SYM-AM-21-053

Excerpt from the Proceedings of the Eighteenth Annual Acquisition Research Symposium

Microeconomics, Competition, and Major Defense Acquisition Program Cost

May 11–13, 2021

Published: May 10, 2021

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

Acquisition Research Program
Graduate School of Defense Management
Naval Postgraduate School

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Defense Management at the Naval Postgraduate School.

To request defense acquisition research, to become a research sponsor, or to print additional copies of reports, please contact any of the staff listed on the Acquisition Research Program website (www.acquisitionresearch.net).

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF DEFENSE MANAGEMENT
NAVAL POSTGRADUATE SCHOOL

Microeconomics, Competition, and Major Defense Acquisition Program Cost

Kenneth L. McElroy Jr.—is a Staff Systems Engineer and Systems Engineering, Integration and Test (SEIT) Lead for the Northrop Grumman Corporation. He is a retired naval officer with 20 years of service as a Surface Warfare Officer and over 15 years of industry experience. He holds a Bachelor of Science degree in economics and general engineering from the U.S. Naval Academy, Master of Science degrees in physics from the Naval Postgraduate School and in systems engineering from The Johns Hopkins University, and a Doctor of Engineering in engineering management from the George Washington University. His research interests include engineering management and systems engineering. [kenneth.mcelroy@ngc.com]

John Kamp—received a Doctor of Engineering in engineering management from the George Washington University, a Master of Engineering in nuclear engineering from Iowa State University, and a Bachelor of Arts in mathematics and French from the University of Nebraska–Lincoln. Dr. Kamp joined the George Washington University research staff in 2019 and is supporting Etemadi's acquisition strategy research project. He is a retired naval submarine officer with extensive experience in research and development and program management. His research interests include engineering management, maritime systems, and acquisition system research. Dr. Kamp is a Fellow in the Royal Institution of Naval Architects and a member of several professional associations. [jckamp2018@gwu.edu]

Abstract

The Major Defense Acquisition Program (MDAP) market is a monopsony facing oligopoly. In the last four decades, the Department of Defense has placed a great deal of emphasis in its acquisition reform efforts on the power of competition to help control cost overruns and cost growth. In this research, quantitative analyses were used to determine the effect of two reform measures—competitive prototyping and competitive contracting—on cost overruns and cost growth during the Engineering and Manufacturing Development (EMD) phase of the acquisition life cycle. We performed a case study of 63 hardware MDAP contracts from all services. The findings show that while competitive prototyping and competitive contracting lead to greater competition, as the defense acquisition community believes, they fail to control cost overruns and cost growth, just as microeconomic theory predicts.

Introduction

Concerns over the increasing cost of U.S. defense programs are not new. In fact, according to Cancian (2010), these concerns date back as far as the earliest days of our republic when Congress, in its oversight role, began questioning the rising costs of the first naval ships, which it authorized in 1794 (Cancian, 2010). Since then, there have been numerous attempts at defense acquisition reform with the goal of controlling cost overruns and cost growth. Two of the most recent and significant acquisition reform initiatives are Congress's Weapon Systems Acquisition Reform Act (WSARA) of 2009 and a series of U.S. Department of Defense (DoD) initiatives championed by Under Secretary of Defense for Acquisition, Technology, and Logistics (AT&L) Frank Kendall, called Better Buying Power (BBP). Both the WSARA and BBP place a great deal of emphasis on the power of competition in controlling defense acquisition costs and in particular, the cost of Major Defense Acquisition Programs (MDAPs).

Despite decades of effort and frequent attempts to control cost overruns and cost growth in MDAPs, these latest initiatives and their predecessors have failed to achieve their objectives regarding cost (Ritschel et al., 2019). Defense acquisition reforms based on competition fail to control cost overruns and cost growth in hardware MDAPs. The question is why. The straightforward answer is microeconomics.

Extensive research exists studying defense acquisition program costs—both overruns and growth. Most studies focused on program management techniques and acquisition policies from the point of view of the government customer with scant attention to defense acquisition reforms from the perspective of industry and the market (i.e., microeconomics). This research uses quantitative analysis to provide insight into whether reform initiatives based on competition contribute to the reduction of cost overruns and cost growth in MDAPs.

Background

To meet the performance requirements, engineers must work within specific design constraints such as system weight, size, and shape, but ultimately systems are constrained by fundamental laws of nature such as the laws of motion, gravitation, and thermodynamics. Similarly, there are many constraints imposed on cost, but ultimately cost is subject to the laws of economics such as the law of supply and demand.

Summarizing from Edwin Mansfield's (1982) undergraduate-level textbook, *Microeconomics Theory and Applications*, economics is in two broad branches—microeconomics and macroeconomic. Microeconomics deals with how individual consumers, firms, and resource owners behave, while macroeconomics is concerned with the behavior of economic aggregates such as inflation, gross national product, and level of employment. In microeconomics, firms operate in markets that are a collection of buyers and sellers for a particular good or service, and the behavior of each market type can be modeled by a demand side and a supply side—the market structure.

According to microeconomics, there are four types of market structures: perfect competition, monopoly, monopolistic competition, and oligopoly. How the price (cost) of a good or service is determined is different depending on the market structure. In perfect competition, the equilibrium price—the price at which there is no tendency to change—is determined where the quantity versus price schedule of buyers (i.e., the demand curve) crosses the quantity versus price schedule of sellers (i.e., the supply curve). In an oligopoly, the equilibrium price occurs at the profit maximizing quantity where the marginal cost equals marginal revenue. Firms in an oligopoly adjust their outputs to gain a share of the profit maximizing quantity (Mansfield, 1982).

A key component of many cost control strategies involves the use of measures to increase competition based on the idea that competition leads to lower price (cost) or can control cost overruns or cost growth. Competitive contracting has been required by law since 2000, and in 2009, WSARA included a requirement to use competitive prototyping to promote competition and control cost despite microeconomics suggesting otherwise.

Our belief was that this confidence in the power of competition is based on a misapplication of microeconomic theory. It assumes that the perfect competition model, where there are many buyers and many sellers, is representative of the MDAP market.

> The U.S. economic system is built on the concept of free enterprise regulated by competition. ... The defense industry does not fit that model. Many defense acquisition problems are rooted in the mistaken belief that the defense industry and the government–industry relationship in defense acquisition fit naturally into the free enterprise model. (Fox, 2011)

However, the MDAP market has a monopsony–oligopoly structure, so the perfect competition model does not apply. The supply side of the MDAP market is an oligopoly, and according to microeconomic theory, firms in an oligopoly market do not compete on price. This is because, as Fudenberg and Tirole (2013) explained, if one firm cuts price to gain market share, this tends to lead to a price war where others in the market react by cutting their price.

The result hurts all players, since "the long-run costs of the price war outweigh any short-run gain" (Fundenberg & Tirole, 2013).

Competition in the defense market is so often cited as an important tool in fighting cost overruns and cost growth that it appears to have become a matter of faith that few bother to challenge. Typical examples include the Government Accountability Office's claim that "competition is the cornerstone of a sound acquisition process and a critical tool for achieving the best return on investment for taxpayers" (GAO, 2015). The enormous confidence that government places in competition comes despite what O'Neil (2011) points out when he notes that in a pair of foundational studies of defense acquisition from 50 years prior, Merton J. Peck and Frederic M. Scherer of the Harvard Business School revealed significant issues that are still largely unaddressed by intervening management efforts (Peck & Scherer, 1962; Scherer, 1964). In particular, Peck and Scherer (1962) argued at length that price competition, which is widely favored as a mechanism for controlling costs, is almost certain to be largely ineffective in major defense system acquisition and is actually much more likely to be counterproductive (O'Neil, 2011). We contend that, while measures to stimulate competition may result in an increase in the number of bids received for MDAP Engineering and Manufacturing Development (EMD) contracts, that increase in competition will not result in cost control.

To establish which is correct—Congress and the DoD's faith in competition or our belief in microeconomic theory—we sought the answers to the following questions:

1. Does competitive prototyping lead to more competition (an increase in the number of bids) in the MDAP market?
2. Does competitive contracting lead to more competition (an increase in the number of bids) in the MDAP market?
3. Does more competition lead to lower cost growth or overruns in the MDAP market?

If market competition does not control cost overruns in MDAP hardware acquisitions, then the defense acquisition community must devise and adopt strategies that do not need competition to reduce cost overruns and cost growth.

Methodology

This research is a case study of 36 MDAP hardware programs of various types and from all the services. We performed a quantitative analysis to determine the answers to our questions by testing the following research hypotheses:

1. Research Hypothesis 1 (RH1): In the MDAP market, competitive prototyping leads to more competition.
2. Research Hypothesis 2 (RH2): In the MDAP market, competitive contracting leads to more competition.
3. Research Hypothesis 3 (RH3): In the MDAP market, competition does not lead to lower cost growth or lower cost overruns.

Research Logic Flow

As a framework for our analysis, we devised a research logic flow to describe the potential outcomes (see Figure 1).

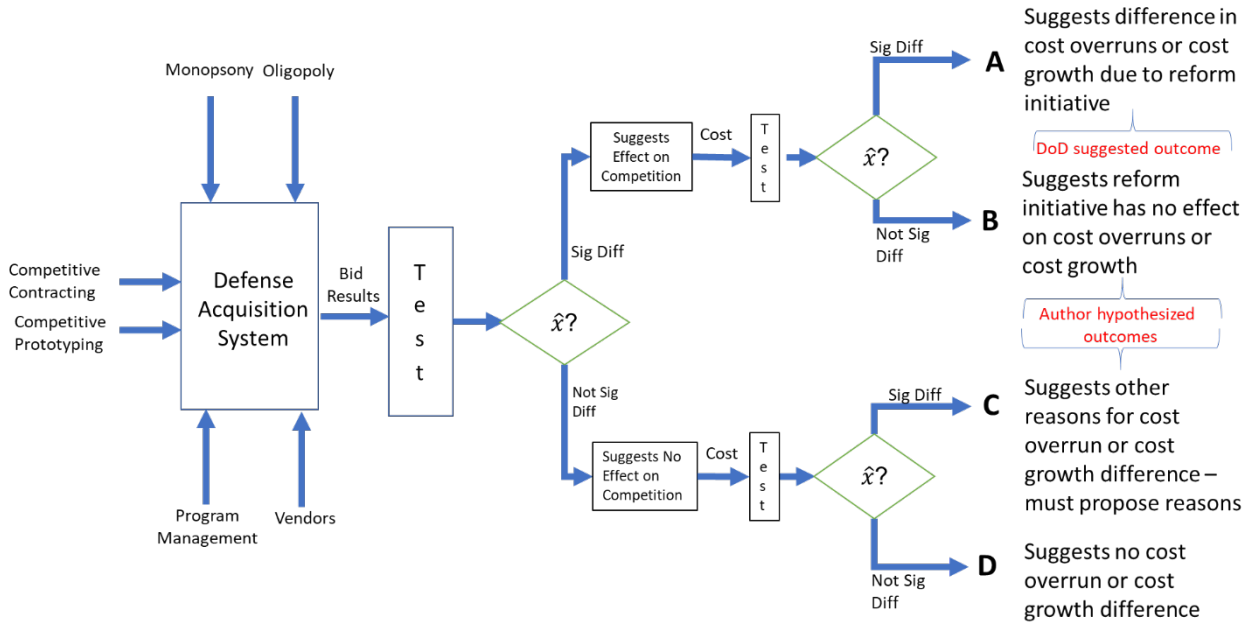

Figure 1. Research Logic Flow

Table 1 shows the potential outcomes.

Table 1. Potential Outcomes Logic Table

Result Measure	Increase Competition?	Reduce Cost Overruns/Cost Growth?	Outcome
Competitive Prototyping	Yes	Yes	A
	Yes	No	B
	No	Yes	C
	No	No	D
Competitive Contracting	Yes	Yes	A
	Yes	No	B
	No	Yes	C
	No	No	D

Data

The data for our analysis came from six sources covering the years 2003 through 2019:

1. U.S. Government Accountability Office (GAO) *Defense Acquisitions: Assessments of Selected Major Weapon Programs* reports,
2. DoD Selected Acquisition Reports (SARs),
3. Federal Procurement Data System (FPDS),
4. Corporate 10-K reports filed with the U.S. Securities and Exchange Commission (SEC),
5. Kamp (2019), and
6. Fast (2016)

The first step in our analysis was to confirm that the MDAP market is, in fact, an oligopoly. We accomplished this as described by both Hayes (2020) and Kenton (2020) by calculating the standard CR_4 concentration ratio, which is the ratio formed by taking the sales of the top four firms and dividing by the total industry sales, which gives us the strength of the oligopoly power in the market. Concentration ratios range from 0.00 to 1.00 where 0.00 indicates perfect competition and 1.00 indicates a perfect monopoly. Table 2 lists typical rules of thumb that characterize the level of concentration.

Table 2. Mapping of Market Concentration to Market Structure and Concentration Indicators (Hayes, 2020; Kenton, 2020)

Level of Concentration	Market Structure	CR_4
Low	Perfect Competition to Oligopoly	0.00–0.40
Medium	Oligopoly	0.40–0.80
High	Oligopoly to Monopoly	0.80–1.00

The higher the market concentration, the less competitive the market. Table 3 shows the authors' calculated CR_4 MDAP market concentrations for the years 2003 to 2018, which shows market concentrations typical of an oligopoly market as described by (Hayes, 2020; Kenton, 2020).

Table 3. MDAP CR_4 Market Concentration for Years 2003–2018

Year 20XX	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
Market Concentration	.83	.90	.94	.87	.86	.83	.87	.82	.86	.82	.81	.80	.80	.72	.77	.78

Once we confirmed our initial premise—the MDAP market is an oligopoly—we then proceeded with our data analysis.

Next, we performed correlation analysis to verify our hypothesized relationships between our variables. The relationships of interest are between the measures claimed to increase competition—competitive prototyping and competitive contracting—and the change in competition and between the change in competition and cost overruns and cost growth.

Additionally, we looked to see if there was a relationship between competitive prototyping and competitive contracting and between cost overruns and cost growth directly (i.e., due to some cause other than a change in competition). For the purposes of this research, we define competitive prototyping like Fast (2016)—as prototyping where two or more contractors develop prototypes prior to Milestone B (MS B), which are tested or demonstrated to the government to verify that they meet requirements. In addition, we define competitive contracting, in accordance with U.S. law, as a contracting strategy that relies on full and open competition. According to the Competition in Contracting Act (CICA, 2000), a procurement is considered as competed under full and open competition if *all responsible sources* are permitted

to submit sealed bids or competitive proposals. Further, we define cost overrun as described by Cancian (2010)—as costs that exceed the estimate for a contract, in our case the EMD phase contract. EMD begins with a MS B decision to continue with development and ends with the Milestone C (MS C) decision to proceed into the production phase. Also, we define cost growth for all cost growth variables as an increase in cost from the estimate at program start to MS C. Finally, we use the definition of competition as "the attempt by two or more companies or other organizations to secure the business of a customer" (Farlex, n.d.). In this research, we measure the degree of competition by the number of bids received for the MDAP's EMD phase contract. Therefore, the greater the number of bids received for the EMD contract, the greater the degree of competition.

The cost overrun variables are Cost Overrun ($M) and Percent Cost Overrun (% Cost Overrun). Cost growth variables are Percent Change in Unit Cost (UC.M.PCT), Program Acquisition Unit Cost (PAUC), Total Procurement Cost (TPC), and Percent Change in Total Procurement Cost (TPC.Pct). We calculated Cost Overrun $M by taking the difference between the baseline estimate at MS B and the current estimate at MS C in Base Year millions of dollars (in BY $M) from the SARs. Base Year is the prescribed DoD reference for measuring cost change because it removes the effect of inflation (Defense, 2020). % Cost Overrun was calculated by dividing Cost Overrun $M by the baseline estimate at MS B. UC.M.PCT came from the Kamp data set and is the percent change in the unit price since program start as reported in the GAO reports at MS C. It includes research and development (R&D) and procurement costs. A broader variable, PAUC, is the Program Acquisition Cost divided by the Program Acquisition Quantity as reported in the SAR reports at MS C. It includes all costs involved in the acquisition, not just R&D and Procurement. TPC was derived by adding the R&D funding (RD.M) and Procurement funding (P.M) since the program start to MS C. RD.M and P.M were included in the Kamp data set and came from the GAO reports. TPC.Pct was taken from the GAO report for MS C and is the percent change in total program cost from program start without regard to changes in quantity.

For our correlation analysis, we used the Spearman rho correlation because it is useful for both linear and nonlinear relationships. There are no universally accepted ranges for weak, moderate, and strong correlation coefficients. For our purposes, we were simply looking for an initial way to focus our analysis. Therefore, we used the following rules of thumb in our analysis: Strong correlations are those relationships with a Spearman correlation coefficient greater than or equal to 0.667; moderate correlations are indicated by Spearman rho values greater than 0.333 but less than 0.667; and weak correlations are those with coefficients that are less than or equal to 0.333. In addition, we considered significance levels for α = 0.05 and 0.01. We found that there is a strong relationship between our competition variables pair combinations of competitive prototyping and competitive contracting and Num_bids that is statistically significant. This indicates that the use of competitive prototyping and competitive contracting is related to an increase in the number of bids. However, there appears to be no relationship between number of bids and our cost variables: Cost Overrun $M, Pct Cost Overrun, RD.M, RD.M.Pct, UC.M.Pct, and PAUC Chg from SAR. These results are favorable to our hypothesized proposition that while competitive prototyping and competitive contracting may increase the number of bids, the increase in competition does not lead to a reduction in cost overruns or cost growth. Armed with this information, we proceeded with our statistical analysis.

Statistical Analysis

We selected the Mood's Median Test as our analysis method because a visual examination of the histograms of our response data and probability plots from the Kolmogorov–Smirnov tests revealed that our data are not normally distributed. This indicates that a nonparametric method is called for, and the Mood's Median Test is a particularly good choice

because our visual inspection also indicated the presence of outliers in our response data, and Mood's is insensitive to outliers. To test our research hypotheses, we evaluated 20 predictor–response variable pairs summarized in Table 4.

Table 4. Summary of Test Pairs

Predictor Variables	**Response Variable**
Competitive prototyping (CP)	Number of bids
Competitive contracting (CC)	Number of bids
CP	Cost Overrun $M
	% Cost Overrun
	RD.M
	RD.M.PCT
	UC.M.PCT
	PAUC
CC	Cost Overrun $M
	% Cost Overrun
	RD.M
	RD.M.PCT
	UC.M.PCT
	PAUC
Number of bids	Cost Overrun $M
	% Cost Overrun
	RD.M
	RD.M.PCT
	UC.M.PCT
	PAUC

Results

From our hypothesis testing, we found that there is evidence to support the claim that competitive prototyping leads to greater competition in the MDAP market, as seen by the statistically significant higher number of bids received on EMD contracts that included competitive prototyping versus those that did not. Similarly, the evidence supports the hypothesis that, when used, competitive contracting also increases the number of bids received and thus the degree of competition on MDAPs. However, we found no evidence to support the claim that an increase in competition (i.e., an increase in the number of bids received for an EMD contract) led to a decrease in cost overruns or cost growth. Furthermore, we found that there is no evidence to support any suspicion that competitive prototyping and competitive contracting themselves affect cost overruns or cost growth in MDAPs with one exception. Competitive contracting does appear to lead to a reduction in PAUC. There is enough evidence to reject the null hypothesis that the median PAUC for MDAPs that used competitive contracting and those that did not are equal. As a result, we can conclude that competitive contracting does lead to a reduction in PAUC. Since we also found that competitive contracting leads to an increase in competitions, one might conclude that this leads to Research Logic Flow Outcome A from Figure 1. However, we believe this would be a mistake. PAUC is the total of all development, procurement, and military construction cost divided by the number of units procured, and since we found no correlation between an increase in competition and procurement cost (P.M), nor did we see evidence that competition reduced development cost (RD.M, RD.M.PCT, UC.D.PCT), we must conclude that this reduction in PAUC is due to the portion from military construction. This seems reasonable because the construction industry is characterized by many small buyers and sellers more closely described by perfect competition where competition does influence price. A summary of these results is provided in Table 5.

Table 5. Summary of Hypothesis Test Results

Research Hypothesis	Explanatory Variable	Response Variable	H_0	*p* Value	Conclusion
RH1	CP (0) CP (1)	# of bids	Medians equal	0.000	CP leads to greater competition
RH2	CC (0) CC (1)	# of bids	Medians equal	0.004	CC leads to greater competition
RH3	# of bids	Cost overruns	Medians equal	0.166	More competition does not lead to lower cost overruns
RH3	# of bids	% change cost overruns	Medians equal	0.360	More competition does not lead to lower % cost overruns
RH3	# of bids	R&D cost growth	Medians equal	0.480	More competition does not lead to lower R&D cost growth
RH3	# of bids	% change R&D cost growth	Medians equal	0.145	More competition does not lead to lower % change in R&D cost growth
RH3	# of bids	% change in unit cost growth	Medians equal	0.802	More competition does not lead to lower % change in unit cost growth
RH3	# of bids	PAUC	Medians equal	0.298	More competition does not lead to lower PAUC
Similar results for CP and CC versus cost variable except CC versus PAUC					
	CC (0) CC (1)	PAUC	Medians equal	0.006	CC leads to lower PAUC
Research Hypothesis 1 (RH1): In the MDAP market, competitive prototyping leads to more competition. Research Hypothesis 2 (RH2): In the MDAP market, competitive contracting leads to more competition. Research Hypothesis 3 (RH3): In the MDAP market, competition does not lead to lower cost growth or lower cost overruns.					

Conclusions and Recommendations

The subject of cost overruns and cost growth in weapon systems programs is clearly not new; nor is defense acquisition reform. These topics reach back to the earliest days of our republic. A major theme of the modern defense acquisition reforms is that competition is good and will control cost. This may be true for items purchased by the DoD that are in a perfect competition market, such as copy paper and other consumables, where there are many buyers and sellers in both the civilian and defense sectors. However, attempting to apply the price minimizing characteristics of perfect competition to the oligopoly structure of the MDAP market—which behaves much differently—is inappropriate. The literature discusses some

virtues of competition in the MDAP market, such as helping to maintain the defense industrial base and improving innovation, but cost control is not among them.

Our research shows that for the 63 hardware MDAPs we investigated in this case study, our assertion regarding the response to competition is correct. We demonstrated that the MDAP market is an oligopoly and that, while it may be possible to increase competition, the resulting competition will not lead to lower cost overruns or cost growth as Congress and the DoD believe.

Moreover, we answer all three of our research questions. Competitive prototyping does lead to more competition (an increase in the number of bids) in the MDAP market. Additionally, we show that competitive contracting also leads to more competition (an increase in the number of bids) in the MDAP market. Finally, we demonstrate that more competition does not lead to lower cost growth or cost overruns in the MDAP market. Table 6 and Figure 2 show these results in terms of our Research Logic Flow. We believed that either Outcome B or C from our Research Logic Flow would be proven to be correct. Our results show that Outcome B is the correct logic flow path as we proposed.

Table 6. Logic Table Outcome

Result Measure	Increase Competition?	Reduce Cost Overruns/Cost Growth?	Outcome
Competitive Prototyping	Yes	Yes	A
	Yes	No	B
	No	Yes	C
	No	No	D
Competitive Contracting	Yes	Yes	A
	Yes	No	B
	No	Yes	C
	No	No	D

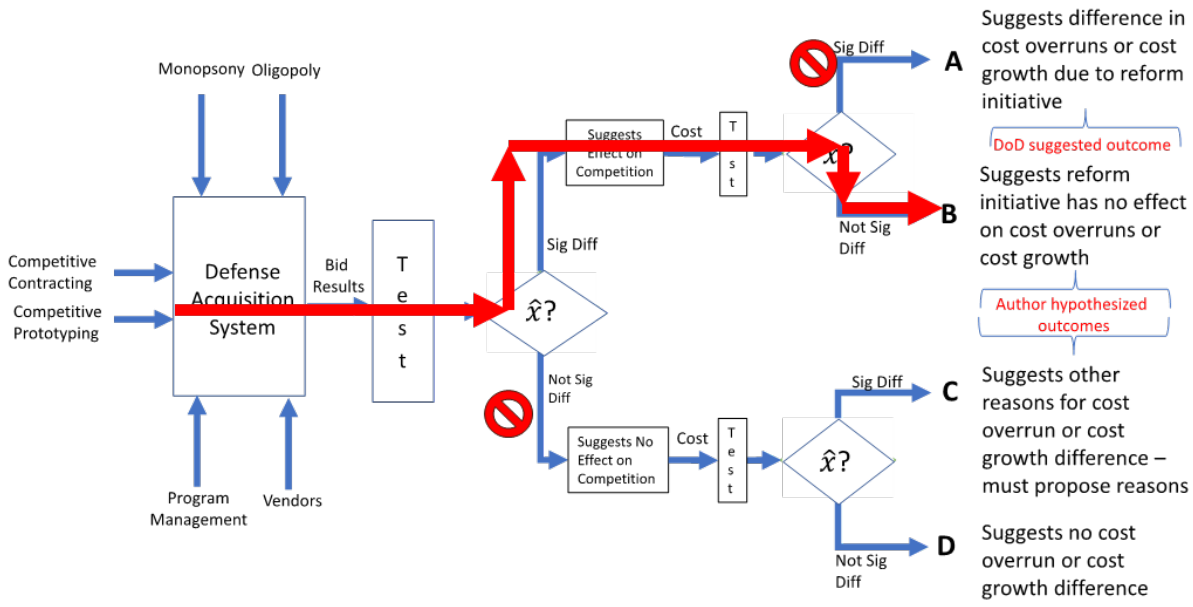

Figure 2. Research Logic Flow Outcome

Lastly, our analysis shows that, in addition to competition not affecting cost outcome for the hardware MDAPs we studied, competitive prototyping and competitive contracting themselves do not affect cost outcomes.

Unfortunately, the DoD's confidence in the power of competition to control cost in MDAPs appears to be based on the perfect competition model rather than the appropriate oligopoly model. This is a misapplication of microeconomic theory. We have shown that for our case study programs, competition does not control cost under oligopoly as microeconomic theory predicts. Therefore, we suggest that the DoD and Congress must look elsewhere for solutions to the problem of cost overruns and cost growth in MDAPS.

References

Cancian, M. F. (2010). Cost growth: Perception and reality. *Defense Acquisition Review Journal*, 389–405.

Competition in Contracting Act, 41 U.S.C. § 253 (2000).

Farlex. (n.d.). Competition. In *The free dictionary*. Retrieved March 24, 2021, from https://financial-dictionary.thefreedictionary.com/competition

Fast, W. R. (2016). An assessment of early competitive prototyping for major defense acquisition programs. *Proceedings of the 13th Annual Acquisition Research Symposium*, 47–66.

Fox, J. R. (2011). *Defense acquisition reform, 1960–2009: An elusive goal*. U.S. Army Center of Military History.

Fundenberg, D., & Tirole, J. (2013). *Dynamic models of oligopoly*. Routledge.

Hayes, A. (2020, February 11). *Financial ratios*. Investopedia. https://www.investopedia.com/terms/h/hhi.asp

Kamp, J. C. (2019, January 10). *Integrating immature systems and program schedule growth* [Doctoral praxis, The George Washington University]. ProQuest.

Kenton, W. (2020, September 6). *Economics*. Investopedia. https://www.investopedia.com/terms/c/concentrationratio.asp

Mansfield, E. (1982). *Microeconomics theory and applications*. W. W. Norton & Company Inc.

O'Neil, W. D. (2011). Cost growth in major defense acquisition: Is there a problem? Is there a solution? *Defense Acquisition Research Journal*, 277–295.

Ritschel, J. D., Lucas, B., White, E., & Mrla, D. (2019). The impact of WSARA on the cost of Air Force weapon systems. *Journal of Public Procurement*, 2–14.

Weapons Systems Acquisition Reform Act of 2009, Pub. L. No. 111-23 (2009). https://www.congress.gov/111/plaws/publ23/PLAW-111publ23.pdf

Acquisition Research Program
Graduate School of Defense Management
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net