SYM-AM-19-069

PROCEEDINGS
OF THE
SIXTEENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM

THURSDAY SESSIONS
VOLUME II

Acquisition Research:
Creating Synergy for Informed Change

May 8–9, 2019

Published: April 30, 2019

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

Do We Need a Different Approach to Statistical Analysis of Research, Development, Test, and Evaluation Cost Growth?

David L. McNicol—joined the Department of Defense (DoD) in 1982. From 1988 until 2002, he was a Deputy Director of Program Analysis and Evaluation (PA&E). Earlier, McNicol taught at the University of Pennsylvania and the California Institute of Technology. He holds a BA in economics from Harvard and an MS in management and a PhD in economics and finance from MIT. Employed at the Institute for Defense Analyses (IDA) since his retirement from the DoD, he became director of the Cost Analysis and Research Division in 2006. Still at IDA, McNicol stepped down in 2012 to return to his previous role as a research staff member. [dmcnicol@ida.org]

Abstract

McNicol (2018; hereafter *Acquisition Policy*) obtained remarkably strong statistical results for a simple model of cost growth in Major Defense Acquisition Programs (MDAPs). Following previous studies, *Acquisition Policy* used Program Acquisition Unit Cost (PAUC), the numerator of which is the sum of Research, Development, Test, and Evaluation (RDT&E) cost and procurement cost. This paper asks whether the model used by *Acquisition Policy* characterizes RDT&E cost growth and growth in procurement cost individually as well as it does PAUC. It does not. As would be expected, the results for Average Procurement Unit Cost (APUC) are very similar to those for PAUC and are marginally stronger statistically. The results for RDT&E also are quantitatively similar to those for PAUC, but the explanatory power of the model is far lower, suggesting either much greater variability in RDT&E cost estimates or flaws in the model as applied to RDT&E. The paper concludes with suggestions for improving models of RDT&E cost growth.

Introduction

McNicol (2018; hereafter *Acquisition Policy*) obtained remarkably strong statistical results for a simple model of root causes of cost growth in Major Defense Acquisition Programs (MDAPs). That study considered Program Acquisition Unit Cost (PAUC). Program acquisition cost is the sum of Research, Development, Test, and Evaluation (RDT&E) cost and procurement cost (that is, the cost of buying a system once it has been developed). PAUC is acquisition cost divided by the number of fully configured units acquired. Procurement typically is four to five times as large as RDT&E. Consequently, PAUC is dominated by Average Procurement Unit Cost (APUC), which is the program's procurement dollars divided by the number of units purchased with them. As would be expected, the model of *Acquisition Policy* works well for APUC. This paper first asks whether it also provides a solid account of RDT&E cost growth. After finding that it does not, the paper examines ways to improve the basic model.

The next section provides the minimal background needed to follow this paper. The Results for APUC and RDT&E Cost Growth section presents estimates of the model for APUC and RDT&E cost growth. The Extensions of the Funding Climate-Acquisition Policy section considers expansion of the basic model to include other variables that may help explain the competition for RDT&E funds at Milestone (MS) B.

Background

The model of *Acquisition Policy* was mainly directed to what have come to be called Errors of Inception[1]—that is, cost growth attributable to unrealistic assumptions embedded in the program's MS B baseline. The proximate causes of Errors of Inception are, by definition, characteristics of the program, e.g., the maturity of critical technologies, concurrency between development and production, and the amount of computer code to be taken from legacy systems, among others. *Acquisition Policy* argues that the root causes of these proximate causes lie in the intensity of competition for funds at MS B, marked by funding climate, as modified by acquisition policy and process. The model will be referred to here as the Funding Climate-Acquisition Policy Model.[2]

The Funding Climate-Acquisition Policy Model focuses on the competition for funds at the Service level during the Program/Budget cycle before an MDAP undergoes MS B review at the Office of the Secretary of Defense (OSD) level. The model of *Acquisition Policy* tacitly assumes that that process will consider the funding decision in terms of the acquisition cost of the program—that is, the sum of RDT&E funding post-MS B and the cost of procuring the system once it has been fully developed. This is a reasonable position, but also one that is subject to a reasonable challenge.

The challenge rests on a combination of two sets of facts. First, the program/budget process develops the Future Years Defense Program (FYDP), which, for most of the period covered by *Acquisition Policy*, included the upcoming budget year and the four succeeding years. The Services must build their FYDPs subject to hard ceilings imposed on the authority of the Secretary of Defense. Second, most MDAPs typically spend at least three years in Engineering and Manufacturing Development (EMD), which begins at MS B, and only then move into the first part of the procurement phase. Consequently, for most MDAPs at MS B, the procurement phase starts late in the FYDP or beyond it. The Services track, and on a case-by-case basis limit, planned funding for MDAPs beyond the FYDP, but these limits are softer than the controls on the FYDP period during the program/budget process. The implication of these comments is that MDAPs coming to an MS B review perhaps compete for RDT&E and procurement funds under somewhat different conditions.

Results for APUC and RDT&E Cost Growth

The model of Acquisition Policy, applied to APUC growth, is

$$Ch_{APUCi} = a_0 + a_1Climate_i + a_2DSARC_i + a_3PCDSARC_i + a_4DAB_i + a_5AR_i + a_6T_{boomi} + a_7T_{busti} + e_i$$

ChAPUCi is computed by comparing the MS B baseline value of APUC—which can be thought of as a goal or a prediction—to the actual APUC reported in the final Selected

[1] This term was introduced by the Office of Program Assessments and Root Cause Analyses (PARCA) in connection with its root cause analyses. The Weapon Systems Acquisition Reform Act of 2009 established PARCA, which in 2018 was renamed the Office of Acquisition, Analytics and Policy (AAP).

[2] The Funding Climate-Acquisition Policy Model is an extension of the "speeding" model of cost growth offered by McNicol (2004, pp. 37–49). *Acquisition Policy* (Chapter 2, pp. 9–24) elaborates on these ideas.

Acquisition Report (SAR) for the program. Both the MS B baseline and the final value3 of APUC are stated in program base year dollars. The actual value is adjusted on the basis of the MS B baseline quantity by moving up or down the cost progress curve as appropriate. The ratio of the MS B baseline value of APUC to the quantity-adjusted actual value is an estimate of what APUC growth would have been had the MS B baseline quantity been acquired.

Table 1 defines the categorical variables used in the study. The study period (Fiscal Year [FY] 1965–FY 2009) includes two complete bust-boom cycles in Department of Defense (DoD) funding. The first of the acquisition policy bins (McNamara-Clifford) does not appear explicitly in the model because it is used as the reference category. Acquisition Policy identifies the factors used to establish the break points between the acquisition policy bins and between bust and boom climates (McNicol, 2018, Chapter 2, pp. 11–13; Chapter 3, pp. 13–16).

Table 1. Categorical Variables of the Funding Climate-Acquisition Policy Model

Variable	Short Name	Period (Fiscal Years)
Climate	bust climates	1965–1982, 1987–2002
	boom climates	1983–1987, 2003–2008
McNamara-Clifford	McNamara-Clifford	1965–1969
Defense System Acquisition Review Council	DSARC	1970–1982
Post-Carlucci DSARC	PC DSARC	1983–1989
Defense Acquisition Board	DAB	1990–1993 2001–2009
Acquisition Reform	AR	1994–2000

Finally, Tboomi and Tbusti are the numbers of years the ith program spent in boom and bust years, respectively. These two variables effectively are measures of program duration. They are included in the Acquisition Policy model of PAUC growth as a rough and ready way of accounting for the cost growth due to Errors of Execution and Program Changes. Errors of Execution are errors that arise post-MS B, typically errors by government or contractor management. Program changes are unforced changes made post-MS B to increase or, in a few cases, decrease, the capabilities of the system acquired. Tboomi and Tbusti are retained in the model for RDT&E growth because long duration programs may incur RDT&E costs to develop improvements or even new variants long after the original EMD work has been completed. Finally, the term ei is a random variable that is assumed to have a constant mean and variance.

Table 2 presents the estimated parameter values and their associated p-values using growth in APUC (adjusted to the MS B quantity) as the dependent variable.4 Given the underlying model, the intercept term is the expected average APUC growth for MDAPs

[3] For a program that is still underway, the most recent estimate (as reported in the SAR) of the final value was used.
[4] Estimates of the model's parameters for PAUC are in the appendix.

that passed MS B during McNamara-Clifford.[5] The actual average for this bin for the sample used to compute the estimates in Table is 88.7%. We expect the estimated coefficient of Climate to be negative, which it is, and the magnitude of the estimate also is reasonable. The estimated coefficient for each of the acquisition policy bins should be negative, which they are. The estimated coefficients of Tboom and Tbust should be positive (they are) and Tboom should have the larger coefficient (it does). The estimated coefficients, then, satisfy prior expectations and each except that for Tbust is significant at the 5% level or less. The estimated equation explains about 22% of the variation in APUC, which is quite high for a pooled time series-cross section dataset and a model that does not include the lagged dependent variable. In short, the statistical results cast the explanation underlying the model estimated in a favorable light.

Table 2. Estimate of the Funding Climate-Acquisition Policy Model for APUC Growth

	Coefficients	**p-value**
Intercept	74.8%***	< 0.001
Errors of Inception–Intensity of Competition for Funds		
Climate	-26.7%**	0.02
Error of Inception–Acquisition Policy		
DSARC	-58.8%***	< 0.001
PC DSARC	-46.4%**	0.004
DAB	-60.8%***	< 0.001
AR	-81.0%***	< 0.001
Errors of Execution and Program Changes		
T_{boom}	3.8%/yr**	0.03
T_{bust}	0.5%/yr	0.61

***Statistically significant at less than the 1% level.

** Statistically significant at less than the 5% level.

Note: R-Squared = 0.22, F = 5.46 (P < 0.001), N= 145. Estimated using ordinary least squares (OLS). The regression was computed using the 145 MDAPs in the database for which both APUC growth and RDT&E growth are available.

The results for RDT&E cost growth are reported In Table 3. Only the estimate of the intercept is statistically significant; the estimated equation explains only 4% of the variation in RDT&E cost growth; and the equation as a whole is not statistically significant. Low explanatory power is understandable, as estimates of RDT&E cost at MS B are generally thought to be more uncertain than estimates of procurement cost (and therefore APUC). Nonetheless, the p-values and other test statistics have nothing good to say about the Funding Climate-Acquisition Policy model as applied to RDT&E cost growth.

[5] The intercept term also will pick up the effects of non-linearities and other specification errors, omitted variables, and errors in measurement of variables that are included.

Table 3. Estimate of the Funding Climate-Acquisition Policy Model for RDT&E Cost Growth

	Coefficients	p-value
Intercept	75.4%**	0.018
Errors of Inception–Intensity of Competition for Funds		
Climate	-13.1%	0.602
Error of Inception–Acquisition Policy		
DSARC	-50.2%*	0.101
PC DSARC	-34.9%	0.309
DAB	-53.8%	0.122
AR	-33.2%	0.397
Errors of Execution and Program Changes		
T_{boom}	2.2%/yr	0.573
T_{bust}	0.8%/yr	0.662

** Statistically significant at less than the 5% level.

* Marginally statistically significant at the 10% level.

Note. R-Squared = 0.04, F = 0.763 (P = 0.619), N= 145. Estimated using ordinary least squares (OLS). The regression was computed using the 145 MDAPs in the database for which both APUC growth and RDT&E growth are available.

The coefficient estimates suggest, however, that the sensible course may not be to scrap the Funding Climate-Acquisition Policy model as applied to RDT&E cost growth but to incorporate within it additional variables. This suggestion is conveyed by the fact that the estimated coefficients all have the expected sign and reasonable magnitudes. This combination—coefficient estimates that are reasonable but not significant—could arise if there is one or more important variables missing from the model estimated and not highly correlated with variables that are included. Given this possibility, the relevant question is: What are these omitted variables? The discussion of this question that follows is exploratory in character. The underlying objective is simply to gauge whether the Funding Climate-Acquisition Policy model as applied to RDT&E cost growth shows substantial signs of promise.

Extensions of the Funding Climate-Acquisition Policy

Within the logic of the Funding Climate-Acquisition Policy model, a relevant "missing variable" would be one that influences competition for acquisition funding during the POM cycle or a change in acquisition policy not captured in the policy bins used. These are discussed in turn.

One obvious consideration in competition for funds is the priority that the sponsoring Service places on a program. Only very rarely does a Service's ranking of its investment priorities become public, however. Consequently, a proxy for program priority must be found if it is to be included in the model. One useful point that can be made in this connection is that each of the Services affords high priority to platforms that have a central role in its main warfighting missions. The F-22, then, was a very high priority program for the Air Force, and, similarly, the M-1 Abrams tank, the DDG-51 Arleigh Burke destroyer, and the V-22 were very high priority programs for the Army, Navy, and Marine Corps, respectively. The data set used in this paper contains 31 MDAPs with both APUC and RDT&E cost growth estimates that acquired a platform central to one of the Services' warfighting mission. These were assigned a value of 1 in the categorical variable called High Priority; all other programs in the dataset were assigned a value of 0 for this variable.

Another obvious consideration is program size—that is, in the present context, the amount of RDT&E funding requested at MS B, which will be treated as distinct from priority. For a given priority level, large programs presumably face stiffer competition if for no other reason than that they attract opposition from programs they would displace. Consequently, again at a given priority level, we would expect larger programs to have higher RDT&E cost growth than smaller programs.

There are two problems with including program size in the model, one statistical and the other a limitation of the database available for this paper. The statistical problem is that program size is correlated with priority. Size is not always a reliable guide to priority, however; there are some large programs (for example, Family of Medium Tactical Vehicles) that have a relatively low priority for funding purposes and some relatively small programs (for example, Javelin) that had a high priority. Accordingly, it is reasonable to include both priority and size in the model, although it may prove to be impossible to capture their separate effects.

The second problem is that the database included the RDT&E cost projected at MS B for only about one-third of the programs, and the resources required to collect the data for the other two-thirds were not available.6 One way to ameliorate this problem is to include in the model the number of MDAPs that passed MS B each year (for each Service and joint programs). This variable (#Competing) should provide a rough measure of the extent of competition for RDT&E funds in the given year. Another is to include categorical variables for satellites, which have large RDT&E funding requirements, and ships, which at MS B require relatively little RDT&E funding. We would expect the estimated coefficient for satellites to be positive and that for ships to be negative.7 Of course, categorical variables for satellites and ships pick up several differences, so even if these expectations are met, we cannot confidently attribute the effects to the size of RDT&E funding.

The discussion now turns to additional acquisition policy and process variables that might be incorporated in the model. The policy variables of the model of Acquisition Policy mark time periods. Within the first one to three years of each of these periods, several major changes in acquisition policy were made, most of which persisted to (and past) the end of this study (FY 2009). It is arguable that no major acquisition policy changes were implemented after the first few years of each period.8 The policy variables currently in the model could be replaced by categorical variables marking the major policy changes. This

---

[6] MS B funding for MDAPs that passed MS B in FY 1997 and later years is readily available on the Defense Acquisition Management Information Retrieval (DAMIR) system. Funding data for MDAPs that passed MS B before FY 1997 are available in the Selected Acquisition Reports (SARs), but their extraction for programs that began EMD can be difficult and require searching information sources other than the relevant SARs.

[7] There is nothing novel about using categorical variables for commodity types in a statistical analysis of cost growth. The novelty here is in the suggestion that differences in cost growth across various commodity types reflect the amounts of RDT&E they require at MS B.

[8] The main challenge to this proposition is the changes adopted by the DoD in 1986 and 1987 as a result of presidential direction and legislation that implemented some of the recommendations of the Packard Commission report and the Goldwater-Nichols Act. While adopted in 1986 and 1987, these changes were not effectively implemented until about 1990. See *Acquisition Policy* (Appendix B, pp. B-10–B-11).

would be a considerable amount of work (there would be two to three dozen such variables) with little prospect of gain, because the changes cluster in distinct sets and none is directed especially to RDT&E cost growth. Acquisition Policy assumed that the policy variables defined in terms of distinct periods was a reasonable if imperfect way to represent changes in acquisition policy over the study period.

The results obtained when the four additional variables are included in the model are presented in Table 4 (Recall Table 3) that the estimated coefficient of only one of the seven variables of the basic model is even marginally statistically significant. In such a circumstance, when additional variables are introduced, it is often found that the signs of the estimated coefficients of the original model change and estimated magnitudes can change dramatically. Such an outcome would have ended discussion of the Funding Climate-Acquisition Policy construct as a useful model of RDT&E cost growth.

Table 4. Estimate of an Extended Funding Climate-Acquisition Policy Model for RDT&E Cost Growth

	Coefficients	p-value
Intercept	77.0%	0.021**
Errors of Inception–Intensity of Competition for Funds		
Climate	-12.8%	0.613
High Priority	-14.5%	0.529
#Competing	1.0%	0.741
Satellites	63.0%	0.113
Ships	-37.1%	0.216
Error of Inception–Acquisition Policy		
DSARC	-41.2%	0.179
PC DSARC	-31.6%	0.363
DAB	-52.8%	0.128
AR	-24.3%	0.547
Errors of Execution and Program Changes		
T_{boom}	0.2%	0.957
T_{bust}	1.0%	0.615

** Statistically significant at less than the 5% level.

Note. R-Squared =0.08, F = 1.060 (P = 0.399), N= 145. Estimated using ordinary least squares (OLS). The regression was computed using the 145 MDAPs in the database for which both APUC growth and RDT&E growth are available.

Those are not the results obtained, however. First, the estimated coefficients for the basic Funding Climate-Acquisition Policy model all have the expected sign, and (except for T_{boom}) their magnitudes do not change drastically. Second, the coefficient of each of the additional variables introduced has the expected sign and a reasonable magnitude, although only that of satellites approaches statistical significance. That is a modest amount of evidence, but enough to suggest that there may be merit in trying to understand more fully the competition for RDT&E funding at MS B and to obtain good measures of the key variables involved.

Concluding Comment

There currently is no consensus model of RDT&E cost growth, and the only contender in the lists seems to be the Funding Climate-Acquisition Policy model.[9] So, in view of the results provided above, the answer to the question asked in the title of this paper is part "no" since the Funding Climate-Acquisition Policy model provides a reasonable basis for further work, and "yes" in that much remains to be done for that model to provide a solid statistical account of RDT&E cost growth of MDAPs.

References

McNicol, D. L. (2004). *Cost growth in major weapon procurement programs*. Alexandria, VA: Institute for Defense Analyses.

McNicol, D. L. (2018). *Acquisition policy, cost growth, and cancellations of major defense acquisition programs* (IDA Report R-8396). Alexandria, VA: Institute for Defense Analyses.

Younossi, O., Arena, M. V., Leonard, R. S., Roll, C. R., Jr., Jain, A., & Sallinger, J. M. (2007). *Is weapon system cost growth increasing?* (MG588). Retrieved from https://www.rand.org/pubs/monographs/MG588.html

Acknowledgments

This paper was reviewed by Dr. Gregory A. Davis of the Institute for Defense Analyses. The author is grateful for his comments on this paper and his continuing support of the project of which this paper is a part.

Appendix. Estimate of the Funding Climate-Acquisition Policy Model for PAUC Growth

Table 5. Estimate of the Funding Climate-Acquisition Policy Model for PAUC Growth

	Coefficients	p-value
Intercept	100.2%***	< 0.001
Errors of Inception–Intensity of Competition for Funds		
Climate	-30.4%**	0.046
Error of Inception–Acquisition Policy		
DSARC	-81.5%***	< 0.001
PC DSARC	-67.7%***	0.001
DAB	-84.7%***	< 0.001
AR	-101.1%***	< 0.001
Errors of Execution and Program Changes		
T_{boom}	4,4%/yr	0.061
T_{bust}	-0.07 %/yr	0.952

** Statistically significant at less than the 5% level.

Note. R-Squared = 0.20, F = 5.047 (P < 0.001), N= 145. Estimated using ordinary least squares (OLS). The regression was computed using the 145 MDAPs in the database for which both APUC growth and RDT&E growth are available.

[9] Younossi et al. (2007) is a statistical study of RDT&E cost growth. It attempts to answer the question of whether cost growth, particularly RDT&E cost growth, has been increasing since the 1970s. It does not attempt to account for either the proximate or root causes of RDT&E cost growth.

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CA 93943

www.acquisitionresearch.net