Nuclear Officer Retention:  
An Economic Model

Michael K. Nakada
James P. Boyle

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Nuclear Officer Retention: An Economic Model

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13. ABSTRACT (Maximum 200 words)
    From FY91 through FY94, the average retention rate at the end of the minimum service requirement (MSR) for nuclear-trained officers dropped to 60 percent from 70 percent, the average MSR retention rate from FY87 through FY90. To combat low retention in this community, the Nuclear Officer Incentive Pay (NOIP) program was designed, but its legislative authorization expires in FY96.

    This report documents the results of an investigation of historical nuclear officer retention behavior at the end of their minimum service requirement. It specifies a 3-choice model and quantifies the impact of the NOIP retention bonus program on MSR retention.

    Separate models of retention at MSR were estimated for the submarine and surface nuclear officer communities. For both communities, the retention elasticities with respect to the NOIP retention bonus program were small, but significant indicating the "pay does matter."

    These models can be used to assess the retention and cost impacts of alternative NOIP retention strategies.

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Foreword

This report was prepared as part of the New Modelling Systems to Forecast the Effects of Compensation on Officer and Enlisted Retention Behavior project (Program Element 0603707N), under the sponsorship of the Chief of Naval Personnel (PERS-2). The objective of this project is to quantify the effect of the Nuclear Officer Incentive Pay program on nuclear officer retention at the conclusion of their minimum service requirement. The work described here was performed in FY95 and FY96.

DENNIS SCHURMEIER
Director
Workforce Management
Summary

Background

In today’s Navy, nuclear-powered ships represent nearly 50 percent of the major combatants. Nuclear-trained officers, on the other hand, constitute only 16 percent of the Navy’s unrestricted line officers. In recent years, the community has been plagued by accession shortfalls, high training attrition, and low retention. For example, from FY91 through FY94, the average percentage rate of officers staying in the Navy at the end of their minimum service requirement dropped to 60 percent from 70 percent, the average percentage rate from FY87 through FY90.

The Nuclear Officer Incentive Pay (NOIP) program was designed to combat low retention in this community, but its legislative authorization expires in FY96. To justify new authority for NOIP, current estimates of its effects on retention were needed.

Objective

The objective of this project was to quantify the effect of the NOIP program on nuclear officer retention at the end of their minimum service requirement (MSR).

Approach

The approach included: (1) developing a model of retention behavior at MSR, and (2) estimating and validating the model.

Results

Separate models of retention at MSR were estimated for the submarine and surface nuclear officer communities. For both communities, the retention elasticities with respect to the Continuation Pay (COPAY) and the Annual Incentive Bonus (AIB) were small. COPAY and AIB are the NOIP program’s retention incentives. For submarine officers, the retention rate elasticity with respect to COPAY was .11. That is, for a 10 percent increase (decrease) in COPAY, a 1.1 percent increase (decrease) in the MSR retention rate for submarine officers was estimated. For surface warfare officers, the retention rate elasticity with respect to COPAY was .39. The retention rate elasticity with respect to AIB for submarine officers was .11; for surface warfare officers, it was .48.

Conclusions

Most retention-compensation research finds that “pay does matter.” While the retention bonus elasticities found in these models are relatively small, their statistical significance also points to the fact that pay matters. These models can be used to assess the retention and cost impacts of alternative NOIP retention strategies.
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8. $P_C$, $P_A$, and $P_L$ Elasticities with Respect to a 10 Percent Change in AIB ........ 10
**Introduction**

In today's Navy, nuclear-powered ships represent nearly 50 percent of the major combatants. Nuclear-trained officers, on the other hand, constitute only 16 percent of the Navy's unrestricted line officers. Demanding scholastic requirements and attractive civilian opportunities have always made recruiting of qualified nuclear officer candidates difficult. From FY81 to FY94, the nuclear submarine officer community made its accession goal in only 3 of the 14 years. Moreover, from FY91 through FY94, the average percentage rate of officers staying in the Navy at the end of their minimum service requirement dropped to 60 percent from 70 percent, the average percentage rate from FY87 through FY90.

The Nuclear Officer Incentive Pay (NOIP) program was initiated in June 1969 to combat the chronic shortage of nuclear-trained submarine officers. Over the years, authorization for the NOIP program has been expanded; nuclear-trained surface warfare officers are now covered under NOIP. Annual payment amounts have also increased. The current authorization, which was enacted in 1987 and expired in 1996, provided for up to $12,000 per year in Continuation Pay (COPAY), $7,200 per year for the Annual Incentive Bonus (AIB), and an accession bonus of $6,000.

Research on the effects of NOIP on nuclear officer retention is long overdue. This issue was last studied in 1981 (CNA 81-0130). New legislative authority for NOIP required more current estimates of its effects on retention.

**Approach**

The approach included: (1) developing a model of retention behavior, and (2) estimating and validating the model.

**Data**

The primary data source for this research was the Navy's Officer Master File. Cohorts of nuclear-trained officers were assembled and tracked by Social Security Number. Cohorts were categorized by the fiscal year in which officers were commissioned. Complete officer data prior to FY74 was not available. Thus, the first cohort in the data set was the FY74 cohort.

The data set contained 10,357 officers. Only unrestricted line officers were considered; limited duty and warrant officers (149 observations) were dropped from the data set. Censored observations totalling 2,121 officers were also deleted. Officers were censored if: (1) they had not completed their minimum service requirement (MSR) (1,817 observations), or (2) they attrited prior to MSR (304 observations).

From the remaining 8,087 observations, 589 additional officers, many who had prior enlisted service and others who had missing data, were excluded from the final data set. The data set that was used to estimate and validate the models, then, contained 7,498 observations. Approximately 10 percent of the 7,498 observations, or 743 officers, were set aside for model validation.

The end of the minimum service requirement for most nuclear officers in this data set was 5 years after commissioning. For the first cohort, the FY74 cohort, most of the officers made their
initial stay-leave decision in FY79. Similarly, for the last cohort, the FY89 cohort, their initial stay-leave decision occurred in FY94. For FY79 through FY94, the following percentages were computed:

CONTRACT Participation Rate = \frac{\# \text{ Making a Decision to Stay in the Navy w/ Contract in FY}}{\# \text{ Eligible to Make a Stay - Leave Decision in FY}} \times 100\%

NOCONTRACT Participation Rate = \frac{\# \text{ Making a Decision to Stay in the Navy w/o Contract in FY}}{\# \text{ Eligible to Make a Stay - Leave Decision in FY}} \times 100\%

Figure 1 displays the historical CONTRACT and NOCONTRACT participation rates for the 6,755 observations used to estimate the model. The sum of the CONTRACT and NOCONTRACT participation rates is the MSR retention rate (or MSR retention rate is equal to 1 minus the leave rate at MSR).

![Graph of CONTRACT and NOCONTRACT participation rates over fiscal years 1979 to 1994.]

Figure 1. CONTRACT/NOCONTRACT participation rates at MSR by fiscal year.

The 6,755 officers were separated into the two nuclear power communities, submarine and surface warfare. A summary of their MSR decisions is displayed in Table 1. The number in parenthesis is the row percentage. Submarine officers had higher MSR retention rates than surface warfare officers (i.e., 67 and 56 percent, respectively). While staying without a contract was favored over a contractual extension among the stayers, submarine officers were more likely to choose a contract than surface warfare officers (i.e., 36 and 30 percent, respectively).
Table 1

MSR Decision by Officer Community

<table>
<thead>
<tr>
<th></th>
<th>Stay w/ Contract</th>
<th>Stay w/o Contract</th>
<th>Leave the Contract</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submarine Officer</td>
<td>1,322 (24%)</td>
<td>2,322 (43%)</td>
<td>1,804 (33%)</td>
<td>5,448</td>
</tr>
<tr>
<td>Surface Warfare Officer</td>
<td>217 (17%)</td>
<td>515 (39%)</td>
<td>575 (44%)</td>
<td>1,307</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,539 (23%)</strong></td>
<td><strong>2,837 (42%)</strong></td>
<td><strong>2,379 (35%)</strong></td>
<td><strong>6,755</strong></td>
</tr>
</tbody>
</table>

The MSR decision of the 6,755 officers by their accession source is displayed in Table 2. Academy accessions made up 38 percent (2591/6755) of the nuclear community with NROTC and other accession sources almost equally dividing the remainder. Academy accessions have the highest MSR retention rate, followed by NROTC accessions. Regardless of accession source, staying without a contract was favored over a contractual extension by nearly a 2 to 1 margin.

Table 2

MSR Decision by Accession Source

<table>
<thead>
<tr>
<th></th>
<th>Stay w/ Contract</th>
<th>Stay w/o Contract</th>
<th>Leave the Contract</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Naval Academy Accession</td>
<td>681 (26%)</td>
<td>1,165 (45%)</td>
<td>745 (29%)</td>
<td>2,591</td>
</tr>
<tr>
<td>NROTC Accession</td>
<td>418 (21%)</td>
<td>885 (44%)</td>
<td>712 (35%)</td>
<td>2,015</td>
</tr>
<tr>
<td>Other Accession Sources</td>
<td>440 (20%)</td>
<td>787 (37%)</td>
<td>922 (43%)</td>
<td>2,149</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,539 (23%)</strong></td>
<td><strong>2,837 (42%)</strong></td>
<td><strong>2,379 (35%)</strong></td>
<td><strong>6,755</strong></td>
</tr>
</tbody>
</table>

Historically, family separation has been a major reason officers give for leaving the Navy. Hence, the number of dependents may influence the stay-leave decision at MSR for these 6,755 officers. Table 3 displays the MSR decision by the number of dependents the officer had at MSR. Most officers were single at MSR, and they had the lowest retention rate, 62 percent. Even when they stayed, single officers were more likely to extend without obligation. In the 1981 study, nuclear submarine officers were more likely to stay at MSR as the number of dependents increased. These data show the same pattern, namely, as the number of dependents increased, the greater the likelihood the officer stayed, and if he stayed, the more likely it was that he obligated.
Table 3

MSR Decision by Number of Dependents

<table>
<thead>
<tr>
<th></th>
<th>Stay w/ Contract</th>
<th>Stay w/o Contract</th>
<th>Leave the Navy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No dependents at MSR</td>
<td>538 (17%)</td>
<td>1,406 (44%)</td>
<td>1,216 (38%)</td>
<td>3,160</td>
</tr>
<tr>
<td>One dependent at MSR</td>
<td>666 (26%)</td>
<td>1,042 (40%)</td>
<td>892 (34%)</td>
<td>2,600</td>
</tr>
<tr>
<td>&gt; Two dependents at MSR</td>
<td>335 (34%)</td>
<td>389 (39%)</td>
<td>271 (27%)</td>
<td>995</td>
</tr>
<tr>
<td>Total</td>
<td>1,539 (23%)</td>
<td>2,837 (42%)</td>
<td>2,379 (35%)</td>
<td>6,755</td>
</tr>
</tbody>
</table>

Model

Nuclear-trained officers at the end of their minimum service requirement (MSR) can choose to: (1) stay in the Navy under contract, (2) stay in the Navy under no obligation, or (3) leave the Navy.

From these 3 choices, an officer chooses that outcome that maximizes his utility. The utility function for each outcome can be written:

\[
U'_{C} = \theta'_{C} + \beta M_{C} + \alpha'_{C} Z + \gamma'_{C}
\]
\[
U'_{A} = \theta'_{A} + \beta M_{A} + \alpha'_{A} Z + \gamma'_{A}
\]
\[
U'_{L} = \theta'_{L} + \beta M_{L} + \alpha'_{L} Z + \gamma'_{L}
\]

where

- \( U'_{C} \) = utility from staying in the Navy at MSR with a contract
- \( U'_{A} \) = utility from staying in the Navy at MSR without a contract
- \( U'_{L} \) = utility from leaving the Navy at MSR
- \( M_{C} \) = vector containing the annualized military pay over the horizon of a COPAY contract
- \( M_{A} \) = vector containing the annualized military pay over the horizon of an AIB extension
- \( M_{L} \) = vector containing the annualized civilian pay
- \( Z \) = vector of observable characteristics of the officer (e.g., accession source, dependents)
- \( \gamma'_{C}, \gamma'_{A}, \gamma'_{L} \) = random error terms

and \( \theta', \alpha', \) and \( \beta \) are coefficients.
Because utility is a random function, the probability of choosing to stay in the Navy under contract, choosing to stay in the Navy without a contract, or leaving the Navy is given by:

\[ P_i = \frac{\exp(\theta_i + \beta M_i + a_i Z)}{\sum_{j=1}^{m} \exp(\theta_j + \beta M_j + a_j Z)} \]

The complete development of the economic model is found in Appendix A. In this general form of the logit model, \( M_i \) is the vector of attribute values for the \( ith \) choice, which includes the compensation variable. Note that the coefficient on \( M_i \) is constant across the choices. The officer-specific variables are described in \( Z \) and its coefficient varies across the choices. A similar model was used by Goldberg and Warner (CRC 476) to describe reenlistment and extension behavior. Maximum likelihood methods were used to estimate the parameters of this model and the findings are described in the Results section.

Model parameters were estimated for (1) submarine officers, (2) surface warfare officers, and (3) submarine and surface warfare officers combined. In Table 4, the variables are defined, the vector of which they are components is identified, and their mean values are presented.

The compensation variables were constructed as follows. Submarine officers’ MILPAYC, for example, is the annualized value of RMC plus SUBPAY plus COPAY over the contract horizon. (Note: Prior to 1981, SUBPAY was only paid while serving on a submarine. From 1981 onward, SUBPAY was paid as long as an officer was sub-qualified.) A 4-year horizon was chosen because it was common throughout the years of observation. In October 1985, the 3- and 5-year COPAY options were added. COPAY is paid in equal annual payments, and the amount of the annual payment does not depend on the contract length. Currently, the annual COPAY payment is $10,000 for each year of a 3-, 4-, or 5-year contract. Surface warfare officers’ MILPAYC was constructed in the same way, but does not include SUBPAY. A discount rate of 10 percent was assumed \((r = .10)\). For submarine officers,

\[
MILPAYC = \frac{\sum_{i=t+1}^{t+4} (RMC_i + SUBPAY_i + COPAY_i) (1 + r)^{t-i+1}}{\sum_{i=t+1}^{t+4} (1 + r)^{t-i+1}}
\]
For surface warfare officers, MILPAYC is given by:

\[
MILPAYC = \frac{\sum_{i=t+1}^{t+4} (RMC_i + COPAY_i) (1 + r)^{t-i+1}}{\sum_{i=t+1}^{t+4} (1 + r)^{t-i+1}}
\]

### Table 4

Variable Descriptions and Mean Values

<table>
<thead>
<tr>
<th>Variables Vector</th>
<th>Description</th>
<th>Submarine Model ( N = 5,448 )</th>
<th>Surface Model ( N = 1,307 )</th>
<th>Combined Model ( N = 6,755 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTRACT</td>
<td>1, if stay in the Navy at MSR w/ a 3-, 4-, or 5-year contract</td>
<td>.243</td>
<td>.166</td>
<td>.228</td>
</tr>
<tr>
<td>NOCONTRACT</td>
<td>1, if stay in the Navy at MSR w/o a 3-, 4-, or 5-year contract</td>
<td>.426</td>
<td>.394</td>
<td>.420</td>
</tr>
<tr>
<td>LEAVE</td>
<td>1, if leave in the Navy at MSR</td>
<td>.331</td>
<td>.440</td>
<td>.352</td>
</tr>
<tr>
<td>MILPAYC</td>
<td>Annualized military pay over a 4-year horizon; military pay includes RMC, SUBPAY (submariners only) and COPAY (FY89 $s)</td>
<td>$53,654</td>
<td>$48,853</td>
<td>$52,725</td>
</tr>
<tr>
<td>MILPAYA</td>
<td>Annualized military pay over a 1-year horizon; military pay includes RMC, SUBPAY (submariners only) and AIB (FY89 $s)</td>
<td>$51,550</td>
<td>$46,755</td>
<td>$50,622</td>
</tr>
<tr>
<td>CIVPAY</td>
<td>Annualized civilian earnings over a 4-year horizon (FY89 $s)</td>
<td>$24,575</td>
<td>$24,382</td>
<td>$24,538</td>
</tr>
<tr>
<td>COPAY345</td>
<td>1, if MSR occurred in FY86 or later</td>
<td>.604</td>
<td>.611</td>
<td>.606</td>
</tr>
<tr>
<td>SUB</td>
<td>1, if submarine officer</td>
<td>.806</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACA</td>
<td>1, if U.S. Naval Academy accession</td>
<td>.374</td>
<td>.423</td>
<td>.384</td>
</tr>
<tr>
<td>NROTC</td>
<td>1, if NROTC accession</td>
<td>.292</td>
<td>.324</td>
<td>.298</td>
</tr>
<tr>
<td>WHITE</td>
<td>1, if officer is white</td>
<td>.952</td>
<td>.930</td>
<td>.948</td>
</tr>
<tr>
<td>DEPEND</td>
<td>Number of dependents at MSR</td>
<td>.752</td>
<td>.640</td>
<td>.731</td>
</tr>
</tbody>
</table>
The major difference in the construction of MILPAYC and MILPAYA was the horizon. While MILPAYC assumed a 4-year horizon, MILPAYA was defined over a 1-year horizon. All nuclear-qualified officers on active-duty at the end of the fiscal year received the AIB payment.

The civilian earnings variable, CIVPAY, assumed a 4-year horizon. Each year’s civilian earnings was determined from the following equation:

\[
\text{LnY} = 9.7060 + 0.0701 \times \text{MILEXP} - 0.014 \times (\text{MILEXP})^2 + 0.0785 \times \text{CIVEXP} - 0.0013 \times (\text{CIVEXP})^2 - 0.0025 \times \text{MILEXP} \times \text{CIVEXP} - 0.2366 \times \text{NONWHITE} + 0.1053 \times \text{BAPLUS}
\]

where
\[
\text{LnY} = \text{natural logarithm of annual earnings in 1989 dollars}
\]
\[
\text{MILEXP} = \text{years of military experience}
\]
\[
\text{CIVEXP} = \text{years of civilian experience}
\]
\[
\text{NONWHITE} = 1, \text{ if the veteran was nonwhite; } = 0, \text{ otherwise}
\]
\[
\text{BAPLUS} = 1, \text{ if the veteran had more than a 4-year degree; } = 0, \text{ otherwise}
\]

The equation was estimated using a cross-sectional sample of veterans from the Census Bureau’s 1990 Public Use Microdata Samples (PUMS). The sample included only male, college-graduate veterans in engineering and managerial occupations. CIVPAY does not include bonuses or benefits. Comparing CIVPAY to basic pay for an officer with 5 years of service would be more meaningful. In 1989 dollars, basic pay for an officer with 5 years of service was approximately $29,000.

As pointed out previously, in October 1985, a 3- and 5-year contract option in addition to the original 4-year contract was made available. Over the observation period, this was the only significant change in NOIP administration affecting the officers at the MSR decision point. The dichotomous variable, COPAY345, captures this change in the choice to stay in the Navy.

Results

Four separate models were estimated: (1) submarine officers only, (2) surface warfare officers only, (3) submarine and surface warfare officers combined, and (4) a combined model with the additional SUB variable. The results are displayed in Table 5. In general, the coefficients are statistically significant at the 5 percent level. At the bottom of the table, the Chi-square ($\chi^2$) statistic is one measure of the model’s goodness-of-fit. In each model, $\chi^2$ is well above the level of statistical significance at the 5 percent level.

The model coefficients are not the partial derivatives of $P_C$ or $P_A$, with respect to a particular variable. The partial derivatives, the effect of a particular variable on $P_C$ or $P_A$, are found in Appendix A. The sign on the coefficient, however, indicates whether the variable had a positive or negative effect on $P_C$ or $P_A$. Within each of the four models, the coefficients on the compensation variables, MILPAYC, MILPAYA, and CIVPAY, are the same, and the positive sign indicates that pay matters in retention decisions. The compensation coefficients for the combined models were

\[\text{1 This earnings equation was estimated by Systems Analytics Group, Inc. under contract to the Navy Personnel Research and Development Center.}\]
close to that of the submarine model because of the size of submarine community relative to the surface community. The other choice variable, COPAY345, had a significant, positive impact on retention. The models suggest that eliminating the 3- and 5-year contract option would lead to pre-FY86 CONTRACT participation rates.

Table 5

<table>
<thead>
<tr>
<th>Variables Describing M</th>
<th>Submarine Model</th>
<th>Surface Model</th>
<th>Combined Model 1</th>
<th>Combined Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MILPAYC, MILPAYA, CIVPAY</td>
<td>0.000417</td>
<td>0.000215</td>
<td>0.000793</td>
<td>0.000536</td>
</tr>
<tr>
<td>COPAY 345</td>
<td>(2.790)</td>
<td>(4.730)</td>
<td>(8.345)</td>
<td>(3.885)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables Describing Z (CONTRACT choice)</th>
<th>Submarine Model</th>
<th>Surface Model</th>
<th>Combined Model 1</th>
<th>Combined Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-3.373 (-6.533)</td>
<td>-9.074 (-7.080)</td>
<td>-4.738 (-13.768)</td>
<td>-4.293 (-10.203)</td>
</tr>
<tr>
<td>ACA</td>
<td>0.624 (5.913)</td>
<td>0.990 (4.393)</td>
<td>0.576 (6.693)</td>
<td>0.680 (7.231)</td>
</tr>
<tr>
<td>NROTC</td>
<td>0.256 (2.451)</td>
<td>0.224 (0.924)</td>
<td>0.156 (1.742)</td>
<td>0.239 (2.520)</td>
</tr>
<tr>
<td>WHITE</td>
<td>0.618 (3.004)</td>
<td>1.669 (3.937)</td>
<td>0.891 (5.174)</td>
<td>0.736 (4.039)</td>
</tr>
<tr>
<td>DEPEND</td>
<td>0.401 (9.364)</td>
<td>0.376 (3.920)</td>
<td>0.396 (10.219)</td>
<td>0.394 (10.128)</td>
</tr>
<tr>
<td>SUB</td>
<td>0.430 (3.800)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables Describing Z (NOCONTRACT choice)</th>
<th>Submarine Model</th>
<th>Surface Model</th>
<th>Combined Model 1</th>
<th>Combined Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.424 (-3.016)</td>
<td>-6.203 (-5.368)</td>
<td>-2.653 (-8.719)</td>
<td>-2.020 (-5.379)</td>
</tr>
<tr>
<td>ACA</td>
<td>0.454 (4.764)</td>
<td>0.368 (2.133)</td>
<td>0.363 (4.918)</td>
<td>0.456 (5.493)</td>
</tr>
<tr>
<td>NROTC</td>
<td>0.285 (3.152)</td>
<td>0.113 (0.655)</td>
<td>0.188 (2.541)</td>
<td>0.260 (3.262)</td>
</tr>
<tr>
<td>WHITE</td>
<td>0.270 (1.622)</td>
<td>1.469 (4.339)</td>
<td>0.564 (4.244)</td>
<td>0.420 (2.898)</td>
</tr>
<tr>
<td>DEPEND</td>
<td>0.075 (1.900)</td>
<td>0.032 (0.400)</td>
<td>0.065 (1.838)</td>
<td>0.068 (1.909)</td>
</tr>
<tr>
<td>SUB</td>
<td>0.145 (1.501)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Log Likelihood Function

-5642.102 | -1292.036 | -6938.697 | -6930.462

Chi-square

408.18  | 126.62  | 563.29  | 579.76
The officer-specific variables described in \( Z \) are interpreted as correlates of taste. There was no a priori hypothesis about the signs of the coefficients, which vary across the choices. Because of the structure of this logit model, coefficients on \( Z \) for the third choice, leave the Navy, were normalized to zero. Hence, Table 5 contains only the coefficients for the remaining two choices.

The significant, positive ACA coefficients in both nuclear communities in both the CONTRACT and NOCONTRACT choices indicate that relative to the omitted accession group (other accession sources), Naval Academy accessions had higher retention propensities. In the submarine community, NROTC accessions also had higher retention propensities than the omitted group (significant, positive NROTC coefficients in both the COPAY and AIB choices). The coefficients on NROTC in the surface model are not statistically significant implying that (relative to the omitted group) being an NROTC accession did not enhance the likelihood of staying in the Navy.

In Table 3, there were indications that the number of dependents affected an officer’s MSR stay-leave decision. The positive DEPEND coefficients in both nuclear communities in both the CONTRACT and NOCONTRACT choices indicate that the greater the number of dependents an officer had at MSR the greater was the likelihood he would stay in the Navy. Moreover, the impact of dependents was statistically significant for both communities in the CONTRACT choice. That is, the greater the number of dependents the higher the likelihood of staying in the Navy under contract.

Another measure of the models’ goodness-of-fit was their ability to predict the stay-leave propensities of the validation sample. Recall that 743 observations were set aside for this validation. The results are presented in Table 6. The models’ predictions are in italics. All the models underpredict leaving the Navy. The submarine model overpredicts staying without a contract and underpredicts staying with a contract. Because of the size of the submarine community relative to the surface warfare community, the combined models also overpredict staying without a contract and underpredict staying with a contract. The surface model, on the other hand, overpredicts staying with a contract and underpredicts staying without a contract.

Table 6

<table>
<thead>
<tr>
<th>Models’ Validation: Actual vs. Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
</tr>
<tr>
<td>CONTRACT</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>NOCONTRACT</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>LEAVE</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Elasticity formulas that measure $P_C$, $P_A$, and $P_L$ responses to changes in MILPAYC ($M_C$) and MILPAYA ($M_A$) were developed in Appendix A. Those formulas do not measure $P_C$, $P_A$, and $P_L$ responses to changes in annual payments of COPAY and AIB. To quantify the responsiveness of $P_C$, $P_A$, and $P_L$ to changes in annual COPAY and AIB payments, the models were exercised twice. The first simulation determined $P_C$, $P_A$, and $P_L$ with a 10 percent increase in annual COPAY payments. A percentage change between these new rates and the current, observed rates was calculated. Dividing this percentage by 10 percent produced the $P_C$, $P_A$, and $P_L$ elasticities with respect to a 10 percent change in annual COPAY payments. These elasticities are found in Table 7. The second simulation determined $P_C$, $P_A$, and $P_L$ with a 10 percent increase in annual AIB payments. Elasticities with respect to a 10 percent change in annual AIB payments were then computed. These elasticities are found in Table 8.

Table 7

$P_C$, $P_A$, and $P_L$ Elasticities with Respect to a 10 Percent Change in COPAY

<table>
<thead>
<tr>
<th>Elasticity</th>
<th>Submarine Model</th>
<th>Surface Model</th>
<th>Combined Model 1</th>
<th>Combined Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_{LC} = e_{AC}$</td>
<td>-0.112</td>
<td>-0.394</td>
<td>-0.201</td>
<td>-0.135</td>
</tr>
<tr>
<td>$e_{CC}$</td>
<td>0.258</td>
<td>1.442</td>
<td>0.507</td>
<td>0.341</td>
</tr>
</tbody>
</table>

Table 8

$P_C$, $P_A$, and $P_L$ Elasticities with Respect to a 10 Percent Change in AIB

<table>
<thead>
<tr>
<th>Elasticity</th>
<th>Submarine Model</th>
<th>Surface Model</th>
<th>Combined Model 1</th>
<th>Combined Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_{LA} = e_{CA}$</td>
<td>-0.108</td>
<td>-0.477</td>
<td>-0.203</td>
<td>-0.135</td>
</tr>
<tr>
<td>$e_{AA}$</td>
<td>0.165</td>
<td>0.812</td>
<td>0.314</td>
<td>0.212</td>
</tr>
</tbody>
</table>

From the elasticity formulas in Appendix A, it was shown that $e_{LC}$ equals $e_{AC}$ and $e_{LA}$ equals $e_{CA}$; increases in COPAY and AIB draw from the other two choices equally in percentage terms. For example, for submarine officers, a 10 percent increase in COPAY increases the probability of staying in the Navy with a contract by $2.58 (e_{CC} * 10)$ percent while decreasing both the probability of staying in the Navy without a contract and the probability of leaving the Navy by $1.12 (e_{LC} * 10)$ percent. Recall that the retention rate is 1 minus $P_L$; thus, $-e_{LC}$ is the retention rate elasticity with respect to changes in COPAY, and $-e_{LA}$ is the retention rate elasticity with respect to changes in AIB. Within the same model, the 10 percent increase in annual COPAY and AIB payments had nearly the same effect on retention. For example, in the submarine model, the 10 percent increase in annual COPAY payments increased the retention rate by $1.12 (-e_{LC} * 10)$ percent; the 10 percent increase in annual AIB payments increased the retention rate by $1.08 (-e_{LA} * 10)$ percent. In the surface model, the 10 percent increase in annual COPAY and AIB payments increased the retention...
rate by 3.94 ($-e_{LC}\times10$) and 4.77 ($-e_{LA}\times10$) percent, respectively. Nuclear surface warfare officers were more responsive to compensation changes than submarine officers.

While increases in COPAY and AIB had nearly the same effect on overall retention, increases in COPAY had larger effects on the probability of staying in the Navy with a contract than increases in AIB had on the probability of staying in the Navy without a contract. This was true across all models. For example, in the submarine model, a 10 percent increase in annual COPAY payments increased the probability of staying in the Navy with a contract by 2.58 ($e_{CC}\times10$) percent; a 10 percent increase in annual AIB payments increased the probability of staying in the Navy without a contract by 1.65 ($e_{AA}\times10$) percent. In the surface model, a 10 percent increase in annual COPAY payments increased the probability of staying in the Navy with a contract by 14.42 ($e_{CC}\times10$) percent. The increase in the probability of staying in the Navy without a contract caused by a 10 percent increase in annual AIB payments was 8.12 ($e_{AA}\times10$) percent. In the 1981 study, increases in COPAY also had a greater effect on staying in the Navy with a contract than increases in AIB had on staying in the Navy without a contract.

Conclusions

Most retention-compensation research, including the first nuclear submarine officer study in 1981, finds that “pay does matter.” While the retention bonus elasticities found in these models are relatively small, their statistical significance also points to the fact that pay matters. There were other similar findings between this model and the earlier one. For example, both studies report that an increase in COPAY increases probability of staying in the Navy with a contract at MSR more than an increase in AIB increases probability of staying in the Navy without a contract at MSR. Second, Naval Academy accessions were found to have higher propensities to stay in the Navy at MSR than other source accessions. Finally, both studies report that the greater the number of dependents an officer has at MSR the higher is the likelihood he will stay in the Navy and the higher is the likelihood he will stay with a contract. These models were used to simulate a 10 percent increase in COPAY and a 10 percent increase in AIB, but they can also be used to assess the retention and cost impacts of other alternative NOIP retention bonus strategies.
References


*Maddala is referenced in Appendix A.*
Appendix A

Nuclear Officer Retention Model
Nuclear-trained officers at the end of their minimum service requirement (MSR) can choose: (1) to stay in the Navy under contract (COPAY), (2) to stay in the Navy under no obligation (AIB), or (3) leave the Navy (Leave). From these 3 choices, an officer chooses that outcome that maximizes his utility. In Goldberg and Warner (1982), the utility function is the sum of two vectors. The first vector contains the annualized income stream associated with that outcome and other outcome characteristics (e.g., contract length). The second vector represents the officer’s taste for military service. Mathematically,

\[ U_{Cj} = M_{Cj} + \delta_C \]
\[ U_{Aj} = M_{Aj} + \delta_A \]
\[ U_{Lj} = M_{Lj} + \delta_L \]

where

- \( U_{Cj} \) = utility from staying in the Navy at MSR with a contract
- \( U_{Aj} \) = utility from staying in the Navy at MSR without a contract
- \( U_{Lj} \) = utility from leaving the Navy at MSR
- \( M_{Cj} \) = vector containing the annualized military pay over the horizon of a COPAY contract
- \( M_{Aj} \) = vector containing the annualized military pay over the horizon of an AIB extension
- \( M_{Lj} \) = vector containing annualized civilian pay
- \( \delta_C, \delta_A, \text{ and } \delta_L \) = tastes for military service

Tastes for military service may vary systematically with individual characteristics such as accession source, race and number of dependents. Let \( \delta_i \) be explained by a vector, \( Z_j \), of observable characteristics for the \( j \text{th} \) individual and a random error, \( \gamma_i \). Then

\[ U_{Cj} = M_{Cj} + \alpha_C Z_j + \gamma_{Cj} \]  \hspace{1cm} (1)
\[ U_{Aj} = M_{Aj} + \alpha_A Z_j + \gamma_{Aj} \]  \hspace{1cm} (2)
\[ U_{Lj} = M_{Lj} + \alpha_L Z_j + \gamma_{Lj} \]  \hspace{1cm} (3)

\[ Z_j \] = vector of observable characteristics for the \( j \text{th} \) individual
\( \alpha_c, \alpha_A, \alpha_L = \text{vector of coefficients} \)

\( \gamma_C, \gamma_A, \gamma_L = \text{random error terms} \)

For ease of exposition, the subscript \( j \) will be left off for the remainder of this section. From Maddala (1983), let the random error terms, \( \gamma_C, \gamma_A, \) and \( \gamma_L \) be linear transformations of independently and identically distributed (IID) standardized extreme value random variables, \( \gamma_i \), i.e.,

\[
\gamma_i = \theta_i + \theta_o \gamma_i', \quad \theta_o > 0, \quad i = C, A, L
\]

The cumulative distribution function (CDF) of the residuals, \( \gamma_i' \), is \( F(\gamma_i' < \gamma) = \exp(-e^{-\gamma}) \). The probability density function (PDF) is \( f(\gamma_i') = \exp(-\gamma_i' - e^{-\gamma_i'}) \).

Substituting for \( \gamma_i' \) into equations (1), (2), and (3) yields

\[
U_C = M_C + \alpha_c Z + \theta_c + \theta_o \gamma_C
\]

\( (4) \)

\[
U_A = M_A + \alpha_A Z + \theta_A + \theta_o \gamma_A
\]

\( (5) \)

\[
U_L = M_L + \alpha_L Z + \theta_L + \theta_o \gamma_L
\]

\( (6) \)

Dividing these utility functions by \( \theta_o \) yields the following normalized utilities:

\[
U_C' = \theta_c' + \beta M_C + \alpha_c' Z + \gamma_C
\]

\( (7) \)

\[
U_A' = \theta_A' + \beta M_A + \alpha_A' Z + \gamma_A
\]

\( (8) \)

\[
U_L' = \theta_L' + \beta M_L + \alpha_L' Z + \gamma_L
\]

\( (9) \)

where

\[
\theta_i' = \theta_i / \theta_o, \quad i = C, A, L
\]

\[
\alpha_i' = \alpha_i / \theta_o, \quad i = C, A, L
\]

\( \beta = 1 / \theta_o \)
Note that the officer’s utility maximization problem is unaffected by dividing the original utility functions, \( U_i \), by \( \theta_i \). Also, \( U_i \) and \( U' \) are not directly observable. Instead, choice \( i \) is observable and is defined as

\[
Y_i = 1 \text{ if } U'_i = \text{Max}(U'_1, U'_2, ..., U'_m) \\
Y_i = 0 \text{ otherwise}
\]

The condition \( U'_i = \text{Max}(U'_1, U'_2, ..., U'_m) \) implies

\[
U'_i > U'_j \text{ for all } j \neq i
\]
or

\[
\theta'_i + \beta M_i + \alpha'_j Z + \gamma'_i > \theta'_j + \beta M_j + \alpha'_j Z + \gamma'_j \text{ for all } j \neq i
\]
or

\[
\gamma'_i < \gamma'_j + \theta'_i + \beta M_i + \alpha'_j Z - \theta'_j - \beta M_j - \alpha'_j Z \text{ for all } j \neq i
\]

Because \( \gamma_i \) are IID with CDF defined above, it follows that

\[
\text{Prob}(Y_i = 1) = \text{Prob}(\gamma'_i < \gamma'_j + \theta'_i + \beta M_i + \alpha'_j Z - \theta'_j - \beta M_j - \alpha'_j Z) \text{ for all } j \neq i
\]

\[
= \int \prod_{j \neq i} F(\gamma'_i + \theta'_i + \beta M_i + \alpha'_j Z - \theta'_j - \beta M_j - \alpha'_j Z) f(\gamma'_j) d\gamma'_j \quad (10)
\]

From the CDF and PDF defined above,

\[
\prod_{j \neq i} F(\gamma'_i + \theta'_i + \beta M_i + \alpha'_j Z - \theta'_j - \beta M_j - \alpha'_j Z) f(\gamma'_j) =
\]

\[
\prod_{j \neq i} \exp(-\exp(-\gamma'_i - \theta'_i - \beta M_i - \alpha'_j Z + \theta'_j + \beta M_j + \alpha'_j Z)) \exp(-\gamma'_i - \exp(-\gamma'_i)) =
\]

\[
\exp \left[ \gamma'_i - \exp(-\gamma'_i) \left( 1 + \sum_{j \neq i} \frac{\exp(\theta'_j + \beta M_j + \alpha'_j Z)}{\exp(\theta'_i + \beta M_i + \alpha'_j Z)} \right) \right] \quad (11)
\]

Let

\[
\lambda_i = \ln \left( 1 + \sum_{j \neq i} \frac{\exp(\theta'_j + \beta M_j + \alpha'_j Z)}{\exp(\theta'_i + \beta M_i + \alpha'_j Z)} \right) = \ln \left( \sum_{j \neq i} \frac{\exp(\theta'_j + \beta M_j + \alpha'_j Z)}{\exp(\theta'_i + \beta M_i + \alpha'_j Z)} \right) \quad (12)
\]

and substituting into (11) yields
\[
\prod_{j=1}^{\infty} F(\gamma_j' + \theta_j + \beta M_j + \alpha_j Z - \theta_j - \beta M_j - \alpha_j Z) f(\gamma_j') = \exp(-\gamma_j' - e^{-(\gamma_j' + \lambda_j)})
\] (13)

Substituting (13) into (10) yields

\[
\int_{-\infty}^{\gamma_i'} \exp(-\gamma_j' - e^{-(\gamma_j' + \lambda_j)}) d\gamma_j' = \exp(-\lambda_j') \int \exp(-\gamma_i' - e^{-\gamma_i'}) d\gamma_i'
\] where \( \gamma_i' = \gamma_i - \lambda_i \)

\[
= \exp(-\lambda_i') (14)
\]

\[
= \frac{\exp(\theta_i' + \beta M_i + \alpha_i Z)}{\sum_{j=1}^{n} \exp(\theta_j' + \beta M_j + \alpha_j Z)} (15)
\]

Thus, because utility is a random function and given the distributional assumption on \( \gamma_i' \), the probability of choosing to stay in the Navy under contract \( (P_c) \), choosing to stay without a contract \( (P_A) \), or leaving the Navy \( (P_L) \) is given by:

\[
P_i = \frac{\exp(\theta_i' + \beta M_i + \alpha_i Z)}{\sum_{j=1}^{n} \exp(\theta_j' + \beta M_j + \alpha_j Z)} (16)
\]

In this general form of the logit model, \( M_i \) is the vector of values of the attributes of the \( i \)th choice, which includes the compensation variable. Note that the coefficient on \( M_i \) is constant across the choices. The officer-specific variables are described in \( Z \) and its coefficient is varies across the choices.

The effects on \( P_i \) in equation (16) above caused by changes in compensation are shown below. For changes in \( P_i \) resulting from changes in \( M_c \), differentiating equation (16) with respect to \( M_c \) yields:

\[
\frac{\partial P_i}{\partial M_c} = -\beta P_c P_L \Rightarrow \epsilon_{LC} = \frac{\partial P_L}{\partial M_c} P_c = -\beta P_c P_L \frac{M_c}{P_L} = -\beta P_c M_c
\]

\[
\frac{\partial P_A}{\partial M_c} = -\beta P_c P_C \Rightarrow \epsilon_{AC} = \frac{\partial P_A}{\partial M_c} P_C = -\beta P_A P_L \frac{M_c}{P_A} = -\beta P_C M_C = \epsilon_{LC}
\]
\[ \frac{\partial P_c}{\partial M_c} = \beta P_c(1-P_c) \Rightarrow e_{cc} = \frac{\partial P_c}{\partial M_c} \frac{M_c}{P_c} = \beta P_c(1-P_c) \frac{M_c}{P_c} = \beta(1-P_c) M_c \]

Since \( \beta \) is positive, increasing \( M_c \) increases \( P_c \) at the expense of \( P_A \) and \( P_L \), i.e., NOCONTRACT participation falls and overall retention rises (number of leavers declines). \( e_{ij} \) is the elasticity of \( P_i \) with respect to \( M_j \).

Similarly, an increase in \( M_A \), increases NOCONTRACT participation, lowers CONTRACT participation, and increases retention. For changes in \( P_i \) resulting from changes in \( M_A \), differentiating equation (16) with respect to \( M_A \) yields:

\[ \frac{\partial P_L}{\partial M_A} = -\beta P_L M_A \Rightarrow e_{LA} = \frac{\partial P_L}{\partial M_A} \frac{M_A}{P_L} = -\beta P_L \frac{M_A}{P_L} = -\beta P_L M_A \]

\[ \frac{\partial P_C}{\partial M_A} = -\beta P_C M_A \Rightarrow e_{CA} = \frac{\partial P_C}{\partial M_A} \frac{M_A}{P_C} = -\beta P_C \frac{M_A}{P_C} = -\beta P_C M_A = e_{LA} \]

\[ \frac{\partial P_A}{\partial M_A} = \beta P_A(1-P_A) \Rightarrow e_{AA} = \frac{\partial P_A}{\partial M_A} \frac{M_A}{P_A} = \beta P_A(1-P_A) \frac{M_A}{P_A} = \beta(1-P_A) M_A \]

Table A-1 displays these elasticities which were evaluated at the sample means. The elasticity of \( P_c \) with respect to MILPAYC, \( e_{cc} \), and the elasticity of \( P_A \) with respect to MILPAYA, \( e_{AA} \), are 1.694 and 1.234, respectively. The 1981 report, which focused only on submarine officers, found an elasticity of extending with respect to military pay of 1.4.

Caution should be used in the interpretation of the elasticities in table A-1. These are not the retention rate elasticities with respect to COPAY or AIB. Recall that MILPAYC was the annualized sum of RMC, SUBPAY (for submarine officers), and COPAY while MILPAYA was the annualized sum of RMC, SUBPAY (for submarine officers), and AIB. So, a 10 percent change in MILPAYC implies a 10 percent change in RMC, SUBPAY (for submarine officers), and COPAY over the 4-year horizon. Hence, the elasticities in table A-1 are the percentage change in retention rate divided by the percentage change in RMC, SUBPAY (for submarine officers), and COPAY or AIB over the appropriate horizon.
Table A-1

\( P_L, P_A, \) and \( P_C \) Elasticities with Respect to MILPAYC \( (M_C) \) and MILPAYA \( (M_A) \)

<table>
<thead>
<tr>
<th>Elasticity</th>
<th>Submarine Model</th>
<th>Surface Model</th>
<th>Combined Model 1</th>
<th>Combined Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \varepsilon_{LC} )</td>
<td>-0.544</td>
<td>-1.634</td>
<td>-0.953</td>
<td>-0.644</td>
</tr>
<tr>
<td>( \varepsilon_{AC} )</td>
<td>-0.544</td>
<td>-1.634</td>
<td>-0.953</td>
<td>-0.644</td>
</tr>
<tr>
<td>( \varepsilon_{CC} )</td>
<td>1.694</td>
<td>8.21</td>
<td>3.228</td>
<td>2.182</td>
</tr>
<tr>
<td>( \varepsilon_{LA} )</td>
<td>-0.916</td>
<td>-3.712</td>
<td>-1.686</td>
<td>-1.14</td>
</tr>
<tr>
<td>( \varepsilon_{CA} )</td>
<td>-0.916</td>
<td>-3.712</td>
<td>-1.686</td>
<td>-1.14</td>
</tr>
<tr>
<td>( \varepsilon_{AA} )</td>
<td>1.234</td>
<td>5.709</td>
<td>2.328</td>
<td>1.574</td>
</tr>
</tbody>
</table>
Distribution List

Chief of Naval Personnel (PERS-00), (PERS-00b), (PERS-00H), (PERS-00W), (PERS-01JJ), (PERS-2), (PERS-23), (PERS-24)
Director, Army Research Institute (PERI-ZT), Alexandria, VA
Operations and Support Directorate, Armstrong Laboratory (AL/DO), (AL/HR-DOKL Technical Library), Brooks Air Force Base, TX
President, Naval War College (Code E-1121)
Superintendent, Naval Postgraduate School
Director of Research, U.S. Naval Academy
Center for Naval Analyses, Acquisition Unit
Pentagon Library
Defense Technical Information Center (4)