2012

How does the cost performance of defense contracts vary among services and contractors? Evidence from major defense acquisition programs (MDAP)

Euske, K.J.

Advances in Management Accounting, Volume 20, pp. 75–100, 2012
http://hdl.handle.net/10945/45318

HOW DOES THE COST PERFORMANCE OF DEFENSE CONTRACTS VARY AMONG SERVICES AND CONTRACTORS? EVIDENCE FROM MAJOR DEFENSE ACQUISITION PROGRAMS (MDAP)

K. J. Euske, Joseph San Miguel and Chong Wang

ABSTRACT

This research examines how the cost performance of defense contracts varies among the Air Force, Army, Navy, and the Department of Defense (DoD) and among five major defense contractors: Boeing, Lockheed Martin, Northrop Grumman, Raytheon, and General Dynamics. Data for these analyses was extracted from the recently established Defense Acquisition Management Information Retrieval (DAMIR) web-based interface for management information on Major Defense Acquisition Programs (MDAP). Note that, in addition to the three military services, MDAP data is also reported for DoD itself.

Advances in Management Accounting, Volume 20, 75–100

ISSN: 1474-7871/doi:10.1108/S1474-7871(2012)0000020010

Data analysis indicates that the Navy ranks last among the military services and DoD in cost performance for MDAP contracts, while the Air Force ranks best. Of the defense contractors, Raytheon ranks last in cost performance and General Dynamics is next to last. Furthermore, the Navy contracts more frequently with Raytheon and General Dynamics than do the other services or DoD. Explanatory factors for poor cost performance may be due to factors such as the Navy's lack of oversight, the quality of the acquisition workforce, the defense contractors' cost inefficiency, ethical lapses, or weak corporate governance, or combinations of these factors.

In addition, the schedule performance data was also identified. Tests of statistical significance on the schedule performance difference generally yield no results except for one relationship which indicates that the Navy is more likely to have Acquisition Program Baseline (APB) schedule breaches than its counterparts. Finally, cost performance data is examined for statistically significant differences between the two major categories of defense contracts: fixed-price contracts and cost-plus contracts. However, no significant findings were discovered.

Keywords: Cost variance; cost performance index; schedule performance index; APB breaches; Nunn-McCurdy breaches

INTRODUCTION

The rapid growth of the defense budget[1] during President George W. Bush's administration is not likely to be repeated soon. The proposed Department of Defense (DoD) budget for fiscal 2011 is $549 billion, an increase of only 1.8% over fiscal 2010. The 2010 total dollar increase in the DoD budget was 2.1% higher than fiscal 2009. The diminishing rate of budget growth is a response to America's difficult economic situation and rising fiscal deficit. Secretary of Defense Robert M. Gates called for improved cost efficiency within an increasingly resource-constrained environment.[2] Lately, a series of legislative and executive actions have been taken to address cost inefficiency[3] believed to be widespread in DoD, especially for Major Defense Acquisition Programs (MDAP).[4] For example, on March 4, 2009, President Barack Obama issued the "Memorandum on Government Contracting" urging

federal contracting agencies to improve the effectiveness of their acquisition practices and contracting performance. On the legislative side, the most notable event was the passage of the Weapons Systems Acquisition Reform Act (WSARA), which was unanimously supported by Congress and signed into law by President Obama on May 22, 2009. On January 6, 2011, Secretary of Defense Robert M. Gates announced a series of efficiency decisions designed to save the DoD more than $150 billion over the next five years primarily by reducing overhead costs, improving business practices, and culling excess or troubled programs. Gates said:

> Meeting real-world requirements. Doing right by our people. Reducing excess. Being more efficient. Squeezing costs. Setting priorities and sticking to them. Making tough choices. These are all things that we should do as a Department and as a military regardless of the time and circumstance. But they are more important than ever at a time of extreme fiscal duress, when budget pressures and scrutiny fall on all areas of government, including defense.

In summary, there is a consensus among Congress, White House, and Pentagon officials that the defense acquisition system needs major reforms to improve cost efficiency.

Motivated by the ongoing defense acquisition reforms mentioned above, we investigate the cross-sectional variation in cost performance among different service departments (Army, Navy, and Air Force) and among major defense contractors (Boeing, Lockheed Martin, Northrop Grumman, Raytheon, and General Dynamics). Using contract and contractor information for MDAPs contained in Defense Acquisition Management Information Retrieval (DAMIR), we document that the Navy has the worst cost performance among the major service departments, while the Air Force is the best performer. Out of the five major defense contractors, Raytheon significantly underperforms other contractors in cost efficiency, followed by General Dynamics. Moreover, the Navy contracts more often with Raytheon and General Dynamics than the other services. So it is not clear if the Navy's underperformance is due to factors such as its lack of oversight, the quality of acquisition workforce, or because the Navy contracts more often with contractors with lower cost efficiency, low ethical standards, or weak corporate governance, or combinations of these factors. And this unanswered question is a potential topic for future research.

In addition, we examine how schedule performance varies across military services and major defense contractors. Most often the results are not statistically significant. One exception is that there is some evidence

suggesting that the Navy is more likely to have Acquisition Program Baseline (APB) schedule breaches than its counterparts. We further assess the existence of a significant difference in cost performance between two major types of contracts: fixed-price contracts and cost-plus contracts. We did not find any link between the contract types and cost performance.

Our major findings suggest that systematic differences on cost performance may exist among services and/or contractors. The documentation of cross-sectional variation serves as the first step to understand the DoD acquisition and contracting system. To the best knowledge, this contribution to the literature is innovative because most of the prior work links the contract performance to the contract-specific characteristics such as contract type, contract design, contract mechanism, rather than service or contractor (Tan, 1996; Tirole, 1999).

Our future research aims to extend along two dimensions. First, we intend to investigate the determinants of cross-sectional variation. The results of this research should provide a good basis for policy makers to address the cost inefficiency problem. Second, improving cost efficiency can possibly be better understood within a broad accounting context. As Euske (2003) argues whether one is studying private or public sector organizations, the costing systems designed with a compliance focus may not meet the information needs of the users. Viewed from a slightly different perspective one could argue that an abundance of data exists but there is a paucity of information (Cokins, Euske, Millish, Nostrom, & Vercio, 2008). The results of this study are based on costs as reported but that does not address the broad managerial accounting issues related to the accuracy of the costs in terms of specific processes. For instance, the Institute of Management Accounting and Ernst & Young (2003) found that accountants who were knowledgeable about the costing systems responded that even though the total reported costs might be accurate, the costs reported in terms of specific cause and effect relationships might not be. So in terms of this study, we can report on overall cost performance across contracts but must recognize that there are underlying costing issues relating to the processes within contracts. One can argue that if the goal is efficient processes within a contract then the within costing issues need to be resolved.

The remainder of the chapter is organized as follows. The second section describes the data used for the analyses. The third section presents the empirical tests and results. The fourth section concludes our presentation.

DATA

Data Source

We use DAMIR as our data source. DAMIR is sponsored by the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, and provides acquisition program information. According to the DAMIR website, the primary goal of DAMIR is to streamline acquisition management and oversight. DAMIR identifies various data sources that the acquisition community uses to manage MDAP and Major Automated Information Systems (MAIS) programs and provides that information through a unified web-based interface. DAMIR enables the Office of the Secretary Defense (OSD), military services, Congress, and other participating communities to access information relevant to their missions regardless of the agency or where the data resides.

We first use DAMIR to identify 101 active (as of November 10, 2010) MDAPs that include 31 Air Force programs, 22 Army programs, 38 Navy programs, and 10 DoD programs. Then for each of these 101 programs, we record its program name, and further, if available, the contractor's name, the contract type, and various contract performance data. The contract performance data include Cost Performance Index (CPI), Schedule Performance Index (SPI), Cost Variance Percentage (CVP), Schedule Variance Percentage (SVP), APB cost breaches, APB schedule breaches, and Nunn-McCurdy breaches.

Performance Variables Definition

The following definitions come from *ACQuipedia*, an online acquisition encyclopedia, provided by *Acquisition Community Connection*, an official website for DoD Acquisition, Technology & Logistics (AT&L) workforce to share knowledge.

Cost Performance Index

The CPI is computed by dividing the Budgeted Cost for Work Performed (BCWP) by the corresponding Actual Cost of Work Performed (ACWP). It measures the cost efficiency. CPIs greater than 1.0 are *favorable;* CPIs less than 1.0 are *unfavorable*.

Cost Variance Percentage

$$\text{CVP} = \frac{\text{BCWP} - \text{ACWP}}{\text{BCWP}}$$

A positive CVP indicates that work was accomplished for less resource expenditure than planned. A negative CVP indicates that work accomplished cost more than planned resource value.

Schedule Performance Index
The SPI is computed by dividing the BCWP by the Budgeted Cost for Work Scheduled (BCWS). It measures the work accomplishment efficiency. SPIs greater than 1.0 are favorable; SPIs less than 1.0 are unfavorable.

Schedule Variance Percentage

$$\text{SVP} = \frac{\text{BCWP} - \text{BCWS}}{\text{BCWS}}$$

A positive SVP indicates being ahead of schedule. A negative SVP indicates being behind of schedule.

APB Cost Breaches and APB Schedule Breaches
All MDAPs must have APBs. APB is a contract between the Program Manger (PM) and the Milestone Decision Authority documenting program performance, schedule and cost objectives, and boundaries. If a deviation from the planned cost (schedule) exceeds certain thresholds, cost (schedule) breaches are triggered.[5] The PM shall immediately notify the Milestone Decision Authority of any cost or schedule breaches. Within 30 days, the PM shall inform the Milestone Decision Authority of the reason for the deviation and planned actions. Within 90 days of breaches, a revised APB shall be submitted for approval. The Milestone Decision Authority shall decide whether it is appropriate to approve a revision to an APB.

Nunn-McCurdy Unit-Cost Breaches
On September 8, 1982, President Ronald Reagan signed into law the DoD Authorization Act, 1983 (P.L. 97-252), which included what has come to be known as the Nunn-McCurdy Act (10 U.S.C. § 2433). This Act mandates reporting to Congress whenever a MDAP experiences cost overruns that exceed certain thresholds. Specifically, "significant" breach happens when

the Program Acquisition Unit Cost – the total cost of development, procurement, and construction divided by the number of units procured – or the Average Procurement Unit Cost – the total procurement cost divided by the number of units to be procured – increases 15% or more over the current baseline estimate[6] or 30% or more over the original baseline estimate.[7] A "critical" breach occurs when the Program Acquisition Unit Cost or the Average Procurement Unit Cost increases 25% or more over the current baseline estimate or 50% or more over the original baseline estimate.

Data Description

Out of 101 MDAPs, we were able to identify whether there was an APB cost breach, APB schedule breach, and Nunn-McCurdy breach for 100 MDAPs.[8] Data availability on CPI, SPI, CVP, and SVP reduced the sample data to 59 MDAPs.[9] Moreover, not every contractor's name or contract type can be identified. We found 21 missing contractor names and 28 missing contract types out of 101 MDAPs.

Table 1 briefly describes the statistics of our major performance variables.

Panel A of Table 1 shows that the mean (median) of the CPI and SPI are 0.9578 (0.9640) and 0.9748 (0.9890), respectively, indicating that on average, the typical MDAP overruns cost and lags behind the schedule. The variance data supports this observation: the mean (median) of the CVP and SVP are −5.16% (−3.80%) and −2.52% (−1.10%), respectively, both unfavorable. In terms of breaching the cost and schedule, 38% of the MDAPs have APB cost breaches, 50% of the MDAPs have APB schedule breaches, and 11% of the MDAPs have Nunn-McCurdy breaches.

Panels B–E in Table 1 demonstrate the similar basic statistics on contract performance by the Air Force, the Army, the Navy, and the DoD. Note that the Navy almost consistently (with few exceptions) has the worst cost and schedule performance as well as the most frequent breaches across various metrics. The Air Force tends to be on the other end of the spectrum. The Air Force's best performance is evidenced by the following facts. (1) Both mean and median CPI are slightly greater than 1, meaning that the Air Force's typical MDAP is right on cost target or even slightly under cost budget, which is unique for the three services and DoD. (2) The mean of CVP is −0.11%, which shows least unfavorable cost variance across the three services and DoD. The median of CVP is 0.10%, the only favorable cost variance across the three services and DoD. (3) The Air Force has the least frequent cost and schedule breaches.

Table 1. The Basic Statistics on Contract Performance Data.

Variable	*N*	Mean	Median	SD
Panel A: The full sample (101)				
CPI	59	0.9578	0.9640	0.0789
SPI	59	0.9748	0.9890	0.0563
CVP	59	−0.0516	−0.0380	0.0933
SVP	59	−0.0252	−0.0110	0.0563
APB cost breach[a]	100	0.3800		
APB schedule breach[a]	100	0.5000		
Nunn-McCurdy breach[a]	100	0.1100		
Panel B: The Air Force sample (31)				
CPI	17	1.0026	1.0010	0.0642
SPI	17	0.9727	0.9940	0.0750
CVP	17	−0.0011	0.0010	0.0627
SVP	17	−0.0273	−0.0060	0.0750
APB cost breach[a]	30	0.2000		
APB schedule breach[a]	30	0.3333		
Nunn-McCurdy breach[a]	30	0.0333		
Panel C: The Army sample (22)				
CPI	10	0.9720	0.9665	0.0346
SPI	10	0.9833	0.9855	0.0149
CVP	10	−0.0301	−0.0345	0.0362
SVP	10	−0.0167	−0.0145	0.0149
APB cost breach[a]	22	0.4545		
APB schedule breach[a]	22	0.4545		
Nunn-McCurdy breach[a]	22	0.0909		
Panel D: The Navy sample (38)				
CPI	25	0.9204	0.9410	0.0817
SPI	25	0.9664	0.9860	0.0557
CVP	25	−0.0956	−0.0630	0.1070
SVP	25	−0.0336	−0.0140	0.0557
APB cost breach[a]	38	0.4474		
APB schedule breach[a]	38	0.6842		
Nunn-McCurdy breach[a]	38	0.1579		
Panel E: The DoD sample (10)				
CPI	7	0.9620	0.9640	0.0933
SPI	7	0.9976	0.9890	0.0434
CVP	7	−0.0477	−0.0380	0.0994
SVP	7	−0.0024	−0.0110	0.0434
APB cost breach[a]	10	0.5000		
APB schedule breach[a]	10	0.4000		
Nunn-McCurdy breach[a]	10	0.2000		

[a]Each breach variable is coded as a dummy that takes value of 1 if there is a breach, and 0 otherwise.

Table 2. The Distribution of Contract Types across Services and DoD.

Contract Type	Air Force	Army	Navy	DoD	Total
FFP	8	0	7	2	17
FPIF	1	0	8	0	9
Fixed-price sum	9	0	15	2	26
(percent)	(37.5%)	(0%)	(50%)	(22.2%)	(35.6%)
CPAF	11	2	8	5	26
CPAF/CPIF	0	0	4	0	4
CPFF	2	3	0	0	5
CPFF/CPAF	0	0	0	1	1
CPIF	2	4	3	0	9
CPIF/CPAF/CPFF	0	1	0	0	1
CPIF/CPFF	0	0	0	1	1
Total	24	10	30	9	73

Please refer to the Appendix for the definition of various contract types.

In Table 2, we tabulate the distribution of contract types by the three services and DoD. Out of the 101 MDAPs, 73 have contract type data available.

For the whole sample, 26 out of the 73 MDAPs use firm-fixed-price (FFP) or fixed-price-incentive-fee (FPIF), which translates to a 35.6% usage of fixed-price contracts. However, across the three services and DoD, the employment of fixed-price contracts varies significantly. At one extreme, the Army employs no fixed-price contracts; at the other extreme, half of the Navy's MDAPs use fixed-price contracts. In between, the Air Force's use of fixed-price contracts is 37.5% and the DoD's frequency of using fixed-price contracts is 22.2%.

Out of the 80 MDAPs for which we can identify the contractor name, the top five are Lockheed Martin (16), Boeing (13), Northrop Grumman (13), Raytheon (10), and General Dynamics (9). All together these top five contractors account for more than three quarters of the 80 MDAPs. The 19 remaining MDAPs are divided among 14 different contractors. (BAE systems and General Atomic have 3 each, United Technology has 2, and the 11 other contractors have 1 each.) Considering the dominance by the top five contractors, we investigate whether systematic cost performance differences exist among the five major players and all the other (small) players.[10] Panel A of Table 3 tabulates the frequency distribution of MDAPs by major contractors across the three services and DoD. Panel B of Table 3 displays the cost performance statistics by major contractors.

Table 3. Analyzing Major Defense Contractors.

Panel A: The Frequency of MDAPs by Top Five Contractors and Services

	Boeing	General Dynamics	Lockheed Martin	Northrop Grumman	Raytheon	The Others	Total (%)
Air Force	6	0	9	6	2	3	26 (32.50)
Army	2	2	1	1	1	4	11 (13.75)
Navy	4	6	3	6	7	8	34 (42.50)
DoD	1	1	3	0	0	4	9 (11.25)
Total (%)	13 (16.25)	9 (11.25)	16 (20.00)	13 (16.25)	10 (12.50)	19 (23.75)	80 (100)

Panel B: The Mean of Contract Performance Data by Top Five Contractors

	Boeing (*N*)	General Dynamics (*N*)	Lockheed Martin (*N*)	Northrop Grumman (*N*)	Raytheon (*N*)	The Others (*N*)
CPI	0.9726 (7)	0.9279 (9)	0.9807 (12)	0.9532 (13)	0.8928 (6)	0.9860 (12)
SPI	0.9910 (7)	0.9611 (9)	0.9876 (12)	0.9756 (13)	0.9738 (6)	0.9623 (12)
CVP	−0.0293 (7)	−0.0890 (9)	−0.0234 (12)	−0.0532 (13)	−0.1372 (6)	−0.0201 (12)
SVP	−0.0090 (7)	−0.0389 (9)	−0.0124 (12)	−0.0243 (13)	−0.0262 (6)	−0.0377 (12)
APB cost breach[a]	0.3846 (13)	0.2222 (9)	0.3750 (16)	0.4615 (13)	0.4000 (10)	0.4211 (19)
APB schedule breach[a]	0.4615 (13)	0.6667 (9)	0.5000 (16)	0.6154 (13)	0.8000 (10)	0.5263 (19)
Nunn-McCurdy breach[a]	0.1538 (13)	0.1111 (9)	0.1875 (16)	0.0769 (13)	0.0000 (10)	0.1053 (19)

[a]Each breach variable is coded as a dummy that takes value of 1 if there is a breach, and 0 otherwise.

EMPIRICAL TESTS AND RESULTS

The Cost Performance Variation Among the Services

Our first research question concerns whether statistically significant cost performance differences exist among the three services and DoD. Preliminary statistics presented in the second section suggests that Navy is the worst performer and Air Force is the best. Here we perform statistical tests to assess this conjecture. The first set of analyses is based on *t*-tests designed to evaluate the null hypothesis that the means of two groups of observations are equal. A significant *p*-value would indicate the rejection of the null hypothesis. Panels A, B, and C in Table 4 present the *t*-test results from comparing the mean of cost performance between "Navy" and "Non-Navy," "Air Force" and "Non-Air Force," and "Navy" and "Air Force," respectively.

Panel A shows that the Navy MDAPs significantly underperform non-Navy MDAPs in CPI and CVP. In addition, the Navy MDAPs are more likely to have APB schedule breaches than non-Navy MDAPs. However, there is no indication that statistical significant difference exists between the two groups on SPI, SVP, APB cost breaches, or Nunn-McCurdy breaches.

Panel B shows that the Air Force MDAPs significantly outperform non-Air Force MDAPs in CPI and CVP. Also, the Air Force MDAPs are less likely to have APB cost breaches, APB schedule breaches, or Nunn-McCurdy breaches than non-Air Force MDAPs. However, there is no indication that statistically significant differences exist between the two groups on SPI and SVP.

Panel C shows the direct comparison between the Navy and the Air Force. It is confirmed that the Air Force MDAPs significantly outperform the Navy MDAPs in CPI and CVP. Also, the Air Force MDAPs are less likely to have APB cost breaches, APB schedule breaches, or Nunn-McCurdy breaches than the Navy's MDAPs. However, there is no indication that statistically significant differences exist between the two groups on SPI and SVP.

The evidence presented in Panels A, B, and C in Table 4 in general supports the premise that among the three services and DoD, the Navy is the worst cost performer, while the Air Force is the best. In addition, Air Force also has the best track record on various breaches, while the Navy tends to have more APB schedule breaches.

Our second set of statistical tests is based on bivariate regressions. Specifically, we test the significance of the Navy effect and the Air Force

Table 4. *t*-Tests for the Equality of the Mean.

Mean	CPI	SPI	CVP	SVP	APB Cost Breach	APB Schedule Breach	Nunn-McCurdy Breach
Panel A: Navy and Non-Navy							
Navy (*N*)	0.9204	0.9664	−0.0956	−0.0336	0.4474	0.6842	0.1579
	(25)	(25)	(25)	(25)	(38)	(38)	(38)
Non-Navy (*N*)	0.9853	0.9809	−0.0192	−0.0191	0.3333	0.3810	0.0794
	(34)	(34)	(34)	(34)	(62)	(62)	(62)
Difference	0.0649	0.0145	0.0764	0.0145	−0.1140	−0.3033	−0.0785
t-stat (*p*-value)	**3.40***** **(0.0013)**	0.98 (0.3315)	**3.15***** **(0.0032)**	0.98 (0.3315)	−1.14 (0.2562)	**−3.06***** **(0.0029)**	−1.14 (0.2601)
Panel B: Air Force and Non-Air Force							
Air Force (*N*)	1.0026	0.9727	−0.0011	−0.0273	0.2000	0.3333	0.0333
	(17)	(17)	(17)	(17)	(30)	(30)	(30)
Non-Air Force (*N*)	0.9396	0.9756	−0.0720	−0.0244	0.4571	0.5714	0.1429
	(42)	(42)	(42)	(42)	(70)	(70)	(70)
Difference	−0.0631	0.0029	−0.0709	0.0029	0.2571	0.2381	0.1096
t-stat (*p*-value)	**−2.96***** **(0.0044)**	0.15 (0.8834)	**−3.33***** **(0.0017)**	0.15 (0.8834)	**2.58**** **(0.0114)**	**2.35**** **(0.0209)**	**2.08**** **(0.0397)**
Panel C: Air Force and Navy							
Air Force (*N*)	1.0026	0.9727	−0.0011	−0.0273	0.2000	0.3333	0.0333
	(17)	(17)	(17)	(17)	(30)	(30)	(30)
Navy (*N*)	0.9204	0.9664	−0.0956	−0.0336	0.4474	0.6842	0.1579
	(25)	(25)	(25)	(25)	(38)	(38)	(38)
Difference	−0.0823	−0.0063	−0.0945	−0.0063	0.2474	0.3509	0.1246
t-stat (*p*-value)	**−3.64***** **(0.0008)**	−0.31 (0.7561)	**−3.60***** **(0.0009)**	−0.31 (0.7561)	**2.28**** **(0.0261)**	**3.16***** **(0.0024)**	**1.73*** **(0.0703)**

Equivalent to univariate regression.
*10% significance level, **5% significance level, and ***1% significance level.

effect jointly.[11] To do this we create a dummy variable for the Navy MDAPs and for the Air Force MDAPs, respectively. Each performance variable is then regressed onto these two dummy variables. For CPI, SPI, CVP, and SVP, we perform Ordinary Least Squares (OLS) regressions. For the breach variables, we perform logistic regressions. Table 5 demonstrates the regression results.

Joint tests based on bivariate regressions show that the Navy continues to show cost inefficiency as evidenced by CPI and CVP, and the Navy is more likely to have APB schedule breaches. The Air Force's superior cost performances in CPI and CVP become less significant in joint tests. Finally, Air Force MDAPs are less likely to have APB cost breaches. All the other tests have no significant results.

Tables 4 and 5 together demonstrate that the Navy MDAPs consistently underperform in the two key measures of cost efficiency: CPI and CVP. The Navy also lags behind in terms of APB schedule breaches. Hence, we conclude that in the context of MDAPs, Navy is the least cost-efficient among the major military services.

On the other hand, there is strong evidence in Table 4 suggesting that the Air Force is the best performer in cost measures as well as in all contract breach measures. The signs of the coefficients remain unchanged in Table 5 yet statistical significance diminished in the joint test (Table 5) with one exception on APB cost breaches, which remains significant. Note that one likely explanation for the reduction in statistical significance is the small power of the test due to small sample size. In such cases, the test lacks the power to reject the null *statistically* even though the difference is significant *economically*. Hence, our view is that there is reasonably strong evidence in support of the premise that the Air Force is the most efficient military service in the MDAP setting.

The Cost Performance Variation Among the Contractors

Our second research question concerns whether statistically significant cost performance differences exist among major contractors. Preliminary statistics presented in the second section (Panel B of Table 3) suggests that Raytheon is the worst performer in CPI and CVP, followed by General Dynamics. Here we perform statistical tests to assess this conjecture. Similar to the section "The Cost Performance Variation Among the Services," the first set of analyses is based on *t*-tests, and the second set of analyses is based on bivariate regressions. The results are shown in Tables 6 and 7, respectively.

Table 5. Bivariate Regressions.

Independent Variables	Dependent Variables						
	OLS regression				Logistic regression (define breach as event)		
	CPI ($N = 59$)	SPI ($N = 59$)	CVP ($N = 59$)	SVP ($N = 59$)	APB cost breach ($N = 100$)	APB schedule breach ($N = 100$)	Nunn-McCurdy breach ($N = 100$)
Navy dummy var.	**−0.0475****	−0.0228	**−0.0582****	−0.0228	−0.0861	**1.0245****	0.2719
(p-value)	**(0.0401)**	(0.2049)	**(0.0347)**	(0.2049)	(0.8580)	**(0.0400)**	(0.6958)
Air Force dummy	0.0348	−0.0165	0.0363	−0.0165	**−1.3019****	−0.4906	−1.4553
var. (p-value)	(0.1643)	(0.3989)	(0.2213)	(0.3989)	**(0.0239)**	(0.3491)	(0.2051)
R^2	0.1968	0.0291	0.1884	0.0291	N/A	N/A	N/A

*10% significance level, **5% significance level, and ***1% significance level.

Panel A of Table 6 shows that Raytheon significantly trails behind other contractors in CPI and CVP. In addition, 8 out of the 10 Raytheon MDAPs experienced APB schedule breaches, which is significantly higher than other contractors. Observe that none of Raytheon's 10 MDAPs has reported a Nunn-McCurdy breach, which may give an impression that Raytheon leads the other contractors in Nunn-McCurdy breach performance. However, we caution that the statistical significance should be downplayed here since one case of a Nunn-McCurdy breach would totally eliminate the significance. This observation is confirmed in Table 7 by the fact that the logistic regression in the last column did not converge to a maximum likelihood estimator.

Although the statistics in the second section suggest that General Dynamics is the second worst cost performer, Panel B of Table 6 finds no statistical significance to support this conjecture.

Table 7 confirms that both Raytheon's inferior cost performance and more frequent APB schedule breaches are supported in the joint test. While the *t*-tests in Table 6 do not show any statistical significance for General Dynamics, the bivariate regression does provide at least marginal significance on two important cost measures: CVP and CPI. Given the small sample size and the resulting lack of power, this significance level (around 10%) provides reasonable support to the conjecture that General Dynamics is the second least efficient cost performer.

The Confounding Effects of Services and Contractors

Sections "The Cost Performance Variation Among the Services" and "The Cost Performance Variation Among the Contractors" suggest that Navy ranks last and Air Force ranks best in terms of cost performance. Moreover, Raytheon and General Dynamics are the two least cost-efficient MDAP contractors. It is possible that these two factors, services and contractors, have confounding effects. For example, the Navy appears to contract with Raytheon and General Dynamics more often than do the other services, while the Air Force contracts least often with these contractors. Specifically, Panel A of Table 3 shows that the Navy accounts for 7 out of the 10 MDAPs (70%) contracted to Raytheon and 6 out of the 9 MDAPs (66.67%) contracted to General Dynamics. These two percentages are much higher than the percentage of the Navy's total MDAPs, which is 42.50%. On the other hand, the Air Force has no contract with General Dynamics and only has 2 MDAPs contracted to Raytheon (0% and 20%,

Table 6. *t*-Tests for the Equality of the Mean.

Mean	CPI	SPI	CVP	SVP	APB Cost Breach	APB Schedule Breach	Nunn-McCurdy Breach
Panel A: Raytheon and Non-Raytheon							
Raytheon (*N*)	0.8928 (6)	0.9738 (6)	−0.1372 (6)	−0.0262 (6)	0.4000 (10)	0.8000 (10)	0.0000 (10)
Non-Raytheon (*N*)	0.9651 (53)	0.9749 (53)	−0.0419 (53)	−0.0251 (53)	0.3736 (90)	0.4615 (90)	0.1209 (90)
Difference	0.0723	0.0011	0.0953	0.0011	−0.0264	−0.3385	0.1209
t-stat (*p*-value)	**2.20****	0.11	**2.47****	0.11	−0.16	**−2.05****	**3.52*****
	(0.0321)	(0.9168)	**(0.0164)**	(0.9168)	(0.8718)	**(0.0426)**	**(0.0007)**
Panel B: General Dynamics and Non-General Dynamics							
General Dynamics (*N*)	0.9279 (9)	0.9611 (9)	−0.0890 (9)	−0.0389 (9)	0.2222 (9)	0.6667 (9)	0.1111 (9)
Non-General Dynamics (*N*)	0.9631 (50)	0.9772 (50)	−0.0448 (50)	−0.0228 (50)	0.3913 (91)	0.4783 (91)	0.1087 (91)
Difference	0.0353	0.0161	0.0442	0.0161	0.1691	−0.1884	−0.0024
t-stat (*p*-value)	1.24	0.56	1.32	0.56	0.99	−1.07	−0.02
	(0.2199)	(0.5922)	(0.1936)	(0.5922)	(0.3225)	(0.2852)	(0.9825)

Equivalent to univariate regression.
*10% significance level, **5% significance level, and ***1% significance level.

Table 7. Bivariate Regressions.

Independent Variables	Dependent Variables						
	OLS regression				Logistic regression (define breach as event)		
	CPI ($N = 59$)	SPI ($N = 59$)	CVP ($N = 59$)	SVP ($N = 59$)	APB Cost Breach ($N = 100$)	APB Schedule Breach ($N = 100$)	Nunn-McCurdy Breach ($N = 100$)
Raytheon dummy (p-value)	**−0.0799**** **(0.0180)**	−0.0039 (0.8766)	**−.1049***** **(0.0081)**	−0.0039 (0.8766)	0.0408 (0.9524)	**1.6314**** **(0.0470)**	The maximum likelihood estimate may not exist
General Dynamics dummy (p-value)	−0.0448 (0.1092)	−0.0166 (0.4296)	**−0.0568*** **(0.0827)**	−0.0166 (0.4296)	−0.8065 (0.3330)	0.9383 (0.2056)	
R^2	0.1197	0.0112	0.1446	0.0112	N/A	N/A	N/A

*10% significance level, **5% significance level, and ***1% significance level.

respectively), which are disproportionally lower than the percentage of the Air Force's total MDAPs, which is 32.50%.

An insight would be gained from determining which of these two is the first-order effect. Explanatory factors for poor cost performance may be due to factors such as the Navy's lack of oversight (or the Air Force's better oversight), the quality of the acquisition workforce, or the defense contractors' cost inefficiency, ethical lapses, or weak corporate governance, or combinations of these factors. A sound judgment requires more accurate data and more robust analysis that warrants future research beyond the scope of this chapter. Nevertheless, a multiple regression is performed to allow both the service and the contractor effects to compete. We show this result in Table 8.

The multiple regressions in Table 8 indicate that the Navy continues to show inferior cost performance and is more likely to have APB schedule breaches. The multiple regression evidence for the Air Force's superior cost performance is somewhat weaker except that the Air Force is still least likely to have APB cost breaches. It is very important to note that a nontrivial part of Raytheon and General Dynamic's inferior cost performance has been subsumed by inclusion of the dummy variable for the Navy. However, the Raytheon factor is still present in CVP and less so in both the CPI and APB schedule breaches. Considering the increase in number of regressors as well as the small sample size and accompanying lack of power, we cannot rule out the contractor effect in any meaningful way. All we can say is that the data suggests perhaps the service effect is of the first-order importance, and the contractor effect is the second order.

Cost Performance and Contract Types

Untabulated results (available upon request) show that no significant difference exists on cost and schedule performances in the context of MDAPs between the two major types of contracts: fixed-price and cost-plus. A widespread perception is that fixed-price contracts are more cost-efficient than cost-plus contracts. We did not find any such evidence, which is consistent with the Defense Business Board's[12] conclusion that cost overruns and schedule delays are less related to contract types, but more related to other factors such as the poor assessment of risks, inadequate planning of requirements, lack of cost realism, instability of requirements, and inferior quality of program leadership. In fact, the Navy, who is the worst cost performer among the three services and DoD, has the highest percentage of contracts (50% according to Table 2) structured as fixed-price contracts.

Table 8. Multiple Regressions.

Independent Variables	Dependent Variables						
	OLS regression				Logistic regression (define breach as event)		
	CPI ($N = 59$)	SPI ($N = 59$)	CVP ($N = 59$)	SVP ($N = 59$)	APB Cost Breach ($N = 100$)	APB Schedule Breach ($N = 100$)	Nunn-McCurdy Breach ($N = 100$)
Raytheon dummy	−0.0487	−0.0002	**−0.0707***	−0.0002	−0.1634	1.3256	The maximum
(p-value)	(0.1484)	(0.9944)	**(0.0756)**	(0.9944)	(0.8229)	(0.1216)	likelihood
General Dynamics	−0.0202	−0.0165	−0.0303	−0.0165	−1.2428	0.4937	estimate may
dummy (p-value)	(0.4717)	(0.4597)	(0.3589)	(0.4597)	(0.1447)	(0.5243)	not exist
Navy dummy (p-value)	**−0.0394***	−0.0217	**−0.0463***	−0.0217	0.0104	**0.8421***	
	(0.0952)	(0.2457)	**(0.0954)**	(0.2457)	(0.9836)	**(0.1005)**	
Air Force dummy	0.0283	−0.0194	0.0268	−0.0194	**−1.4002****	−0.4992	
(p-value)	(0.2667)	(0.3398)	(0.3713)	(0.3398)	**(0.0162)**	(0.3519)	
R^2	0.2296	0.0395	0.2385	0.0395	N/A	N/A	N/A

*10% significance level, **5% significance level, and ***1% significance level.

Robustness Tests

It is a legitimate concern that correlated omitted variable problems may exist in the sense that our empirical results could be driven by some hidden factors rather than service or contractor as we conjecture. To address this issue, we examine whether our results are robust to inclusion of two variables, namely, the size of the contracts and the time horizon of contracts.[13] Empirically, we use "contract target price" as proxy for size, and the difference between "estimated completion date" and "work start date" as the time horizon of contracts. The idea is that if systematic differences exist between the Navy and the Air Force (or among different contractors) on contract size and/or contract time horizon, and if size and/or time horizon do(es) impact contract performance,[14] then the inclusion of size and/or time horizon variables could subsume our "service" and/or "contractor" effect.

Untabulated statistics reports show that in general, the Air Force MDAP projects are larger than the Navy MDAP projects, and also take longer to complete. So if any size/time horizon effect kicks in, we argue that it will probably work against finding our results since bigger and longer projects usually equate to more uncertainty and complexity and therefore are more likely to underperform. Given we do find that Air Force contracts outperform Navy contracts, our prior is that either the difference in size/time horizon is too small to matter or if it does matter, it only makes our results even stronger than documented in previous sections. To assess our prior, we perform *t*-tests to test the null that these differences are not statistically significant at conventional confidence levels. Our results fail to reject the null indicating that no systematic difference exists.

Nevertheless,[15] we reran our major tests (Tables 5, 7, and 8),[16] with the inclusion of our size and time horizon variables. As expected, all of our results stay intact. The two new added variables (whether tested alone or together) are nonsignificant in all scenarios. This demonstrates that the contract performance variations across different services and/or contractors are not attributable to the size and/or time horizon factors.

CONCLUSION

Our research documents that, in the context of MDAP, Navy programs are least cost-efficient and Air Force programs are the most cost-efficient. For the top five major contractors identified in DAMIR, Raytheon ranks last in

cost efficiency, followed by General Dynamics. The results of multiple regressions show that confounding effects may exist (contractor effect and military services/DoD effect), but it is unlikely that one can completely subsume the other. Preliminary evidence suggests that the service/DoD effect plays a more important role in explaining cost performance than does the contractor effect. Finally, the statistical tests on schedule performance (with few exceptions) and the relationship between performance and contract types generally yield no results.

NOTES

1. During the eight years after the September 11 attacks, the defense budget grew an average of 4% annually, excluding supplemental appropriations for the wars in Iraq and Afghanistan.
2. "The attacks of September 11th, 2001, opened a gusher of defense spending that nearly doubled the base budget over the last decade, … (Now) the gusher has been turned off, and will stay off for a good period of time…. Therefore, as the Defense Department begins the process of preparing next year's Fiscal 2012 budget request, I am directing the military services, the joint staff, the major functional and regional commands, and the civilian side of the Pentagon to take a hard, unsparing look at how they operate- in substance and style alike. The goal is to cut our overhead costs and to transfer those savings to force structure and modernization within the programmed budget."–Remarks delivered by Secretary of Defense Robert M. Gates, Abilene, KS, May 08, 2010.
3. A recent Government Accountability Office (GAO) study found that in 2008 approximately 70% of 96 MDAPs were experiencing huge cost overruns, reaching over $295 billion (a 26% overrun) over the life of the projects.
4. MDAPs are programs that are estimated by the Under Secretary of Defense for Acquisition, Technology and Logistics to require an eventual total expenditure for research development, test, and evaluation of more than $365 million, including all planned increments, based on fiscal year 2000 constant dollars (approximately $509 million in fiscal year 2010 dollars); $2.190 billion of procurement funding, including all planned increments (approximately $3.054 billion in fiscal year 2010 dollars); or are designated as a major defense acquisition program by the milestone decision authority.
5. The default threshold for schedule breaches is six months after the objective date; for cost breaches the threshold is 10% above objective values.
6. A *current baseline estimate* is the baseline estimate that is included in the most recently revised APB. If the original baseline estimate has not been revised, the original baseline estimate is also the current baseline estimate.
7. An *original baseline estimate* is the cost estimate included in the original (first) APB that is prepared prior to the program entering "engineering and manufacturing development" (also known as "Milestone B"), or at program initiation, whichever occurs later.

8. We code all the breach variables as a dummy where the variable takes value of one if a breach happened, and zero otherwise. We do not distinguish between a "significant" and a "critical" breach for Nunn-McCurdy.

9. This was partly due to the absence of associated data for Firm-Fixed-Price (FFP) contracts, which account for 17 out of the 101 MDAPs.

10. We group all the non-top-five contractors into one category.

11. The joint test assesses the Navy effect and the Air Force effect simultaneously, and examines whether the presence of one effect may subsume the other, or vise versa.

12. Defense Business Board, "Best Business Practices for Fixed-Price Contracting," Report to the Secretary of Defense, Report FY10-03, January 2010.

13. We thank an anonymous referee for raising this point.

14. For example, one possible conjecture is that size and/or time horizon represent(s) the degree of complexness and uncertainty of the contracts and hence can explain the cross-sectional variation in contract performance.

15. Though our prediction on the direction of the impact due to size/time horizon is one-way, we cannot exclude potential alternative conjectures that may predict the other direction.

16. Results are available upon requests.

ACKNOWLEDGMENTS

We thank an anonymous referee and John Lee (the editor) for their invaluable comments and suggestions. Financial support from the Acquisition Research Program at Naval Postgraduate School is greatly appreciated.

REFERENCES

Chapman, C., & Ward, S. (1994a). The efficient allocation of risk in contracts. *Omega, International Journal of Management Science*, *22*(6), 537–552.

Chapman, C., & Ward, S. (1994b). Choosing contractor payment terms. *International Journal of Project Management*, *12*(4), 216–221.

Cokins, G., Euske, K. J., Millish, G., Nostrom, P., & Vercio, A. (2008). Let's certify the quality of a manager's information. *Strategic Finance* (December), 39–45.

Euske, K. J. (2003). Public, private, not-for-profit: Everybody is unique? *Measurement Business Excellence*, *7*(4), 5–11.

Institute of Management Accounting and Ernst & Young. (2003). 2003 Survey of Management Accounting. London, UK: ERNST & YOUNG.

Laffont, J.-J., & Tirole, J. (1986). Using cost observation to regulate firms. *Journal of Political Economy*, *94*(June), 619–641.

Laffont, J.-J., & Tirole, J. (1993). *A theory of incentives in procurement and regulation*. Cambridge, MA: MIT Press.

Loeb, M., & Surysekar, K. (1994). On the optimality of cost-based contracts in sole source procurement. *Management Accounting Research*, *5*, 31–44.

McAfee, R. P., & McMillian, J. (1987). Competition for agency contracts. *Rand Journal of Economics*, *18*(Summer), 296–307.

Melumad, N., & Reichelstein, S. (1989). Value of communications in agencies. *Journal of Economic Theory*, *47*(April), 334–368.

Reichelstein, S. (1992). Constructing incentive schemes for government contracts: An application of agency theory. *The Accounting Review*, *67*(4), 712–731.

Tan, G. (1996). Optimal procurement mechanisms for an informed buyer. *Canadian Journal of Economics*, *29*(3), 699–716.

Tirole, J. (1999). Incomplete contracts: Where do we stand? *Econometrica*, *67*(4), 741–781.

APPENDIX: THE FORMS OF FIXED-PRICE CONTRACTS AND COST-PLUS CONTRACTS

The two broad categories of contract types in DoD are fixed-price contracts and cost-plus contracts. For each of these two types of contracts, the advantages and disadvantages have been extensively investigated in the extant literature (Chapman and Ward (1994a, 1994b), Loeb and Surysekar (1994)) and hence are repeated here. Instead, we focus on introducing various forms of fixed-price and cost-plus contracts found in practice. The following descriptions of each contract type are based on Federal Acquisition Regulations (FAR), except for the "budget-based-cost-plus" scheme, which is not defined by FAR and has no application thus far in MDAP.

Firm-Fixed-Price Contracts

A firm-fixed-price (FFP) contract provides for a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. This contract type places maximum risk and full responsibility for all costs and resulting profit or loss on the contractor. It provides maximum incentive for the contractor to control costs and perform effectively and imposes a minimum administrative burden upon the contracting parties.

Fixed-Price-Incentive-Fee Contracts

A fixed-price incentive-fee (FPIF) contract is a fixed-price contract that provides for adjusting profit and establishing the final contract price by a formula based on the relationship of final negotiated total cost to total target cost. A fixed-price incentive contract specifies a target cost, a target profit, a price ceiling (but not a profit ceiling or floor), and a profit-adjustment formula. These elements are all negotiated at the outset. The price ceiling is the maximum that may be paid to the contractor, except for any adjustment under other contract clauses. When the contractor completes performance, the parties negotiate the final cost, and the final price is established by applying the formula. When the final cost is less than the target cost, application of the formula results in a final profit greater than the target profit. Conversely, when final cost is more than target cost, application of the formula results in a final profit that is less than the target

profit, or possibly a net loss. If the final negotiated cost exceeds the price ceiling, the contractor absorbs the difference as a loss. Because the profit varies inversely with the cost, this contract type provides a positive, calculable profit incentive for the contractor to control costs.

Cost-Plus-Fixed-Fee Contracts

A cost-plus-fixed-fee (CPFF) contract is a cost-reimbursement contract that provides for payment to the contractor of a negotiated fee that is fixed at the inception of the contract. The fixed fee does not vary with actual cost, but may be adjusted as a result of changes in the work to be performed under the contract. This contract type permits contracting for efforts that might otherwise present too great a risk to contractors, but it provides the contractor only a minimum incentive to control costs.

Cost-Plus-Incentive-Fee Contracts

A cost-plus-incentive-fee (CPIF) contract is a cost-reimbursement contract that provides for an initially negotiated fee to be adjusted later by a formula based on the relationship of total allowable costs to total target costs. This contract type specifies a target cost, a target fee, minimum and maximum fees, and a fee-adjustment formula. After contract performance, the fee payable to the contractor is determined in accordance with the formula. The formula provides, within limits, for increases in fee above target fee when total allowable costs are less than target costs, and decreases in fee below target fee when total allowable costs exceed target costs. This increase or decrease is intended to provide an incentive for the contractor to manage the contract effectively. When total allowable cost is greater than (or less than) the range of costs within which the fee-adjustment formula operates, the contractor is paid total allowable costs, plus the minimum (or maximum) fee.

Cost-Plus-Award-Fee Contracts

A cost-plus-award-fee (CPAF) contract is a cost-reimbursement contract that provides for a fee consisting of (a) a base amount (which may be zero) fixed at inception of the contract, and (b) an award amount, based on a judgmental evaluation by the government, sufficient to provide motivation

for excellence in contract performance. Since the award fee determination is made unilaterally by the government, this contract type is only appropriate when achievement is measurable by subjective evaluation rather than objective data, which is unlikely to be true under significant information asymmetry.

Budget-Based-Cost-Plus-Scheme Contracts

A budget-based-cost-plus-scheme (BBCPS) contract is a refinement of CPIF in the following: (a) under BBCPS, the job of estimating target cost is shifted from the government to the contractor; and (b) moreover, both target fee and cost share coefficient vary with the estimated target cost rather than being constants under CPIF. A carefully designed BBCPS contract will desirably induce the contractor's "truth-telling" behavior and hence effectively mitigates the agency problem and reduces information asymmetry.

BBCPS belongs to the larger topic of "menu of contracts" discussed in the principal-agent literature. This body of literature has broad applications in executive compensation contracts, regulation, and government procurement contracts (Laffont & Tirole, 1986, 1993; McAfee & McMillian, 1987; Melumad & Reichelstein, 1989; Reichelstein, 1992).