, but promotion rates for those occupation series grew substantially between FY 2014 and FY 2018. In FY 2014, those occupations had similar promotion rates to non-cyber occupations for GS/GG employees. Pay-banded employees in series 854 tended to have higher promotion rates (10 percent in FY 2018) than non-cyber pay-banded employees. Promotion rates for pay-banded workers in series 855 and 1550 were similar to those of non-cyber pay-banded workers between FY 2014 and FY 2018.

Pay for GS/GG positions is similar to that of the private sector for all occupations. However, pay for pay-banded positions is higher than that of GS/GG positions or the private sector.

Modeling GS/GG Cyber Worker Retention

The CES DRM follows the structure of previous versions of the DRM in which the parameters were estimated using the entire DoD civil service (e.g., Asch, Mattock, and Hosek, 2014; Knapp, Asch, et al., 2016). We modeled civil service retention beginning with the start of each employee's career. Each year, each individual compares the value of staying in civil service with that of leaving and bases their decision on the alternative with the maximum value. Individuals who remain repeat the comparison each subsequent year. The value of staying depends on civil service earnings, other civil service compensation, time-invariant preferences for DoD civil service relative to the external market ("tastes" for civil service), a period- and individual-specific environmental disturbance term (or "shock") that can either positively or negatively affect the value placed on civil service in that period, and the discounted expected value of the maximum of staying or leaving in the next period. The value of leaving includes pay in the external market, any civil service retirement benefits the individual is entitled to receive, and an individual- and period-specific shock term that can either positively or negatively affect preference for the external alternative. Although we cannot observe individuals' tastes for civil service or external employment, or the size of the shock terms for staying and leaving the civil service, we assume that they follow a known distribution.

The parameters we estimated are the mean and standard deviation of the taste distribution, the scale parameter of the shock distribution, and the discount factor. The model is estimated separately for each of the four cyber occupations and for three levels of education (less than a bachelor's degree [BA], BA, and more than a BA). The relative magnitudes of estimated coefficients for the shock term and the taste term seem to indicate that retention behavior is mainly driven by shocks and less by individual taste. The models fit observed retention well. Given the model parameter estimates, we use the DRM to simulate the retention effects of alternative policy scenarios related to CES training.

Training as a Retention Lever

Our simulation results suggest that training by itself is not, in general, an effective means of improving retention without a payback obligation, some increase in the internal wage, or both. In all instances, we assume that training is voluntary, that is, that individuals can choose whether to take the training offered and thus whether they might incur an associated service obligation (if any). In addition, we assume that individuals know in advance the level of improvement in internal and external opportunities resulting from training. The key findings are as follows:

- When training improves external opportunities on net (i.e., training results in a greater increase in external opportunities than internal opportunities), training without a payback obligation reduces retention.[2] The negative retention effect is larger
  - when the improvement in external opportunities is greater
  - when training occurs earlier in the career, when workers have less attachment to the workforce.

  For example, in the training scenarios we consider for occupation 855 (Electronics Engineering Series), training at year of service (YOS) 5 that improves external opportunities by 1 percent on net reduces overall retention by 2.8 percent. Furthermore, training that improves external opportunities by 3 percent on net reduces overall retention by 9 percent. Were training that improved external opportunities by 1 percent on net to occur in YOS 1 rather than YOS 5, overall retention would fall by 5.8 percent.
- Training with a payback obligation produces only a temporary improvement in retention if CES pay does not also increase. The postobligation drop in retention
  - is smaller if the training length is longer or when training occurs later in the career
  - can be addressed with a sufficiently large increase in CES pay.

  For example, in the scenarios we consider, training at YOS 5 with an associated three-year payback obligation that improves external opportunities by 3 percent on net results in a 1.3 percent decrease in overall retention. However, if CES pay increases by 1 percent, then overall retention rises by 3.1 percent.

Wrap-Up

Training is an essential component of initial and ongoing skill development and is especially important in cyber, where technology changes at a rapid pace. Although training is necessary to ensure the continual productivity of the DoD cyber workforce, our simulation results suggest that an aggressive training policy should be accompanied by the development of internal opportunities and pay commensurate with external opportunities. Otherwise, trained personnel

[2] This points to the importance of understanding how internal opportunities improve compared to how external opportunities improve for CES employees who receive training with no payback obligation. In cases in which the internal opportunities lag behind external opportunities, what can be done to strengthen internal opportunities? While these research questions are beyond the scope of this study, these results point to the importance of launching an effort to learn more about these opportunities and how internal opportunities could be improved, if desired.

will have a relative disincentive to stay, assuming their training is equally valuable and remunerative elsewhere. Therefore, training policy should not be developed in isolation but in concert with internal pay, opportunities for advancement, and engaging work experiences.

Given the importance of the civilian workforce to DoD's cyber mission, it is imperative to understand how pay, promotion, and retention has varied over time and to continue to identify and refine strategies for retaining civilians with cyber expertise.

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Chapter 1. Introduction

The U.S. Department of Defense (DoD) cyber workforce consists of military personnel, civilians, and contractors. DoD has implemented and continues to implement policies and procedures to manage the talent of personnel in each of these populations, and these policies aim to successfully recruit, retain, and develop personnel to maintain a competitive advantage in the cyber domain (Sherman, 2021). The foundation of DoD's approach to managing the cyber workforce is the DoD Cyber Workforce Framework (DCWF). In addition to defining 54 "work roles" that cover the full array of skills required to support DoD's cyber mission, the framework involves the development of career paths and progression for each work role, which includes training and developing the skills of personnel over their career.

The focus of the analysis summarized in this report is on civilians in DoD's cyber workforce and specifically those in the Cyber Excepted Service (CES). In the 2016 National Defense Authorization Act (Pub. L. 114-92), Congress recognized the need to recruit and retain a civilian workforce with specific expertise in cybersecurity and granted the Secretary of Defense the authority to create the CES personnel system under 10 U.S.C. § 1599f. This personnel system provides DoD greater flexibility in hiring individuals and in adjusting compensation to remain competitive in the labor market for cyber talent. To provide analytic support in making use of this greater flexibility for the CES workforce, the DoD Chief Information Officer asked the RAND Corporation's National Defense Research Institute to conduct a study that included seven tasks. The first four tasks focused on analyzing labor demand and supply in seven high-priority work roles, and the results were summarized in Knapp, Beaghley, Schwindt, et al., 2021a; and Knapp, Beaghley, Smith, et al., 2021b. This report summarizes the results of the last three tasks: (1) creating a descriptive analysis of the demographics of DoD cyber workers and of trends in retention, promotion, and pay; (2) modeling; and (3) simulating the results of training and education as a potential lever to improve CES retention.

As part of its implementation of the DCWF, DoD is developing pathways for each work role that indicate the required knowledge, skills, abilities, and tasks over the career and the training and certificates needed to help members of the workforce gain and demonstrate these capabilities. Training might be a retention lever if it improves the job and pay opportunities within the civil service, making staying more attractive than leaving. Training could also improve retention if DoD requires a service obligation associated with any training that it funds. The U.S. Office of Personnel Management (OPM) wiki article on Continued Service Agreements notes, "The law states that an agency can require an employee who participates in training to continue to work in the Federal Government for at least three times the length of the training period" (OPM, undated-b). A sample Department of the Army Continued Service Agreement specifies a three-to-one payback for any training in excess of 120 days (OPM, undated-a).

Because members of the workforce are under a service obligation, retention improves during the obligation period. On the other hand, if training and certification programs offered as part of DoD employment also improve the external job market opportunities for employees, or improve external opportunities more than internal opportunities, these programs could hurt retention. For programs that require a service obligation, retention could improve during the service obligation but drop once the employee is free to leave.

To assess the retention effects of training for the CES workforce, we extended RAND's dynamic retention model (DRM) capability to four cyber occupations, identified by the DoD Chief Information Officer as the focus for this study. The DRM is a stochastic dynamic programming model of individual retention behavior over a career with econometrically derived parameters. In this case, the model is over a CES career. The DRM has been used to assess the retention of active and reserve military personnel and of DoD civilians (e.g., Knapp, Asch, et al., 2016; Mattock et al., 2016), and the model has been documented extensively.

In short, the DRM is a model of a civilian worker's decision, made each year, to stay in or leave the civil service. These decisions are structured as a dynamic program in which the individual seeks to choose the best career path, but the path is subject to uncertainty. The model is formulated in terms of parameters that are estimated with longitudinal data on retention in the DoD civil service in the four selected occupations, obtained from the Defense Manpower Data Center (DMDC). The model is then applied to each occupation to see how well the estimated model corresponds to observed retention. We estimated the parameters of the models in terms of occupations rather than work roles because work roles are a new concept and we required longitudinal data between 2000 and 2019. Once we have estimated the parameters of the models, we then use the estimated parameters to simulate the retention effects of alternative hypothetical training scenarios. The scenarios vary the following five aspects of training:

- the length of training
- the timing of training during the career (beginning of the career, early career, mid-career)
- the required service obligation associated with DoD's provision of training
- the effect of training on internal DoD pay opportunities
- the effect of training on external pay opportunities.

In each of the scenarios we consider, we assume the training is voluntary for employees. The advantage of our approach is that the DRM allows us to simulate hypothetical training scenarios and scenarios for which information is unavailable. That is, it permits "what if" analyses in which actual data on specific programs do not exist. This aspect of the DRM was particularly desirable in this study because we were unable to acquire detailed descriptions from the services of existing CES training programs used in DoD. An alternative approach to using the DRM capability is to estimate the retention effects of an existing training program, but such an approach requires data on specific training programs. Past studies have assessed civil service retention using the DRM approach (Asch, Mattock, and Hosek, 2014; Knapp, Asch, et al., 2016) but have not focused on the CES workforce or on training specifically. Knapp, Beaghley, Smith, et al., 2021b, analyzes the CES workforce, but its focus was on compensation and not retention per se. Hardison, Payne et al., 2021b, provides an assessment of training for the U.S. Air Force cyber workforce, and Hardison, Whitaker et al., 2021a, analyzes the recruitment and retention of the Air Force cyber workforce, but both studies focus on military rather than civilian personnel. Thus, no previous study has provided estimates of the retention effects of CES training on civilian personnel.

The next chapter provides contextual background on the retention of CES personnel and shows recent trends in CES retention. It also shows tabulations of selected demographic characteristics of CES personnel and trends in pay and promotion. Chapter 3 details our application of the DRM to CES personnel and presents our model estimates and assessment of how well the model fits the data. The chapter also describes the capability we developed to simulate the retention effects of the different training scenarios. In Chapter 4, we present the simulation results. We provide a wrap-up of the main conclusions in Chapter 5.

Chapter 2. Cyber Worker Demographics, Retention, Pay, and Promotion

In this chapter, we provide the results of a descriptive analysis of cyber worker demographics, retention, promotion, and pay at DoD. We also provide information on the differences among cyber occupations and on differences by type of pay plan. We find differences in demographics, retention, promotion, and pay between cyber workers and the rest of DoD and across cyber occupations. We find differences in retention across pay plans for only one occupation series (2210: Information Technology Management). We generally do not attempt to explain why the patterns that we observe exist; the patterns should not be taken to be causal because we generally do not control for characteristics (observed or unobserved) of employees in different occupation series that might be associated with differences in retention, promotion, or pay. In that vein, our analysis should not be taken as an assessment of the adequacy of retention rates, promotion rates, or pay for civilian cyber workers at DoD but instead as simply an assessment of differences in these variables across occupational series and pay plans.

Defining DoD Cyber Occupations and Pay Plans

Both the description of historical demographics, retention, promotion, and pay described in this chapter and the DRM presented in Chapter 3 require a consistent classification of different types of cyber employees over a long period. Although CES currently uses work roles to describe different types of cyber employees, work roles for CES did not exist for the entire study period and are still unobservable in DMDC data. We therefore use four DoD occupation series (rather than work roles)—identified in coordination with the DoD Chief Information Officer—to capture variations in demographics, retention, promotion, and pay across different types of cyber workers. These occupation series are

- **854—Computer Engineering Series:** A professional occupational series (indicating that a bachelor's degree [BA] or equivalent training is typically required) covering workers who perform "engineering and scientific work involving the design, construction, and operation of computer systems, including hardware and software and their integration" (OPM, 2018, p. 71).
- **855—Electronics Engineering Series:** A professional occupational series covering workers who perform "engineering and scientific work involving electronic circuits, circuit elements, equipment, systems, and associated phenomena concerned with electromagnetic or acoustical wave energy or electrical information for purposes such as communication, computation, sensing, control, measurement, and navigation" (OPM, 2018, p. 71).

- **1550—Computer Science Series:** A professional occupational series covering workers whose work involves "the application of, or research into, computer science methods and techniques to store, manipulate, transform or present information by means of computer systems" (OPM, 2018, p. 102). The main requirements of these positions are knowledge of the theoretical foundations of computer science, specialized knowledge of computer systems, and knowledge of mathematics and statistics.
- **2210—Information Technology Management Series:** An administrative occupational series (indicating that a BA is not required) covering workers who "manage, supervise, lead, administer, develop, deliver, and support information technology (IT) systems and services." The main requirement for jobs in this series is "paramount knowledge of IT principles, concepts, and methods" (OPM, 2018, p. 123). Broadly, this series includes specialist IT work (rather than IT support) that does not require a BA, although some workers in this series have BAs (OPM, 2001, pp. 2–3).

Types of Pay Plans for Cyber Workers

Federal employees are primarily paid using a grade-step structure. In a grade-step pay structure, each position is assigned to a pay grade. Each pay grade is divided into steps; higher steps earn higher pay. An employee can progress to higher steps with additional tenure or education. The most common grade-step pay structure used by the federal government is the general schedule (GS), which has a total of 15 pay grades divided into ten steps per grade. Another grade-step structure is the government grade (GG) schedule, which also has 15 pay grades but might allow more steps per grade. The GG schedule is used for some positions in the excepted service, including CES. Throughout this report, we refer to DoD civilian employees on grade-step pay systems as *GS/GG* employees, and references to various GS pay grades include employees in the GG system with the same pay grade.

The federal government also uses pay-banded pay schedules for some positions. In a pay-banded pay schedule, a position or common group of jobs is assigned a range or *band* of pay. Beyond this range of pay, there is limited structure imposed on where salaries are set within the range or band, allowing individual managers much more discretion in setting pay. This method of setting pay is similar to many private-sector positions. Pay bands tend to be wider than the pay range within a grade in the GS. Assignment to a pay-banded pay schedule in DoD is based on the part of DoD for which an employee works, and certain subcomponents of DoD opt into a pay-banded pay system for all employees. Appendix A provides more details.

Data and Approach for Descriptive Analysis

Data

We used the following data sources for our analyses:

- **DoD Civilian Master File from 2000 to 2019:** Snapshots of the inventory of civilian appropriated fund employees in September of each fiscal year (FY).

- **DoD Civilian Pay File from 2000 to 2019:** Annual (FY) pay for each DoD civilian (including locality pay) in constant 2019 dollars.
- **American Community Survey (ACS) from 2018:** Annual (FY) pay for private-sector workers in computer occupations (series 15-1 in the Standard Occupational Classification) by educational attainment in constant 2019 dollars. ACS data are provided by IPUMS USA (Ruggles et al., 2021).

Although our data extend back to FY 2000, we focus the analysis in this chapter on FY 2014–2018. This is because the FY 2012 transition out of the National Security Personnel System (NSPS), a DoD-wide pay-banded pay system, distorts our measurement of promotion rates in FYs 2012 and 2013. However, the DRM analysis in the following chapters uses the full set of historical data on retention, which was unaffected by the transition out of NSPS.[3] We subset the data to individuals who were full-time permanent employees for their entire observed tenure in DoD and have no gaps in DoD employment longer than two years.

Measurement of Retention, Promotion, and Pay

We measure retention using the annual continuation rate, which is the share of full-time DoD personnel in service at the end of a fiscal year who are still employed full-time at DoD at the end of the following fiscal year. In other words, retention is calculated using

$$\frac{\textit{Personnel in service at end of FY } t \textit{ and FY } t{+}1}{\textit{Personnel in service at end of FY } t}.$$

We measure promotion using movement between pay grades,[4] or

$$\frac{\textit{Personnel whose grade at end of FY } t \textit{ is lower than their grade at end of FY } t{+}1}{\textit{Personnel in service at end of FY } t}.$$

Note that promotion rates are not comparable across pay plans because the bands in pay-banding systems are wider than grades in the GS/GG system and might therefore correspond to several GS/GG grades (i.e., one band on a pay-banded schedule might correspond to GS/GG 5–7). Promotion rates on GS/GG are therefore larger by construction than promotion rates on pay-banded pay schedules.

Finally, following Knapp, Beaghley, Smith, et al., 2021b, we measure pay for cyber workers using regression-smoothed salary trajectories, which represent the pay that a typical cyber worker would receive on the GS/GG schedule, a pay-banded pay schedule, or in the private

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[3] For the DRM analysis, individuals on NSPS are coded as GS/GG employees.

[4] Individuals who switch pay plans (i.e., from GS/GG to a pay-banded pay plan or to a different type of pay plan, or within the set of pay bands to a different pay-banded pay plan) or whose grade level is missing in either year are excluded from the promotion analysis. This measure of promotion is not conditional on remaining employed at DoD; i.e., individuals who choose not to continue their employment at DoD are included in the denominator.

sector at each year of potential experience (YOPE).[5] To calculate the salary trajectories, we first run the following regression for DoD employees using least squares, separately for GS/GG and pay-banded pay plans:

$$ln(Salary) = \beta_0 + \beta_1 Male + \beta_2 Education + f(YOPE) + \theta_j + \varepsilon.$$

$f(YOPE)$ is a linear spline for five-year increments of YOPE, education has four levels (less than BA, BA, more than BA, and unknown), and θ_j is a fixed effect for occupation. We then run an analogous regression for computer occupations in the ACS, dropping θ_j. We use the estimated coefficients to predict salary by YOPE for male employees in each occupation group, education level, and pay plan. The descriptive analysis in this chapter uses the weighted average of the salary trajectories for each pay plan occupation, where the weights are equal to the proportion of DoD employees in that occupation with each level of education. The salary trajectories are also used as an input to the DRM.

Throughout the rest of this chapter, we present descriptive statistics (that is, means and some standard deviations) on the demographics, retention, promotion, and pay of cyber employees by occupation and the rest of DoD. We also present some analyses by occupation and pay plan. These descriptive statistics are unconditional on any control variables, except in the case of salary (as we described earlier). Assignment to occupation and pay plan at DoD is nonrandom, and there are likely systematic differences between the types of employees in different occupations and pay plans even beyond those described in the demographics section. Any observed differences (or lack thereof) should not be taken as causal, and we do not attempt to explain why we observe the differences that we do. In addition, this analysis is not meant to be an assessment of the adequacy of retention rates, promotion rates, or pay for civilian cyber workers at DoD.

Demographics of Cyber Employees

There are several differences between cyber and non-cyber occupations in DoD and differences across the four cyber occupations. Series 854, 855, and 1550 are similar in many ways, whereas series 2210 is usually different from other cyber occupations and the rest of DoD.

Table 2.1 provides descriptive characteristics of cyber workers and the rest of DoD in FY 2018. The largest differences between cyber workers and the rest of DoD are in education level and veteran status. Nearly all employees in series 854, 855, and 1550 have at least a BA, whereas only 55 percent of employees in series 2210 and 48 percent of the rest of DoD have at least a BA. Between 6 percent and 7 percent of employees in 854, 855, and 1550 are veterans, as compared with 40 percent of 2210 and 30 percent of the rest of DoD. Cyber and non-cyber

[5] YOPE is defined as age minus the approximate age at graduation, where age at graduation is set to 20 for individuals with less than a BA, 22 for individuals with a BA, and 24 for individuals with more than a BA.

occupations, as well as the four cyber occupations, also differ in terms of race and ethnicity, gender, retirement eligibility, age at entry to federal service, and tenure in DoD.

Table 2.1. Descriptive Statistics of Cyber Workers and the Rest of DoD, FY 2018

	Series 854	Series 855	Series 1550	Series 2210	Rest of DoD	*p*-value for Difference Across Occupations[a]
Education Level						
% Less than BA	0.80%	0.62%	0.82%	45.75%	51.96%	0.000
% BA	58.96%	59.49%	63.94%	35.39%	26.65%	
% More than BA	40.24%	39.88%	35.24%	18.83%	21.33%	
% Unknown	0.00%	0.01%	0.00%	0.04%	0.07%	
Veteran Status						
% Veteran	12.47%	14.60%	15.52%	57.79%	46.61%	0.000
% Not a Veteran	87.53%	85.40%	84.48%	42.21%	53.39%	
Race and Ethnicity						
% White	62.16%	64.88%	69.09%	68.74%	67.98%	0.000
% Black	7.43%	6.83%	8.39%	15.30%	15.19%	
% Hispanic	8.42%	6.71%	4.73%	5.96%	6.76%	
% Other[b]	19.83%	19.45%	15.46%	7.36%	7.71%	
% Unknown	2.16%	2.14%	2.34%	2.64%	2.36%	
Retirement Eligibility						
% Eligible to Retire	25.29%	43.11%	21.31%	36.73%	34.51%	0.000
% Not Eligible to Retire	74.71%	56.89%	78.69%	63.27%	65.49%	
Gender						
% Female	15.76%	12.10%	23.15%	25.57%	36.69%	0.000
% Male	84.24%	87.90%	76.85%	74.43%	63.31%	
Mean Age at Entry to Federal Service	31.61	33.47	32.93	39.19	36.92	0.000
Mean Tenure	13.01	17.71	11.04	14.53	14.14	0.000

SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.

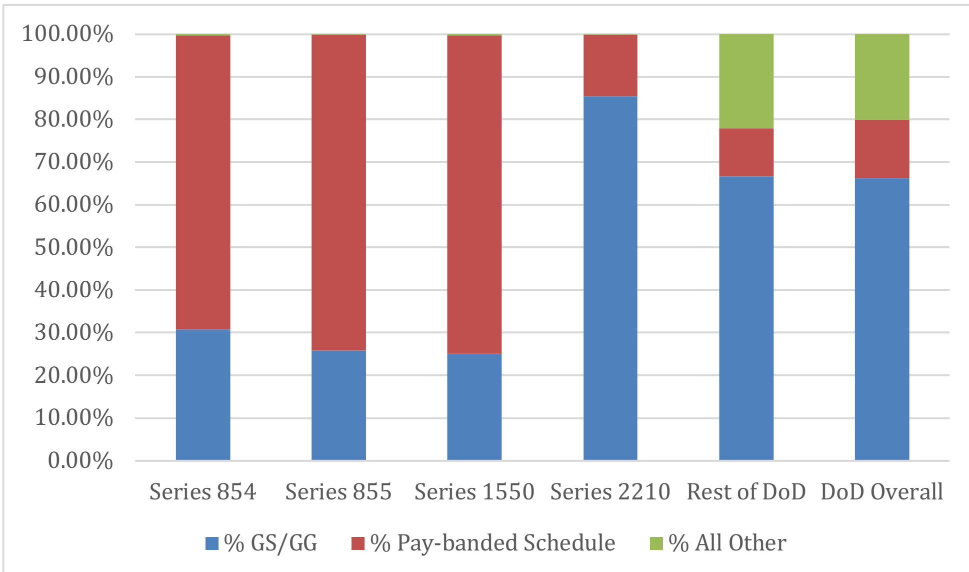
NOTE: Table A.2 provides descriptive statistics by occupation and pay plan.

[a] *p*-values for differences across occupations in education level, veteran status, race and ethnicity, retirement eligibility, and gender are based on a Pearson chi-squared test. *p*-values for differences in mean age at entry to federal service and years of service (YOS) at DoD are from a Wald test allowing heterogenous covariance matrices. Individuals with missing information are not included in significance tests, with the exception of individuals with unknown education level or race and ethnicity.

[b] Includes Asian or Pacific Islander, non-Hispanic in Puerto Rico, Native American or Alaska Native, or two or more races.

Occupations also differ in type of pay plan. Figure 2.1 displays the distribution of pay plans by occupation in FY 2018. Employees in series 854, 855, and 1550 are substantially more likely than employees in series 2210, the rest of DoD, or DoD overall to be covered by a pay-banded pay plan: 70 percent of series 854, 74 percent of series 855, and 75 percent of series 1550 were covered by pay-banded pay plans in FY 2018, versus 14 percent of series 2210 employees, 11 percent of the rest of DoD, and 14 percent of DoD overall. Employees in series 854, 855, and 1550 are also substantially less likely than the rest of DoD to be under the GS/GG pay plan, whereas those in series 2210 are substantially more likely than the rest of DoD to be under the GS/GG pay plan. Very few cyber employees are under other types of pay plans.

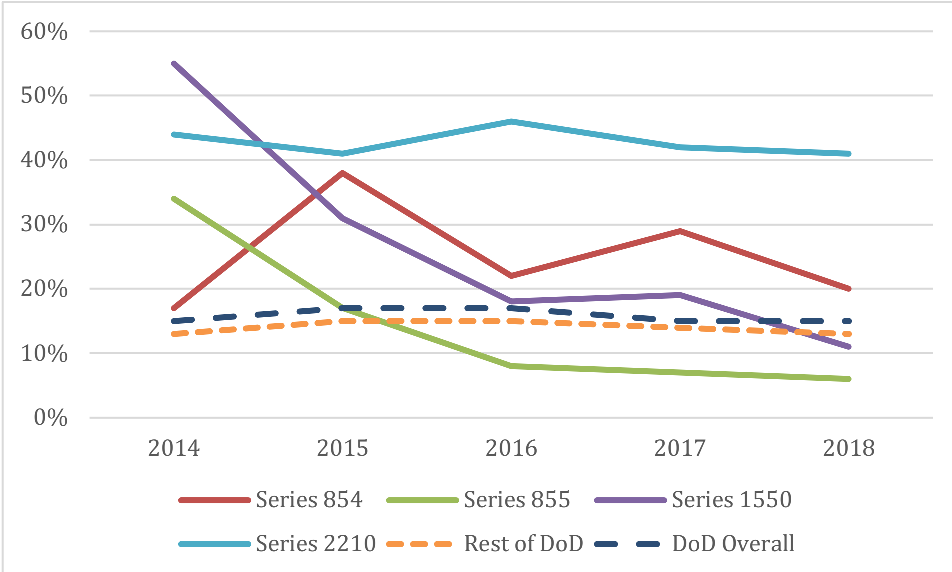
Figure 2.1. Distribution of Pay Plans by Occupation, FY 2018



SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.

Finally, within the GS/GG system, occupations differ in the pay grades of new hires. Figure 2.2 displays the percentage of new GS/GG hires who are GS-12 or above by occupation from FY 2014 to FY 2018. The occupation with the highest proportion of new hires at GS-12 or above in FY 2018 was series 2210, at 41 percent, followed by series 854, in which 20 percent of new hires were GS-12 or above. Although series 855 and 1550 had a larger proportion of new GS/GG hires at GS-12 or above than the other two cyber occupations in FY 2014, by FY 2018 their proportions of new hires at GS-12 or above had fallen to a level below that of the rest of DoD, indicating that the average seniority of new hires dropped between FY 2014 and 2018.

Figure 2.2. Percentage of New GS/GG Hires Who Are GS-12 or Above by Occupation, FY 2014–2018



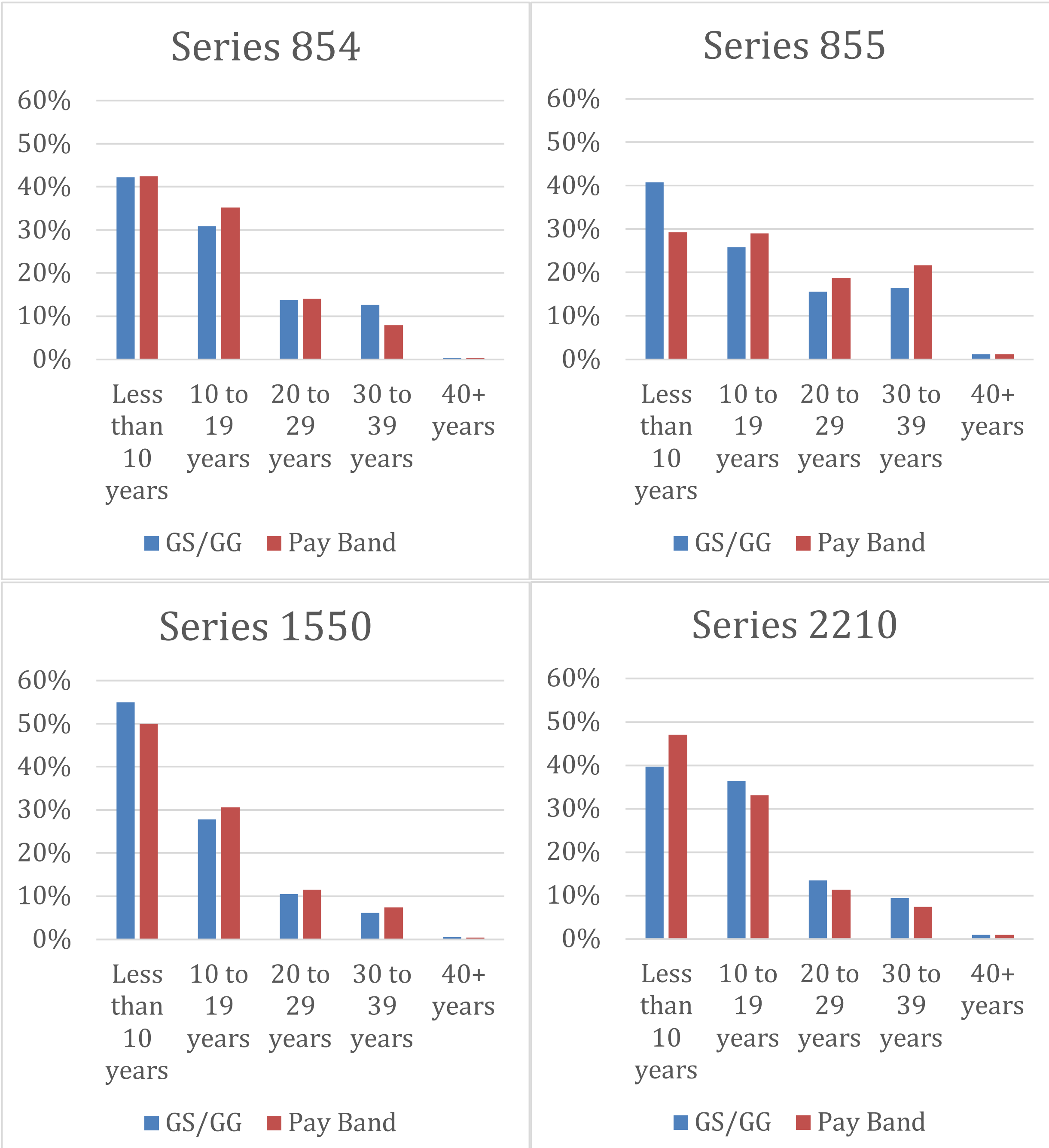
SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.
NOTE: Figure excludes rehires.

Differences Between GS/GG and Pay-Banded Cyber Employees

Figure 2.3 displays the distribution of tenure for each occupation and pay plan. Although there is no systematic pattern, we find statistically significant differences in tenure by pay plan within cyber occupations: GS/GG employees in series 854 and 2210 tend to have higher tenure than pay-banded employees, whereas GS/GG employees in series 855 and 1550 tend to have lower tenure than pay-banded employees. Differences in tenure at DoD could suggest that there might have been historical differences in retention across cyber occupations and pay plans. However, differences in tenure might also be indicative of differences in timing of hiring for each occupation and pay plan.

Descriptive statistics by pay plan are available in Table A.2.

Figure 2.3. Distribution of Tenure by Occupation and Pay Plan, FY 2018



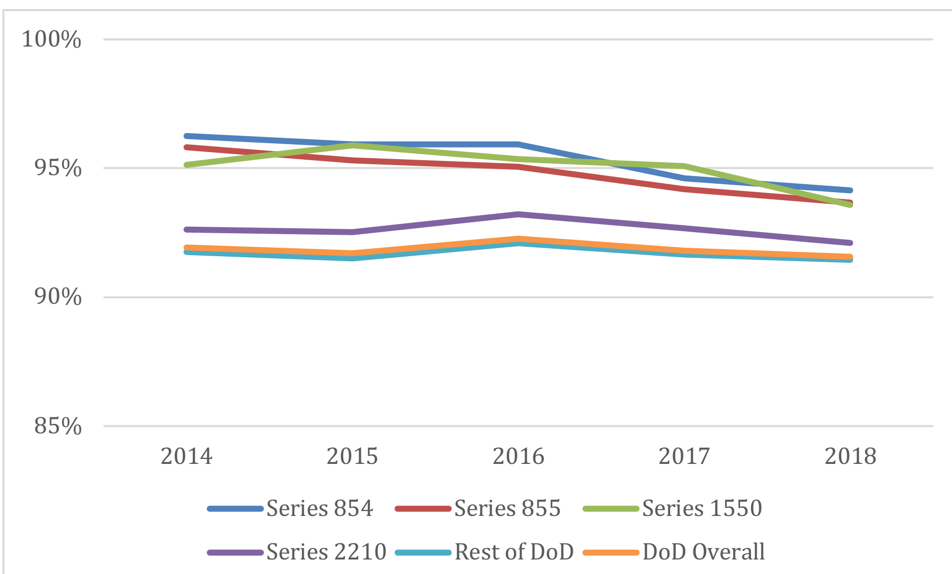
SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.
NOTE: The *p*-value for difference in mean tenure, according to a two-sided *t*-test for difference in means, is 0.001 for series 854 and 0.000 for other occupations.

Retention

We find differences in retention between cyber and non-cyber occupations and across the cyber occupations. As in the analysis of demographics, we often find that retention is similar across series 854, 855, and 1550, whereas series 2210 differs both from the other cyber occupations and from the rest of DoD.

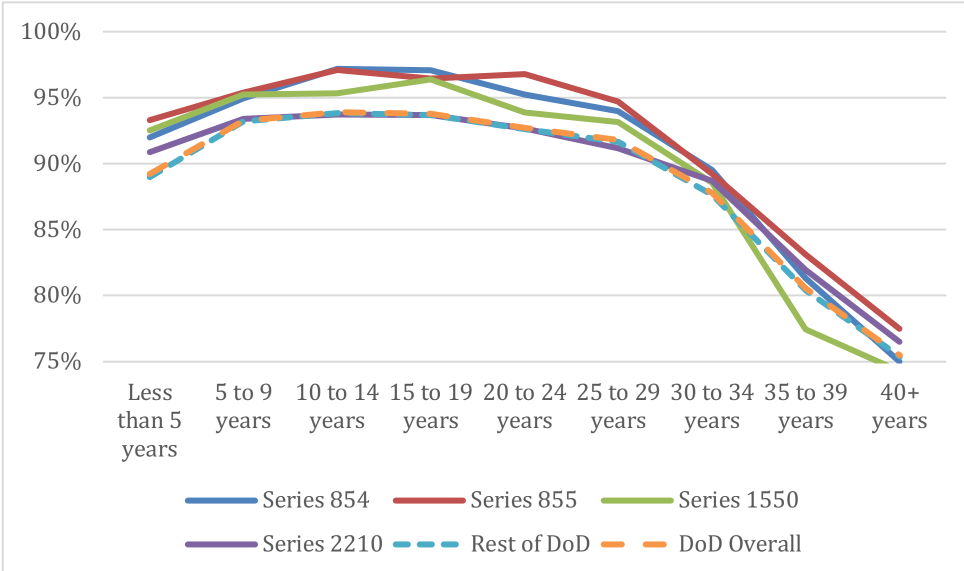
We first examine differences in tenure across occupations for employees on all types of pay plans. Figure 2.4 displays annual continuation rates by occupation from FY 2014 to FY 2018. DoD civilian cyber employees tend to have higher retention than the rest of DoD and DoD as a whole. Series 854, 855, and 1550 also have higher retention than series 2210. Figure 2.5 breaks down retention by tenure and occupation in FY 2018. Series 854, 855, and 1550 tend to have higher retention than the rest of DoD prior to 30 YOS. After 30 YOS, series 1550 has lower retention than the rest of DoD; however, there are very few cyber employees at DoD with more than 30 YOS, so the difference might be because of small cell size. Series 2210 has higher retention than non-cyber occupations prior to five YOS and after 30 YOS, although prior to five YOS, series 2210 has lower retention than the other cyber occupations.

Figure 2.4. Continuation Rates for DoD Civilian Cyber Employees by Occupation, FY 2014–2018



SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.

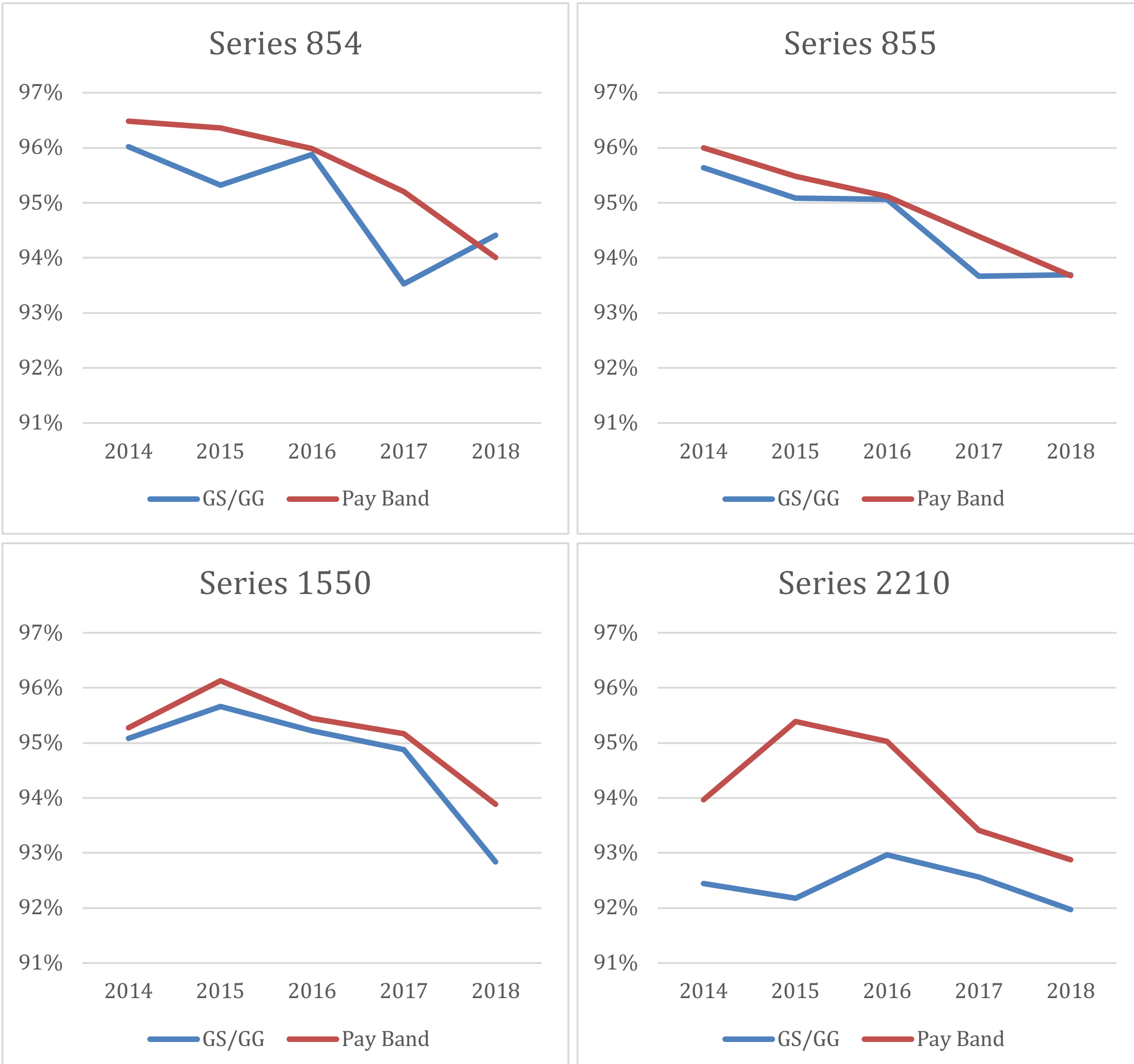
Figure 2.5. Continuation Rate by Tenure and Occupation, FY 2018



SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.

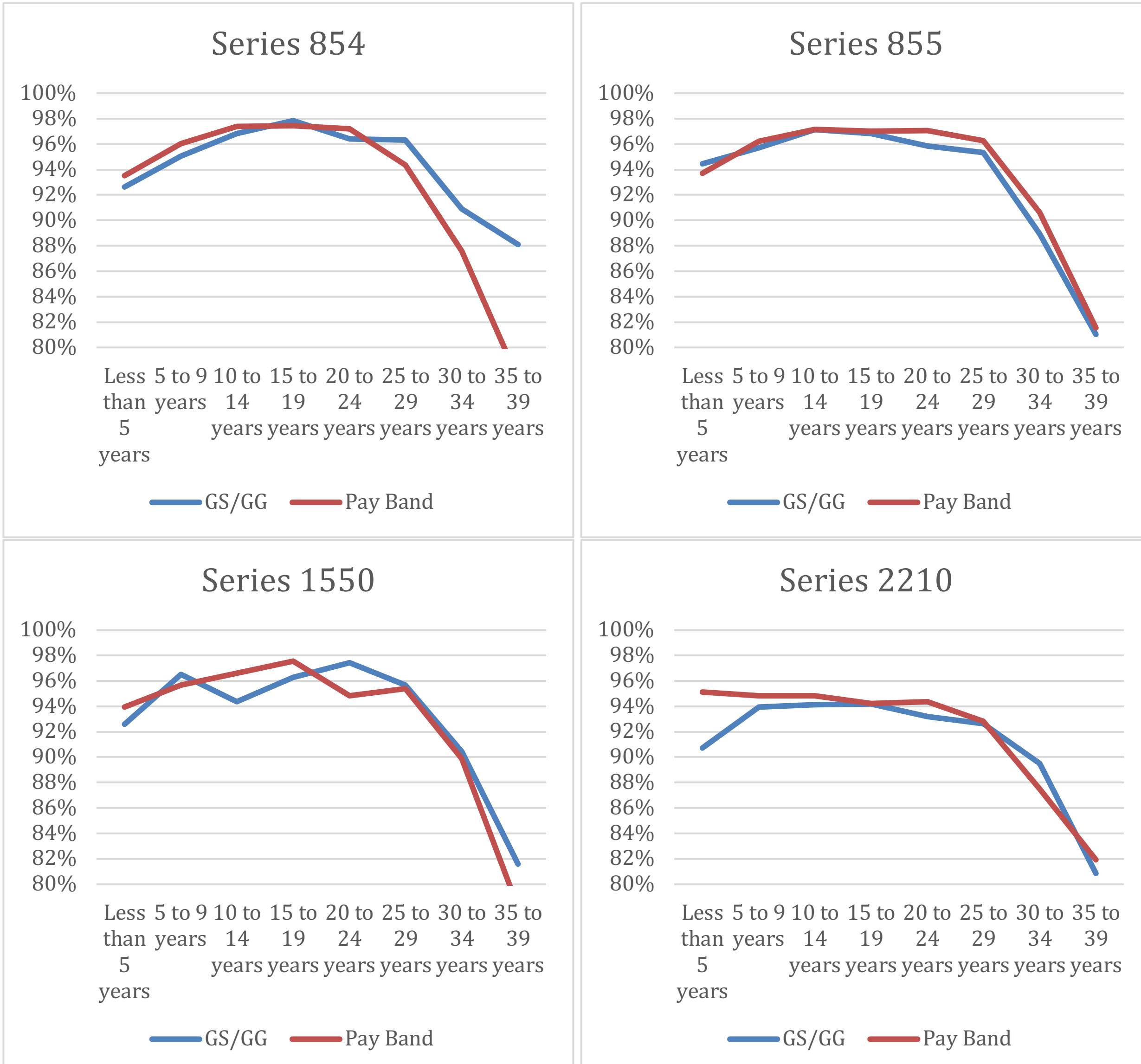
We next examine how tenure differs by pay plan within each occupation. Figure 2.6 displays annual continuation rates by occupation and pay plan from FY 2014 to FY 2018. We find that, although continuation rates are slightly higher under pay-banded pay plans in occupation series 854, 855, and 2210, the difference is not statistically significant. However, retention of pay-banded employees *is* statistically significantly higher for occupation series 2210. Figure 2.7 displays annual continuation rates by occupation and tenure at DoD in FYs 2016–2018. We find that retention is higher for pay-banded employees in series 855 and 2210 conditional on tenure, but there are no statistically significant differences in retention conditional on tenure for series 854 and 1550.

Figure 2.6. Continuation Rates by Occupation and Pay Plan, FY 2014–2018



SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.
NOTE: The difference between GS/GG and pay bands is statistically significant at the 5 percent level for 2210 using a two-sided *t*-test for difference in means. The difference between GS/GG and pay bands is not statistically significant for other occupations.

Figure 2.7. Continuation Rates by Tenure and Pay Plan, Average from FY 2016–2018



SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.

NOTE: The difference between GS/GG and pay bands is statistically significant conditional on tenure for series 855 and 2210. Employees with more than 40 YOS are included in the regression used to calculate statistical significance but are not displayed on the graph because of small cell sizes.

Promotions

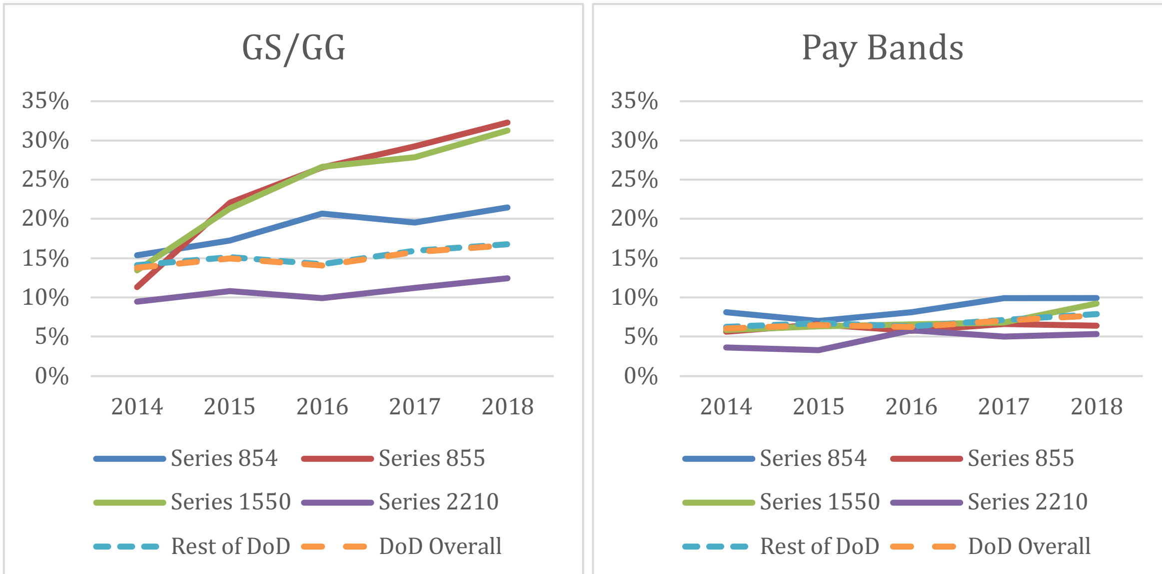
We find differences in promotion rates between cyber and non-cyber occupations and across the cyber occupations. As in the analysis of demographics and retention, we often find that series 2210 differs both from the other cyber occupations and from the rest of DoD. Note that promotion rates are not comparable between GS/GG and pay-banded employees because we calculate promotion rates using movement to higher pay grades (pay bands have a smaller number of pay grades than GS/GG, and the pay bands for each position within the schedule are much wider than GS/GG pay grades, making their promotion rates lower by construction).

Figure 2.8 displays annual promotion rates for employees with fewer than 25 YOS by occupation for both GS/GG and pay-banded pay plans from FY 2014 to FY 2018.[6] Promotion rates are similar for GS/GG employees in series 855 and 1550. GS/GG employees in series 855 and 1550 have higher promotion rates than the other cyber occupations and the rest of DoD in every year except FY 2014, and GS/GG employees in series 854 have higher promotion rates than 2210 and non-cyber occupations in every year. However, this is not consistently true of pay-banded employees in these series: Pay-banded employees in series 854, 855, and 1550 have higher promotion rates than pay-banded employees in non-cyber occupations in only some years. Employees in series 2210 have lower promotion rates than those in non-cyber occupations in every year for both pay plans. As shown in Figure 2.9, the higher promotion rates among GS/GG employees in series 854, 855, and 1550 occur during the first five YOS. After five YOS, promotion rates among GS/GG employees in these occupation series are lower than promotion rates among other DoD GS/GG employees.[7]

[6] We limit the promotion analysis to employees with fewer than 25 YOS because our measure of promotion does not capture promotion into the senior executive service. Most senior executive service employees have more than 25 YOS. Generally, movement between grade levels is low for employees with more than 25 YOS.

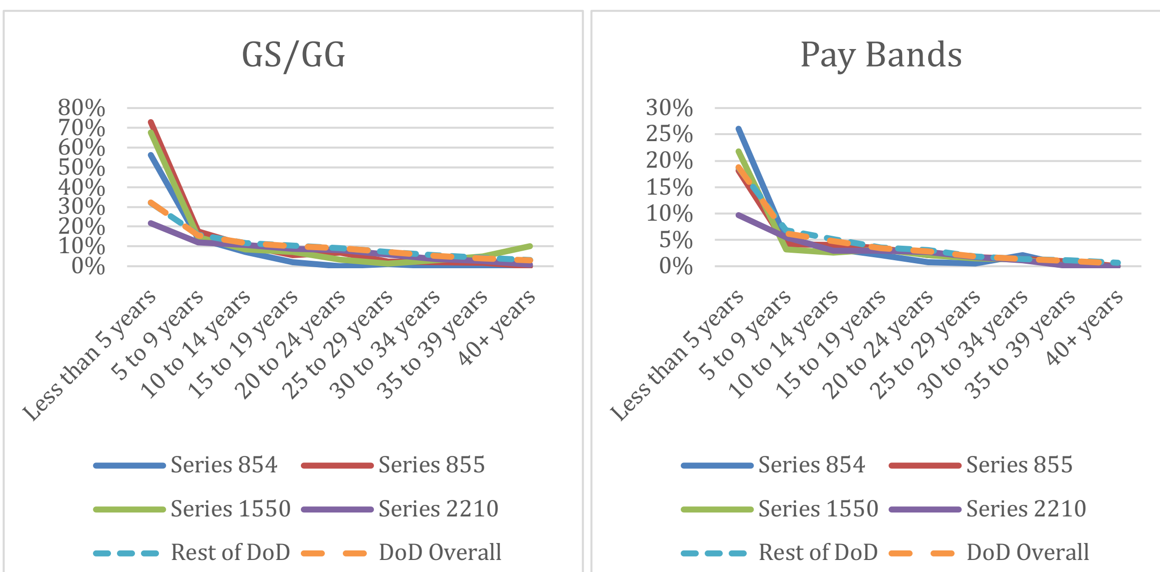
[7] This is consistent with evidence that the wage premia for engineering and computer science jobs in the college-educated private-sector workforce fade after age 30 as skills become obsolete. The highest-skilled workers in these types of jobs tend to transition to management positions after that time to maintain earnings growth (Deming and Noray, 2020).

Figure 2.8. Promotion Rates for Employees with Fewer Than 25 YOS by Occupation and Pay Plan, FY 2014–2018



SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.
NOTE: Promotion rates are not comparable between GS/GG and pay-banded employees because we calculate promotion rates using movement to higher pay grades. Individuals whose pay grade is missing from the data are excluded from the graphs. All employees excluded on this basis are in series 2210 in FY 2016.

Figure 2.9. Promotion Rates by YOS and Pay Plan, FY 2018



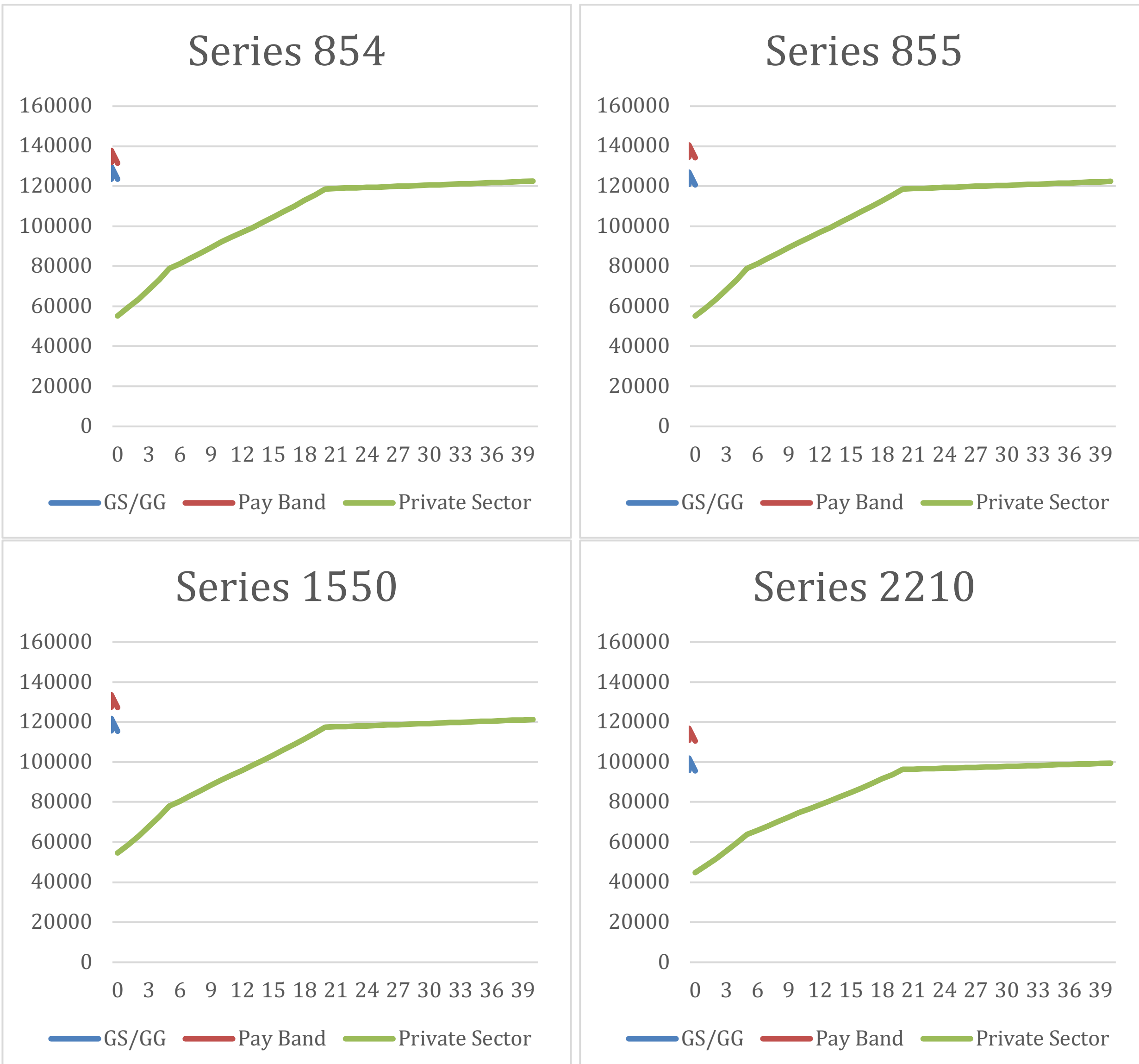
SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.

Pay

Our pay analysis involves creating pay trajectories for each cyber occupation. As described earlier in this chapter, these trajectories represent the pay that a typical male employee in each occupation would earn at each YOPE in each occupation if they were on the GS/GG pay plan, the typical pay-banded pay plan, or in the private sector, accounting for gender and education level. The pay trajectories analyzed in this section are used as inputs for the DRM in the next chapters.

Figure 2.10 displays FY 2018 pay trajectories for each cyber occupation and each type of pay (GS/GG, pay band, or private sector). The displayed pay trajectories are the weighted average of the pay trajectory by education level (less than BA, BA, more than BA); the weights are equal to the proportion of employees in the occupation series in FY 2018 with each level of education. Although pay is similar for GS/GG and private-sector workers in each occupation, pay tends to be higher over the career on pay bands. The higher pay of pay-banded employees is notable, given that we found no statistical difference in retention between pay-banded and GS/GG cyber employees in series 854, 855, and 1550 (and no statistical difference in retention conditional on tenure for 854 and 1550). However, this result is consistent with prior analyses of the Civilian Acquisition Workforce Personnel Demonstration Project (AcqDemo), a demonstration project for a pay-banded pay plan in the acquisition community (Lewis et al., 2017).

Figure 2.10. Pay Trajectories for Cyber Occupations in FY 2018, Government by Pay Plan Versus Private Sector



SOURCE: Authors' calculations using the 2019 ACS and the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.
NOTE: Pay trajectories are calculated separately by education level (less than BA, BA, more than BA). These graphs display the weighted average of the pay trajectories; weights are equal to the proportion of individuals in the occupation whose education is known and falls into the given category.

Summary

This chapter describes differences in demographics, retention, promotion rates, and pay trajectories between DoD cyber and non-cyber employees and across cyber occupations. We find that demographics vary across cyber occupations and are generally different from the rest of DoD. Employees in series 854, 855, and 1550 are better educated, less likely to be veterans, and more likely to be in pay band systems than the rest of DoD. Those in series 2210 are better educated, more likely to be veterans, and equally likely to be in pay-banded systems than the rest of DoD.

We find that cyber employees tend to have higher retention than the rest of DoD, and those in series 854, 855, and 1550 have higher retention than series 2210 employees. We also find no difference in retention between pay-banded and GS/GG cyber employees, except in series 2210, in which pay-banded employees have higher retention than GS/GG employees. GS/GG cyber employees, except in series 2210, have higher promotion rates than non-cyber employees, but the pattern is less clear for pay-banded employees. Both GS/GG employees and pay-banded employees in series 2210 have lower promotion rates than non-cyber employees. The pay trajectory for GS/GG positions is similar to that of the private sector for all occupations, but the pay trajectory for pay-banded positions is higher than that of GS/GG positions or the private sector.

Chapter 3. Modeling GS/GG Cyber Worker Retention

The DRM is a model of individual employee retention decisions over their career for which decisions change as the value of staying or leaving the civil service changes. We estimated the parameters of the model using longitudinal data that track civil service careers for up to 20 years at the individual level for cyber workers in occupations 854, 855, 1550, and 2210 who entered the workforce between 2000 and 2007.[8] We estimated the parameters of separate models for each occupational category. The models enable us to simulate the retention effects of changes to policies, including changes that have not been previously considered; in this project, we focus on training as a retention lever.

We begin this chapter with an informal overview of the DRM for civil service employees. This draws from an earlier document (Asch, Mattock, and Hosek, 2014), which provides a more formal discussion of the DRM and a review of the earlier literature on modeling retention behavior.

Overview of the DRM

The DRM is a stochastic dynamic programming model of individual retention behavior over a career with econometrically derived parameters. In it, employees make retention decisions each year over their career with a given employer. The model assumes that these employees are rational and forward-looking, considering their expected future earnings from the employer, their own preference for employment with that employer, and uncertainty about future events that could cause them to value their current service more or less, relative to their external opportunities. Once the parameters of the underlying decision process are estimated, we can use these estimates to simulate the baseline retention profile of an entry cohort of civil service personnel and the retention profile under alternative compensation policies. By appropriately scaling the results, we can make inferences about the effect of those policies on the size of the workforce that is retained and the required accessions needed to sustain the workforce should it decrease. Although we do not explicitly model accessions, accessions are a by-product of the analysis, because they provide an estimate of how much accession levels must change to sustain a given workforce size, given changes in retention resulting from a policy change.

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[8] During this time, most workers entering these occupations were under the GS/GG pay scale. A minority of the workers entered under pay banding in these years, so we chose to model the retention of GS/GG cyber workers only. CES workers are under a grade-step pay system, so workers who entered under the GS/GG pay scale provide the most relevant analog. The model we present in this chapter could be extended to model the retention behavior of cyber workers under pay banding in future work.

We used a simple version of the DRM in this analysis. Although the simple version has been described in several studies (e.g., Asch, Mattock, and Hosek, 2014; Knapp, Asch, et al. 2016), we give a broad overview here for readers who are unfamiliar with those studies.

We modeled civil service retention from the start of employees' careers there. Although we did not model the decision to enter the civil service and, specifically, when to enter it, employees in the model can enter the civil service for the first time at any age. In the data we used here, civil service employees enter between the ages of 22 and 52.

Each year, the individual compares the value of staying in civil service with that of leaving and bases their decision on which alternative has the maximum value. In the basic DRM, we assume that once individuals leave DoD civil service, they do not reenter at a later date. Individuals who stay revisit the choice between DoD civil service employment and external opportunities in each future period until retirement from the labor force. All these decisions will depend on the employee's distinct circumstances at a given point in time. Those circumstances include time-invariant preference for DoD civil service relative to external opportunities and random events that might affect relative preferences in a given period.

In the model, the value of staying depends on the annual civil service earnings in each period. Annual earnings vary with age (YOPE), education, and occupation, and those who begin their civil service career at older ages begin at higher pay than their younger counterparts, because they have more YOPE.

Again, the value of staying also depends on the individual's time-invariant preference for DoD civil service relative to the external market ("taste" for civil service), other civil service compensation, and a period- and individual-specific environmental disturbance term (or "shock") that can either positively or negatively affect the value placed on civil service in that period. For example, a one-time job offer from a high-profile tech company could be a shock that decreases the value placed on civil service employment. The taste for civil service is assumed to be constant over time for a given individual and can be thought of as the net effect of idiosyncratic, persistent differences related to the individual's perceived value of working in the civil service relative to the external market. The net effect includes all nonmonetary and monetary factors the individual perceives as relevant to the civil service over and above monetary factors included in the model. These factors might include patriotism and desire for public service, positive and negative things the individual perceives about the civil service (e.g., hours of work and differences in paid leave), and persistent differences in civil service and private-sector earnings apart from the differences accounted for in the model. We use a single curve to represent GS salary, given educational attainment and occupation and external salary by YOPE. But an individual might believe their GS and external salaries are persistently higher or lower than those curves. The net effect of these perceived differences would affect taste. Another way of describing taste, then, is as a person-specific fixed effect.

Individuals are heterogeneous with respect to their tastes for civil service: that is, their tastes differ. We as researchers do not directly observe these tastes, but we assume they are distributed according to a known type of probability distribution but with unknown parameters. One goal of the estimation process is to estimate these parameters.

The value of staying in the civil service also includes the value of the option to leave: that is, knowing that they can revisit and reoptimize the decision to stay or leave in the next period. Of course, the future is uncertain, so the value of being able to choose to stay or leave in the future is expressed as the discounted expected value of the maximum of staying or leaving in the next period. Individuals might reoptimize and change their decision in the future because new information (for instance, a new shock) makes it reasonable to do so or because the discounted expected value of future benefits of leaving becomes greater relative to the benefits of staying. Having the option to leave at a future time is valuable, and policies that obligate individuals to stay (such as a service obligation on completion of a training course) have an implicit cost to the individual.

Furthermore, choices made today can affect the value of choices in the future. An individual who chooses to stay in the civil service today adds a YOS, moving closer to retirement eligibility and increasing retirement benefits, thereby influencing the value of choosing the civil service in the future. Similarly, past choices can affect the value of current and future choices.

The value of leaving includes the value of the external alternative, which includes pay in the external market,[9] any civil service retirement benefits the individual is entitled to receive,[10] and an individual- and period-specific shock term that can either positively or negatively affect preference for the external alternative. Pay in the external market varies with education and YOPE (age); those entering the civil service with more YOPE (older ages) have higher external pay opportunities.

Estimation

The parameters we estimated are the mean and standard deviation of the taste distribution, the scale parameter of the shock distribution, and the discount factor. We would like to emphasize that the model was estimated from actual data, not calibrated. Calibration would select parameter values from a sequence of guesses that depend on model fit under prior guesses, whereas estimation finds the parameters that simultaneously maximize the model's fit to the data and provides standard errors of the estimates by which to judge their statistical significance.

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[9] Note that because the value of the external alternative is assumed to be the same for all occupational series (though it is estimated separately by education level), variance across occupations in the difference in pay between the civil service and the external market will be partly reflected by variance in the estimated taste parameters.

[10] All individuals in the data we used to estimate the DRM are covered by the Federal Employees Retirement System, which was introduced in 1987. It consists of three parts: a defined benefit plan that bases retirement benefits on the employee's earnings and YOS, Social Security coverage, and a defined contribution plan called the Thrift Savings Plan. All new entrants with less than five YOS are automatically placed under the Federal Employees Retirement System. Because the individuals in our analysis had no prior service in 1988, they fall into this category.

The model's parameters were estimated with maximum likelihood. Optimization was done using standard hill-climbing methods. Standard errors of the estimates were computed using numerical differentiation of the likelihood function and taking the square root of the absolute value of the diagonal of the inverse of the Hessian matrix.

To judge goodness of fit, we used the parameter estimates to simulate retention rates by YOS of DoD civil service personnel and compared those rates to the actual data. We show goodness-of-fit diagrams below along with the model parameter estimates.

Parameter Estimates and Fit Graphs

We estimated our model by education and occupation. The educational categories are (1) less than BA, (2) BA only, and (3) more than BA. We were able to estimate the model for all four occupations for categories 2 and 3, but the sample sizes were large enough to estimate the model for people with less than a BA only in occupations 855 and 2210.

We recognize that individuals can gain additional education while they are in the civil service and can switch occupations. However, as discussed in Asch, 2001, the civil service data do not appear to always update the education information as individuals obtain more education, so we opted to use the entry education level. Moreover, although the DRM could be expanded to consider occupational choice, we do not pursue that avenue here, so we focus only on entry occupation.

Table 3.1 shows the parameter estimates by occupation for those with a BA only. The first column lists the parameter name, where *lambda* is the scale of the shock parameter, *mu* is the mean of the taste distribution, *sd* is the standard deviation of the taste distribution, and *beta* is the discount factor. In addition, this column includes *lnL*, or negative one times the value of the log likelihood at the estimated maximum, and *N*, which indicates the sample size. The second and third columns give the standard error and the *z* value, respectively, and the final column gives the transformed value of the parameter estimates. The parameter estimates are all scaled in thousands of dollars, with the exception of the discount factor (*beta*), for which the magnitude of the coefficient is a logit transformation of the discount factor itself. Because beta is the only value transformed, this is the only value that changes between the Coefficient column and the Parameter Estimate column.

The first thing to notice about the coefficients is that, in all cases, the estimated value for the shock parameter lambda is significant, ranging from about \$52,000 to \$87,000. This corresponds to a shock standard deviation of \$67,000 to \$112,000, given that the standard deviation of a random variable with an extreme value distribution is equal to $\pi/\sqrt{6} \cong 1.28$ times the scale parameter. The mean of the taste distribution ranges from about −\$27,000 to \$9,000, and the standard deviation ranges from about \$3,000 to \$8,000. The relative magnitudes of the shock term and the taste term seem to indicate that retention behavior is mainly driven by shocks and less by individual taste. The mean of the taste distribution is generally significant, whereas the standard deviation is generally not significant, most likely because of the relatively small number of observations used to estimate the model. The discount factor ranges from 0.94 to 0.97 and is highly significant in all cases, and the estimated discount factor is significantly less than one in all cases.

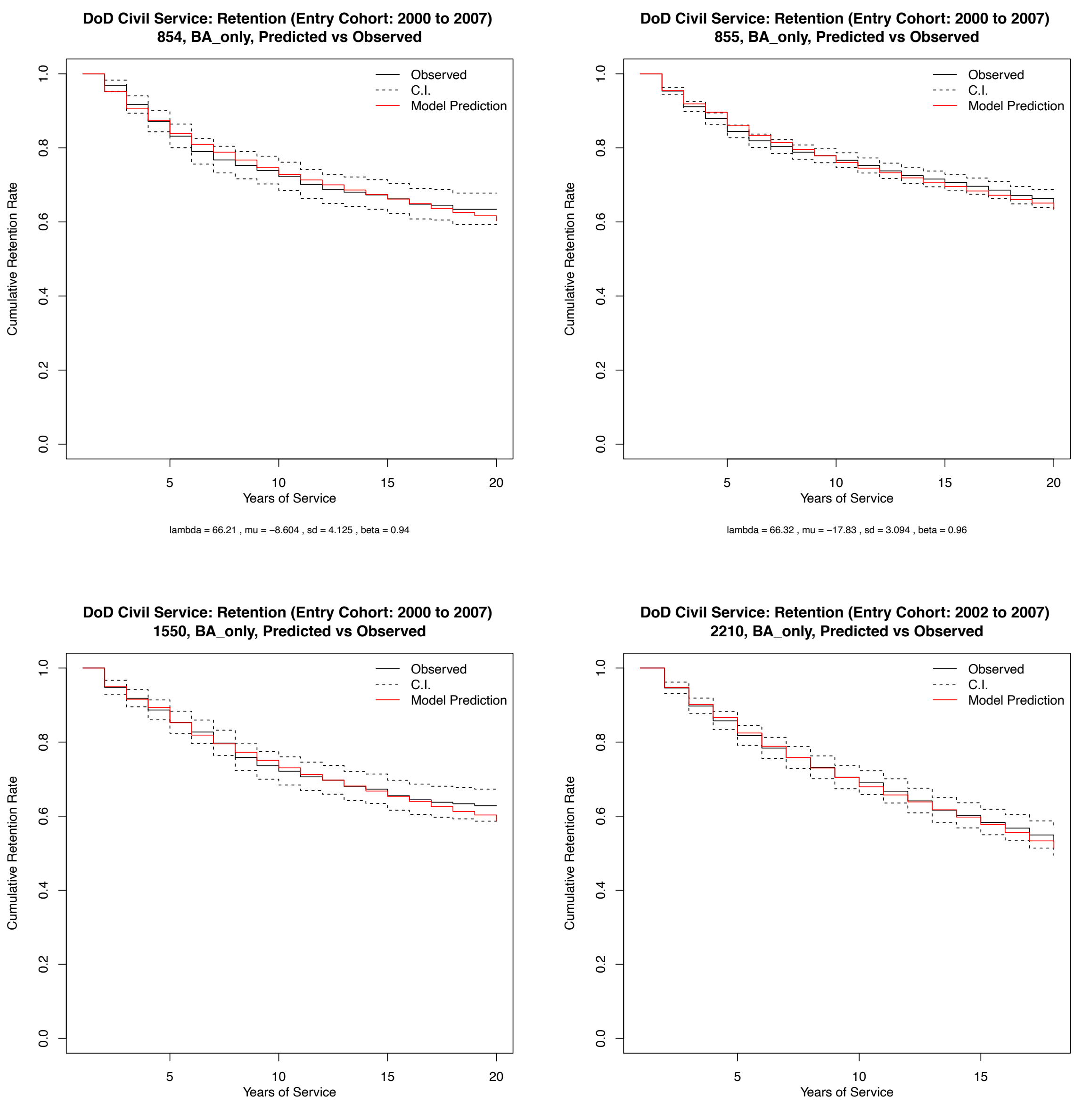
Table 3.1. Parameter Estimates for BA Only

Series 854	Coefficient	Standard Error	*z* Value	Parameter Estimate
lambda	66.2098	17.1264	3.8660	66.2098
mu	−8.6043	5.3472	−1.6091	−8.6043
sd	4.1246	8.2564	0.4996	4.1246
beta	2.7928	0.0224	124.6452	0.9423
−lnL	829.4577			
N	529			
Series 855	**Coefficient**	**Standard Error**	***z* Value**	**Parameter Estimate**
lambda	66.3248	8.1906	8.0977	66.3248
mu	−17.8271	6.0384	−2.9523	−17.8271
sd	3.0937	3.6435	0.8491	3.0937
beta	3.1327	0.1529	20.4836	0.9582
−lnL	2490.7510			
N	1735			
Series 1550	**Coefficient**	**Standard Error**	***z* Value**	**Parameter Estimate**
lambda	87.0142	24.909	3.4933	87.0142
mu	−27.3416	11.6917	−2.3385	−27.3416
sd	5.7942	5.2225	1.1095	5.7942
beta	3.5071	0.2625	13.359	0.9709
−lnL	846.2475			
N	538			
Series 2210	**Coefficient**	**Standard Error**	***z* Value**	**Parameter Estimate**
lambda	51.6854	8.3637	6.1797	51.6854
mu	8.6943	1.8285	4.7550	8.6943
sd	8.4016	1.9756	4.2526	8.4016
beta	2.7928	0.0232	120.1578	0.9423
−lnL	1445.7690			
N	800			

NOTE: *Lambda* is the scale of the shock parameter, *mu* is the mean of the taste distribution, *sd* is the standard deviation of the taste distribution, and *beta* is the discount factor. *−lnL is* negative one times the value of the log likelihood at the estimated maximum. *N* is the sample size. All coefficients except those for beta, the discount factor, are in thousands of dollars.

Figure 3.1 shows how the model corresponds to the observed retention for the BA only population. Each graph in Figure 3.1 shows the cumulative retention by YOS. The solid black lines show the Kaplan-Meier (K-M) nonparametric retention estimate, and the dotted black lines show the 95 percent confidence intervals for the K-M estimate. The red lines show the DRM model prediction. The models fit well; the predicted retention typically falls well within the K-M confidence intervals.

Figure 3.1. Model Fit for All Cyber Occupations, BA Only



SOURCE: Authors' calculations using DMDC data and ACS data.

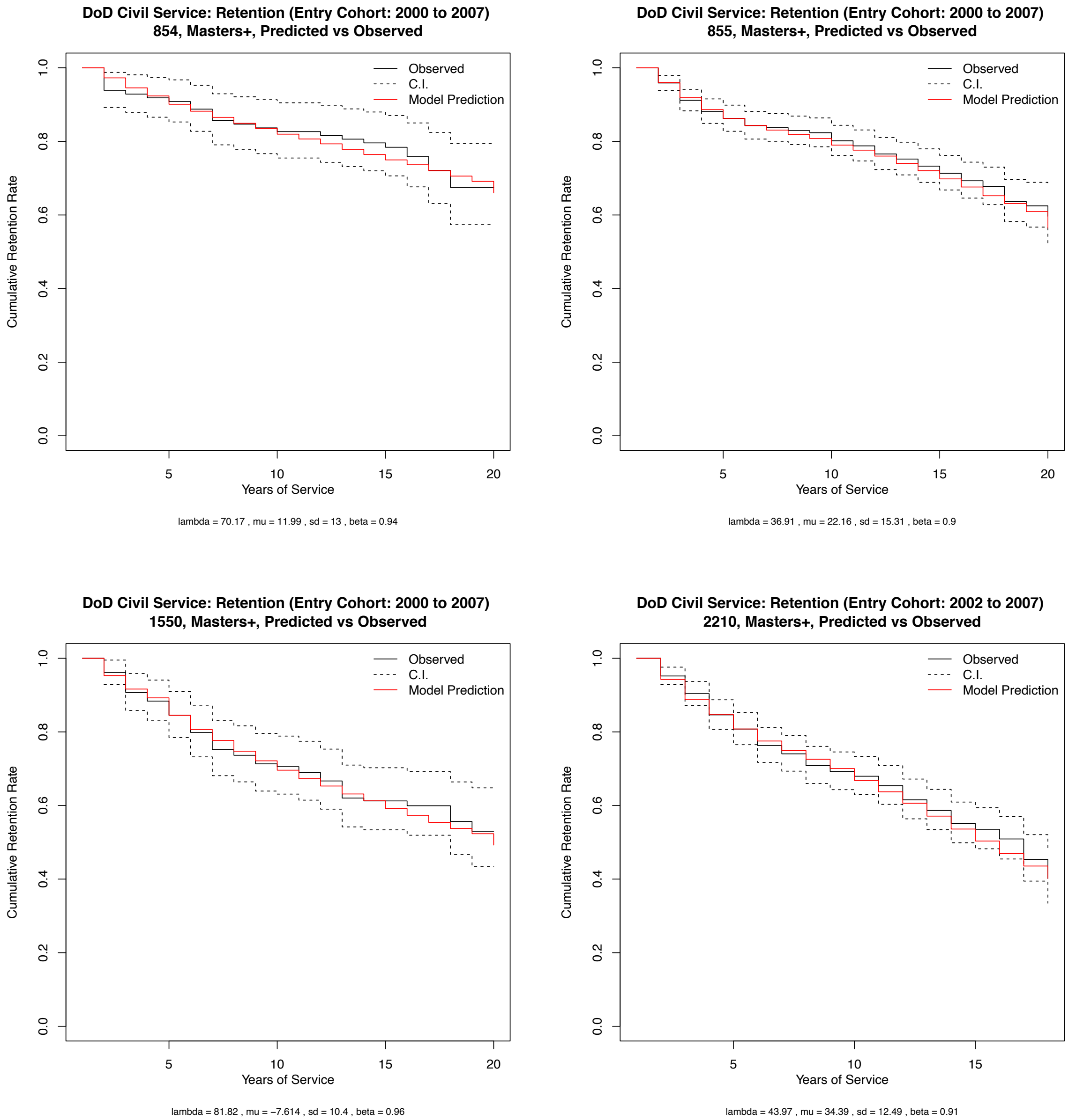
Similar to Table 3.1 and Figure 3.1, Table 3.2 and Figure 3.2 give the parameter estimates and fit graphs, respectively, for individuals with more than a BA. These parameter estimates tend to show a wider range than those for BA only, which might in part be because of the smaller sample sizes.

Table 3.2. Parameter Estimates for More Than BA

Series 854	Coefficient	Standard Error	*z* Value	Parameter Estimate
lambda	70.1691	34.6181	2.0269	70.1691
mu	11.9870	30.8989	0.3879	11.987
sd	13.0045	13.0037	1.0001	13.0045
beta	2.7400	0.6794	4.0329	0.9393
−lnL	127.6706			
N	98			
Series 855	**Coefficient**	**Standard Error**	***z* Value**	**Parameter Estimate**
lambda	36.9065	6.6147	5.5795	36.9065
mu	22.1648	10.1290	2.1882	22.1648
sd	15.3113	4.8848	3.1344	15.3113
beta	2.2070	0.2944	7.4962	0.9009
−lnL	522.1105			
N	363			
Series 1550	**Coefficient**	**Standard Error**	***z* Value**	**Parameter Estimate**
lambda	81.8203	42.4839	1.9259	81.8203
mu	−7.6141	19.7649	−0.3852	−7.6141
sd	10.4000	7.0539	1.4744	10.4000
beta	3.2686	0.4459	7.3296	0.9633
−lnL	228.2759			
N	129			
Series 2210	**Coefficient**	**Standard Error**	***z* Value**	**Parameter Estimate**
lambda	43.9710	10.3421	4.2516	43.971
mu	34.3921	9.5546	3.5995	34.3921
sd	12.4851	3.5770	3.4904	12.4851
beta	2.2997	0.3083	7.4588	0.9088
−lnL	629.2168			
N	312			

NOTE: *Lambda* is the scale of the shock parameter, *mu* is the mean of the taste distribution, *sd* is the standard deviation of the taste distribution, and *beta* is the discount factor. *−lnL is* negative one times the value of the log likelihood at the estimated maximum. *N*, is the sample size. All coefficients except those for beta, the discount factor, are in thousands of dollars.

Figure 3.2. Model Fit for All Cyber Occupations, More Than BA Only



SOURCE: Authors' calculations using DMDC data and ACS data.

Finally, Table 3.3 and Figure 3.3 give the parameter estimates and model fits for those with less than a BA.

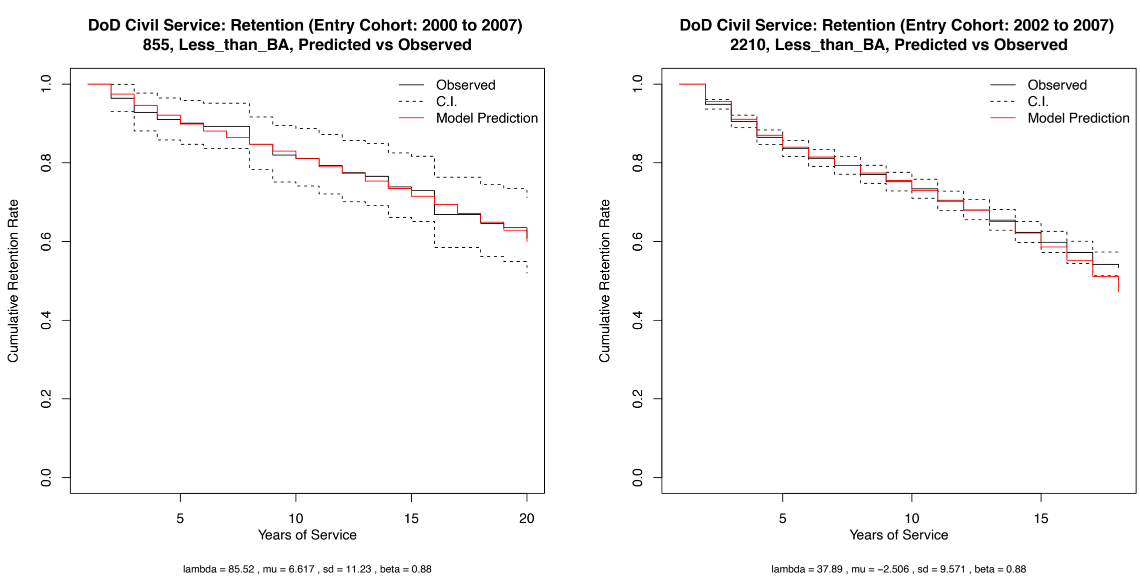
Table 3.3. Parameter Estimates for Less Than BA

Series 855	Coefficient	Standard Error	*z* Value	Parameter Estimate
lambda	85.5159	36.1851	2.3633	85.5159
mu	6.6168	15.7318	0.4206	6.6168
sd	11.2275	9.6110	1.1682	11.2275
beta	1.9924	-	-	0.8800
−lnL	186.1235			
N	111			

Series 2210	Coefficient	Standard Error	*z* Value	Parameter Estimate
lambda	37.8948	3.9293	9.6442	37.8948
mu	−2.5055	1.6256	−1.5413	−2.5055
sd	9.5715	1.1958	8.0039	9.5715
beta	1.9924	-	-	0.8800
−lnL	2270.783			
N	1285			

NOTE: *Lambda* is the scale of the shock parameter, *mu* is the mean of the taste distribution, *sd* is the standard deviation of the taste distribution, and *beta* is the discount factor. *−lnL is* negative one times the value of the log likelihood at the estimated maximum. *N* is the sample size. All coefficients except those for beta, the discount factor, are in thousands of dollars.

Figure 3.3. Model Fit for Cyber Occupations 855 and 2210, Less Than BA



SOURCE: Authors' calculations using DMDC data and ACS data.

Summary

The DRM is a model of individual employee retention decisions over their career for which decisions change as the value of staying or leaving the civil service changes. We gave an informal description of the DRM and presented statistical estimates of the model parameters for different occupations and levels of educational attainment. We also presented figures showing the fit of the models by education and occupation; in all instances, the models fit the empirical data well. The models enable us to simulate the retention effects of changes to policies, including changes that have not been previously considered. In the following chapter, we focus on using training as a retention lever.

Chapter 4. Training as a Retention Lever

In this chapter, we use our retention model to investigate how training can be used as a retention lever. Specifically, we use the DRM with the estimated parameters to simulate the effect of training when course completion improves the external opportunity wage for CES cyber workers. The effect that training will have on retention varies depending on when training is offered in a career, the length of training, the length of the payback obligation (if any), and the relative improvement in the external and internal wages. We find that training alone is not, in general, an effective means of improving retention without a payback obligation, some increase in the internal wage, or both.

What Do We Expect?

Before we go into our simulation results on the effect of training on retention, it is useful to consider what we might expect. First, if training is valuable either intrinsically or in the internal or external labor market, we would expect an increase in retention prior to when training is offered. That is, if training is offered in the fifth YOS, we would expect to see an increase in retention in YOS two through four in anticipation of the training being offered. Second, if training increases the external opportunity wage more than the internal wage, then we would expect to see increased attrition once training (and any concomitant service obligation) is completed. Third, any training obligation would serve to mitigate the reduced retention after completion of training, because the combined length of training plus the service obligation enforces retention at essentially 100 percent for the duration of the commitment. Fourth, we would expect to see fewer people elect to take training as training gets longer, as any service obligation gets longer, and as the outside opportunity decreases. Conversely, we would expect to see more people take training as the course length gets shorter, service obligation gets shorter, internal opportunities improve for those who take training, and the relative increase in the outside opportunity wage gets larger.

A central contribution of the analysis is its ability to provide empirically based estimates of the extent to which the expectations are borne out and to indicate the compensation and promotion policies that, if implemented, can increase or sustain retention and, in any case, prevent its decline.

Approach

In the following section, we present detailed simulation results for alternative training scenarios. In all instances, we assume that training is voluntary: that is, that individuals can choose whether to take the training offered and thus whether they might incur an associated service obligation. These alternative scenarios consider different training lengths, different service payback obligations, and different internal and external wage increases on completion of training. Specifically, we use the DRM with estimated parameters to simulate the retention effect of a series of notional training scenarios in which we systematically vary the following training characteristics:

- timing of training (early, intermediate, or advanced stages of career)
- length of training
- payback formula
- assumed effect on CES earnings
- assumed effect on external market earnings.

We consider internal and external wage effects separately in part because of the possibility that the productive value of training might differ persistently between DoD CES and the economy at large. Differences in the productive value can be expected to have a direct effect on salary, and a permanent increase in external salaries will have an indirect effect on DoD CES salaries, causing them to increase to sustain retention.

The ranges over which we varied these characteristics can be seen in Table 4.1. We adopted this approach rather than estimating a model that includes training for two reasons. First, CES training is still being developed, and our simulations are meant to provide an estimate of the potential retention effects of several training options to help DoD choose the one that best suits their needs. Second, modeling training would require historical knowledge of training since 2000, including the timing of training, duration of training, duration of any service obligation, and the effect of the training on internal and external wages. We were unable to get long-term historical information on key training events from the services, and it is possible that such information does not exist in a unified source.

Table 4.1. Training Parameters Varied over Scenarios

Timing of Training (YOS)	Length of Training (Years)	Payback Formula (Multiple of Length of Training)	Assumed Effect on CES Earnings (Percentage)	Assumed Effect on External Market Earnings (Percentage)
1, 5, or 8	0.5, 1	0× or 3×	0%, 1%, 2%, 3%	0%, 1%, 2%, 3%

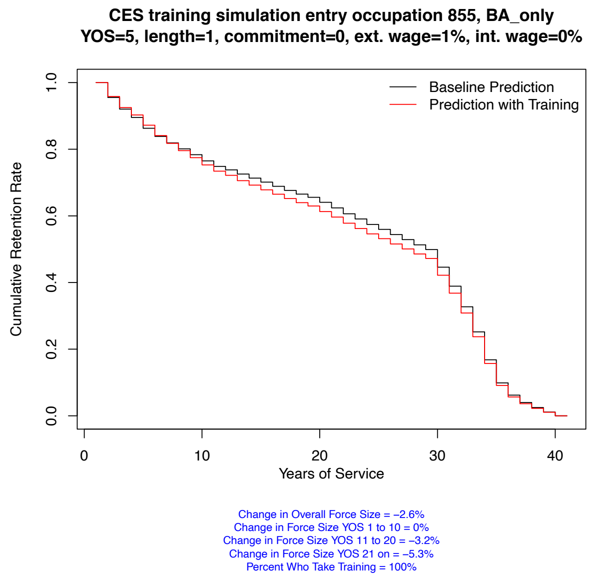
For the purposes of illustration, we show the effect of alternative training policies on occupation 855, Electronics Engineering Series, for people who hold a BA. The results for other occupational areas and levels of educational attainment are qualitatively similar, as we show in Appendix B for series 2210. That is, despite differences in retention across occupations and by educational attainment, the simulated effects of training associated with an improvement in the external opportunity wage on retention behavior are similar.

Before showing the results for the retention simulations, a word about the figures. The figures used to illustrate the alternative training all have a similar format, and we will use Figure 4.1 as an example. The figure title gives information about the occupation and level of educational attainment under consideration and the parameters of the scenario under consideration: the YOS when training is offered, the length of training, the commitment or length of the payback service obligation incurred for the training, the percent increase in the external opportunity wage, and the percent increase in the internal wage. For example, the title in Figure 4.1 indicates that the occupation is 855, education is BA only, training happens in the fifth YOS and lasts one year, there is no service obligation associated with the training, the external wage would increase by 1 percent, and there would be no increase in the internal wage.

The vertical axis is the cumulative retention rate for an occupation. The horizontal axis is the number of YOS. In Figure 4.1, the baseline cumulative retention rate (the black line) starts at 1 (100 percent) in the first year. It stays above 0.5 (50 percent of the entering cohort remaining) until the 30th YOS and then drops off rapidly thereafter as people leave and collect their retirement benefits. The red line shows the simulated effect of training for the scenario under consideration, and a comparison of the black and the red lines shows how retention changes.

Finally, beneath the figure are summary statistics for the simulation, including the increase or decline in retention overall and by selected ranges of YOS. The percentage of people choosing to take the training is also reported. Often, the percentage of people choosing to take the training will be 100 percent, particularly when the impact on the external opportunity wage is high. However, when training is long, has an associated long payback obligation, and has a low impact on the external opportunity wage, the percentage of people who choose to take the training will dip to 50 percent or lower.

Figure 4.1. Training Without a Payback Obligation Reduces Retention



SOURCE: Authors' calculations using the RAND DRM.

Results

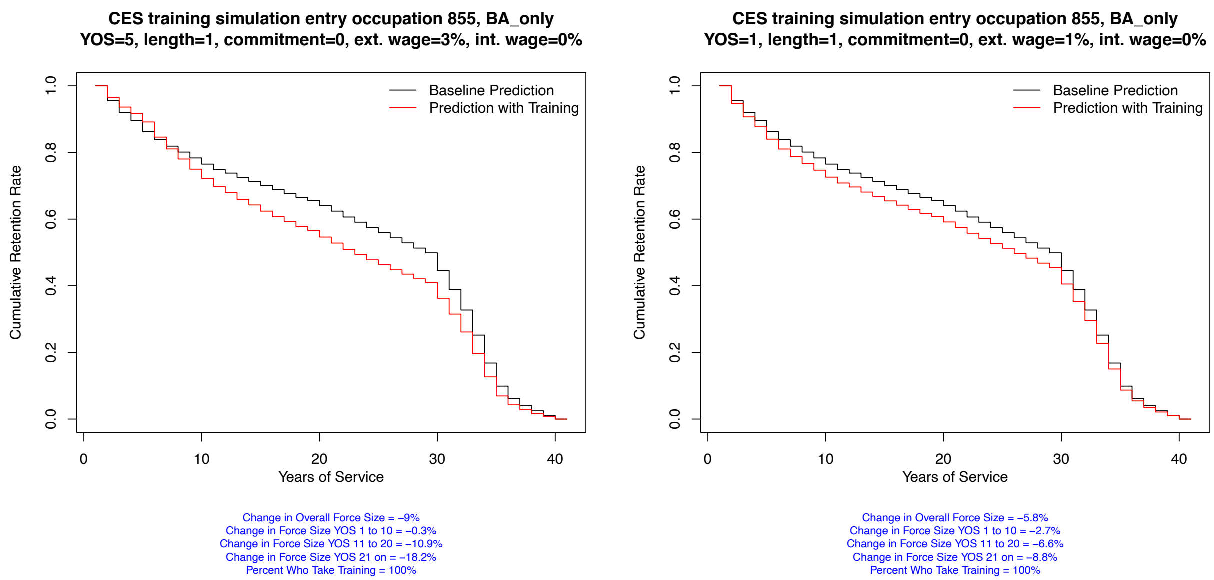
Training Without a Payback Service Obligation

Training without a payback obligation reduces retention if training increases the external wage even by a small amount relative to the internal wage, because CES workers might choose to pursue better civilian opportunities when training is complete. Figure 4.1 shows that in occupation 855, a yearlong training program at YOS 5 without a service obligation would reduce overall retention by 2.6 percent in the steady state. We find that 100 percent of those who reach YOS 5 would take the training. Although there is a small increase in retention in YOS 2–5 in anticipation of the training opportunity, this increase is overwhelmed by the increased attrition after YOS 5.

The negative retention effect is larger if the increase in external wage is larger or if training occurs earlier in career. The better the external opportunities, the larger the drop in retention, as can be seen in the left panel of Figure 4.2. We find that an increase in the external wage of 3 percent results in a 9 percent decline in the overall size of the workforce, more than triple the decline seen with a 1 percent increase in the external wage shown in Figure 4.1. The right panel of Figure 4.2 shows the effect of training earlier in a career, in YOS 1. The population of junior workers includes more individuals who have less attachment (lower taste) for CES employment, so the drop associated with training earlier in a career is larger. The decline in the overall size of the workforce is more than double that seen in Figure 4.1, in which training is deferred to YOS 5.

Figure 4.2. Negative Retention Effect Is Larger If External Wage Is Larger or Training Occurs Earlier

Larger External Wage	Earlier In Career



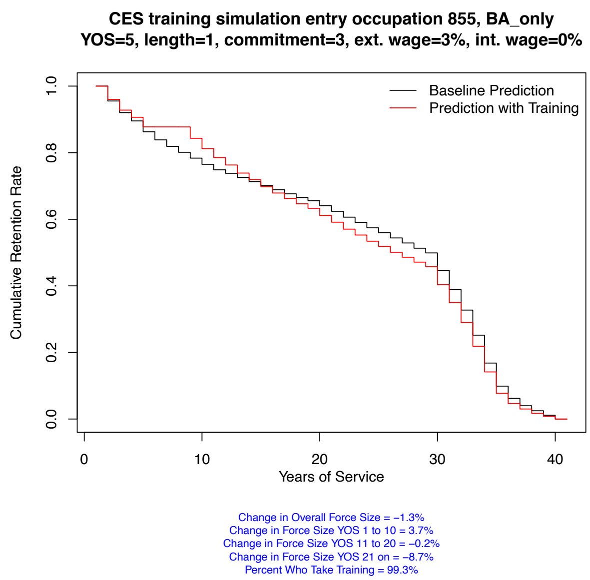
SOURCE: Authors' calculations using the RAND DRM.

Training With a Payback Service Obligation

Training with a payback obligation but without an increase in CES pay might produce only a temporary increase in retention because of increased retention in anticipation of training and the 100 percent retention during training and the payback period for those who choose to take training with payback obligations. Once training and the associated obligation are complete, people show an increased propensity to leave, given their better external wage.

Figure 4.3 shows an example of this effect when a year of training occurs in YOS 5, followed by a three-year payback obligation, producing an initial increase in retention relative to the baseline. The external wage increases by 3 percent on completion of training, and the internal wage trajectory remains unchanged, which results in lower year-to-year retention once the training payback obligation is completed. Although retention among those in YOS 1–10 increases by 3.7 percent, it falls by 0.2 percent for those with 11–20 YOS and by 8.7 percent for those with more than 21 YOS. As a result, overall force size falls by 1.3 percent for occupation 855. The drop is less severe if the training length and payback obligation are longer, occurs later in the career, or the external wage increase is smaller. Figure 4.4 provides an illustration of the effect of a longer versus shorter length of training: The left panel of the figure shows the retention effect of a six-month course of training followed by an 18-month obligation, while the right panel shows the effect of a one-year course followed by a three-year obligation. In both cases, the training occurs in YOS 5, and the effect on the external wage is assumed to be the same regardless of the course length.

Figure 4.3. Training With Payback but No Internal Wage Increase Might Result in a Temporary Increase in Retention

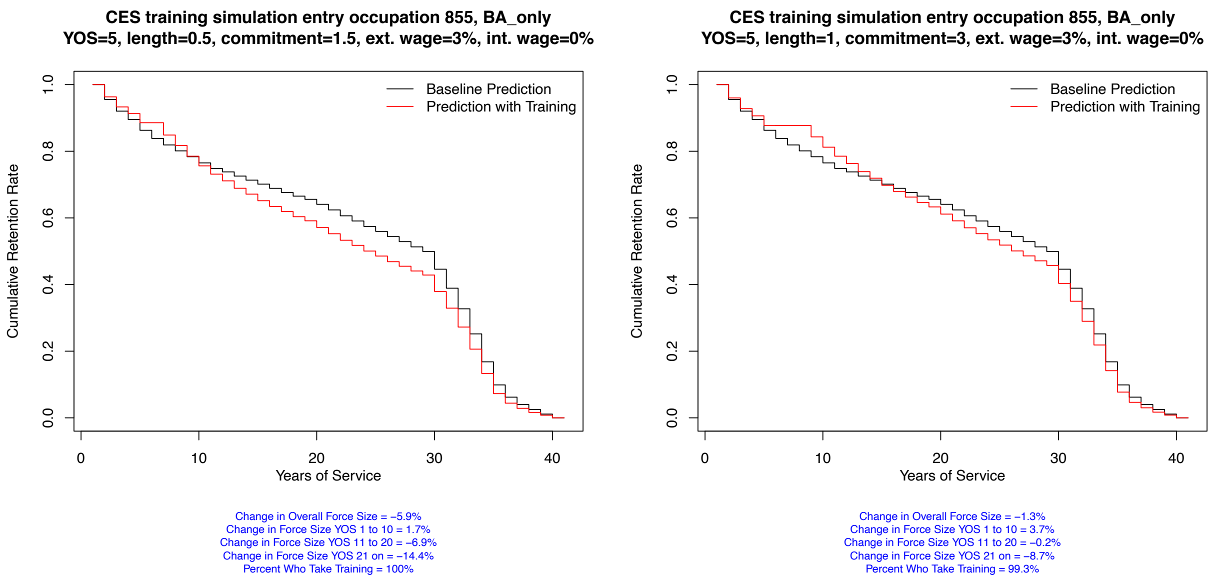


SOURCE: Authors' calculations using the RAND DRM.

The drop in retention associated with the longer course length is 1.3 percent, or less than one-fourth the drop in retention associated with the shorter course length, 5.9 percent. This difference is caused by two effects, one of which is largely mechanical and one of which is behavioral. The mechanical effect is that the enforced retention of two additional years associated with the longer training means that retention is higher in the eighth year and remains consistently higher, and retention declines after the eighth year at approximately the same rate as the retention curve associated with the shorter training. The behavioral effect is that fewer people take training when training is lengthy; only those with taste sufficiently high to compensate for making the commitment to serve through the end of the obligation associated with training will choose to take training. As a result, the percentage of people who take the longer training is lower than the percentage who take the shorter training, 99.3 percent versus 100 percent. If the increase in the external wage was lower, 1 percent instead of 3 percent, then the percentage of people who would voluntarily take the training would be much lower, 51.1 percent. This difference illustrates the importance of external wage opportunities as a determinant of willingness to take training.

Figure 4.4. The Drop in Retention Is Less Severe If the Training Length Is Longer

Six-Month Training Length	One-Year Training Length

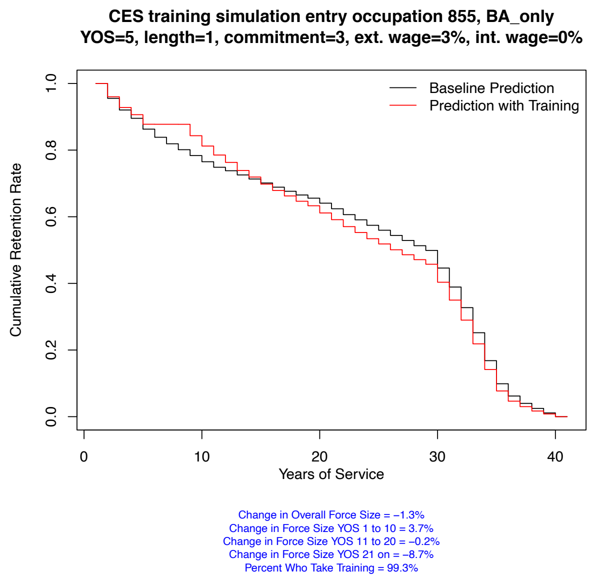


SOURCE: Authors' calculations using the RAND DRM.

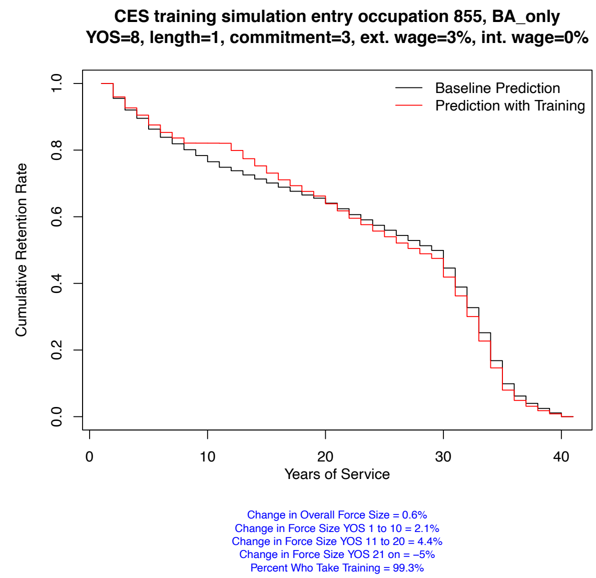
The drop is also less severe if the training occurs later in the career. This is because, as each year passes, the workers who remain tend to be those who have a higher taste for their job compared with those workers who leave. As a result, the population of workers in higher YOS has a higher mean taste: that is, higher job attachment on average. Thus, the increase in the external opportunity wage has less of an effect on overall retention. This effect can be seen in Figure 4.5. The left panel shows the retention effect of training offered in the fifth YOS, whereas the right panel shows it for the eighth YOS. The remainder of the model parameters are the same, which isolates the effect of the timing of training. Overall retention falls by 1.3 percent if training is offered in the fifth YOS but increases by 0.6 percent if training is deferred by three years to the eighth YOS.

Figure 4.5. The Drop in Retention Is Less Severe If Training Occurs Later in the Career

Training at YOS 5



Training at YOS 8

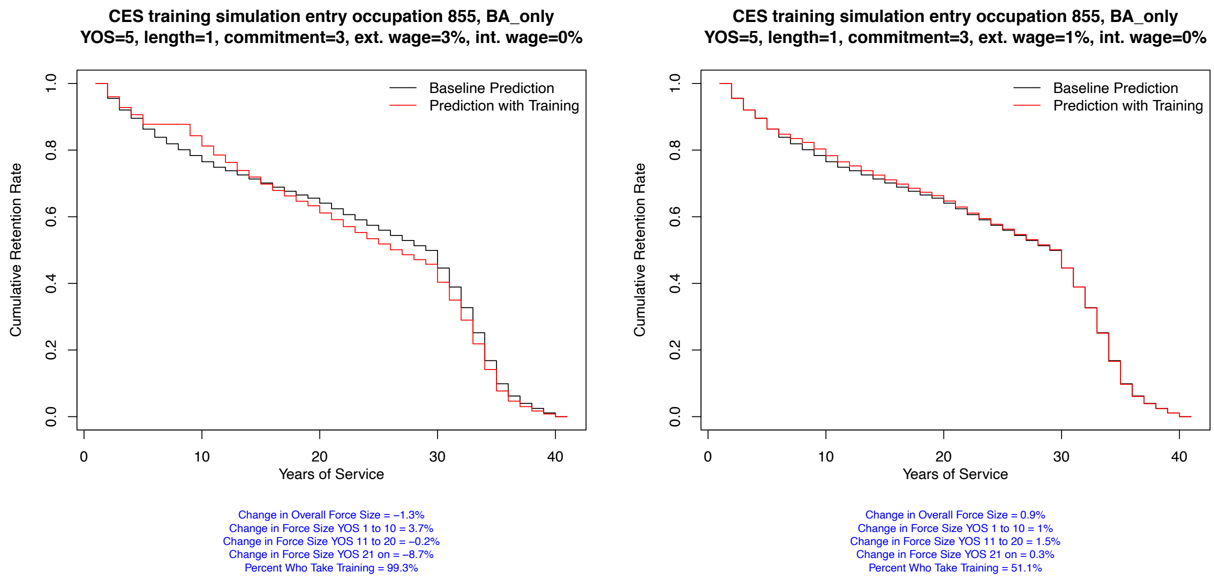


SOURCE: Authors' calculations using the RAND DRM.

The drop is also less severe if the external wage increase is lower. When the external wage increase is lower, fewer people will be motivated to take the training, and thus fewer people will be subject to the increase in external opportunity wage. In addition, the retention effect of the external wage increase will be lower on those who complete training. This can be seen in Figure 4.6, which compares the effect of a 3 percent increase in external wage with a 1 percent increase in external wage. The 3 percent increase leads to a drop of 1.3 percent in the overall force size, whereas the 1 percent increase results in a 0.9 percent *increase* in overall force size. The value of the training serves to increase overall retention in the case in which the increase in the external wage is relatively small.

Figure 4.6. The Drop in Retention Is Less Severe If External Wage Increase Is Lower

3% Increase in External Wage	1% Increase in External Wage

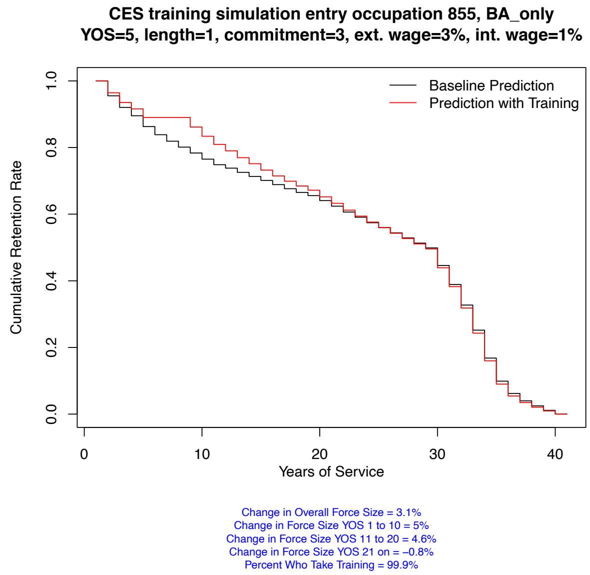


SOURCE: Authors' calculations using the RAND DRM.

Training With a Payback Obligation and Internal Pay Increase

Training with a payback obligation and an increase in CES pay can increase retention over the career. Consider the scenario shown in Figure 4.7. It is identical to the scenario shown in Figure 4.3, with the exception that the internal pay is increased by 1 percent. Retention no longer drops precipitously following completion of the training service obligation, and overall retention rises by 3.1 percent.

Figure 4.7. Training With a Payback Obligation and an Increase in CES Pay Can Increase Retention



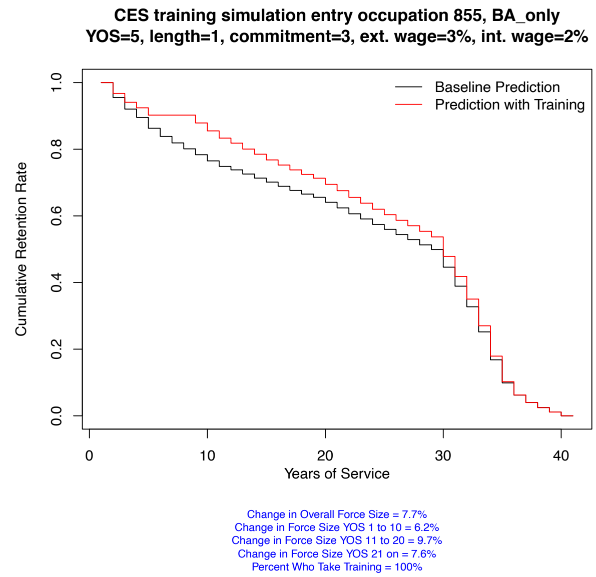
SOURCE: Authors' calculations using the RAND DRM.

One thing to note is that the increase in the internal wage does not have to match the increase in the external wage to be effective in sustaining retention. In the example shown in Figure 4.7, a 1 percent internal increase was sufficient to counter a 3 percent external wage increase. This is because of the higher retention brought about by training and the payback obligation helping to compensate for the steeper decline in retention after completion of the payback obligation.

In general, the positive retention effect is larger if the CES pay increase is larger. The effect of the CES pay increase is moderated by the both the length and timing of training. If the training (and payback obligation) length is shorter, the posttraining drop in retention remains unless the CES pay increase is sufficiently high. Similarly, if training occurs earlier, then the posttraining dropoff remains unless CES pay is raised sufficiently.

Unsurprisingly, a larger increase in CES pay produces a larger retention effect over the career, as can be seen in Figure 4.8. A larger CES pay increase (in this case, a 2 percent increase versus the 1 percent increase shown in Figure 4.7) induces higher retention and offsets the posttraining drop in retention. Overall retention now increases by 7.7 percent instead of 3.1 percent.

Figure 4.8. A Larger Increase in CES Pay Produces a Larger Retention Effect over the Career

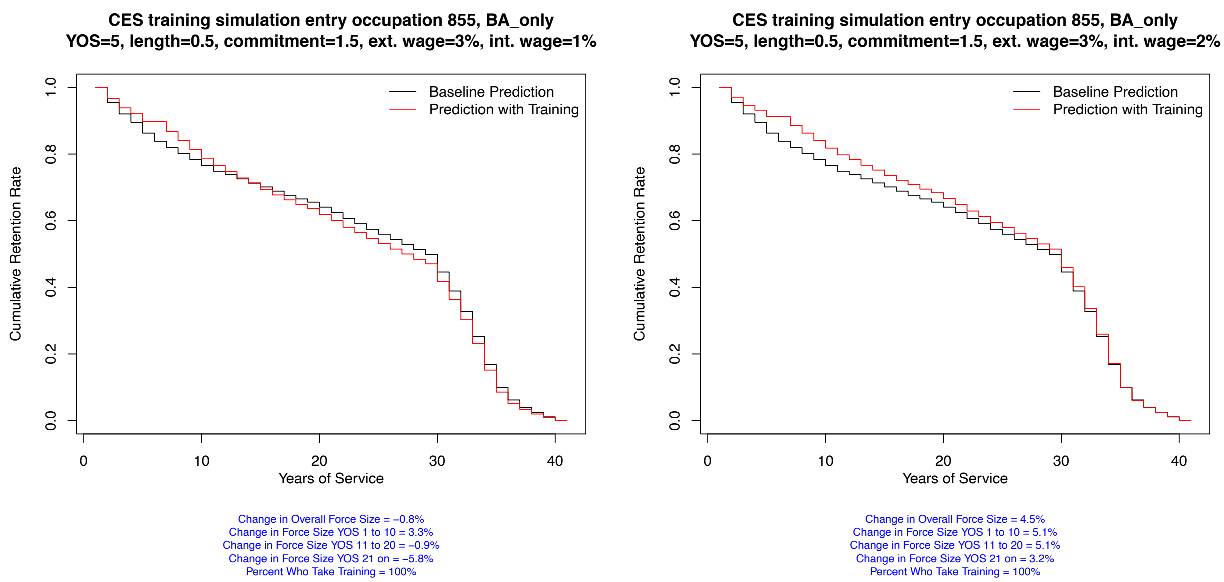


SOURCE: Authors' calculations using the RAND DRM.

If training length is shorter, the posttraining drop in retention remains, unless the CES pay increase is sufficiently large, as can be seen in Figure 4.9. Both panels show a scenario in which a six-month training course followed by an 18-month service obligation result in a 3 percent increase in the external opportunity wage. In the left panel, the internal wage increases by 1 percent on completion of training, while in the right panel, the internal wage increase is doubled to 2 percent. The overall retention declines by 0.8 percent if the internal wage rises by 1 percent, but the overall retention increases by 4.5 percent if the internal wage increases by 2 percent. In both scenarios, retention increases in the early career (YOS 1–10) by 3.3 percent and 5.1 percent, respectively. The early career retention increase is in part because of an anticipation effect, which can be seen by the gap between the red and black lines in YOS 2–5: The anticipated option to pursue training helps to maintain retention. The early career retention increase is further supported by the high rate of participation in training—100 percent participate under both scenarios—which leads to no losses in YOS 5–6. Finally, the increase in early career retention benefits from the increase in the internal wage that occurs on completion of training, resulting in a lower negative slope under both scenarios in YOS 7–10, compared with the scenario in which there is no internal wage increase (as in the left panel of Figure 4.4).

Figure 4.9. If the Training Length Is Shorter, a Higher Internal Wage Might Be Needed to Sustain Retention

Training Length = 0.5 Years 1% Increase in Internal Wage	Training Length = 0.5 Years 2% Increase in Internal Wage



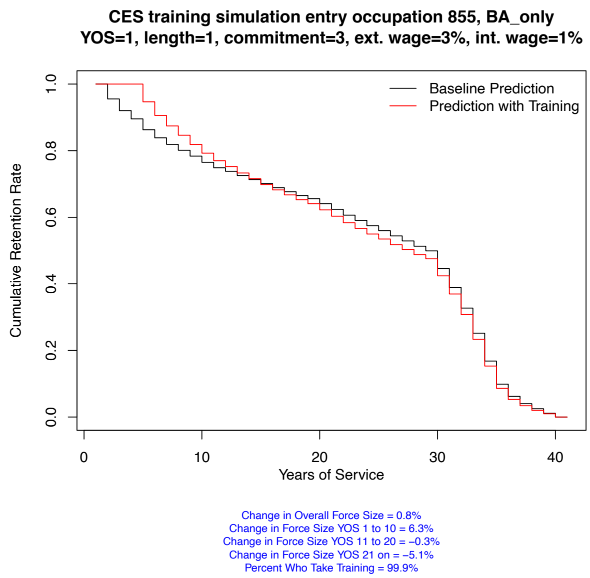
SOURCE: Authors' calculations using the RAND DRM.

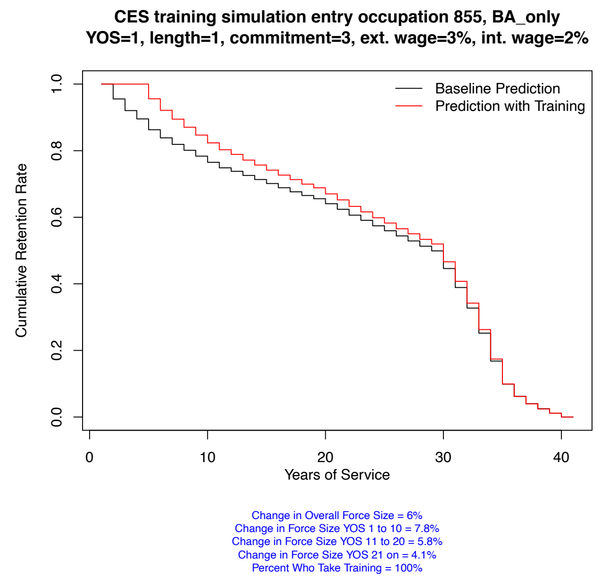
Note again that retention increases even though external wages rise by more than the increase in internal wages (albeit for only part of the career in the scenario depicted in the left panel of Figure 4.9). This is because of the service obligation and its positive effect on retention. To prevent people leaving when the obligation is over, the internal pay increase must be greater than zero but can be less than the increase in external wages.

As Figure 4.10 illustrates, the posttraining drop also happens if training is earlier in a career. The drop in retention is larger if training happens earlier in a career, as the individuals present later in a career tend to be those with higher taste for their job (i.e., greater intrinsic job attachment). In general, the later in the career that training is offered, the smaller the drop in retention on completion of training and any concomitant service obligation.

Figure 4.10. If the Training Occurs in an Earlier YOS, the Posttraining Drop in Retention Still Happens

Training YOS = 1 1% Increase in Internal Wage	Training YOS = 1 2% Increase in Internal Wage





SOURCE: Authors' calculations using the RAND DRM.

Involuntary Training

As noted, in all our scenarios, training is voluntary. Individuals are free to choose whether to avail themselves of the training and thus whether to incur any associated training obligation. Thus, individuals in our scenarios face three alternatives in the YOS when training occurs: (1) stay, take the training, and revisit their decision to stay once the training and any service obligation has been completed; (2) stay, do not take the training, and revisit the decision to stay in the next period; or (3) leave. If training and any associated service commitment is involuntary, then the decision is reduced to two alternatives: (1) stay, take the training, and revisit their decision to stay once the training and any service obligation has been completed or (2) leave. This scenario could be implemented in the model by restricting simulated individuals to the latter two choices and eliminating the alternative of staying without taking training. We expect that, under such a restriction, the broad results of our model would still hold, in that any training that improves external opportunities on net would cause year-to-year retention to fall relative to the baseline once any payback obligation has completed. We also expect that the negative retention effect would be larger under the same conditions in which it is larger in the "voluntary" model. The main difference in the model with involuntary training would be an increase in the level of attrition associated with those people who would have preferred to stay and not the take the training. These people would tend to attrite prior to the year in which training is offered.

Summary

Training, by itself, can improve retention only in the YOS prior to when the training is offered and for the duration of the training and payback obligation, although there might be some natural attrition. On completion of the payback obligation, any training that improves external opportunities on net will cause year-to-year retention to fall relative to the baseline. This negative retention effect is larger when the improvement in external opportunities is larger, when training (and the associated payback obligation) is shorter, and when training occurs earlier in the career, when the population of workers includes more people with lower taste for the job. Conversely, the negative retention effect is smaller when the improvement in external opportunities is smaller, when training (and the payback period) is longer, and when training occurs later in the career, as the population remaining later in the career tends to include those with more attachment to their jobs.

Training with a payback obligation produces only a temporary improvement in retention if internal pay does not also increase. The increase in internal pay in general does not need to match the increase in external pay to be sufficient to cause a net increase in retention because of the improved retention for the duration of training and the payback obligation.

Chapter 5. Conclusions

In this report, we assess the retention effects of training for the CES workforce by extending RAND's DRM capability to four CES occupations and simulating alternative hypothetical training scenarios that vary aspects of training. We considered hypothetical scenarios because CES training is still under development, and we wanted to provide the results of several potential options to help DoD choose which best serves its needs. In addition, we were unable to obtain and assess detailed descriptions of existing CES training programs used in DoD. We also provide descriptive statistics on retention, promotion, and pay for DoD civilian cyber workers, and we describe differences by occupation series and type of pay plan.

We find that when training improves the external pay opportunities of CES personnel, retention declines if the training does not also involve a "payback" service obligation. This negative retention effect is larger when the improvement in external opportunities is larger and when training occurs earlier in the career. In the latter case, the retention effect is larger because more-junior workers have less attachment to the CES workforce (and more years remaining in their careers to enjoy the higher external income), so a given improvement in external opportunities has a larger negative retention effect.

We also find that training with a payback obligation can mitigate the negative effects on retention resulting from improved external opportunities, but this mitigation effect is temporary if internal CES pay does not increase. That is, retention is improved during the training and posttraining obligation periods, but once the obligation is over, retention drops as workers who postponed their separation until the obligation is over leave. This postobligation drop in retention is smaller if training is longer or the training occurs later in the career. In both cases, workers who choose longer training or who undertake training later in their careers have a stronger attachment to the CES workforce, so the negative retention effect is less.

Retention improves when internal CES pay increases. In the context of the training scenarios, we find that the drop in the retention rate of workers associated with improved external opportunities can be offset with a sufficiently high internal pay increase. In our model, we do not explicitly consider whether this pay increase occurs through faster promotion or faster pay increases within a pay grade.

To sum up, training is an essential component of initial and ongoing skill development and is especially important in cyber, where technology changes at a rapid pace. Although training is necessary to ensure the continual productivity of the DoD cyber workforce, an aggressive training policy should be accompanied by the development of internal opportunities and pay commensurate with external opportunities; otherwise, trained personnel will have a relative disincentive to stay assuming their training is equally valuable and remunerative elsewhere.

Therefore, training policies should not be developed in isolation but in concert with internal pay, opportunities for advancement, and engaging work experiences.

In our descriptive analysis, we find differences in demographics, retention, promotion, and pay between cyber workers and the rest of DoD and across cyber occupation series. We find differences in retention across pay plans for only one occupation series (2210, Information Technology Management). Our descriptive estimates should not be taken to be causal, as we generally do not control for characteristics (observed or unobserved) of employees in different occupation series or pay plans that might be associated with differences in retention, promotion, or pay. In that vein, our analysis should not be taken as an assessment of the adequacy of retention rates, promotion rates, or pay for civilian cyber workers at DoD but instead as simply an assessment of differences in these variables across occupational series and pay plans.

Areas for Future Research

The results presented in this report suggest several areas where more research might be useful for additional understanding of the DoD civilian cyber workforce.

Our analysis in Chapter 2 found that, although cyber employees in pay-banded pay systems are typically paid more than GS/GG cyber employees who are otherwise similar, retention is higher for pay-banded employees in the IT management occupation series (2210) only. That is, for three of the four cyber occupations we studied, pay bands are not associated with higher retention, despite higher pay. It is possible that, rather than having no effect on retention, pay-banded pay schedules might be acting as a compensating differential to offset negative nonpecuniary characteristics, such as undesirable locations of pay-banded organizations, that lead to lower retention. In addition, there might be systematic unobserved differences between the types of employees on the GS/GG system and pay-banded pay schedules, leading to different retention outcomes. Future research should identify the following:

- differences between pay-banded and GS/GG cyber workers
- nonpecuniary differences between pay-banded and GS/GG cyber worker jobs and jobsites.

Several extensions to the DRM might be fruitful. The DRM used in this report could be extended to examine pay-banded cyber employees, who make up the majority of the computer engineering, electrical engineering, and computer science occupational series. Outside of cyber, and as noted by Knapp, Asch, et al., 2016, the DRM could be extended to focus on other priority occupation groups in DoD, other pay systems, particular demographic groups, particular locations of interest, or other parts of the federal civil service. Finally, as training for cyber workers matures and becomes fully developed, future research should assess the retention effects of specific training programs.

Appendix A. Pay Bands at DoD

There are several pay-banded pay plans used for cyber employees at DoD. Assignment to a pay-banded pay plan is determined by where in DoD an employee works, rather than by occupation: Some DoD organizations implemented pay-banded pay systems for their employees, and the distribution of employees in different occupations between the GS/GG system and pay-banded pay plans is determined by the distribution of those employees across DoD organizations. Each organization generally has several pay-banded schedules that employees are assigned to based on their occupational series. There are three areas within DoD that had pay-banded pay schedules between FY 2014 and FY 2018: the intelligence community, the acquisition community, and Science and Technology Reinvention Laboratories (STRL).

Pay-banded employees in the intelligence community were under the Defense Civilian Intelligence Personnel System (DCIPS) beginning in FY 2009, and DCIPS ended in FY 2021. DCIPS had five pay bands, and assignment to those depended on education level and occupation (Intelligence Community Directive Number 652, 2008; DCIPS, undated). Although some cyber employees were on the DCIPS pay bands between 2009 and 2011, no cyber employees were on this pay band system by FY 2018.

Pay-banded employees in the acquisition community are under AcqDemo, which was established in 1998, converted to NSPS in 2006, and was reinstated in 2011 with the end of NSPS. Organizations with an acquisition mission can voluntarily participate in AcqDemo. All cyber employees in AcqDemo are assigned to the same pay-banded pay schedule (DoD, undated; see also 82 FR 52104 at DoD, 2017). Previous RAND research suggests that employees in AcqDemo have higher salaries but similar retention compared with GS/GG acquisition employees (Lewis et al., 2017).

STRL is a general term for several research labs overseen by DoD and the services. STRL employees in general were moved to pay-banded pay plans in 2012 after the end of NSPS, but employees at the Army Research Lab were under a pay-banded pay plan as early as 1998. Generally speaking, the pay band a position is assigned to is determined by occupational series. In most cases, all cyber employees are on the same pay-banded plan, but under Army Research Lab, series 2210 is on a different pay-banded plan from the other cyber occupations (DoD, 2010; DoD, 2020).

Table A.1 shows the number of employees from each occupation on the AcqDemo and STRL pay bands.

Table A.1. Distribution of Cyber Employees Between Pay-Banded Systems

Occupation	Number of Employees on AcqDemo	Number of Employees on STRL Pay Bands
Series 854	340	2,229
Series 855	3,496	8,315
Series 1550	955	4,375
Series 2210	1,657	4,000

SOURCE: Authors' calculations using the 2000–2019 DoD Civilian Master File and DoD Civilian Pay File from DMDC.

Differences in Demographics Between Pay-Banded and GS/GG Employees

Table A.2 provides descriptive statistics for cyber employees, divided into GS/GG and pay bands.

Table A.2. Descriptive Statistics by Occupation and Pay Plan

	GS/GG Employees					Pay-Banded Employees				
	Series 854	**Series 855**	**Series 1550**	**Series 2210**	**Rest of DoD**	**Series 854**	**Series 855**	**Series 1550**	**Series 2210**	**Rest of DoD**
Education Level										
% Less Than BA	1.11%	1.68%	0.85%	47.13%	46.15%	0.67%	0.26%	0.79%	38.63%	20.52%
% BA	60.70%	66.55%	65.75%	34.56%	31.44%	58.29%	57.21%	63.48%	39.85%	37.88%
% More Than BA	38.19%	31.74%	33.40%	18.26%	22.36%	41.04%	42.53%	35.74%	21.53%	41.59%
% Unknown	0.00%	0.03%	0.00%	0.04%	0.04%	0.00%	0.00%	0.00%	0.00%	0.01%
Veteran Status										
% Veteran	13.36%	17.31%	18.97%	58.38%	50.18%	12.07%	13.64%	14.37%	54.34%	34.22%
% Not a Veteran	86.64%	82.69%	81.03%	41.62%	49.82%	87.93%	86.36%	85.63%	45.66%	65.78%
Race and Ethnicity										
% White	54.67%	58.07%	66.60%	67.88%	66.01%	65.42%	67.15%	69.87%	73.39%	77.66%
% Black	6.53%	7.61%	8.99%	16.01%	17.09%	7.84%	6.58%	8.22%	11.57%	9.78%
% Hispanic	10.45%	10.16%	6.23%	6.12%	7.14%	7.53%	5.55%	4.26%	5.08%	4.85%
% Other	25.43%	21.67%	15.07%	7.33%	7.37%	17.38%	18.70%	15.56%	7.46%	5.83%
% Unknown	2.91%	2.49%	3.11%	2.66%	2.39%	1.83%	2.03%	2.09%	2.50%	1.88%

	GS/GG Employees					Pay-Banded Employees				
	Series 854	Series 855	Series 1550	Series 2210	Rest of DoD	Series 854	Series 855	Series 1550	Series 2210	Rest of DoD
Retirement Eligibility										
% Eligible to Retire	28.84%	37.04%	19.75%	37.98%	36.30%	23.57%	45.10%	21.71%	29.94%	37.51%
% Not Eligible to Retire	71.16%	62.96%	80.25%	62.02%	63.70%	76.43%	54.90%	78.29%	70.06%	62.49%
Gender										
% Female	15.58%	12.36%	23.35%	25.87%	45.50%	15.82%	12.03%	23.10%	24.06%	34.03%
% Male	84.42%	87.64%	76.65%	74.13%	54.50%	84.18%	87.97%	76.90%	75.94%	65.97%
Mean Age at Entry to Federal Service	32.81	32.84	32.35	38.97	15.01	31.07	33.67	33.09	40.37	35.47
Mean Tenure	13.94	15.12	9.71	15.01	14.50	12.57	18.57	11.44	11.97	15.71

SOURCE: Authors' calculations using DMDC data.
NOTE: Within occupations, differences between GS/GG and pay bands are statistically significant at a 5 percent level for retirement eligibility, race/ethnicity, tenure in federal service, and age at entry to federal service in series 854; retirement eligibility, educational attainment, race/ethnicity, tenure in federal service, and age at entry to federal service in series 855; veteran status, race/ethnicity, tenure in federal service, and age at entry to federal service in series 1550; and retirement eligibility, veteran status, educational attainment, race/ethnicity, tenure in federal service, and age at entry to federal service in series 2210.

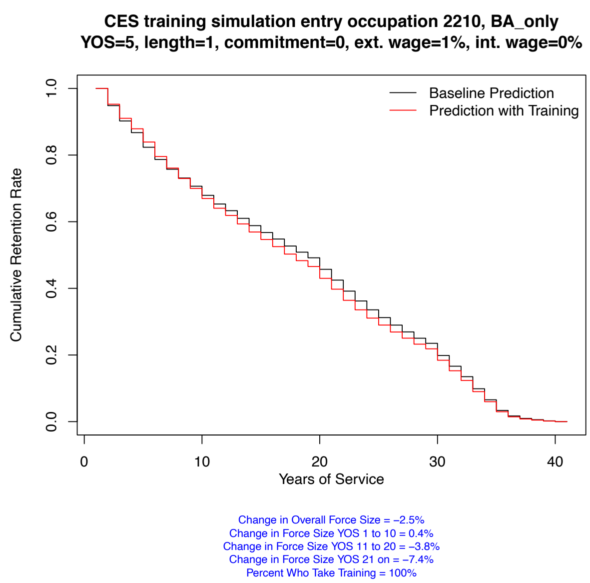
Appendix B. Training Simulation Results for Series 2210

As we mentioned in Chapter 4, the results of the training policy simulations are qualitatively similar across occupations. To demonstrate this qualitative similarity, we have replicated the scenarios we explored in Chapter 4 for occupation 855, the Electronics Engineering Series, using series 2210, the Information Technology Management Series. Although the specific quantitative results are different, the qualitative results are replicated.

Results

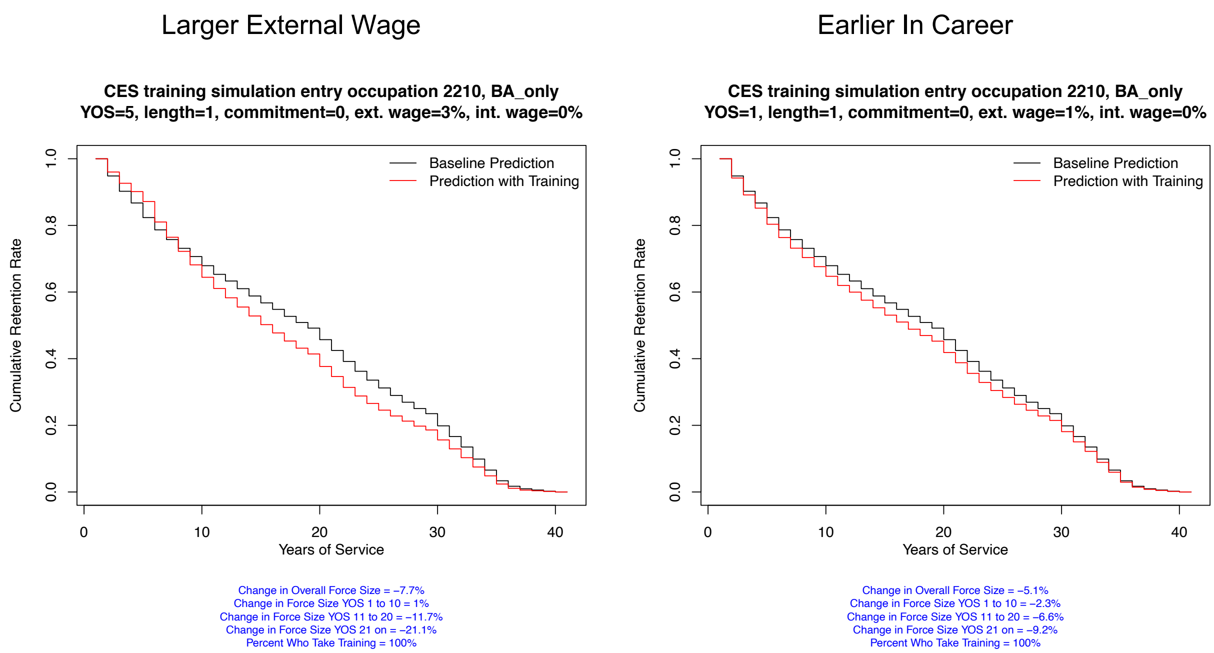
Training Without a Payback Service Obligation

Figure B.1. Training Without a Payback Obligation Reduces Retention



SOURCE: Authors' calculations using the RAND DRM.

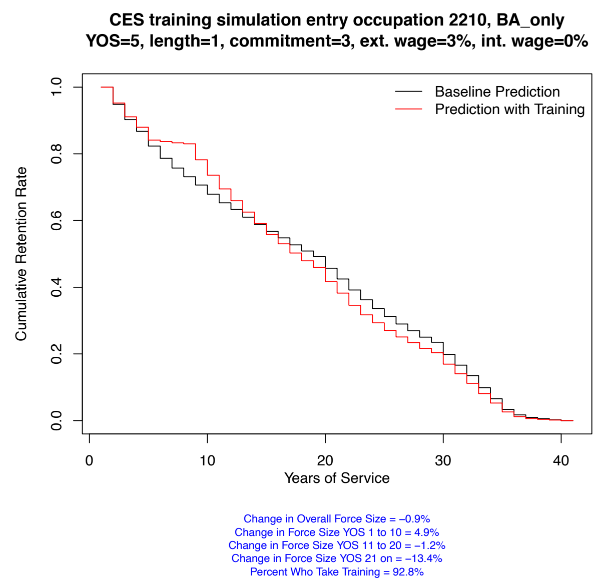
Figure B.2. Negative Retention Effect Is Larger If External Wage Is Larger or Training Occurs Earlier



SOURCE: Authors’ calculations using the RAND DRM.

Training With a Payback Service Obligation

Figure B.3. Training With Payback but No Internal Wage Increase Might Result in a Temporary Increase in Retention

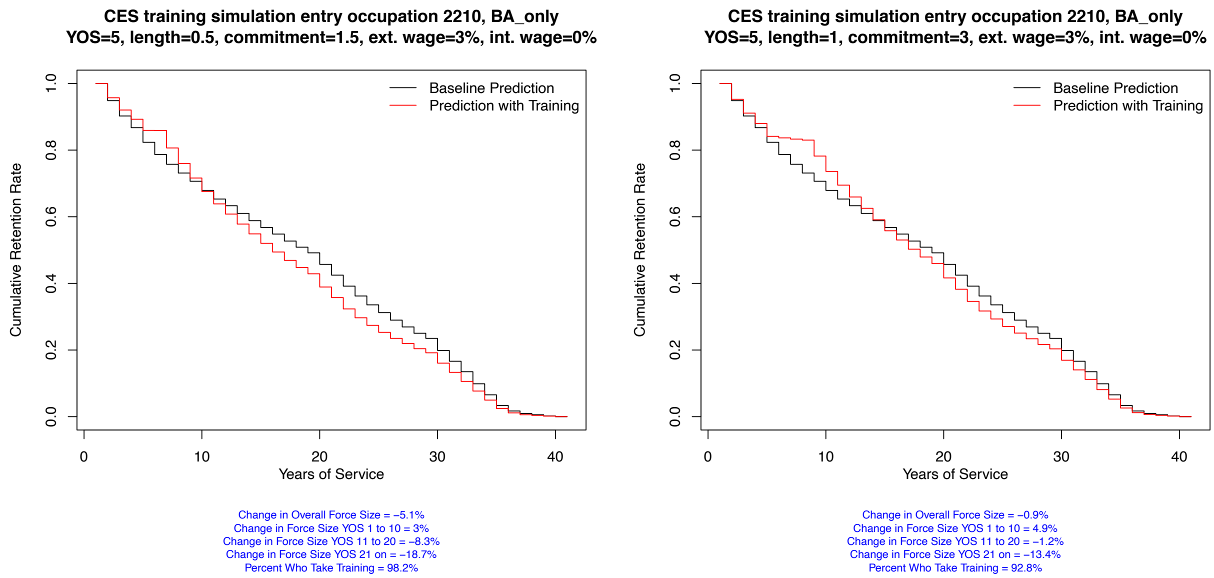


SOURCE: Authors' calculations using the RAND DRM.

Figure B.4. The Drop in Retention Is Less Severe If the Training Length Is Longer

Six-Month Training Length

One-Year Training Length

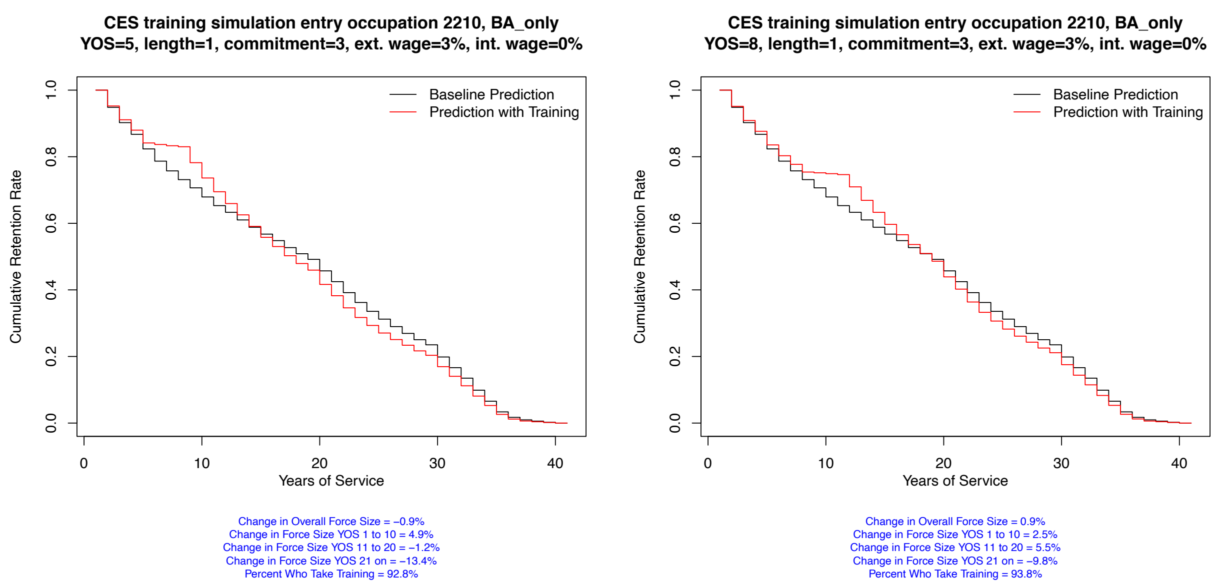


SOURCE: Authors' calculations using the RAND DRM.

Figure B.5. The Drop in Retention Is Less Severe If Training Occurs Later in the Career

Training at YOS 5

Training at YOS 8

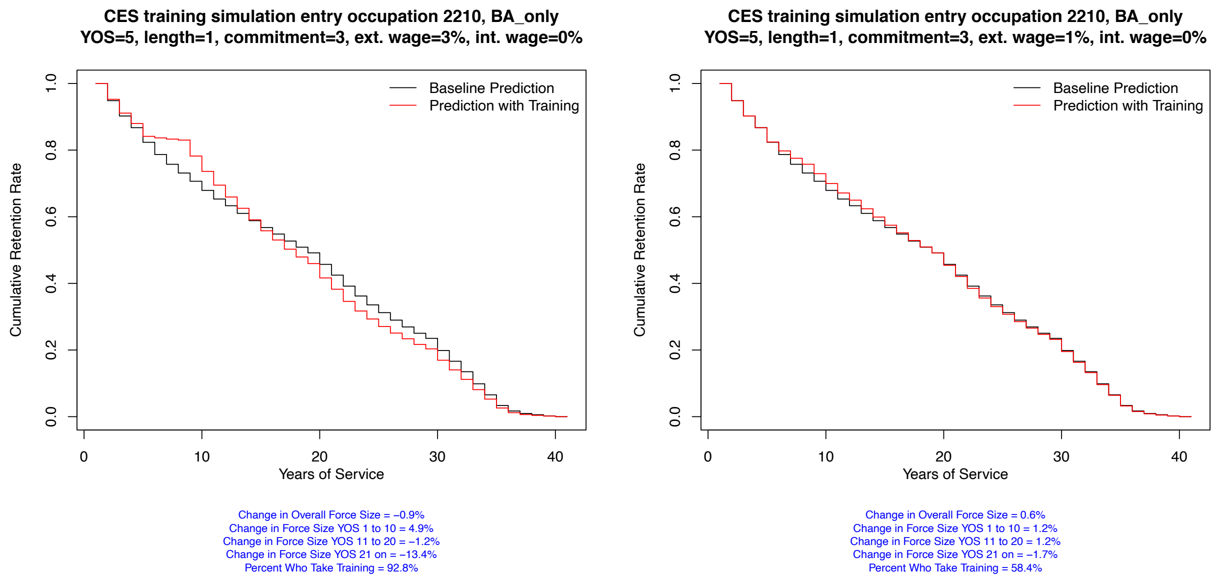


SOURCE: Authors' calculations using the RAND DRM.

Figure B.6. The Drop in Retention Is Less Severe If External Wage Increase Is Lower

3% Increase in External Wage

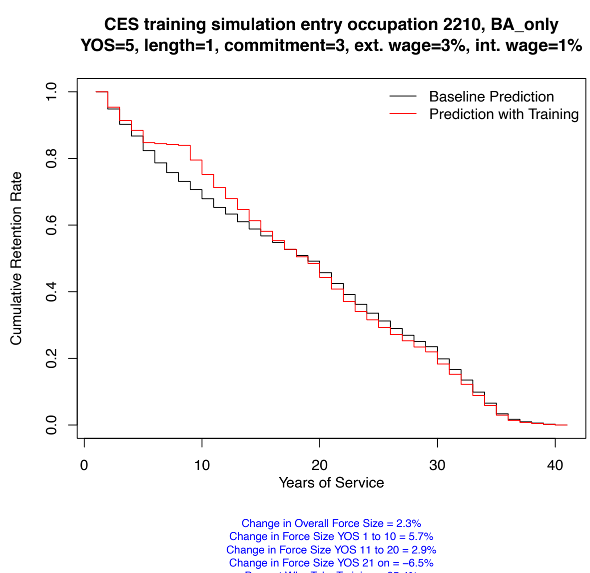
1% Increase in External Wage



SOURCE: Authors' calculations using the RAND DRM.

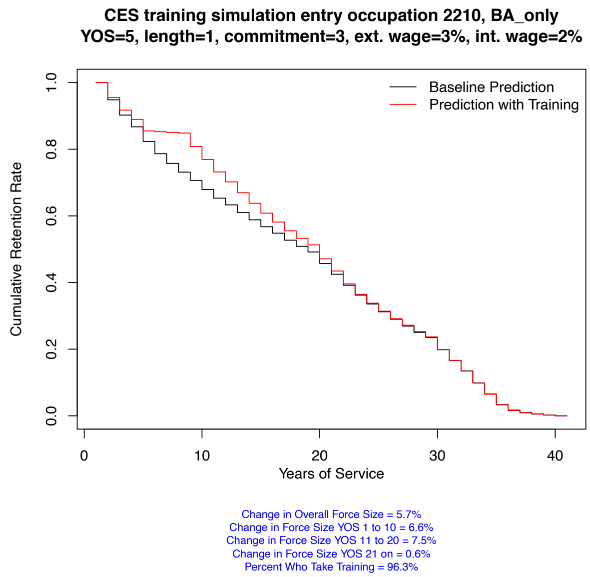
Training With a Payback Obligation and Internal Pay Increase

Figure B.7. Training With a Payback Obligation and an Increase in CES Pay Can Increase Retention



SOURCE: Authors' calculations using the RAND DRM.

Figure B.8. A Larger Increase in CES Pay Produces a Larger Retention Effect over the Career

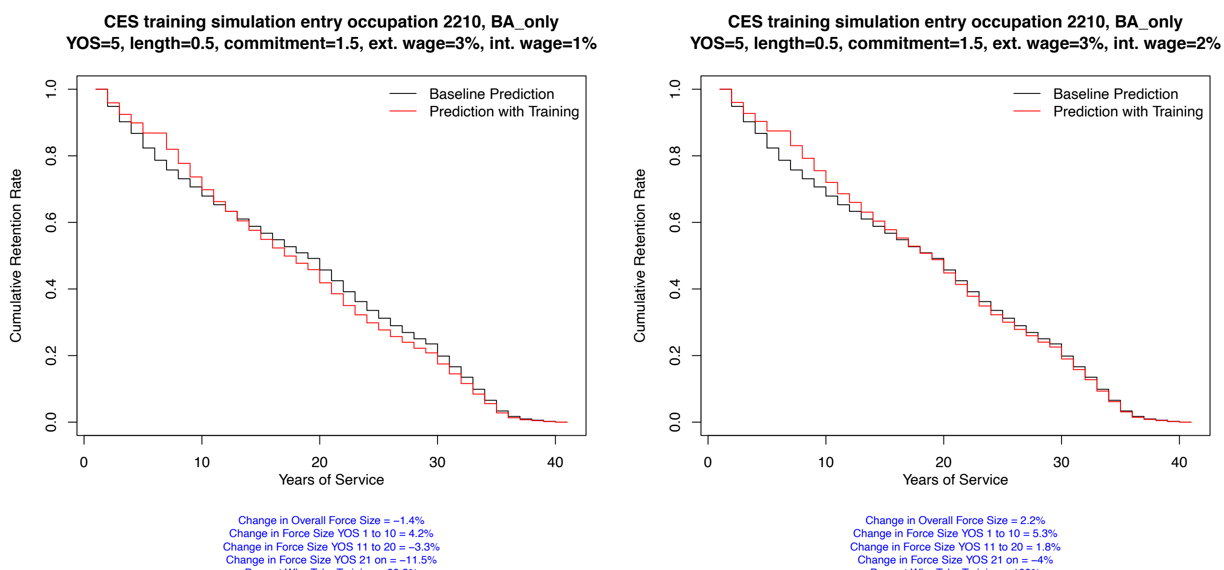


SOURCE: Authors' calculations using the RAND DRM.

Figure B.9. If the Training Length Is Shorter, a Higher Internal Wage Might Be Needed to Sustain Retention

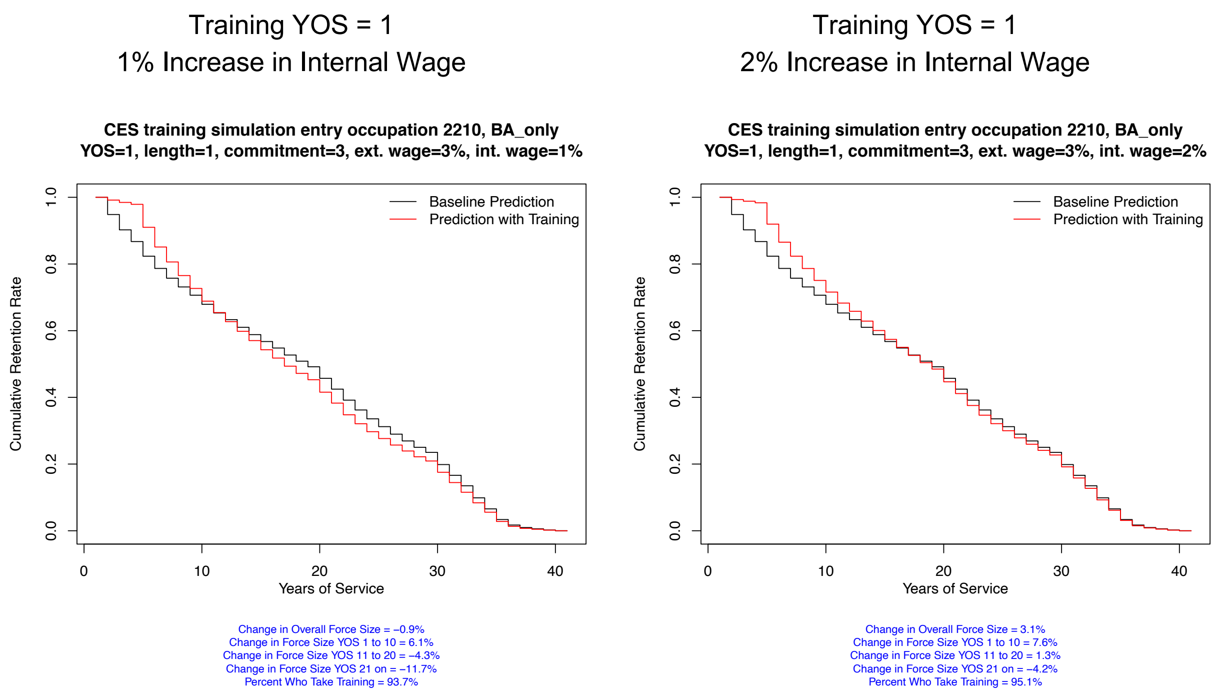
Training Length = 0.5 Years
1% Increase in Internal Wage

Training Length = 0.5 Years
2% Increase in Internal Wage



SOURCE: Authors' calculations using the RAND DRM.

Figure B.10. If the Training Occurs in an Earlier YOS, the Posttraining Drop in Retention Still Happens



SOURCE: Authors’ calculations using the RAND DRM.

Abbreviations

AcqDemo	Civilian Acquisition Workforce Personnel Demonstration Project
ACS	American Community Survey
BA	bachelor's degree
CES	Cyber Excepted Service
DCIPS	Defense Civilian Intelligence Personnel System
DCWF	DoD Cyber Workforce Framework
DMDC	Defense Manpower Data Center
DoD	U.S. Department of Defense
DRM	dynamic retention model
FY	fiscal year
GG	government grade
GS	general schedule
IT	information technology
K-M	Kaplan-Meier
NSPS	National Security Personnel System
OPM	U.S. Office of Personnel Management
STRL	Science and Technology Reinvention Laboratories
YOPE	year(s) of potential experience
YOS	year(s) of service

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Given the importance of the civilian workforce to U.S. Department of Defense's (DoD's) cyber mission, it is imperative to understand how pay, promotion, and retention has varied over time and to continue to identify and refine strategies for retaining civilians with cyber expertise. After establishing that these personnel outcomes vary across cyber occupations and differ from the outcomes for the rest of DoD, researchers explore how training might be used as a retention lever for cyber employees.

Training is an essential component of initial and ongoing skill development and is especially important in cyber where technology changes at a rapid pace. Although training is necessary to ensure the continual productivity of the DoD cyber workforce, simulation results suggest that an aggressive training policy should be accompanied by the development of internal opportunities and pay commensurate with external opportunities. Otherwise, trained personnel will have a relative disincentive to stay, assuming their training is equally valuable and remunerative elsewhere. Therefore, training policy should not be developed in isolation but in concert with internal pay, opportunities for advancement, and engaging work experiences.

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