NPS-AM-14-C11P08R01-039

PROCEEDINGS
OF THE
ELEVENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM

WEDNESDAY SESSIONS
VOLUME I

A Model for Understanding the Relationship Between Transaction Costs and Acquisition Cost Breaches

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Published April 30, 2014

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Panel 8. Causal Factors for Cost Breaches in DoD Acquisition

Wednesday, May 14, 2014	
3:30 p.m. – 5:00 p.m.	**Chair: Gary R. Bliss,** Director, Performance Assessments and Root Cause Analyses (PARCA), Office of the Assistant Secretary of Defense (Acquisition) ***Regulatory Burden and Poor Defense Acquisition Program Outcomes*** R. Bruce Williamson, Institute for Nuclear Security Justin Roush, University of Tennessee ***A Model for Understanding the Relationship Between Transaction Costs and Acquisition Cost Breaches*** Diana Angelis, Naval Postgraduate School Laura Armey, Naval Postgraduate School Carl Biggs, U.S. Navy ***Digging Out the Root Cause: Nunn-McCurdy Breaches in Major Defense Acquisition Programs*** Bill Shelton, RAND Corporation Irv Blickstein, RAND Corporation Jerry Sollinger, RAND Corporation Charles Nemfakos, RAND Corporation

A Model for Understanding the Relationship Between Transaction Costs and Acquisition Cost Breaches

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Abstract

Many studies have examined cost growth in DoD programs, yet little research has been done on the relationship between transaction costs and cost overruns. This study expands the work done by Biggs in 2013 to examine the relationship between transaction costs (using the SE/PM cost ratio as a proxy) and the likelihood of cost breaches experienced by a program. We do this in two ways. First we look at the data using a survival model to explore the relationship, which allows us to model the hazard of cost breaches over program maturity time. Second, we look at Nunn-McCurdy breaches as well as APB breaches. We find that higher SEPM ratios, either to date or estimated at completion, significantly increase the risk of both kinds of cost breaches in many models. In the models of APB breaches, a 1 percentage point increase in estimated SEPM at completion increases the risk of breach by 3–5%. The estimated impact is reduced in the model with to date SEPM, where it is about 2% when we do not control for contract type. Our results suggest that the SEPM ratio is a promising measure of the likelihood that programs will experience a cost breach.

Introduction

Controlling cost growth for major defense acquisition programs (MDAPs) has been problematic in the Department of Defense (DoD) for many years. A 2007 RAND study of 46 weapons system programs in the DoD found an average of almost 50% cost growth from Milestone B (program initiation; Obaid Younossi et al., 2007, xvi). According to the GAO, active MDAPs in FY 2011 collectively experienced a cost growth of $74.4 billion (GAO, 2011, 2).

Selected Acquisition Reports (SARs) were introduced in 1967 to provide the DoD and the Congress a summary of the MDAP's ability to meet cost, performance and schedule objectives. If a program exceeds an established cost threshold, a breach has occurred and the program manager must provide a brief explanation in the SAR of how or why the cost breach occurred. In 1981, Senator Samuel Nunn and Congressman David McCurdy introduced the Nunn-McCurdy Amendment (10 U.S.C. § 2433 2006) in an effort to control MDAP cost growth by holding the DoD accountable to Congress for management of program costs. The Nunn-McCurdy Amendment became law with the FY 1983 Department of Defense Authorization Act, which establishes consequences for MDAPs which exceed established cost thresholds.

Many studies (e.g., Bolten et al., 2008) have examined cost growth in DoD programs, yet little research has been done on the relationship between transaction costs and cost overruns as suggested by Angelis et al. in 2008. A 2006 RAND study established that MDAP SE/PM costs vary between programs depending on the program type (Stem, Boito, & Younossi, 2006) and Angelis et al. (2008) suggested using the SE/PM cost as a proxy for transaction costs to examine the relationship between transaction costs and cost overruns. Biggs (2013) showed that as the EAC SE/PM cost ratio rises there is a statistically significant corresponding increase in the probability of a cost threshold breach occurring.

This study examines transaction costs, a component of system cost that is not explicitly included in most cost estimates. To measure transaction costs, we will use a proxy measure first suggested by Angelis, et al. in 2008 that includes systems engineering (SE) and program management (PM) costs reported by MDAP contractors. A SE/PM ratio based on the total program cost is developed to allow comparison of transaction costs across different programs. It seems reasonable to assume that the SE/PM costs may increase as program managers respond to actual or anticipated increases in program costs.

We look at the relationship between transaction costs and cost breaches in MDAPs initially reported by Biggs (2013) and seek to expand our understanding of this relationship by using survival analysis and considering whether cost breaches can be predicted by transaction costs. A better understanding of this relationship could lead to improved forecasting of cost breaches, which would be of great interest to both program managers and Congress.

Cost Breaches in Major Defense Acquisitions Programs

A cost breach is considered to occur when cost expenditures exceed the approved baseline cost estimate for an MDAP—also known as the acquisition program baseline (APB). The initial APB cost estimate is established early in the acquisition phase when there may be a considerable amount of uncertainty about specific requirements and technology. If an MDAP has been officially rebaselined cost breaches are measured relative to the current baseline.

There are six categories of appropriations where cost breaches often occur: average procurement unit cost (APUC); program acquisition unit cost (PAUC); procurement;

research, development, testing and evaluation (RDT&E); military construction (MILCON); and acquisition-related operations and maintenance (O&M). Each of these cost breaches was included in the data set for this study.

Nunn-McCurdy cost threshold breaches, or cost overruns, are based on original cost estimates for PAUC and APUC at project completion and in the case of a program which has rebaselined, cost threshold breaches are also based on the current (i.e., rebaselined) cost estimate for PAUC and APUC at project completion. For the purposes of this study, an APB cost breach is any cost breach reported in the SAR that is greater than or equal to 10% above the APB. Table 1 summarizes the types of breaches and their corresponding thresholds.

Table 1. Nunn-McCurdy Cost Breach Thresholds

	APB Breach (RDT&E, Procurement, MILCON, O&M)	Nunn-McCurdy “Significant” Breach (PACU & APUC)	Nunn-McCurdy “Critical” Breach
Current Baseline	10%	+15%	+25%
Original Baseline	N/A	+30%	+50%

Figure 1 can be used to illustrate cost overrun calculations. The budgeted cost of work performed (BCWP) represents the total amount budgeted for work packages that are open or completed at any given point in time. The budgeted cost of work scheduled (BCWS) represents the total amount budgeted for the work that was scheduled for completion at a given point in time. The ACWP is the sum of actual costs that have been incurred to accomplish the work performed as of a point in time.

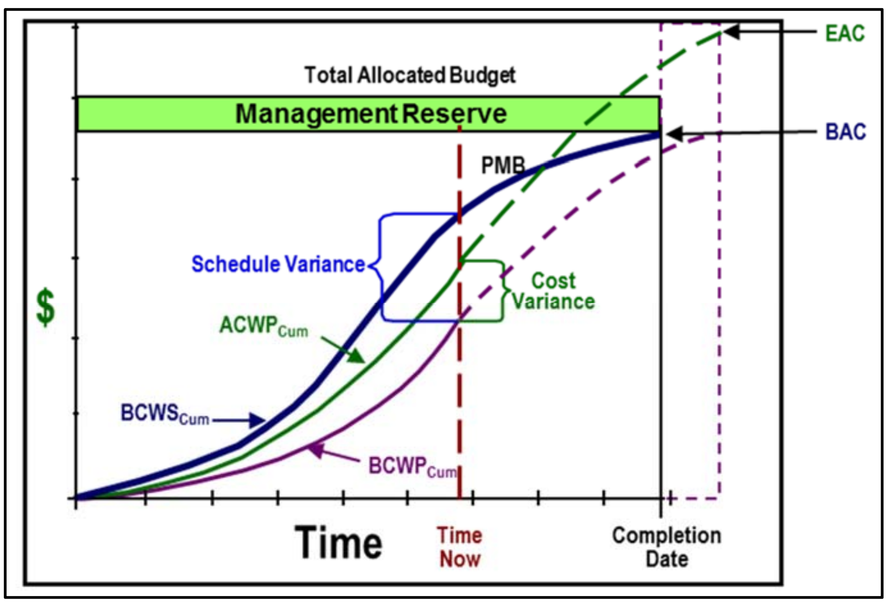

Figure 1. Earned Value Management
(Defense Acquisition University, 2012)

The Estimate at Completion (EAC) is the sum of the ACWP and the estimate to completion (ETC) for the remaining work. The ETC can be calculated using the cost performance index (CPI) and the schedule performance index (SPI). The formula for calculating ETC is

$$ETC = (BAC-BCWP) / (CPI*SPI) \quad (1)$$

When the EAC, a cost estimate for the total cost of the contract, is higher than the BAC, the baseline cost estimate of the contract, a cost overrun is projected. To calculate the expected cost overrun the current cost estimate must be revised to incorporate actual costs (ACWP). This adjusted EAC is then compared to the BAC, the acquisition program baseline for the contract. The percentage of cost overrun projected can be calculated using the following equation:

$$\text{Projected \% Cost Overrun} = \left[\frac{EAC}{BAC} \times 100\right] - 100 \quad (2)$$

Transaction Costs

In general, a program has two types of costs: production costs and transaction costs. Production costs are usually captured in the WBS, but transaction costs may not be adequately captured in the WBS. Because traditional cost estimates are based on the production costs found in the WBS, they do not explicitly include transaction costs (Angelis et al., 2008).

Transaction costs are the costs associated with "source selection, periodic competition and renegotiation, contract negotiation and management, performance measuring and monitoring and dispute resolutions" (Angelis et al., 2008). Transaction costs are driven by the complexity and riskiness of the work to be accomplished. There are three generally accepted categories of transaction costs: search and information costs; bargaining and decision costs; and policing and enforcement costs (Johnson, 2005). Although they are not often captured in the accounting records, the time and effort associated with these three types of transactions represent real costs to the organization.

Transaction costs are difficult to measure because they are not easily identified and seldom captured in the accounting records. In previous research Angelis et al. (2008) examined how transaction costs might be captured in the cost estimates of DoD acquisition programs. Angelis, et al. identified a number of issues with DoD program management cost data reported for major weapon systems and found that it is not well suited for developing a cost model that includes transaction cost variables.

As an alternate approach, they explored using contractor program management data from Cost Data Summary Reports (DD Form 1921) and suggested using the Systems Engineering/Program Management (SE/PM) category as a proxy for transaction costs. According to MIL-STD-881C, system engineering is defined as "the technical and management efforts of directing and controlling a totally integrated engineering effort of a system or program" and program management is defined as "the business and administrative planning, organizing, directing, coordinating, controlling, and approval actions designated to accomplish overall program objectives, which are not associated with specific hardware elements and are not included in systems engineering" (DoD, 2011, 222). As such SE and PM seem to capture many of the activities typically related to transaction costs.

The SE/PM Cost Ratio

The SE/PM cost values used in this study are extracted from the WBS line item values for "SE/PM cost" which are listed on the Cost Data Summary Report (CDSR), DD Form 1921. The SE/PM cost to date is the total expended on SE/PM as of the report date. The EAC SE/PM cost is the projected SE/PM cost at contract completion. The SE/PM costs are inclusive of the total contract costs less the contractor's profit/loss or fees. We note that the costs included in this category may differ from program to program and from contract to contract due to subjective interpretations among contractors (and program managers) about the definition of SE/PM costs and non-uniform standards regarding which costs qualify to be categorized as SE/PM costs (Stem, Boito, & Younossi, 2006).

This study uses the SE/PM cost ratio for a program, as shown in Equation 3:

$$\text{SE / PM Cost Ratio} = \frac{\text{SE /PM Costs}}{\text{Total Costs}} \quad (3)$$

The numerator of the SE/PM cost ratio is the sum of SE and PM cost expenditures and the denominator is total program expenditures. A ratio is calculated to provide a perspective on the relative magnitude of SE/PM expenditures as well as to allow for comparison across different programs.

Time and Risk

Survival analysis uses "time at risk" as its relevant time metric. In this study we examine the risk of a cost breach over time. We measure "survival time" in terms of the maturity of the design and technology of the system, where program maturity is measured by the time elapsed since Milestone B, the entry point into the Engineering and Manufacturing Development phase. For a program to receive approval to begin Milestone B in the DoD, the design and technology associated with the system must be considered "mature."[1]

The type of contract used for a program is an indication of the perceived risk associated with the execution of the contract. As the level of performance risk increases, the risk of cost overruns also increases and the amount of cost risk that the contractor is willing to assume tends to decrease. Contract types differ in how the cost risk is shared between the government and the contractor. In a firm fixed-price contract there is no cost sharing between the government and the contractor and the contractor has full responsibility for the performance costs and resulting profit (or loss). In a cost-plus contract, a share ratio based on the contract cost and the contractor's fee (profit) is negotiated so that the contractor has a pre-determined responsibility for the performance costs which will directly affect the fee (GSA, 2005). By including contract type in our analysis we can account for basic cost risk differences recognized by both the government and the contractor at the onset of the program.

Hypothesis

It seems reasonable to assume that programs with riskier contractual relationships will have higher transaction costs, since more time, effort and resources are expended to meet performance and schedule deadlines when compared to less risky contracts. If those transaction costs were not adequately included in the cost estimate then it is possible that a program with high transaction costs (as measured by the SE/PM ratio) would be more likely to experience cost overruns. Our hypothesis is that programs with higher SE/PM cost ratios are more likely to experience cost breaches than programs with lower SE/PM cost ratios.

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[1] Milestone B approval authorizes an MDAP to enter the Engineering and Manufacturing Development phase of the acquisition process. Statutory requirements for MDAPs to achieve Milestone B approval are found in Title 10 U.S.C. § 2366b.

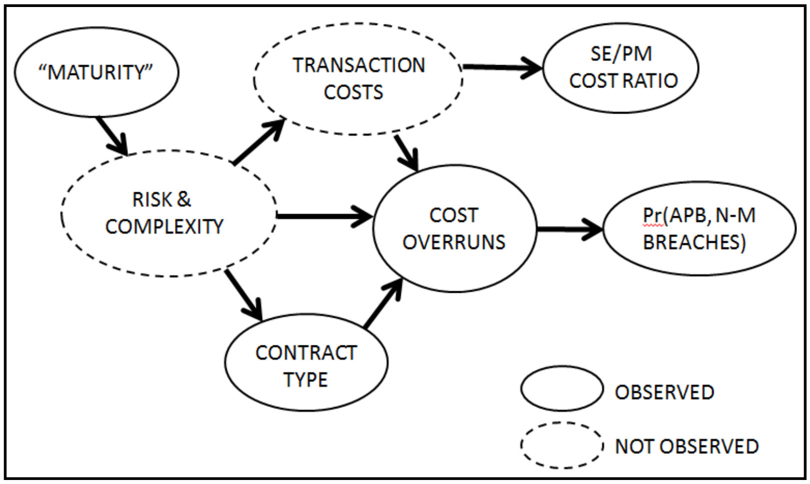

Figure 2. Cost Breach Influence Diagram
(Biggs, 2013)

The influence diagram in Figure 2 describes the interactions between factors which may be associated with the occurrence of a cost breach. The dashed lines in Figure 2 represent factors that must be dealt with qualitatively or by using proxies. The solid lines represent factors that can be quantitatively evaluated. While the risk and complexity of a program may directly contribute to a cost overrun, the SE/PM efforts and the contract type can influence the magnitude and frequency of cost overruns as measured by cost breaches.

Figure 2 indicates that the risk and complexity of the MDAP will guide program managers and contractors in their selection of an appropriate contract type which in turn can influence the government's exposure to cost overruns. It is also likely that the risk and complexity of a program will drive the level of monitoring and negotiation (transaction costs) required to manage the program and that riskier, more complex programs will require higher levels of transaction costs which may contribute to cost overruns.

In this study we will examine how the SE/PM ratio and contract type are related to the probability of incurring an APB or Nunn-McCurdy cost breach over time. Our assumption is that programs with higher SE/PM cost ratios are in riskier contractual relationships and have higher transaction costs and will have a higher probability of cost breaches than those programs with lower SE/PM cost ratios.

Data

This study used two different data sources: selected acquisition reports (SAR) and the cost and software data reporting system (CSDR). The SAR contains details of critical parameters of an MDAP including threshold breaches, schedule, performance, current contracts and cost details. MDAPs typically require several contracts to be executed, often concurrently and SARs provide information for the overall program and not for individual contracts. A SAR may list a single contract or many contracts for a single MDAP. Because threshold breaches are associated with contract estimates, only MDAPs which listed a single contract in the "Contracts" section of the SAR were selected for our study. In addition to cost threshold breaches, the SAR indicates the time since program initiation at Milestone B, which was used in this study to indicate program maturity.

The program cost data found in the DD Form 1921 (Cost Data Summary Report, CDSR) provided by the Defense Cost and Resource Center (DCARC) in the Defense Automated Cost Information Management System (DACIMS) database contains significantly more contract detail than the SARs. The work breakdown structure (WBS) format of the CDSR allows us to obtain information on SE and PM costs. To simplify the data collection process, only the cost data provided by the prime contractor was recorded for further analysis. The type of contract used for the program was also obtained from the CDSRs. Programs were noted as having either firm fixed price type contracts or cost-plus type contracts.

A total of 32 MDAPs representing Air Force, Army, Navy, and Joint programs since 1988 were included in this study and are listed in the appendix. Descriptive statistics for the data are shown in Table 2. Note that each program had several years of observations.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
APB Breach	84	0.3095238	0.4650739	0	1
NM Breach	84	0.1071429	0.3111524	0	1
SEPM – EAC	84	15.18071	11.88479	0.15	49.75
SEPM – To Date	78	16.47692	15.95705	0	87
Type (0 = Fixed)	78	0.525641	0.5025741	0	1

Methodology

This study expands the work done by Biggs in 2013 to determine the nature of any potential relationship between transaction costs (using the SE/PM cost ratio as a proxy) and the likelihood of cost breaches experienced by a program. We do this in two ways. First we look at the data using a survival model to explore the relationship, which allows us to model the hazard of cost breaches over program maturity time.

Second, we look at Nunn-McCurdy breaches. Cost breaches result when the amount of the cost overrun exceeds certain parameters defined by regulation. There are two types of cost breaches: APB and Nunn-McCurdy breaches. In order for a program to incur an APB breach estimated program expenditures must be greater than the APB estimate at completion (EAC) by at least 10%. If the difference is 15% or more, it is a Nunn-McCurdy breach. Biggs looked at APB breaches. In this study we look at both APB and Nunn-McCurdy breaches separately since Nunn-McCurdy breaches have more serious consequences for program managers.

Both APB cost breaches and Nunn-McCurdy cost breaches are considered the binary-outcome dependent variable in this analysis: cost breach or no cost breach in a given year of program maturity. There are two explanatory variables that were included in the analysis: EAC SE/PM cost ratio and program contract type (fixed price or cost-plus). While the exact nature of the relationship between cost threshold breaches and these explanatory variables is unknown, it is reasonable to suppose that the explanatory variables influence the cost performance of the MDAPs as shown in Figure 2.

Using survival analysis we construct a hazard function for cost breaches. Our analysis builds on Biggs (2013) which used a population averaged logit to look differences in probability of program failure. While the logit is a good starting point to estimate the probability of a cost breach some time during a program's development, the survival model complements this analysis, allowing for multiple breaches over time, and allowing us to estimate how the hazard of cost breaches varies with our explanatory variables. Hazard models are also more tolerant of gaps and censoring and can be thought of as conditional logits (Cleves et al., 2010).

In this analysis, we use the Cox-Relative Hazard. It is considered semi-parametric because it does not imply a specific functional form on the hazard of breaches over time. The proportional hazard model is specified as

$$h_j\ (t) = h_0(t)\exp(x_j \beta_x) \quad (4)$$

Equation 4 states that the hazard a particular subject j faces at time t is a function of the baseline hazard modified proportionally by the vector of regression coefficients β_x. The Cox model does not estimate the baseline hazard. We can convert coefficients from these regressions to hazard ratios to understand the marginal effect on the baseline hazard of a change in the coefficient. This is done simply by calculating the exponent of the coefficient and using as a multiplier (e.g., a 0.9 would be a 10% reduction, and 1.1 would be a 10% increase.) While we report coefficients, we offer interpretation from the exponentiated hazard ratios.

Results

For the 32 programs included in this study, Figures 3 and 4 show the cumulative risk of APB and Nunn-McCurdy breaches over program maturity. Despite not having greatly disparate thresholds, there were far more APB breaches in our sample, with 26 program-years with APB breaches and only 9 program-years with NM breaches.

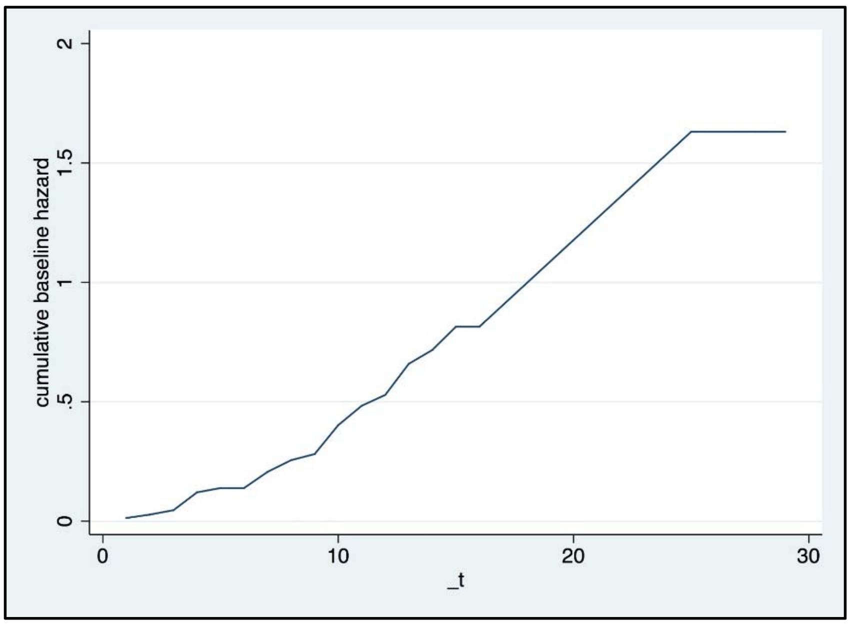

Figure 3. Cumulative Risk of APB Breach

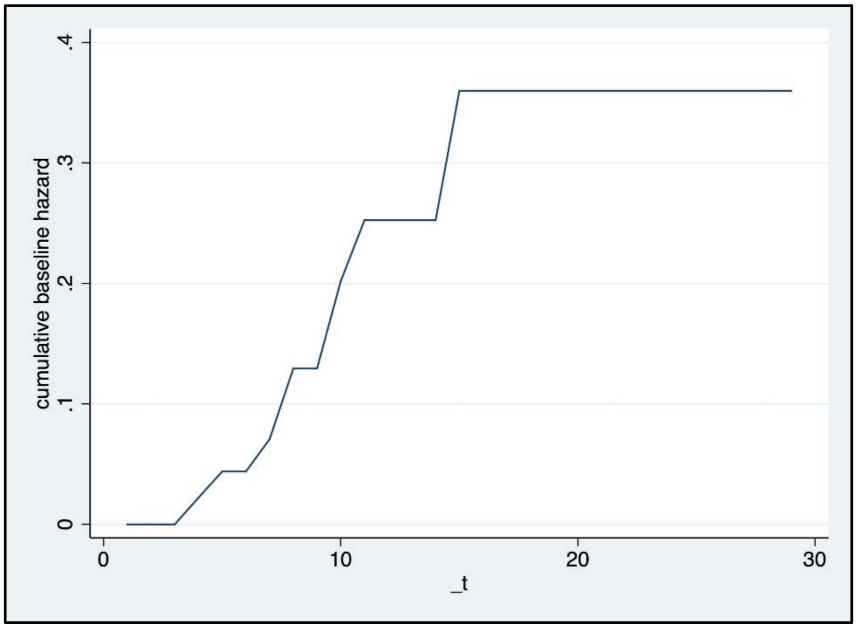

Figure 4. Cumulative Risk of Nunn-McCurdy Breach

Table 3 shows the results for Hazard models for APB Breaches and Table 4 shows the results for Nunn-McCurdy breaches. We find that higher SEPM ratios, either to date or estimated at completion, significantly increase risk of both kinds of cost breaches in many models. In the models of APB breaches, a 1 percentage point increase in estimated SEPM at completion increases the risk of breach by 3–5%. The estimated impact is reduced in the model with to date SEPM, where it is about 2% when we do not control for contract type.

Table 3. APB Breach Hazard

Model	SEPM – EAC		SEPM – To Date	
		with Type		with Type
	0.0494*** (0.01)	0.0323** (0.02)		
		1.090* (0.56)		
			0.0229** (0.01)	0.00 (0.01)
				1.424*** (0.52)
Observations	84	84	78	78
Standard errors in parentheses *** p < .01, ** p < .05, * p < .1				

Table 4. Nunn-McCurdy Hazard

Model	SEPM – EAC		SEPM – To Date	
		with Type		with Type
	0.0410* (0.02)	0.0244 (0.03)		
		0.91 (0.97)		
			0.02 (0.02)	0.00 (0.02)
				1.23 (0.92)
Observations	84	84	78	78
Standard errors in parentheses *** p < .01, ** p < .05, * p < .1				

SEPM is only a significant predictor of Nunn-McCurdy breaches in one of the models. In the model where we do not control for contract type, Nunn-McCurdy breaches are about 4% more likely per one percentage point increase in SEPM estimate at completion. The result is significant at the 10% level.

Looking at the impact of contract type, cost-plus models are, unsurprisingly, more likely to experience cost breaches than fixed price contracts. In the case APB breaches, cost-plus programs are two to three times more likely to experience a cost breach. In the case of Nunn-McCurdy breaches, the result is never statistically significant though it is of a similar magnitude.

Conclusion

In this study we expand the work done by Biggs (2013) using survival analysis to consider whether transaction costs as measured by the SEPM cost ratio can help predict cost breaches in major acquisition programs. We estimate how the hazard of cost breaches varies with SEPM and contract type. Our results confirm previous findings that as the EAC SE/PM cost ratio rises there is a statistically significant corresponding increase in the probability of a cost threshold breach occurring. We find a similar relationship when we look at SEPM to date.

Interestingly, we find less statistically significant evidence that the SEPM ratio is related to the likelihood of a Nunn-MuCurdy breach. This may be due to the considerable penalties associated with a Nunn-McCurdy breach leading to significant efforts by program managers to avoid such breaches. If this is the case, then we are likely to see SEPM ratios increase as more resources are expended to avoid a Nunn-McCurdy breach and if those efforts are successful, no breach will occur.

It seems reasonable to assume that higher SEPM ratios can be associated with more complex and risky programs. Our results suggest that the SEPM ratio is a promising measure of the likelihood that such programs will experience a cost breach. To be clear, the SEPM ratio is a symptom and not a cause of cost breaches, much like the temperature of a patient does not cause the disease. As such, program managers and others interested in controlling cost growth in DoD programs should consider using the SEPM ratio as an early indicator of the risk of a cost breach.

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Appendix

Programs Selected for Study

Active Electronically Scanned Array (AESA) Radar
AIM-9X/Short Range Air-to-Air Missile
AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM)
Airborne and Maritime/Fixed Station Joint Tactical Radio System (AMF JTRS)
AN/WQR-3, Advanced Deployable System (ADS)
Apache Block IIIA Remanufacture (AB3A REMANUFACTURE)
AV-8B/Attack, V/STOL, Close Air Support (Harrier II+ Remanufacture)
B-2 Radar Modernization Program
Cobra Judy Replacement (Cobra Judy Replacement)
EA-18G Growler (EA-18G)
Expeditionary Fighting Vehicle (EFV)
E-3 AWACS Radar System Improvement Program (RSIP)
E-2C Reproduction
Family of Advanced Beyond Line-of-Sight Terminals (FAB-T)
Family of Medium Tactical Vehicles (FMTV)
Guided Multiple Launch Rocket System/DPICM/Unitary/Alternative Warhead (GMLRS/GMLRS AW)
Joint Common Missile (JCM)
Joint Tactical Radio System Ground Mobile Radio (formerly Cluster 1) (JTRS GMR)
Longbow Hellfire—subsystem of the AH-64 Apache Weapon System
LHA Replacement Amphibious Assault Ship
MQ-4C Unmanned Aircraft System Broad Area Maritime Surveillance (MQ-4C UAS BAMS)
Multi-Platform Radar Technology Insertion Program (MP-RTIP)
National Polar-orbiting Operational Environmental Satellite System (NPOESS)
Presidential Helicopter Replacement (VH-71) Program
P-8A Poseidon
Sense and Destroy Armor (SADARM)
Small Diameter Bomb Increment II (SDB II)
Space Based Infrared System (SBIRS) High Program
Standard Missile (SM)–2 Block IV
Stryker Family of Vehicles (STRYKER)
UH-72A Light Utility Helicopter (LUH)
Warfighter Information Network–Tactical (WIN-T)