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The Impact of Economic Factors and Acquisition Reforms on the Cost of Defense Weapon Systems

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THE IMPACT OF ECONOMIC FACTORS AND ACQUISITION REFORMS ON

THE COST OF DEFENSE WEAPON SYSTEMS

THESIS

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Abstract

Cost overruns in weapon system purchases have plagued the Department of Defense (DoD) throughout its history and have resulted in schedule delays and potentially reduced combat capability. This thesis created an empirical model that begins to explain those cost overruns. The model describes how changes in defense budgets, consolidation of the defense industry, acquisition reform, war, and cost estimating error are related to cost overruns.

The cost performance of 186 major weapon system programs managed by the Air Force, Army, and Navy from 1970 to 2002 was described using a panel regression model. This research found that funding instability resulting from changing levels of defense budgets accounted for an increase of over $13.3 billion in weapon system costs since 1970. This research also found that the defense industry consolidation of the 1990's did not result in significant savings to the DoD. Finally, this research found that contrary to past studies, several acquisition reforms are correlated with a decrease in weapon system cost overruns. In particular, reforms resulting from the Nunn-McCurdy Act of 1982, the Packard Commission Recommendations of 1986 and the Federal Acquisition Streamlining Act (FASA) of 1994 resulted in savings of almost $124 billion since 1982.

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To my son

Acknowledgments

When I first started this journey 18 months ago, I had no idea how challenging it would be or how much I would end up learning. I have a great sense of satisfaction having completed this project but I could not have done it without the love and support of my wife. Thank you for giving up so many evenings and weekends to allow me to work even while you were pursuing your own graduate degree and career. I would like to thank Mari Curtin from the OSD Comptroller's office for helping me obtain historical DoD inflation forecasts. I would also like to thank Captain Pat Armstrong for letting me use him as a sounding board for my ideas and for motivating me to get those ideas on paper and also Major Judy Davis for allowing me to benefit from her tireless efforts to collect data from US Census reports. Lastly, I would like to thank my thesis advisor, Dr. Michael Hicks for giving me the knowledge and confidence to take on this project and for making me believe in it.

James P. Smirnoff

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THE IMPACT OF ECONOMIC FACTORS AND ACQUISITION REFORMS ON THE COST OF DEFENSE WEAPON SYSTEMS

I. Introduction

The problem of cost growth in weapon system development…has been a reoccurring theme in acquisition reform for the last several decades. Despite its high visibility, there has been little systematic and consistent analysis of cost growth patterns and trends and factors that effect cost growth.
-Jarvaise et al., 1996:iii

General Issue

According to a 1993 RAND study, the average cost growth of a Department of Defense (DoD) Acquisition Category I (ACAT I) program was 20 percent (Drezner et al., 1993:xiii). More recent research, such as an October 2000 study by the Defense Acquisition University (DAU), has identified cost growth in research and development programs as high as 40 percent (Swank et al, 2000:iii). Figure 1 depicts the percentage of cost overruns per year on major Air Force, Army, and Navy programs from 1970 to 2002.

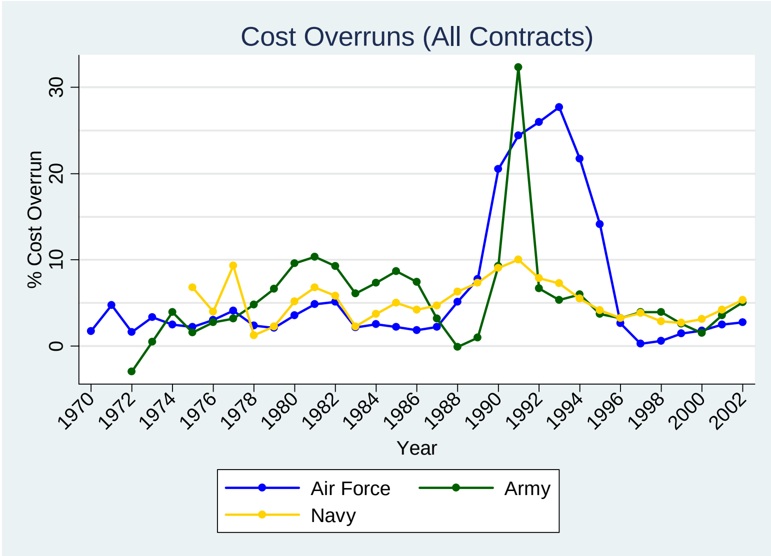


Figure 1. Cost Overruns All Services (1970-2002)

(DAES Database, Author's Calculations:2006)

To understand the magnitude of this problem, consider that in 2004 the Air Force alone had an annual budget of over $127 billion, enough that if it were a company it would be the eleventh largest in the world. Similarly, with a 2004 budget of over $441 billion, the Department of Defense (DoD) would be by far the largest company in the world according to Forbes Magazine's list of largest companies by total sales (Forbes Magazine, 2004). Notice in Table 1 that nearly a third of the DoD budget in 2004 was dedicated to Production and Research and Development activities.

Table 1. 2004 DoD Budget Summary (National Defense Budget Estimates, 2006:67)

2004 DoD Budget Summary (In billions of FY2004 Dollars)		
Appropriation	Obligation Authority	Percentage
Production and R&D	$158.0	33%
Operations and Maintenance and Other	$322.3	67%

Since defense budgets are essentially fixed in a given year, cost overruns create serious problems for defense acquisition managers and for policy makers. They necessitate extensions of program schedules, and potentially cause a reduction in weapon system quantities and capabilities, as well as funding instability in even those programs that did not experience cost overruns but were affected by reprogramming of funds. This instability in funding only further exacerbates cost overruns (McNutt, 1998:307).

In response to cost and schedule growth and other problems, Congress, the DoD, and the individual military services have instituted a series of changes to the acquisitions process that include changes to the law, updates to military regulation, and an overhaul of the DoD acquisition training process. Table 2 is a list of major reforms to the defense acquisition process in the last 20 years.:

Table 2. Major Acquisition Reforms (Modified from Scofield, 2003:19)

Major Acquisition Reforms Efforts	
Year	**Effort**
1982	Nunn-McCurdy Act
1986	Packard Commission
1990	Defense Acquisition Workforce Improvement Act (DAWIA)
1994	Federal Acquisition Streamlining Act (FASA)

Specific Issue

Research on DoD cost overruns is abundant and has ranged from descriptive studies, like the 1993 and 1996 RAND studies by Jarvaise et al. and Drezner et al., to case studies like Singleton's 1991 Air Force Institute of Technology (AFIT) thesis and McNutt's 1998 Massachusetts Institute of Technology dissertation. Others such as Searle (1997), Christensen et al. (1999), Holbrook (2003), and Phillips (2004) have investigated the impact of acquisition reforms on cost overruns.

The whole of this research has identified several factors that may be correlated with cost overruns yet in large part, past research has not been able to empirically quantify or model their relative impact. Table 3 is a list of some of the factors identified by past research as being related to cost overruns and the direction of impact suggested by the past research.

Table 3. Factors Impacting Cost Overruns

Factors	Expected Direction of Impact
Acquisition Reforms	Inconclusive
Funding Instability	+
Estimation Error	+
Defense Industry Consolidation	-
War	+

While past research on cost overruns has been split with some researchers investigating its causes and others studying the impact of acquisition reform, this research will illustrate that those two areas of research are really one and that an aggregate model of cost overruns that accounts for these factors in a single model is needed.

Research Objectives

The motivation for this research is the lack of empirical models that explain the causes of cost overruns in defense weapon system purchases. The purpose of this research is to create a model of defense weapon system cost growth that can be used to answer the following questions:

1. Did the defense industry consolidation and concurrent decrease in defense budgets that occurred in the 1990's affect the cost of defense weapon systems?
2. Is war correlated with an increase in weapon system cost overruns?
3. Is estimation error caused by unexpected inflation correlated with an increase in weapon system cost overruns?
4. Did acquisition reforms have an impact on cost overruns when defense industry consolidation, inflation, changes in the defense budget, and war are considered?

This is not an exhaustive list of the factors potentially correlated with defense weapon system cost overruns. However these are many of the major factors and by modeling them, this study will add greatly to the understanding of the causes of defense cost overruns.

Scope and Methodology

This research is limited to the study of contract cost overruns on Acquisition Category (ACAT) I programs of the Army, Navy, and Air Force from 1970 until 2002. Defense contract cost overruns for each cross-sectional unit are analyzed using a panel regression model with annual contract cost overruns over time as the dependant variable and defense budgets, industry concentration, inflation, acquisition reforms, and war as the independent variables. The panel regression model is more robust than a hypothesis test design or case studies that are common in past research because the panel model reveals the relative importance of each variable and its contribution to cost overruns in a dynamic setting. Consistent with past studies such as Searle (1997) and Holbrook (2003), this research investigates cost overruns by contract type and program phase. Table 4 lists these four models.

Table 4. Model Descriptions

Model	Description
Model 1	Fixed Price Cost Overruns
Model 2	Cost-Plus Cost Overruns
Model 3	Production Cost Overruns
Model 4	Research and Development Cost Overruns

Organization of the Study

This chapter presented the problem of cost overruns in defense weapon system purchases. Additionally, this chapter identified the research questions that will be explored throughout this thesis. Chapter II will present a detailed discussion of past research on cost overruns, followed by a discussion of the data and methods used in this research in Chapter III, a presentation of analysis and results in Chapter IV, and a discussion of key findings in Chapter V.

II. Literature Review

Chapter Overview

This chapter reviews the previous research on the subject of cost overruns incurred by DoD in the acquisition of weapon systems. Additionally, this chapter summarizes the major efforts by DoD and the United States Congress to reform that process. Also, in the years following the various acquisition reforms, much research has been conducted assessing the impact of those reforms on cost growth. This chapter will review that literature and summarize its major findings. Additionally, while past research on cost growth has been split with some researchers investigating its causes and others studying the impact of acquisition reform, this literature review will illustrate that those two areas of research are really one and that an aggregate model of cost growth that accounts for these factors in a single model is needed.

Past Research on Cost Growth

As implied above, much research on cost overruns has been conducted, ranging from case studies that investigate managerial issues contributing to cost growth, to descriptive studies that measure and characterize cost growth. Table 5 is a summary of some of this research. A discussion of selected research follows.

Table 5. Summary of Research on Weapon System Cost Overruns

Summary of Research on Weapon System Cost Overruns			
Author	**Year**	**Method**	**Main Findings**
Singleton	1991	Case Study	Factors Causing Cost Growth: Funding Instability, Configuration Instability, Technology Readiness
RAND	1993,1996	Descriptive	20% Average Cost Growth in ACAT 1 Programs, Program Maturity Affects Cost Growth
Czelusniak and Rogers	1997	Descriptive	Funding Instability from Contingency Operations lead to cost growth
GAO	1998	Descriptive	DoD expects significant savings from defense industry consolidation
McNutt	1998	Case Study	Complex Acquisition Process, Poor Portfolio Management, Increased Cycle Time, and Funding Instability drive Cost Growth
Swank et al.	2000	Descriptive	40% Cost Growth in Research and Development Programs
Coleman et al	2003	Empirical	No Relationship between Cost and Schedule Growth
GAO	2005	Descriptive	Consolidation of the Defense industry is at a 50 year high. DoD expects significant savings from consolidation

In her 1991 thesis, Singleton attempted to predict "a range of potential cost growth around the most probable cost estimate" (Singleton, 1991:7). She accomplished this goal by "researching the cost growth experienced in recent programs and categorizing (those) programs based on several factors" (Singleton, 1991:7) spelled out in her thesis. She then identified the top three contributing factors through a selection process involving a panel of cost analysts. Her research identified technical risk, configuration stability, and schedule risk as the top three factors contributing to cost growth.

According to a 1998 GAO report entitled *Defense Industry: Consolidation and Options for Preserving Competition*, the Department of Defense has identified 12 industrial market sectors comprised of types of products or weapons systems important to U.S. national security interests (GAO, 1998:2). The report lists ten of those sectors and identifies them as experiencing industry consolidation between 1990 and 1998 (GAO, 1998:10). The report goes on to say that "DoD expects significant cost savings will result from (this) consolidation (GAO, 1998:2)."

Table 6. Reduction in the Number of Prime Contractors (GAO, 1998:10)

Reduction in the Number of Prime Contractors

Sector	1990	1998
Tactical Missiles	13	4
Fixed-Wing Aircraft	8	3
Expendable Launch Vehicles	6	2
Satellites	8	5
Surface Ships	8	5
Tactical Wheeled Vehicles	6	4
Tracked Combat Vehicles	3	2
Strategic Missiles	3	2
Torpedoes	3	2
Rotary-Wing Aircraft	4	3

Note: The Electronics sector is not included.

Following their 1998 report, the GAO issued another report in 2005 called "Consolidation and Options for preserving Competition" in which they state "The sharp decline in spending by DoD since 1985 has resulted in a dramatic consolidation of the defense industry, which is now more concentrated than at any time in more than a half century." (GAO, 2005: 1) and then go on to reiterate that the DoD expected significant savings from consolidation. (GAO, 2005:2)

Coleman, Summerville, and Dameron (2003) investigated the relationship between cost growth and schedule growth. They used data from the Selected Acquisition Report (SAR) compiled in the 1993 RAND Cost Growth Database to perform this analysis. The major conclusion of the analysis was that there is no correlation between schedule length and cost growth (Coleman et al, 2003:120). One limitation of this research is that when the requirements of a program change significantly, the estimate in the SAR is rebaselined. This rebaselining can obscure the actual cost and schedule overruns. If the researchers did not account for this technique, and there is no evidence that they did, then the conclusion that cost and schedule growth are unrelated is in doubt.

One common theme in much of the research on cost overruns is the idea that funding instability causes cost overruns. As far back as 1991, Singleton identified this as one of the key contributing factors. McNutt (1998) argues among other things that the complex acquisition and budget process leads managers to make suboptimal funding choices that lead to poor portfolio management and a chronic under-funding of long-term projects (McNutt, 1998:307). He suggests that this instability in funding leads to increased acquisition cycle time which in turn leads to increased cost overruns. In support of this idea, a quick glance at Figure 2 reveals a clear countercyclical relationship between cost overruns and changes in defense budgets:

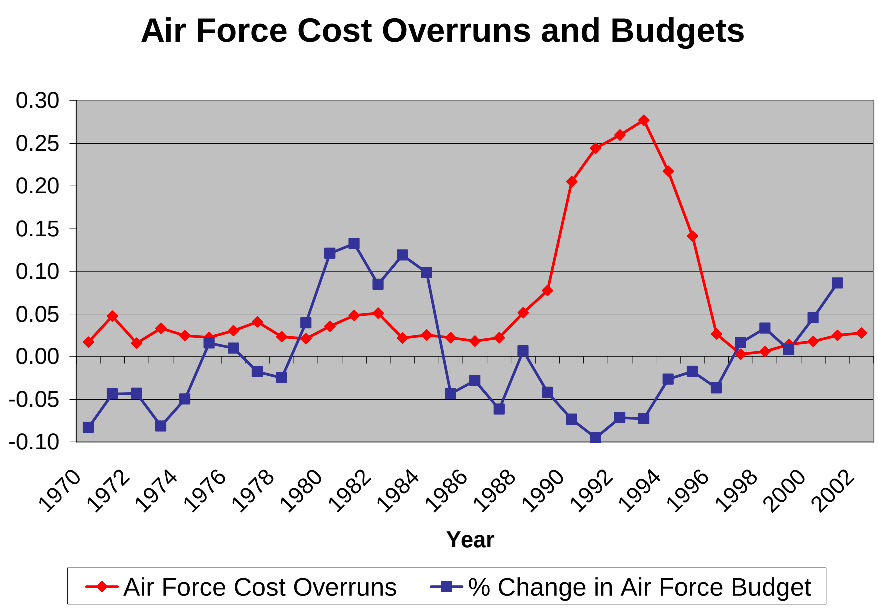


Figure 2. Air Force Cost Overruns and Percent Change in Budgets

This idea is summed up well by the US Senate in a recent report on defense acquisition policy in which they state: "….the committee believes that one answer can be found in the inability of the Department (of Defense) to address the budget and program instability issues. …Funding and requirements instability continue to drive up costs and delay eventual fielding of new systems" (Kadish et al., 2005:1).

Past research also suggests that funding needs related to contingency operations such as Bosnia, Afghanistan, and Iraq also contribute to cost growth. Christensen et al. (1999) characterize this finding by Czelusniak and Rogers (1997) as follows: "…Czelusniak and Rodgers (1997) report that Congressional decisions to shift funds to near-term priorities external to the program (e.g. unplanned contingency operations in Bosnia) account for up to one-half of the cost growth in major weapons systems."

Finally, the idea that estimation error can lead to cost overruns is briefly suggested by Christensen et al. (1999:1) and Drezner et al. (1993:iii). Essentially, the idea is that cost overruns can be caused by poor initial estimates of program cost. One way estimates can be inaccurate is if they fail to accurately capture inflation. This is especially true in programs of longer duration or high dollar value. An estimate of inflation prepared by the DoD Comptroller is included in all cost estimates. If inflation is unexpectedly high in a given year then that forecasting error could contribute to cost overruns.

Acquisition Reform

In an attempt to make the DoD more responsive and efficient in the procurement of weapon systems, Congress, the DoD, and the individual military services have instituted various reforms to the acquisitions process. Major reforms and initiatives from 1971 to 2003 are listed in Table 7. However, a quick glance at the table reveals the challenge in trying to discern the impact of a given acquisition reforms. Almost every year, some type of reform effort is undertaken and it becomes difficult to identify the major reforms.

Table 7. Acquisition Initiatives and Legislation (Scofield, 2003:19)

Acquisition Initiatives and Legislation

1971	DODD 5000.1 (major systems acquisitions)
1972	Commission on Government Procurement
1973	DODD 5000.4 (Cost Analysis Improvement Group)
	DODD 5000.3 (Test & Evaluation)
1975	DODI 5000.2 (major systems acquisitions)
	DODD 5000.28 (design to cost)
1976	OMB Circular A-109
1978	Defense Science Board Acquisition Cycle Task Force
1979	Defense Resource Management Study
1981	Carlucci Initiatives; Defense Acquisition Improvement Program
1982	Nunn-McCurdy (thresholds)
1983	Office of Federal Procurement Policy Act
	Grace Commission
1984	DOD Authorization Act (Public Law 98-94) created Office of Operational Test & Evaluation
1984	Competition in Contracting Act (CICA)
1985	DOD Procurement Reform Act
	DOD 5000.43 (streamlining)
1986	Packard Commission
	Goldwater-Nichols Department of Defense Reorganization Act
	Defense Procurement Improvement Act
	Defense Acquisition Improvement Act
1987	DODD 5134.1 (Undersecretary of Defense, Acquisition)
	DODD 5000.49 (Defense Acquisition Board)
1989	Defense Management Review
	Ethics Reform Act
1990	Defense Acquisition Workforce Improvement Act
1991	Revised DODI 5000.2 (major systems acquisitions)
	Section 800 Panel created by 1991 National Defense Authorization Act (Public Law 101-510)
1994	Defense Acquisition Reform
	Federal Acquisition Streamlining Act (FASA)
1995	Federal Acquisition Improvement Act (FASA II)
	Air Force Lightning Bolts 1
1996	Federal Acquisition Reform Act
	Clinger-Cohen Act
	Rewrite DOD 5000 Series
1999	Air Force Lightning Bolts 2
2000	Revised DOD 5000 Series
2002	Agile Acquisition Initiatives (Air Force Light-ning Bolts 3)
2003	Rewrite DOD 5000 Series

However, past research illustrates that four reforms are singular in their scope and potential impact on cost overruns. Table 8 presents a list of those key acquisition reforms, laws, and studies that have been highlighted by past research and based on a review of this research, four are selected for study.

Table 8. Key Reforms Identified by Past Research

ACQUISITION REFORM/STUDY	Year	Christensen et al. (1999)	Reig (2000)	Cooper (2002)	Scofield (2003)	Holbrook (2003)	Phillips (2004)	Count
Nunn-McCurdy Act	**1982**				**X**			**1**
Grace Commision	1983					X	X	2
DoD Authorization Act	1984				X			1
Packard Commission	**1986**	**X**		**X**	**X**	**X**	**X**	**5**
Goldwater Nichols Act	1986				X			1
Defense Management Review	1989					X		1
DAWIA	**1990**			**X**				**1**
National Performance Review I	1993					X		1
FASA	**1994**		**X**			**X**		**2**
Cost as an Independent Variable	1995		X					1
Clinger-Cohen Act	1996					X		1
Evolutionary Acquisition	2000			X				1

<u>Nunn McCurdy Act of 1982</u>

The Nunn McCurdy Act of 1982 was enacted by Congress in an attempt to control the spending of the Department of Defense and to force the DoD to provide information to Congress when a major program experiences significant cost overruns. To accomplish this goal, the bill called for “the termination of weapons programs whose total costs grew by more than 25 percent above original estimates, unless they were certified as critical systems by the Secretary of Defense or if the cost growth was attributable to certain specified changes in the program” (Center for Defense Information:2005).

Such a clear attempt by Congress to curtail cost overruns in defense weapons systems deserves study. Yet, over twenty years later there has been little research to evaluate its impact.

Packard Commission of 1986

According to Cooper "the 'modern' era of acquisition reform commenced in 1986 with the President's Blue Ribbon Commission on Defense Management (Packard Commission) (Cooper, 2002:11)." The commission was chartered by President Reagan in late 1985 to study the defense acquisition process and was chaired by former Deputy Secretary of Defense David Packard. The primary conclusion of the study was that "major weapons systems cost too much, take too long to field," and as a result, end up fielding "obsolete technology" (Searle, 1997: 32). In response to this, the Packard Commission offered the following recommendations presented in Table 9:

Table 9. Packard Commission Recommendations (Modified from Searle, 1997:34)

Packard Commission Recommendations
Streamline the Acquisition Process
Increase Tests and Prototyping
Change the Organizational Culture
Improve Planning
Model the DoD after a Competitive Firm

Unlike the Nunn-McCurdy, act, the impact of the Packard Commission recommendation have been extensively researched by authors such as Searle (1997), Christensen et al. (1999), and Holbrook (2003). And, the conclusion drawn by all of these studies is virtually the same. The conventional wisdom is that either the Packard

Commission recommendations made no difference (Holbrook: 2003:81) or that the cost performance of defense contracts actually got worse in the period following Packard (Christensen et al.,1999:257).

Defense Acquisition Workforce Improvement Act (DAWIA) of 1990

"The Defense Acquisition Workforce Improvement Act (DAWIA) of 1990 (Public Law 101-510) required the Secretary of Defense…to establish education and training standards, requirements, and courses for the DoD civilian and military workforce" (Cooper, 2002:12). While not traditionally viewed as an acquisition reform, DAWIA "shaped the way education and training is provided to DoD acquisition personnel…" (Cooper, 2002:12) and therefore is considered by this research to be worthy of study. Intuitively, a well-trained acquisition workforce should be able to deliver increased combat capability more quickly and at a reduced cost.

Federal Acquisition Streamlining Act (FASA) of 1994

The Federal Acquisition Streamlining Act was enacted in 1994 and was "the first major rewrite of government procurement regulations in a decade" (Cooper, 2002:15). The primary intent of FASA was to empower the acquisition workforce to make decisions about how to manage their programs. This was a movement away from the restrictive and centralized procurement practices of the past (Cooper, 2002:15). Other key provision of FASA were the increased use of performance based contract payments, and the push towards more "commercial or off the shelf products" (Cooper, 2002:18).

Most important for this study were the requirements that contractors have a certified cost accounting system that complies with accepted cost accounting standards and also the increased scrutiny of a contractor's past performance in the source selection criterion of major weapon system purchases. Clearly these provisions should have led to decreases in weapon system cost and should be investigated. Indeed, in their 1999 paper, Christensen et al. suggest that the impact of the FASA reform is worthy of study but that some time would have to pass before its impact could be felt. (Christensen et al, 1999:258). Now, twelve years after the reform, the impact can be modeled and studied.

Clinger-Cohen Act of 1996

The Clinger-Cohen Act of 1996 is an extension of the ideas of FASA. So similar are the provisions of Clinger-Cohen that Holbrook used the phrase FASA II to describe it (Holbrook, 2003:20). As such, the Clinger-Cohen Act and FASA are modeled as a single reform in this study.

Challenges in Implementing Reforms

One challenge in evaluating the impact of acquisition reform is deciding when to consider a reform to be implemented. This is an important decision if the effects of the reforms are to be studied properly. Clearly, if Congress passes a law restructuring the defense acquisition process today, it should not be considered fully implemented tomorrow. Intuitively, one would expect any reform of a large bureaucracy to take some time to be implemented and an even longer time before its results appeared in contract cost data. Indeed, organizational behavior literature suggests that changes can take years to become fully implemented within a large bureaucracy (Geert et al., 2002:11). The issue is eloquently described by Geert et al. in their 2002 working paper *A Framework for Assessing Commitment to Change. Process and Context Variables of Organizational Change.*

> "Time plays at least in two ways a central role in the change process. First, implementation of change goes through different phases. ..These phases take time. Common to all the implementation models is the message that efforts to bypass these phases seldom yield a satisfactory result (Armenakis & Bedeian, 1999: 303)."

In an organization as large and complex as the Department of Defense, one would expect acquisition reforms would take some time to fully implement. Compounding the problem is the frequency with which such reforms occur. No doubt, different reforms have been implemented to varying degrees and with varying effectiveness.   In his 2002 Naval Postgraduate School (NPS) Thesis, Michael Cooper alludes to this problem when he lists "Reduce the number of Reform Initiatives" (Cooper, 1997:97) as one of its recommendations. The paper goes on to emphasize that reforms need to be clearly identified and prioritized to the workforce (Cooper, 1997:97).

In his 2000 article in the *Acquisition Review Quarterly*, Raymond W. Reig confronts the problem of identifying when a reform has been implemented and attempts to measure or baseline the effective date of modern acquisition reform. Choosing one date as the effective date for some many disparate initiatives proves to be a formidable challenge. However, he does settle on a date of January 1996 as the date that acquisition reforms "first became effective within the field…" (Reig, 2000:38).   He then states that any program with a Milestone III (Milestone C) that occurred after July 1996, would be beneficially affected by acquisition reform. However, one must ask how reasonable it is to choose one date by which all acquisition reforms are considered implemented.

Acquisition Reform Cost Research

> "Despite the implementation of more than two dozen regulatory and administrative initiatives, there has been no substantial improvement in the cost performance of defense programs for more than 30 years."
>
> (Christensen et al., 1999:252)

The second major area of research on cost overruns looked at whether acquisition reforms had any measurable impact on cost overruns. The consensus among this research is that acquisition reforms had no measurable impact on cost overruns. However, this research is subject to some limitations including a subjective treatment date and omitted variable bias. Table 10 is a summary of key research in this area:

Table 10. Acquisition Reform Impact on Cost Overruns

Author (Year)	**Main Findings**
Searle (1997)	Cost Overruns worsened after the Packard Commission
Christensen et al. (1999)	Cost Estimating Error is a causal factor in cost overruns
Holbrook (2003)	Acquisition Reform had no significant Impact on contract cost performance
Phillips (2004)	

Choosing one date as the effective date of acquisition reform is a convenient tool for analysis employed by all of this research. Phillips used December 31, 1996 as the treatment date for comparing pre-reform and post-reform cost growth. Using Selected Acquisition Report (SAR) data derived from the 1993 RAND cost growth database he concluded that acquisition reform has had no impact on cost growth (Phillips, 2004:70). Holbrook arrived at a similar conclusion looking at data from the DAES database. Also looking at data from the DAES database, Christensen, Searle, and Vickery used December 31, 1991 as the treatment date for determining the impact of the Packard Commission's recommendations (Christensen et al., 1999:254) and concluded the following:

> "Based on a review of 269 completed defense contracts, we found that the Packard Commission's recommendations did not reduce cost overruns. This result is consistent with similar research involving an analysis of cost growth on 197 defense programs (Drezner, Jarvaise, Hough, and Norton, 1993)."

Despite the apparent clarity of these results there is some question in the wisdom of choosing a single date to represent the effective date of all acquisition reforms as was done by Holbrook and Phillips. Additionally, none of these studies include other previously identified variables such as changes in defense budgets, industry concentration, inflation, or war. The absence of these variables could bias the result of their research. Christensen et al. recognized this issue when they identified threats to internal validity in the footnotes of their research article.

To their credit, this research was a needed first step in studying the effectiveness of acquisition reform and the researchers did recognize that additional research needed to be done. For example, in his concluding chapter, Holbrook states "There appears to be a relationship between acquisition reform events and an immediate change in cost performance. However…this study cannot provide answers as to why these changes occurred and why they appear to be short lived" (Holbrook, 2004: 80). Similarly, Searle, in his 1997 thesis suggested that future research "investigate other possible causes of the dramatic change in cost performance after Dec 31, 1991." He went on to say that "Perhaps other significant factors not accounted for in this thesis may have been responsible for the changes noted" (Searle, 1997:89).

Chapter Summary

This chapter identified the problem of cost overruns in the purchase of defense weapon systems and reviewed the attempts of past researchers to explain its causes. As discussed in this chapter, past research identified funding instability, war, cost estimating error, and defense industry consolidation as contributing factors but has not been able to create an empirical model to measure their relative impact. Also, this chapter reviewed the major acquisition reforms of the last 20 years and discussed the challenge in identifying major reforms as well as measuring their effective date. This research further looked at studies that evaluated the effectiveness of acquisition reform and concluded that while the consensus among previous research is that acquisition reform had no impact on reducing cost overruns, that research is subject to some limitations which potentially bias their results and suggest that further study is needed.

III. Data and Methods

Chapter Overview

This chapter explains the methods employed in this research effort and describes the data used to answer the research questions discussed in Chapter I. The primary purpose of this research is to develop an empirical model that can be used to study the impact of acquisition reforms, changing levels of defense industry consolidation and defense budgets, unexpected inflation, and war on the cost of defense weapon systems. To accomplish this goal, data was collected on the dependent variable (cost overruns of weapon systems contracts for Air Force, Army, and Navy) and the independent variables (defense budgets, industry concentration levels, acquisition reforms, predicted and actual inflation rates, and war).

The relationships between the variables are then described using fixed-effects panel regression models to describe cost overruns in fixed-price and cost-plus contract types as well as the production and research and development program phases. This chapter provides a brief discussion of the advantages of the fixed-effect panel model in cross-sectional time series analysis, an overview of the model data, and a detailed description of the econometric analysis that is employed in the next chapter.

Description of the Models

In total, four models are presented. Models 1 and 2 describe how cost overruns relate to each contract type and Models 3 and 4 describe cost overruns by program phase. Recall that past researchers such as Searle (1997), Christensen et al. (1999), and Holbrook (2003) also studied contract cost overruns by contract type and program phase.

This is because the different types and phases are expected to behave differently. For example, the cost-plus contract type is expected to put more risk on the government. Consequently, the overall magnitude of cost overruns for this contract type is expected to be greater.

Advantages of the Fixed-Effects Panel Model

As stated above, this research employs a fixed effects panel model to analyze annual cost overruns of the Air Force, Army, and Navy. Since the cost overruns are over time and involve multiple cross sections, a panel model is the ideal analytical tool. Cost overruns could have been studied using a simple time series regression model using ordinary least squares regression. However, modeling the data as a panel model "creates more variability, through combining variation across micro-units with variation over time." This increased variability makes the fixed-effects panel model more robust to multicollinearity (Kennedy, 2003:302).

Perhaps more important is that since a panel model accounts for heterogeneity in the cross-sectional values, it can correct for omitted variables. This is important because omitted variables bias the regression results. (Kennedy, 2003:303) Put simply, the issue of omitted variables is a serious limitation of past research on cost overruns. The fact that the panel model can account for this problem is perhaps the biggest single advantage of this technique.

Data

Dependent Variable

The dependent variable in this analysis is the annual percentage of contract cost overruns on ACAT I weapons programs for the United States Air Force, Army and Navy from 1970 to 2002. Contract cost overruns were measured using Earned Value Management (EVM) data from the Defense Acquisition Executive Summary (DAES) database. Cost overruns from contracts contained in the DAES database were separated by service and by contract type and phase and then used to calculate average percentage contract cost overruns per year.

There are two main sources of cost information for defense weapon systems: The Selected Acquisition Reports (SAR) and the Defense Acquisition Executive Summary Database (DAES). SARs were created by the Department of Defense in 1967 in order to generate a consistent database of cost, schedule, and performance information on major defense acquisition programs. The DAES database is a collection of cost information on ACAT 1 programs by acquisition contract (Holbrook, 2003:33)."

Compilations of SAR cost and schedule information have been used extensively in past cost research. However, due to the highly aggregated nature of the data in the SAR database (Christensen et al, 1999:252), there are several limitations to this database that reduce its effectiveness in explaining cost growth (Jarvaise et al., 1996:11). Consequently, for this research the DAES database is used.

In the DAES database is the Earned Value Management (EVM) data derived from contractor reports called Cost Performance Reports (CPRs). EVM is a tool used by contractors and the government to track costs on defense contracts (Holbrook, 2003:25). Since each EVM system is validated by the government prior to use, the data from the EVM system is considered valid (Searle, 1997:42).

The cost data used in this study covers ACAT I contracts from 1970 to 2002 and consists of 14,003 entries from 186 ACAT I programs from the Air Force, Army and Navy. Table 11 shows the number of programs per service and Figure 3 is an excerpt from the database:

Table 11. Number of Programs per Service

Service	Number of Programs
Air Force	61
Army	50
Navy	75

SUBMITDATE	Contract ID	Service	ProgramName	ACWP	BCWP	BCWS	BAC	Contract Type	Program Phase
3/25/1976	N0003074C0100	Navy	TRIDENT SUB	1005.5	973.7	987.9	2028.6	CP	DEVELOPMENT
4/25/1976	N0001975C0424	Navy	F/A-18 C/D	20.6	21.8	21.9	1020.2	CP	DEVELOPMENT
5/25/1976	DAAK4072C0106	Army	PATRIOT	532.7	522	529.7	569.2	CP	DEVELOPMENT
5/25/1976	DAAK4072C0773	Army	STINGER	64.5	53.6	55.3	62.9	CP	DEVELOPMENT
6/25/1976	F1962870C0218	Air Force	E-3A Hawkeye	697	662.2	673.9	768.3	CP	DEVELOPMENT
6/25/1976	F1962870C0218	Air Force	E-3A Hawkeye	142.9	142.2	146.6	259.3	FPI	PRODUCTION
6/25/1976	F1962874C0127	Air Force	E-4 (AABNCP)	80.4	81.7	83.4	181.3	CP	DEVELOPMENT
6/25/1976	N0001976C0261	Navy	F/A-18 C/D	23.3	22.9	23.1	330.6	CP	DEVELOPMENT
6/25/1976	F3365770C0300	Air Force	F-15	827	803	804	809.3	CP	DEVELOPMENT
6/25/1976	F3365775C0310	Air Force	F-16	114.2	109.1	127.7	389.5	FPI	DEVELOPMENT
6/25/1976	N0003074C0100	Navy	TRIDENT SUB	1105.4	1084.2	1087.5	2026.2	CP	DEVELOPMENT
7/25/1976	F3365775C0310	Air Force	F-16	127.1	119.8	140	399	FPI	DEVELOPMENT
8/25/1976	DAAJ0175C0360	Army	AH-64 Apache	12.8	13	11.6	32.5	CP	DEVELOPMENT
8/25/1976	N0001975C0267	Navy	C/MH-53E	36.6	32.7	34.5	69.7	CP	DEVELOPMENT
8/25/1976	DAAA0976C2001	Army	COPPERHEAD	11.6	11.3	11.5	41.6	CP	DEVELOPMENT
8/25/1976	N0001975C0424	Navy	F/A-18 C/D	49.5	51.9	52.9	1022.2	CP	DEVELOPMENT
8/25/1976	F3365776C0100	Air Force	F-15	135.6	136.9	134.8	852.9	FPIF	PRODUCTION
8/25/1976	F0470475C0014	Air Force	Minuteman III	18.4	19.4	18.6	75.8	FPI	PRODUCTION

Figure 3. Excerpt from DAES Database

A complete list of programs studied and the number of contract entries per program can be found in Appendix A.

To identify the lead service and program name, an identifier from the DAES database called a PNO number was matched with a list of PNO numbers compiled by Carden in the completion of his 2006 AFIT Master's Thesis. Data was then further grouped by contract type into fixed-price contracts and cost-plus contracts. Contracts that were a mix of the two types or contracts where the contract was unknown were not included in either the fixed-price contract model or the cost-plus contract model. Additionally, the contracts were segregated by program phase into production contracts and research and development (R&D) contracts. Again, contracts where the phase was unknown were not included in either of these models. Contracts where no lead service was known or contracts that were managed by the Office of the Secretary of Defense (OSD) were also not included in this study. Table 12 shows the number of contract entries in the database per contract type:

Table 12. Number of Contract Entries per Service and Contract Type

Service	Fixed Price	Cost-Plus	Grand Total
Air Force	3485	1588	5073
Army	907	1839	2746
Navy	3243	2247	5490
Grand Total	**7635**	**5674**	**13309**

Table 13 shows the number of contract entries in the database per program phase:

Table 13. Number of Contract Entries per Service and Program Phase

Service	Production	Development	Grand Total
Air Force	2267	2151	4418
Army	855	1385	2240
Navy	2924	1418	4342
Grand Total	**6046**	**4954**	**11000**

The dependent variable in this analysis is the annual percentage of contract cost overruns per service per year. These values were derived from the EVM data of each contract entry by first using the following formula for percentage contract cost variance (%CV) from the Earned Value Management Gold Card on all contract entries:

$$\%CV = \frac{(ACWP - BCWP)}{BCWP} \cdot 100 \tag{1}$$

where: %CV = Percentage Cost Variance

BCWP = Budgeted Cost of Work Performed

ACWP = Actual Cost of Work Performed

Then, the %CV from each contract entry is aggregated by year, service, program type, and program phase and an annual cost overrun percentage is calculated using a weighted average of the individual %CV's. Graphs of cost overruns over time and for each model are found in Chapter IV.

<u>Independent Variables</u>

Table 14 lists the independent variables used in this analysis. A discussion of each variable type follows.

Table 14. List of Independent Variables

Independent Variables	
Variable Description	**Variable Name**
Percent Change in Operations and Maintenance Budget	ombudgetpercent
Percent Change in Procurement Budget	procbudgetpercent
Percent Change in Research and Development Budget	rdbudgetpercent
Industry Concentration (CR4)	concentrationcr4
Unexpected Inflation	inflationdifference
Packard Commission	packard
Federal Acquisition Streamlining Act (FASA)	fasa
Nunn-McCurdy Act	nunnmccurdy
Defense Acquisition Workforce Improvement Act (DAWIA)	dawia
War	war

Defense Budgets

In the models presented in this research, the annual percentage change in defense budgets is a proxy for funding instability. Annual budget data is obtained from Chapter 6 of the National Defense Budget Estimates for 2006, a report prepared annually by the Office of the Undersecretary of Defense (Comptroller). Budget data from this document is collected per cross-sectional unit (Air Force, Army, and Navy), and per appropriation. For the purposes of this study, the budget remaining after Procurement and R&D funds are subtracted is referred to as the Operations and Maintenance (O&M) budget. Finally, budget values are then converted into annual percentage changes to be consistent with the dependent variable and for ease of interpretation of model coefficients. A table of budget amounts for each service is presented in Appendix C.

Acquisition Reforms

The acquisition reforms studied in this research are coded as dummy variables with a "1" representing the presence of the reform and a "0" indicating that the reform is not in effect. The Nunn-McCurdy act was enacted in 1982 so it is coded as a “1” from 1982 until 2002. The Packard Commission recommendations were issued in 1986 so from 1986 until 1994, Packard is coded as a “1”. In 1994, the Federal Acquisition Streamlining Act (FASA) was enacted and superseded many of the Packard Commission reforms so after 1994, Packard is coded as a “0” and from 1994 until 2002, FASA is coded as a “1”. Finally, in 1990, the Defense Acquisition Workforce Improvement Act (DAWIA) became law so from 1990 until 2002, DAWIA is coded as a “1”.

War

War is also modeled as a dummy variable and is coded as a “1” for the Vietnam War, the Gulf War, the conflict in Bosnia in 1999, and the period after September 11th.

Industry Consolidation

The level of consolidation in the defense industry is measured by an industry concentration ratio called the CR4. The CR4 measures “how much of the total output of an industry is produced by the largest (four) firms in that industry…. When an industry is composed of a very large number of firms, each of which is very small, the (CR4) is close to zero. When four or fewer firms produce all of an industry’s output, the (CR4) is close to 1” (Baye, 2003:233).

CR4 data was gathered from the Economic Census reports generated every five years by the US Census Bureau. For the purposes of this study, North American Industry Classification System (NAIC) category 366411, Aerospace Products and Parts Manufacturing represents the industry concentration of the Air Force, the Army concentration level is represented by NAIC 3795, Tank and Tank Components, and the Navy is represented by NAIC 3731, Ship Building and Repair. Figure 4 is a graph of the concentration ratios from 1970-2002:

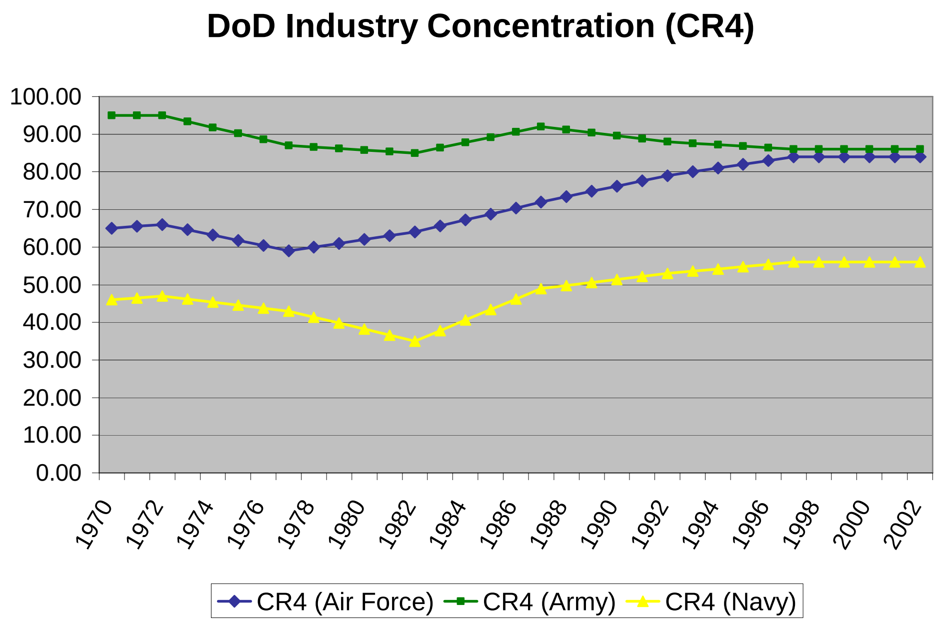


Figure 4. Industry Concentration Ratios by Service

Unexpected Inflation

Recall that cost estimating error was identified in past research as a causal factor in cost overruns (Christensen et al., 1999:251).   One factor that contributes to cost estimating error is error in the inflation prediction of a cost estimate. Future inflation of defense spending is forecasted by OSD Comptroller and as they discuss in Chapter 5 of National Defense Budget Estimates for 2006, forecasts of inflation are adjusted several times before the final forecast.   Even then, the forecast does not exactly match the actual inflation in that year.

Given this discrepancy, this research models a variable called Unexpected Inflation and tests whether it is correlated with cost overruns. Unexpected inflation is defined as the difference between actual inflation and expected inflation in the year the money is used.

In reality, each service and appropriation has a different annual prediction of expected inflation and a different actual inflation. However, for this model, the aggregate difference is used for each cross section (Air Force, Army, and Navy). Table 18 displays the expected and actual inflation values for each year as well as the calculated difference referred to in this research as Unexpected Inflation. The availability of historical budget and forecast data at the time of this research precludes the use of values before 1980.

Table 15. Unexpected Inflation in DoD

	Actual Inflation	Expected Inflation	Unexpected Inflation
1980	11.7%	5.9%	5.8%
1981	10.4%	8.1%	2.3%
1982	7.5%	8.9%	-1.4%
1983	3.6%	6.3%	-2.7%
1984	3.0%	3.7%	-0.7%
1985	3.3%	4.5%	-1.2%
1986	2.6%	4.0%	-1.4%
1987	2.9%	3.4%	-0.5%
1988	3.6%	4.5%	-0.9%
1989	3.9%	3.4%	0.5%
1990	3.0%	3.0%	0.0%
1991	4.6%	4.0%	0.6%
1992	1.9%	2.9%	-1.0%
1993	2.9%	3.7%	-0.8%
1994	2.3%	2.0%	0.3%
1995	2.0%	2.2%	-0.2%
1996	2.2%	2.8%	-0.6%
1997	2.2%	2.6%	-0.4%
1998	2.3%	2.2%	0.1%
1999	2.2%	2.0%	0.2%
2000	2.5%	2.2%	0.3%
2001	3.0%	2.8%	0.2%
2002	2.7%	3.0%	-0.3%

Methods

The model proposed in this research is that contract cost overruns are a function of budgets, industry concentration, inflation, acquisition reform, and war such that:

$$\text{COST OVERRUN \%} = f\begin{pmatrix}\text{FE}_{\text{i}} + \Delta\text{O \& M Budget} + \Delta\text{Procurement Budget} + \Delta\text{R \& D Budget} \\ + \text{Industry Concentration} + \text{Unexpected Inflation} + \text{Packard} \\ + \text{FASA} + \text{NunnMcCurdy} + \text{DAWIA} + \text{War} + \text{AR1 disturbance} + \text{error}\end{pmatrix} \tag{2}$$

The fixed-effects panel model notation is:

$$y_{it} = \alpha + x_{it}\beta + v_i + \varepsilon_{it} \tag{3}$$

where i = {Air Force, Army, Navy}

j = {1970,1971,…2002}

The dependant variable is assumed to have lag 1 autocorrelation so an AR 1 disturbance term is added to the model (Stata, 2005:311). Consequently, the error term is represented as follows:

$$\varepsilon_{it} = \rho\varepsilon_{i,t-1} + \eta_{it} \tag{4}$$

Using this notation, the basic representation of all four models is:

$$\begin{aligned}\text{COST OVERRUN \%} = {} & \alpha_{\text{i}} + \beta_1\Delta\text{O \& M Budget}_{\text{it}} + \beta_2\Delta\text{Procurement Budget}_{\text{it}} + \\ & \beta_3\Delta\text{R \& D Budget}_{\text{it}} + \beta_4\text{Industry Concentration}_{\text{it}} \\ & + \beta_5\text{Unexpected Inflation}_{\text{it}} + \beta_6\text{Packard}_{\text{it}} + \beta_7\text{FASA}_{\text{it}} \\ & + \beta_8\text{NunnMcCurdy}_{\text{it}} + \beta_9\text{DAWIA}_{\text{it}} + \beta_{10}\text{War}_{\text{it}} + \text{v}_{\text{i}} + \varepsilon_{\text{it}}\end{aligned} \tag{5}$$

The first step in this analysis was to check for stationarity of the dependent variable for each of the four models. According to Kennedy, regression analysis of panel data could result in spurious correlations if the dependent variable is non-stationary (Kennedy, 2003:325). This research tests for stationarity by two methods. The first method is by inspection of a time series plot of each dependent variable. The second method is a more formal test called the Augmented Dickey Fuller Test. The Augmented Dickey-Fuller test tests if a variable "follows a unit root process….. The null hypothesis is that the variable contains a unit root, and the alternative is that the variable was generated by a stationary process" (Stata, 2005).

According to Makridakis et al. in their *Forecasting Methods and Applications text*, the four assumptions of multiple linear regression are model form, independence of residuals (lack of autocorrelation), constant variance (homoskedasticity), and normality of residuals (Forecasting, 1998:259). However, a reading of Kennedy's *A Guide to Econometrics* illustrates that the fixed-effects panel model is robust to normality and is also effective at dealing with omitted variable bias that would make model form a more serious concern. Therefore, this research tests each panel model only for independence or a lack of autocorrelation and homoskedasticity or constant variance.

Autocorrelation means that model residuals are not independent of their lagged values (Forecasting, 1998:265). The presence of autocorrelation in time series models such as the panel model is a serious concern to econometricians (Kennedy, 2003:134) because it introduces bias to the model coefficients. To measure autocorrelation, the

Baltagi Wu Locally Best Invariant (LBI) test was calculated. The Baltagi-Wu LBI is an extension of the Durbin-Watson statistic to unbalanced panel models and tests a model for lag 1 autocorrelation (Stata, Longitudinal/Panel Data, 2005:316).

Like the Durbin-Watson statistic, the Baltagi-Wu LBI ranges from 0 to 4 with values significantly lower or higher than 2 indicating autocorrelation. The further the calculated value is away from 2, the more evidence of positive (less than 2) or negative (greater than 2) autocorrelation of the dependant variable. No p-values are available for the Baltagi-Wu LBI, so the presence of autocorrelation is a subjective determination of the researcher. In the event that the AR(1) disturbance term does not adequately account for the remaining autocorrelation, lagged dependent variables are added until the Baltagi-Wu LBI approaches 2.0

To test for homoskedasticity, the Breusch-Pagan test is employed. The null hypothesis of the Breusch-Pagan test is that the variance is equal to zero. Heteroskedasticity "…does not lead to biased coefficients. But when the homoskedasticity assumption is violated, the coefficients of a regression model are not efficient…" (Koeler and Kreuter, 2005:214).

Finally, lagged values of the acquisition reform and budget variables were added to the specified model. While it is expected that budgets and acquisition reforms are correlated with cost overruns, past research suggests that the effect may take a while to materialize. Intuitively, this makes sense. Changes in the current year's budget are not likely to have as much of an impact on existing contracts as would changes in the previous number of years. Similarly, with acquisition reform, organizational behavior literature as well as past cost research suggests that reforms take years to be implemented.

As stated by Kennedy in *A Guide to Econometrics*, "It is common for practitioners to use selection criteria such as the Akaike Information Criterion (AIC) or adjusted R^2 to aid in model specification particularly in determining things like the number of lags to include (Kennedy, 2003:88)." Based on this guidance, this research used the AIC to determine the lag structure for the budget and acquisition reform variables.

Summary

This research analyzes the cost overruns of defense weapon system contracts by contract type and program phase over time. This chapter describes how a fixed-effects panel model is used to create these empirical models. Additionally, this chapter described how the data for the dependent and independent variables was gathered and prepared. Finally, this chapter outlined the process of analysis that is undertaken on each of the four models in the next chapter.

IV. Analysis and Results

Chapter Overview

Recall from previous chapters that cost overruns in defense weapons systems are hypothesized to be correlated with changes in defense budgets, levels of concentration in the defense industry, unexpected inflation, acquisition reform, and war. Table 16 is a summary of the independent variables and their expected impact on cost overruns derived from a review of past research.

Table 16. Summary of Independent Variables

Factor	Model Variable	Expected Impact
Funding Instability	Percentage Change in Defense Budgets	+
Industry Consolidation	Industry Concentration (CR4)	-
War	War Dummy (Vietnam, Gulf War, Bosnia, Post-September 11th)	+
Cost Estimating Error	Unexpected Inflation in DoD	+
Acquisition Reform	Dummy Variables for Nunn-McCurdy, Packard, FASA, DAWIA	Inconclusive

This chapter presents the analysis described in Chapter III and is organized by model in the following manner:

Table 17. Order of Model Presentation

Model	Description
Model 1	Fixed Price Cost Overruns
Model 2	Cost-Plus Cost Overruns
Model 3	Production Cost Overruns
Model 4	Research and Development Cost Overruns

The general model takes the form of an unbalanced panel model with cost overruns as the dependent variable. Additionally, the model has an AR(1) disturbance term represented as v_i to account for autocorrelation:

$$\begin{aligned}\text{COST OVERRUN \%} = {} & \alpha_i + \beta_1 \Delta\text{O \& M Budget}_{it} + \beta_2 \Delta\text{Procurement Budget}_{it} + \\ & \beta_3 \Delta\text{R \& D Budget}_{it} + \beta_4 \text{Industry Concentration}_{it} \\ & + \beta_5 \text{Unexpected Inflation}_{it} + \beta_6 \text{Packard}_{it} + \beta_7 \text{FASA}_{it} \\ & + \beta_8 \text{NunnMcCurdy}_{it} + \beta_9 \text{DAWIA}_{it} + \beta_{10} \text{War}_{it} + v_i + \varepsilon_{it}\end{aligned} \tag{6}$$

As described in Chapter III, the dependent variable of each model was checked for stationarity and in all four models, the data was found to come from a stationary process. Additionally, all model residuals were tested for heteroskedasticity and found to have a constant variance. All four models were found to have significant autocorrelation so an AR(1) disturbance term was added to each model. This was sufficient in all but the research and development model (Model 4) in which the first two lagged dependent variables were added. With this specification change, the R&D model had a Baltagi-Wu LBI of 2.07 which indicates that the autocorrelation was properly accounted for.

As the model results are discussed and interpreted, recall the expected direction of impact of each variable and also the four research questions presented in Chapter I. Essentially, the research questions ask two things: how are decreases in budgets (which proxy funding instability), industry concentration, unexpected inflation, and war correlated with cost overruns and did acquisition reforms have a measurable impact on those overruns once the other factors are considered.

Model 1: Contract Cost Overruns (Fixed Price Contracts)

The dependent variable in this model is the average annual cost overrun per service per year for fixed-price contracts. Figure 5 is a visual depiction of these overruns. Notice the significant increases and decreases in cost overruns from year to year. This is the behavior that the empirical model seeks to explain.

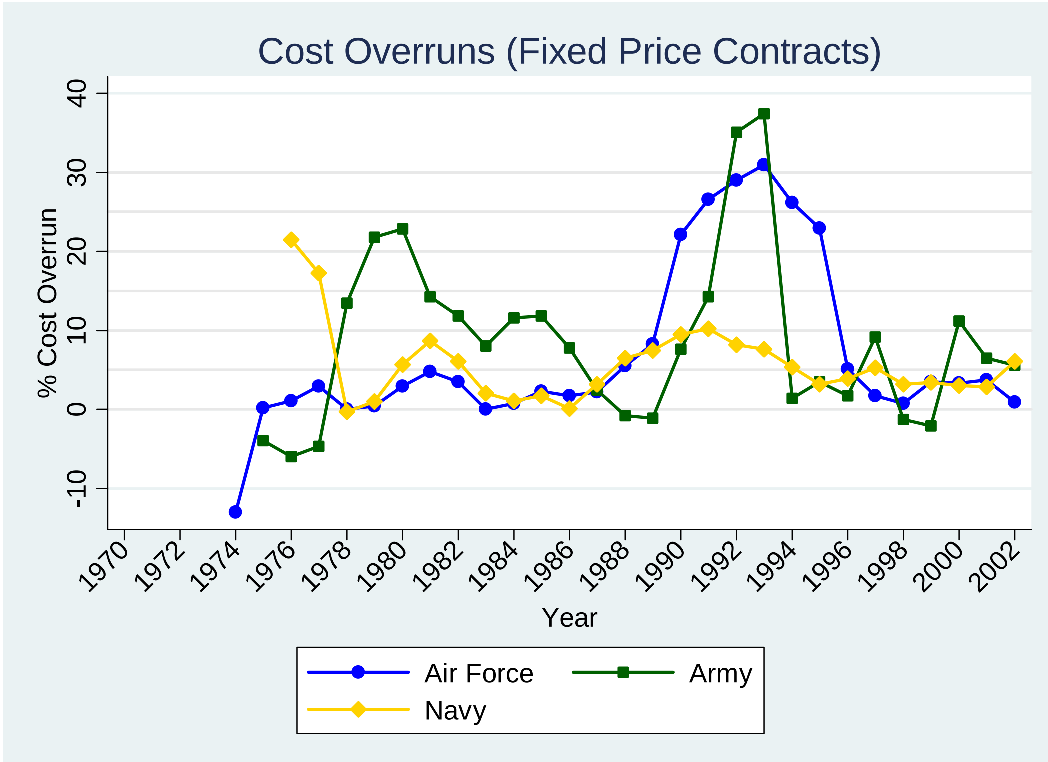


Figure 5. Cost Overruns of Fixed-Price Contracts (1970-2002)

As suggested in Chapter III, acquisition reforms and budgets are expected to be most significant as lagged independent variables. The lag structure for model 1 was determined by minimizing the Akaike Information Criterion (AIC) and is presented in Table 18. For more on how the lags were determined see Appendix D.

Table 18. Model 1 Lag Structure

Model 1 Lag Structure (Fixed Price Cost Overruns)	
Variable	**Using AIC**
Packard	0
FASA	0
DAWIA	2
Nunn-McCurdy	0
Budgets	0

From the regression results in Table 20 below, the Baltagi-Wu LBI test for lag 1 autocorrelation has a value of 1.22. This appears to indicate some remaining autocorrelation of the residuals. However, since an AR(1) disturbance term is already included in the model, no additional specification changes are made.

Using the Breusch-Pagan test shown in Table 19 below, the prob>chi2 is greater than $\alpha = .05$, therefore we fail to reject the null hypothesis of constant variance and conclude that the model does not suffer from heteroskedasticity.

Table 19. Test for Constant Variance (Model 1)

Model 1: overrunpercentfp100			
Breusch-Pagan Test (H_o=Constant Variance)			
Estimated Results	**Variance**		**Standard Deviation**
overrunpercent100		79.13309	8.895678
e		35.06199	5.921317
u		0	0
chi2(1)	=		0.47
prob>chi2	**=**		**0.4928**

Using the lag structure from Table 18 above, the Fixed-Effects Panel model regression results are as follows:

Table 20. Panel Results Model 1: Fixed-Price Cost Overruns

Model 1: Panel Results (Fixed-Price Cost Overruns)					
Fixed-effects (within) Regression with AR(1) Disturbance				Number of obs =	66
Group variable (i): service				Number of groups =	3
R-sq:	**within =**	**0.4774**		Obs per group: min =	22
	between =	0.807		avg =	22
	overall =	0.5659		max =	22
				F(10,53)	4.84
				Prob > F =	0.0001
overrunpercentfp100		**Coef.**	**Std. Err.**	**t**	**P>|t|**
O&M Budget (%Change)		-31.5013	11.4969	-2.7400	0.0080
Procurement Budget (% Change)		-42.8579	12.3519	-3.4700	0.0010
R&D Budget (% Change)		-52.4508	14.5825	-3.6000	0.0010
Industry Concentration (CR4)		0.1516	0.3572	0.4200	0.6730
Unexpected Inflation		134.0035	92.9629	-1.4400	0.1550
Packard Commision (Lag 5)		-6.3498	3.5810	-1.7700	0.0820
FASA (Lag 2)		-21.9962	4.8244	-4.5600	0.0000
Nunn-McCurdy Act (Lag 7)		-9.1006	3.9929	-2.2800	0.0270
DAWIA		13.0930	3.3530	3.9000	0.0000
War		1.2876	1.6230	0.7900	0.4310
_cons		11.7176	11.0470	1.0600	0.2940
Baltagi-Wu LBI		**1.2163**			

The results of this analysis show that budgets are negatively correlated with cost overruns as are the Packard Commission reforms, the Federal Acquisition Streamlining Act (FASA), and the Nunn-McCurdy act while the Defense Acquisition Workforce Improvement Act (DAWIA) is positively correlated with cost overruns. Table 21 compares the actual impact of each independent variable on cost overruns of Fixed-Price contracts with the expected impact from past research. Independent variables that are not significantly correlated with cost overruns are left blank in the actual impact column.

Table 21. Comparison of Expected and Actual Impact on Cost Overruns

Model 1 (Fixed-Price Cost Overruns)		
INDEPENDENT VARIABLES	**Expected Impact from Past Research**	**Actual Impact**
%ΔOperations and Maintenance Budget	-	-
%ΔProcurement Budget	-	-
%ΔResearch and Development Budget	-	-
Industry Concentration (CR4)	-	
Unexpected Inflation	+	
Packard Commission	+	-
FASA		-
Nunn-McCurdy Act		-
DAWIA		+
War	+	

Notice that the percentage change in budgets had the hypothesized impact but that the other variables were either not significant or had an impact different than what was expected from past research. Most notable is that the Packard commission reforms are correlated with a decrease in cost overruns. This is contrary to other finding such as those by Searle (1997), Christensen et al. (1999) and Holbrook (2003). Those studies either concluded that the Packard Commission recommendations were correlated with an increase in cost overruns or they were unable to show any significant relationship.

The difference in this study is the inclusion of other relevant variables such as changing defense budgets. In effect, this result suggests that the Packard Commission and many other acquisition reforms would have reduced cost overruns had the other factors such as decreasing defense budgets not overwhelmed their impact.

Indeed, a quick glance at the summary of regression results in Table 22 reveals that the budget variable which is a proxy for funding instability has a much greater impact on cost overruns than the acquisition reforms

Table 22. Fixed Price Cost Overrun Model Results

Model 1 (Fixed-Price Cost Overruns)	within R^2=.4774	
INDEPENDENT VARIABLES	**Coefficient**	**p-value**
%ΔOperations and Maintenance Budget	-31.5013	0.0080
%ΔProcurement Budget	-42.85786	0.0010
%ΔResearch and Development Budget	-52.45078	0.0010
Industry Concentration (CR4)	0.1515838	0.6730
Unexpected Inflation	134.0035	0.1550
Packard Commission	-6.349819	0.0820
FASA	-21.99616	0.0000
Nunn-McCurdy Act	-9.100645	0.0270
DAWIA	13.09299	0
War	1.287618	0.4310

In this model, if budgets decrease, cost overruns of fixed price contracts increase. Since:

$$\begin{aligned} \text{COST OVERRUN \%} = {} & \alpha_i + \beta_1 \Delta \text{O \& M Budget}_{it} + \beta_2 \Delta \text{Procurement Budget}_{it} + \\ & \beta_3 \Delta \text{R \& D Budget}_{it} + \beta_4 \text{Industry Concentration}_{it} \\ & + \beta_5 \text{Unexpected Inflation}_{it} + \beta_6 \text{Packard}_{it} + \beta_7 \text{FASA}_{it} \\ & + \beta_8 \text{NunnMcCurdy}_{it} + \beta_9 \text{DAWIA}_{it} + \beta_{10} \text{War}_{it} + v_i + \varepsilon_{it} \end{aligned} \tag{7}$$

an x percent **decrease** in budget can be interpreted as a βx **increase** in the value of the cost overruns in any given year. For example, if the procurement budget were to drop by 1 percent, this model predicts that cost overruns would increase in value by approximately (-42.86)*(-0.01) or about 0.43 meaning that that weapon system costs would increase by 0.43 percent. Similarly, if the Research and Development (R&D) budget decreased by 10%, cost overruns would be expected to increase in value by approximately -52.45*-0.1 or -5.245 meaning that weapon system costs would be expected to increase by about 5.2%.

To clarify this second example, the combined R&D budget for the Air Force, Army, and Navy in 2002 was $35.7 billion so a 10 percent decrease would be a cut in budget of $3.57 billion. Fixed-price contract cost overruns for that year averaged approximately 4.2 percent on $19.4 billion for a cost overrun in that year of about $815 million. As stated above, the model predicts that in the event of a 10% cut in R&D budgets, cost overruns would increase by 5.2 percent to 9.4% and consequently total overruns would increase from $815 million to $1.8 billion. Said another way, a cut of about $3.5 billion in R&D budgets is correlated with an increase in cost overruns of about $1 billion. This is a very important result because it reveals the magnitude and significance of funding instability on cost overruns for fixed-price contracts.

Model 2: Contract Cost Overruns (Cost-Plus Contracts)

The dependent variable in Model 2 is the average annual cost overrun per service for cost-plus contracts. Figure 6 is a visual depiction of these overruns.

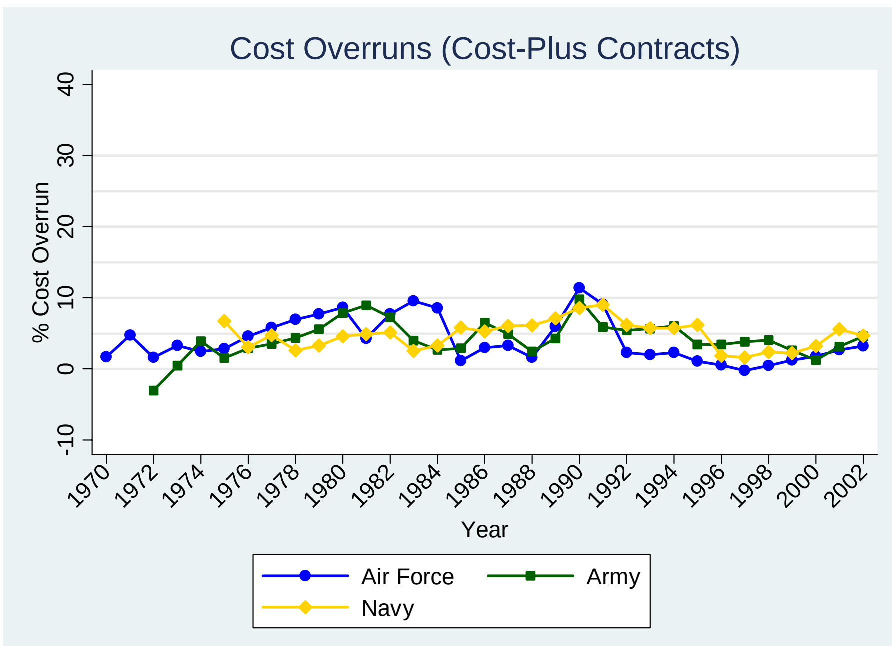


Figure 6. Cost Overruns of Cost-Plus Contracts (1970-2002)

As suggested in Chapter III, acquisition reforms and budgets are expected to be most significant as lagged independent variables. The lag structure for Model 2 was determined by minimizing the Akaike Information Criterion (AIC) and is represented in Table 23 below.

Table 23. Model 2 Lag Structure

Model 2 Lag Structure (Cost-Plus Cost Overruns)	
Variable	**Using AIC**
Packard	7
FASA	2
DAWIA	0
Nunn-McCurdy	2
Budgets	2

From the regression results in Table 25 below, the Baltagi-Wu LBI test for lag 1 autocorrelation in model 2 has a value of 1.45. This possibly indicates some remaining autocorrelation of the residuals. However, since an AR(1) disturbance term is already included in the model, no additional specification changes are made.

Using the Breusch-Pagan test shown in Table 24 below, the prob>chi2 is greater than $\alpha = .1$, therefore we fail to reject the null hypothesis of constant variance and conclude that the model does not suffer from heteroskedasticity.

Table 24. Test for Constant Variance (Model 2)

Model 2: overrunpercentcp100		
Breusch-Pagan Test (H_o=Constant Variance)		
Estimated Results	**Variance**	**Standard Deviation**
overrunpercent100	6.895362	2.625902
e	3.620331	1.902717
u	0	0
chi2(1)	=	0.45
prob>chi2	=	**0.5047**

Using the AIC as the lag structure criteria, the regression results are as follows:

Table 25. Model 2 Regression Results

Model 2: Panel Results (Cost-Plus Cost Overruns)					
Fixed-effects (within) Regression with AR(1) Disturbance				Number of obs =	66
Group variable (i): service				Number of groups =	3
R-sq:	**within =**	**0.4255**		Obs per group: min =	22
	between =	0.1698		avg =	22
	overall =	0.3924		max =	22
				F(10,53)	3.93
				Prob > F =	0.0005
overrunpercentcp100		**Coef.**	**Std. Err.**	**t**	**P>|t|**
O&M Budget (%Change) (Lag 2)		5.7208	3.8505	1.4900	0.1430
Procurement Budget (% Change) (Lag 2)		4.6562	4.1008	1.1400	0.2610
R&D Budget (% Change) (Lag 2)		9.7971	4.8812	2.0100	0.0500
Industry Concentration (CR4)		41.8028	31.1135	-1.3400	0.1850
Unexpected Inflation		-0.0868	0.0872	-1.0000	0.3240
Packard Commision (Lag 7)		-3.4107	0.9626	-3.5400	0.0010
FASA (Lag 2)		-2.2000	0.8337	-2.6400	0.0110
Nunn-McCurdy Act (Lag 2)		-0.9894	1.0894	-0.9100	0.3680
DAWIA		4.1948	1.0319	4.0700	0.0000
War		-1.5748	0.7680	-2.0500	0.0450
_cons		11.4387	3.7272	3.0700	0.0030
Baltagi-Wu LBI		**1.4548**			

The results of this analysis show R&D budgets and O&M budgets are positively correlated with cost overruns as is the Defense Acquisition Workforce Improvement Act (DAWIA) while the Packard Commission reforms, the Federal Acquisition Streamlining Act (FASA), and war are negatively correlated. Table 26 compares the actual impact of each independent variable on cost overruns of Cost-Plus contracts with the expected impact from past research. Independent variables that are not significantly correlated with cost overruns are left blank in the actual impact column.

Table 26. Comparison of Expected and Actual Impact on Cost Overruns

Model 2 (Cost-Plus Cost Overruns)		
INDEPENDENT VARIABLES	**Expected Impact from Past Research**	**Actual Impact**
%ΔOperations and Maintenance Budget	-	+
%ΔProcurement Budget	-	
%ΔResearch and Development Budget	-	+
Industry Concentration (CR4)	-	
Unexpected Inflation	+	
Packard Commission	+	-
FASA		-
Nunn-McCurdy Act		
DAWIA		+
War	+	-

Notice that the all variables in this model were either not significant or had an impact different than what was expected from past research. As with the Fixed-Price model, the Packard commission reform is again correlated with a decrease in cost overruns. This is again contrary to the findings of others like Searle (1997), Christensen et al (1999) and Holbrook (2003). Those studies either concluded that the Packard Commission recommendations were correlated with an increase in cost overruns or they were unable to show any significant relationship. Again, the difference in this study is the inclusion of other relevant variables in the model. In effect, this result suggests that the Packard Commission and many other acquisition reforms would have reduced cost overruns had the other factors not overwhelmed their impact.

One major difference between the cost-plus model and the fixed-price model is that in this model, R&D and O&M budgets are now positively correlated with cost overruns. This means that an increase in R&D or O&M budgets would result in an increase in cost-overruns for cost-plus contracts. This is counter to the research that suggested that decreases in budgets would result in increases in cost overruns. It is worth noting though that the magnitude of the coefficient is much smaller than in the fixed-price model so while the direction is unexpected, the predicted impact is much smaller.

Table 27. Model 2 Coefficients and P-Values

Model 2 (Cost-Plus Cost Overruns)	Within R^2=0.4255	
INDEPENDENT VARIABLES	**Coefficient**	**p-value**
%ΔOperations and Maintenance Budget	5.720776	0.143
%ΔProcurement Budget	4.656242	0.261
%ΔResearch and Development Budget	9.797075	0.05
Industry Concentration (CR4)	41.80284	0.185
Unexpected Inflation	-0.0868203	0.324
Packard Commission	-3.410674	0.001
FASA	-2.199959	0.011
Nunn-McCurdy Act	-0.9894184	0.368
DAWIA	4.19476	0.000
War	-1.574791	0.045

Also, it is interesting to note that for the second straight model, industry concentration is not significant. As discussed in the literature review, DoD expected some cost savings from consolidation. However, empirically this has not been observed in the model of fixed-price or cost-plus contracts. In fact, with a p-value of .185 and a large positive coefficient, the data may suggest the opposite is true. That is, it could be that the increased industry consolidation resulted not in savings but increases in cost overruns in defense contracts.

This leads one to conclude that if there where savings from consolidation it did not come from a decrease in the cost overruns in defense contracts. One has to wonder, if the savings are not in the contracts then were they actually DoD savings or just savings to the defense contractors as they sized their businesses to fit the market size dictated by the post-cold war environment of decreasing defense budgets?

Also worth noting is that acquisition reforms are generally significant and for the most part negatively correlated with cost overruns. This is an important finding because past research on acquisition reform’s impact on cost overruns was inconclusive. The only reform that does not fit this pattern is the Defense Acquisition Workforce Improvement Act which is again positively correlated with cost overruns. This suggests that cost overruns increased after DAWIA was enacted. Perhaps this is a result of time away from the job for training or perhaps this reveals that there are other omitted variables that should be included in the analysis.

The final significant variable in the cost-plus contract model is war. This model reveals that war is negatively correlated with cost overruns. This suggests that the presence of war reduces contract cost overruns of cost-plus contracts. Perhaps this is because some weapon system programs are expedited during wartime. The urgency of getting the system out the door precludes the desire of the acquisitions and requirements communities to “gold plate” the system requirements. It could be that that last amount of added capability that would have otherwise increased the cost is not included as a result of war.

Model 3: Contract Cost Overruns (Production Contracts)

The dependent variable form Model 3 is the average annual cost overrun per service for Production contracts. Figure 7 is a visual depiction of these overruns.

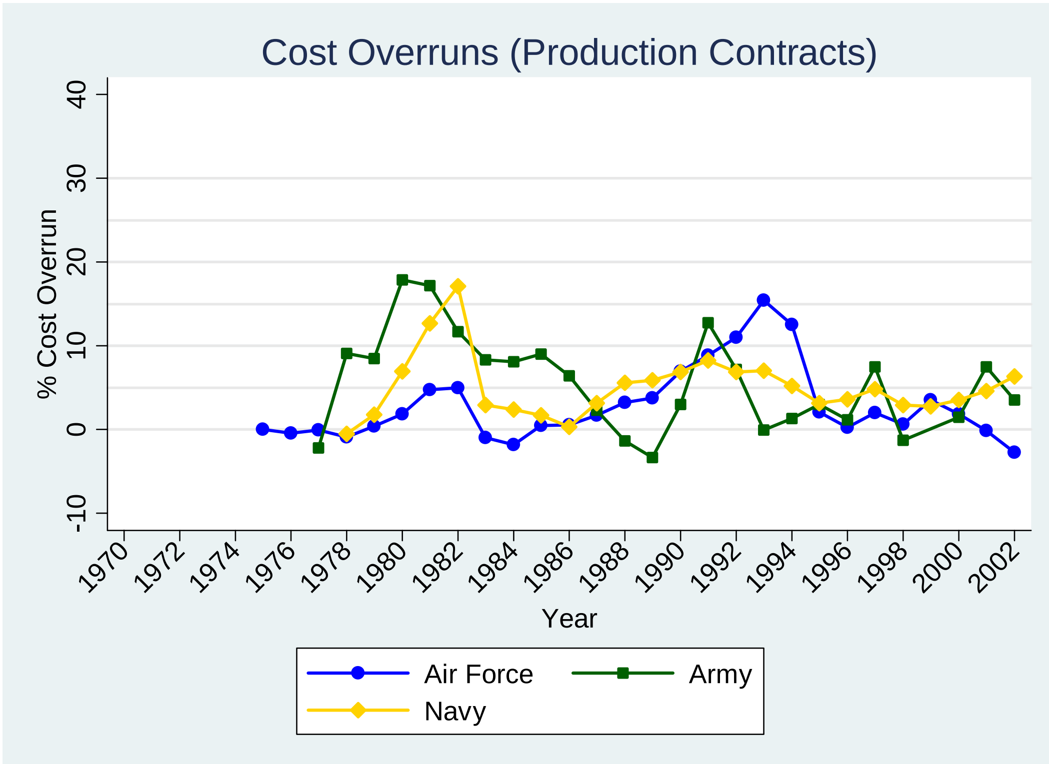


Figure 7. Cost Overruns of Production Contracts (1970-2002)

As suggested in Chapter III, acquisition reforms and budgets are expected to be most significant as lagged independent variables. The lag structure for Model 3 was determined by minimizing the Akaike Information Criterion (AIC). For more on how the lags were determined see Appendix D.

Table 28. Lag Structure (Model 3)

Model 3 Lag Structure (Production Cost-Overruns)	
Variable	**Using AIC**
Packard	4
FASA	1
DAWIA	0
Nunn-McCurdy	0
Budgets	3

From the regression results in Table 30 below, the Baltagi-Wu LBI test for lag 1 autocorrelation in the specified model has a value of 1.18. This appears to indicate some remaining autocorrelation of the residuals. However, since an AR(1) disturbance term is already included in the model, no additional specification changes are made.

Using the Breusch-Pagan test from Table 29, the prob>chi2 is greater than $\alpha = .1$, therefore we fail to reject the null hypothesis of constant variance and conclude that the model does not suffer from heteroskedasticity.

Table 29. Test for Constant Variance (Model 3)

Model 3: overrunpercentproc100 (min AIC)		
Breusch-Pagan Test (H_o=Constant Variance)		
Estimated Results	**Variance**	**Standard Deviation**
overrunpercent100	22.82678	4.777738
e	18.2617	4.273371
u	0	0
chi2(1)	=	0.02
prob>chi2	**=**	**0.8893**

Using the lag structure from Table 28 above, the regression results are as follows:

Table 30. Regression Results for Model 3: Production Cost Overruns

Model 3: Panel Results (Production Cost Overruns)					
Fixed-effects (within) Regression with AR(1) Disturbance				Number of obs =	65
Group variable (i): service				Number of groups =	3
R-sq:	**within =**	**0.3873**	Obs per group: min =		21
	between =	0.1069		avg =	21.7
	overall =	0.4191		max =	22
				F(10,52)	3.29
				Prob > F =	0.0023
overrunpercentproc100		**Coef.**	**Std. Err.**	**t**	**P>|t|**
O&M Budget (%Change) (Lag 3)		-5.0048	6.4718	-0.7700	0.4430
Procurement Budget (% Change) (Lag 3)		-6.1097	6.8092	-0.9000	0.3740
R&D Budget (% Change) (Lag 3)		-7.3763	8.1314	-0.9100	0.3690
Industry Concentration (CR4)		0.0372	0.1799	0.2100	0.8370
Unexpected Inflation		4.8517	49.0284	0.1000	0.9220
Packard Commision (Lag 4)		2.6483	1.8005	1.4700	0.1470
FASA (Lag 1)		-3.3674	1.8021	-1.8700	0.0670
Nunn-McCurdy Act		-8.4624	2.2343	-3.7900	0.0000
DAWIA		0.5980	2.4087	0.2500	0.8050
War		1.9695	1.0019	1.9700	0.0550
_cons		9.3682	5.2320	1.7900	0.0790
Baltagi-Wu LBI		**1.1934**			

The results of this model reveal that the Federal Acquisition Streamlining Act (FASA), and the Nunn-McCurdy Act are negatively correlated with cost overruns in production contracts while the Packard Commission reforms and war are positively correlated. Table 31 compares the actual impact of each independent variable on cost overruns of Production contracts with the expected impact from past research. Independent variables that are not significantly correlated with cost overruns are left blank in the actual impact column.

Table 31. Comparison of Expected and Actual Impact on Cost Overruns

Model 3 (Production Cost Overruns)		
INDEPENDENT VARIABLES	**Expected Impact from Past Research**	**Actual Impact**
%∆Operations and Maintenance Budget	-	
%∆Procurement Budget	-	
%∆Research and Development Budget	-	
Industry Concentration (CR4)	-	
Unexpected Inflation	+	
Packard Commission	+	+
FASA		-
Nunn-McCurdy Act		-
DAWIA		
War	+	+

Unlike the models of contract type, in this model of production contracts, budgets are not significantly correlated with cost overruns. Also, as with the previous models, industry concentration is not significantly correlated with cost overruns or cost savings like the DoD expected (GAO, 1998:2).

Table 32. Model 3 Coefficients and P-Values

Model 3 (Production Cost Overruns)	within R^2=0.3873	
INDEPENDENT VARIABLES	**Coefficient**	**p-value**
%∆Operations and Maintenance Budget	-5.0048	0.4430
%∆Procurement Budget	-6.1097	0.3740
%∆Research and Development Budget	-7.3763	0.3690
Industry Concentration (CR4)	0.0372	0.8370
Unexpected Inflation	4.8517	0.9220
Packard Commission	2.6483	0.1470
FASA	-3.3674	0.0670
Nunn-McCurdy Act	-8.4624	0.0000
DAWIA	0.5980	0.8050
War	1.9695	0.0550

Also, in this model, the Packard Commission recommendations have a p-value of .147 and a positive correlation with cost overruns. While only bordering on statistical significance and small in magnitude, this result is consistent with research by Searle (1997) and Christensen et al (1999).

Further, a trend appears to be emerging that indicates the Federal Acquisition Streamlining Act (FASA) and the Nunn-McCurdy Act are correlated with decreases in cost overruns. Since the Nunn-McCurdy act was enacted with the intent to control defense weapon system cost overruns it reassuring to note that it is passage appears to be correlated with a decrease in cost overrun though admittedly the magnitude is small.

The final significant variable in the production model is war. In this model, war is positively correlated with an increase in cost overruns. This contrasts with the result of the cost-plus contract model. A possible explanation for this is that products are rushed from R&D into production in times of war at an increased production cost.

Model 4. Contract Cost Overruns (Research and Development Contracts)

The dependent variable in the R&D model is the average annual cost overrun per service for R&D contracts. Figure 8 is a visual depiction of these overruns.

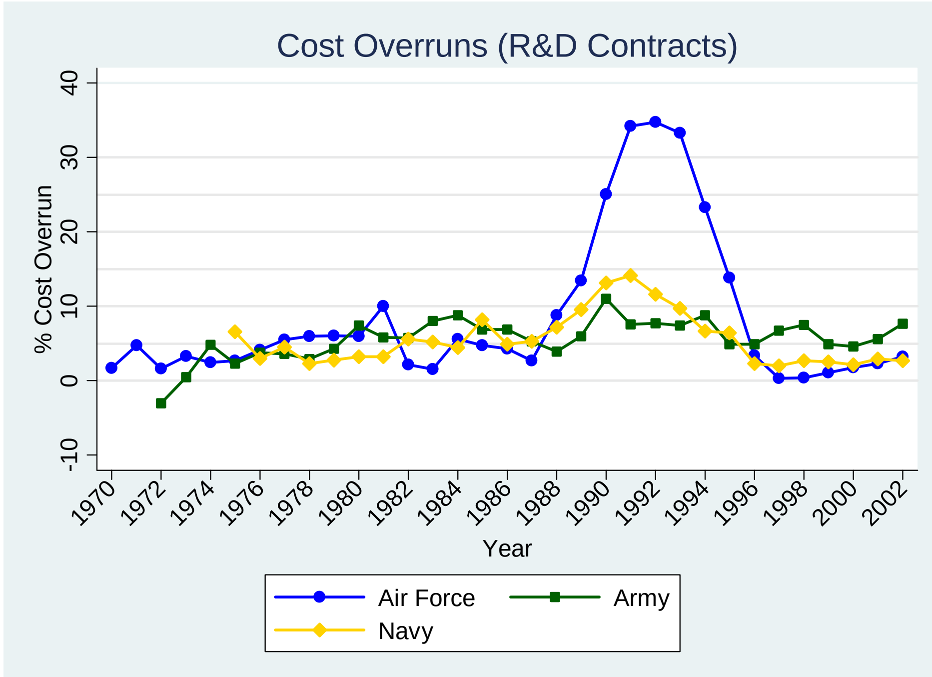


Figure 8. Cost Overruns of R&D Contracts (1970-2002)

As suggested in Chapter III, acquisition reforms and budgets are expected to be most significant as lagged independent variables. The lag structure for model 1 was determined by minimizing the Akaike Information Criterion (AIC). For more on how the lags were determined see Appendix D.

Table 33. Lag Structure (Model 4)

Model 4 Lag Structure (R&D Cost Overruns)	
Variable	**Using AIC**
Packard	3
FASA	1
DAWIA	0
Nunn-McCurdy	3
Budgets	0

From the regression results in Table 34 below, the Baltagi-Wu LBI test for lag 1 autocorrelation in the specified model has a value of .598. This appears to indicate significant remaining autocorrelation of the residuals.

Table 34. Regression Results for R&D Contract Model Before Lags

Model 4: Panel Results (R&D Cost Overruns)					
Fixed-effects (within) Regression with AR(1) Disturbance				Number of obs =	66
Group variable (i): service				Number of groups =	3
R-sq:	**within =**	**0.3372**		Obs per group: min =	22
	between =	0.1297		avg =	22
	overall =	0.0695		max =	22
				F(10,53)	2.7
				Prob > F =	0.0095
overrunpercentrd100		**Coef.**	**Std. Err.**	**t**	**P>|t|**
O&M Budget (%Change)		-12.8577	6.5148	-1.9700	0.0540
Procurement Budget (% Change)		-13.2747	6.9110	-1.9200	0.0600
R&D Budget (% Change)		-11.4385	8.2788	-1.3800	0.1730
Industry Concentration (CR4)		-0.3274	0.4640	-0.7100	0.4830
Unexpected Inflation		45.0504	44.6357	1.0100	0.3170
Packard Commision (Lag 3)		2.1285	1.4304	1.4900	0.1430
FASA (Lag 1)		-5.1298	1.9871	-2.5800	0.0130
Nunn-McCurdy Act (Lag 3)		-1.7796	2.1933	-0.8100	0.4210
DAWIA		6.1415	1.9696	3.1200	0.0030
War		0.7912	0.9122	0.8700	0.3900
_cons		31.3844	5.6378	5.5700	0.0000
Baltagi-Wu LBI		**0.5975**			

Also, from the p-value of the Breusch-Pagan test, it is clear that this model suffers from heteroskedasticity or non-constant variance of the error terms. This makes the coefficients of the panel model less efficient.

Table 35. Test for Constant Variance (Model 4)

Model 4: overrunpercentrd100 (min AIC)			
Breusch-Pagan Test (H_o=Constant Variance)			
Estimated Results	**Variance**		**Standard Deviation**
overrunpercent100		51.91042	7.204889
e		26.03706	5.102652
u		0	0
chi2(1)	=		7.34
prob>chi2	**=**		**0.0067**

To account for the autocorrelation, the first two lagged dependent variables are included as independent variables. With this change in model specification, the Baltagi-Wu LBI increases to 2.07 indicating that the autocorrelation is sufficiently accounted for. Table 35 is a summary of the new regression results for Model 4 with the lagged dependent variables included.

Table 36. Regression Results for R&D Contract Model with Lags

Model 4: Panel Results (R&D Cost Overruns)					
Fixed-effects (within) Regression with AR(1) Disturbance				Number of obs =	66
Group variable (i): service				Number of groups =	3
R-sq:	**within =**	**0.7711**		Obs per group: min =	22
	between =	0.8059		avg =	22
	overall =	0.8353		max =	22
				F(12,51)	14.32
				Prob > F =	0.0000
overrunpercentrd100		**Coef.**	**Std. Err.**	**t**	**P>|t|**
overrunpercentrd100 Lag 1		0.8776	0.1447	6.0700	0.0000
overrunpercentrd100 Lag 2		-0.2647	0.1390	-1.9000	0.0630
O&M Budget (%Change)		-16.9281	6.4919	-2.6100	0.0120
Procurement Budget (% Change)		-17.4210	7.1730	-2.4300	0.0190
R&D Budget (% Change)		-18.0752	8.4405	-2.1400	0.0370
Industry Concentration (CR4)		-0.0287	0.1377	-0.2100	0.8360
Unexpected Inflation		-55.6643	54.1644	-1.0300	0.3090
Packard Commision (Lag 3)		0.0614	1.3637	0.0500	0.9640
FASA (Lag 1)		-3.8548	1.7174	-2.2400	0.0290
Nunn-McCurdy Act (Lag 3)		-0.9449	1.9207	-0.4900	0.6250
DAWIA		2.9565	1.7072	1.7300	0.0890
War		0.0938	1.0970	0.0900	0.9320
_cons		3.2714	6.6569	0.4900	0.6250
Baltagi-Wu LBI		**2.0787**			

Below is a table depicting the expected impact from past research of each independent variable on cost overruns and the actual impact for the R&D cost overrun model.

Table 37. Comparison of Expected and Actual Impact on Cost Overruns

Model 4 (R&D Cost Overruns) INDEPENDENT VARIABLES	Expected Impact from Past Research	Actual Impact
%ΔOperations and Maintenance Budget	-	-
%ΔProcurement Budget	-	-
%ΔResearch and Development Budget	-	-
Industry Concentration (CR4)	-	
Unexpected Inflation	+	
Packard Commission	+	
FASA		-
Nunn-McCurdy Act		
DAWIA		+
War	+	

In this model, O&M and Procurement budgets are negatively correlated with cost overruns of R&D contracts. This implies that all else being equal, an increase in defense budgets would result in a decrease in cost overruns and a decrease in defense budgets would result in an increase in cost overruns. This finding is consistent with past research by Singleton (1991), and Drezner et al. (1996) and this is the second model of this research where this relationship has appeared.

Notice from Table 38 that as with all previous models, the Federal Acquisition Streamlining Act (FASA) is negatively correlated with cost overruns. To understand the magnitude of this result, consider that the FASA reforms are correlated with more than a 5% reduction in the annual cost overrun percentage. So, for example, in 1993, the year before FASA was enacted, the R&D budget was just over $32 billion and cost overruns in that year averaged 16.8 percent. According to this model, all else being equal, having the FASA reforms in 1993 would have resulted in only an 11.7 percent cost overrun for a savings in that year of over $1.6 billion.

Table 38. Model 4 Coefficients and P-Values

Model 4 (R&D Cost Overruns)	within R^2=0.3372	
INDEPENDENT VARIABLES	**Coefficient**	**p-value**
%∆Operations and Maintenance Budget	-12.8577	0.0540
%∆Procurement Budget	-13.2747	0.0600
%∆Research and Development Budget	-11.4385	0.1730
Industry Concentration (CR4)	-0.3274	0.4830
Unexpected Inflation	45.0504	0.3170
Packard Commission	2.1285	0.1430
FASA	-5.1298	0.0130
Nunn-McCurdy Act	-1.7796	0.4210
DAWIA	6.1415	0.0030
War	0.7912	0.3900

Chapter Summary

This chapter presented the results of four panel models created to explain cost overruns in defense weapon system contracts. Chapter V continues the discussion of these findings and their implications as well as presents recommendations for further research.

V. Conclusions and Recommendations

Review of Research Objectives

The primary purpose of this research was to create an empirical model to explain cost overruns in defense weapon system programs. This was accomplished using four fixed-effects panel models. Recall that prior to this study no empirical model existed to examine the relative impact of factors contributing to cost overruns in a dynamic setting. Past research had instead focused on qualitative explanations or hypothesis tests which are limited by a subjective treatment date and biased by omitted variables.

To create the panel model, data was gathered from the DAES database on the cost overruns of 186 major weapon system programs of the Air Force, Army, and Navy from 1970 to 2002. The cost data was then separated into overruns by contract type and program phase. Since past research identified funding instability, industry consolidation, estimation error, and acquisition reform as potentially impacting cost overruns, data on these independent variables was compiled and used to create the panel model. In this research, the annual change in budgets was a proxy for funding instability while the CR4 measured industry consolidation. Estimation error was modeled as the amount of unexpected inflation in the initial estimate and acquisition reforms and war were modeled as dummy variables.

Table 39. Independent Variables in the Panel Model

Factor	Model Variable	Expected Impact
Funding Instability	Percentage Change in Defense Budgets	+
Industry Consolidation	Industry Concentration (CR4)	-
War	War Dummy (Vietnam, Gulf War, Bosnia, Post-September 11th)	+
Cost Estimating Error	Unexpected Inflation in DoD	+
Acquisition Reform	Dummy Variables for Nunn-McCurdy, Packard, FASA, DAWIA	Inconclusive

The study proposed four research questions:

1. Did the defense industry consolidation and concurrent decrease in defense budgets that occurred in the 1990's affect the cost of defense weapon systems?
2. Is war correlated with an increase in weapon system cost overruns?
3. Is estimation error caused by unexpected inflation correlated with an increase in weapon system cost overruns?
4. Did acquisition reforms have impact on cost overruns when defense industry consolidation, inflation, changes in the defense budget, and war are considered?

Discussion of Results

Table 40 is a summary of the regression results from the four models and is referenced throughout this chapter as each research question is discussed.

Table 40. Summary of Model Results

Variable	Fixed-Price	Cost-Plus	Production	R&D
O&M Budget (%Change)	-31.50***	5.72*	-5.00	-16.93***
Procurement Budget (% Change)	-42.86***	4.66	-6.11	-17.42***
R&D Budget (% Change)	-52.45***	9.80**	-7.38	-18.08***
Industry Concentration (CR4)	0.15	41.80	0.04	-0.03
Unexpected Inflation	134.00	-0.09	4.85	-55.66
Packard Commission	-6.35*	-3.41***	2.65	0.06
FASA	-22.00***	-2.20**	-3.37*	-3.85***
Nunn-McCurdy Act	-9.10**	-0.99	-8.46***	-0.94
DAWIA	13.09***	4.19***	0.60	2.96*
War	1.29	-1.57**	1.97*	0.094

Defense Industry Consolidation

Despite the Department of Defense expectation that the defense industry consolidation of the 1990's would result in cost savings (GAO,1998:1), this research was unable to find any evidence of that savings. A quick glance at Table 40 and it is clear that industry consolidation was not significant regardless of program phase or contract type. If anything, industry concentration may have resulted in increased cost to DoD especially in cost-plus contracts with a coefficient of 41.8 and a p-value of .18 which is right outside the traditional level of statistical significance but significant in magnitude.

Defense Budgets

In this research, defense budgets were a proxy for funding instability. Past research suggested that funding instability was negatively correlated with cost overruns. In other words, decreases in defense budgets were expected to result in increases in cost overruns. This result held in the Fixed Price and Research and Development models and was highly statistically significant.

To illustrate the magnitude of this finding, if the 2002 R&D budget were to drop by 1 percent in the fixed price model, cost overruns would be expected to increase by approximately (-52.45*-.01) or 0.52 percent. At first this does not sound significant but consider that cost overruns in that year averaged approximately 4.2 percent on $19.4 billion for a cost overrun in that year of about $815 million. An increase in cost overruns of a half a percent to 4.7% for the year would result in an additional $96 million in overruns. In other words, for every dollar of R&D budget cuts, overruns increase by 50 cents.

Why might funding instability result be so strongly correlated with increases in cost overruns? One possible answer is that when budgets decrease, existing programs engage in a fight for available funding and implicitly, the lower priority programs get their funding cut. But, the programs are not cancelled. Instead, they just continue on with inadequate funding that causes schedule delays and increased cost due to production breaks and orphaned technology. In the final analysis, perhaps the funding instability is so highly correlated with increases in cost overruns because of poor portfolio management by the DoD during times of decreasing budgets. This idea that the DoD "corporate process" for acquisitions exacerbates cost and schedule delays is one first proposed by McNutt (1998) but not previously empirically quantified. What McNutt meant by portfolio management is that the DoD essentially has a portfolio of weapon systems in development that they manage much like a car company would manage their line of products. In the case of DoD, he suggested that the Air Force and by extension DoD does a poor job managing their product line essentially in times of decreasing budgets. .

War

Past research by Czelusniak and Rogers (1997) suggested that funding instability from contingency operations leads to cost growth. This study attempted to replicate that finding by modeling war with a dummy variable in the panel model. Model results reveal that war is positively correlated with cost overruns in Cost-Plus contract types and negatively correlated with cost overruns in the Production phase.

Why might this be? At the onset of any war, service chiefs call on the acquisition community to provide any increase in weapon system capability that they can quickly push out to the battlefield. These programs are likely to be in the R&D phase and using cost-plus contracts because of their increased risk. Products nearing the end of R&D are likely moved quickly out of R&D and into production, skipping any "gold plating" of requirements that would have otherwise been done. In this scenario, it is reasonable to expect cost-plus contracts to decrease during war time. Then, those same products would be rushed into production intuitively causing production costs to increase during a war.

Cost Estimation Error

Error in the cost estimate is identified as a causal factor in cost overruns by Christensen et al. (1999). This research modeled cost estimation error as unexpected inflation in the cost estimate. All cost estimates and budgets include assumptions about future inflation. These inflation predictions, prepared annually by the Undersecretary of Defense, Comptroller are not always accurate. For example, in the early 1980's inflation was very high but DoD predictions did not anticipate this. Consequently, inflation was underestimated.

This research included this in the models of cost overruns. However, the results shown in Table 40 show that unexpected inflation is not significantly correlated with cost overruns. The implication of this finding is that while cost estimating error may contribute to cost overruns, it is not as a result of errors in the inflation predictions. It is worth noting however, that the coefficient in the fixed-price model is very high and just outside the range where it would traditionally be considered significant. Perhaps if inflation data from the 1970's were able to be obtained and included in future research, it would prove to be significant.

Acquisition Reforms

The fourth question asked if acquisition reforms had an impact on cost overruns when defense industry consolidation, inflation, changes in the defense budget, and war were considered. Specifically, this study surveyed past research on acquisition reform and identified four reforms as being most significant. Table 41 list the reforms modeled in this study.

Table 41. Acquisition Reforms Studied

Acquisition Reforms Studied
Nunn-McCurdy Act of 1982
Packard Commission Recommendations of 1986
The Defense Acquisition Workforce Improvement Act of 1990
The Federal Acquisition Streamlining Act of 1994

Past research on acquisition reform has been unable to show any improvement as a result of reform. This idea is summed up be Christensen et al (1999) when they said "Despite the implementation of more than two dozen regulatory and administrative initiatives, there has been no substantial improvement in the cost performance of defense programs for more than 30 years" (Christensen et al, 1999:252).

However, as discussed in earlier chapters, past research on the impact of acquisition reform suffered from the use of subjective treatment dates and omission of variables that biased their results. Additionally, the techniques such as qualitative case studies and hypothesis tests limited the robustness of past results. Indeed, once the other factors mentioned above were modeled, all four of the reforms studied were correlated with cost overruns in at least one model.

Nunn-McCurdy Act of 1982

The Nunn-McCurdy Act of 1982 was significantly correlated with a decrease in cost overruns in Fixed-Price contracts and Production contracts. Recall that the purpose of the Nunn-McCurdy Act was to curtail cost overruns in defense weapon systems. Yet, over 20 years after its enactment, there had been little research studying its impact. To understand the magnitude of this finding, consider that model results suggest that all else being equal, the added presence of the Nunn-McCurdy act lowered contract cost overruns by 9.1 percent in Fixed Price contracts and by 8.5 percent in Production contracts.

The Packard Commission (1986)

One of the most researched acquisition reforms was the Packard Commission recommendations of 1986. This purpose of this reform was to improve the defense acquisition process by streamlining the chain of command, improving tests and prototyping and planning, and modeling the DoD after a competitive firm (Searle, 1997:33).

The idea was that these changes would result in weapon systems that could be produced more quickly and at a lower cost. Yet, past research by Searle (1997) and Christensen et al. (1999) suggested that the Packard Commission recommendations had no impact on cost overruns and that the overruns actually got worse after the Packard Commission reforms were implemented.

This research contradicts these findings somewhat. In two of the four models, fixed price and cost-plus cost overruns, the Packard Commission recommendations are negatively correlated with contracted cost overruns. In other words, the presence of the Packard Commission reforms was correlated with a decrease in contract cost overruns. Especially significant is the result in the Cost-Plus contract model which illustrated that all else being equal, the presence of the Packard Commission reforms resulted in a 3.4 percent decrease in cost overruns. This result is significant to the $\alpha = .01$ level.

DAWIA (1990)

In 1990, the Defense Acquisition Workforce Improvement Act was enacted to improve the level of education of the acquisition workforce. Intuitively, one would expect that a more well trained and educated workforce would be able to deliver weapon systems at a decreased cost. However, results of this analysis show that DAWIA is positively correlated with cost overruns. The cause of this result is unknown. Perhaps the finding suggests that the time away from work that is instead spent on training is causing cost performance to suffer. Or, perhaps this correlation is just contemporaneous meaning that it is statistically significant but not as a result of any causal link.

FASA (1994)

In 1994, the Federal Acquisition Streamlining Act was created to empower the acquisition workforce to make decisions about how to manage their programs. This was a movement away from the restrictive and centralized procurement practices of the past. (Cooper, 2002:15). Other key provision of FASA were the increased use of performance based contract payments, and the push towards more "commercial or off the shelf products" (Cooper, 2002:18). Most important for this study were the requirements that contractors have a certified cost accounting system that complies with accepted cost accounting standards and also the increased scrutiny of a contractor's past performance in the source selection criterion of major weapon system purchases. Clearly these provisions should have led to decreases in weapon system cost and should be investigated. Indeed, in their 1999 paper, Christensen et al. suggest that the impact of the

FASA reform is worthy of study but that some time would have to pass before its impact could be felt (Christensen et al, 1999: 258).

Now, twelve years after the reform, the impact was investigated by this research and indeed FASA did reduced cost overruns. This result held in all models regardless of contract type or program phase and all else being equal, the presence of FASA reduced cost overruns by as little as 2% in Cost-Plus contracts to as much as 21% in Fixed-Price contracts.

Conclusions

The purpose of this research was to create an empirical model that described cost overruns in defense weapon systems. This was accomplished by modeling cost overruns of 186 major weapons system programs of the Air Force, Army, and Navy over a period of 32 years.

Major findings of this research are as follows:

- The Defense Industry Consolidation of the 1990's did not result in significant cost savings for the Department of Defense and might even have resulted in increases in cost overruns.

- Funding Instability is highly correlated with an increase in cost overruns in Fixed-Price contracts and contracts in the Research and Development Phase. This could be a result of poor portfolio management by the DoD in times of decreasing budgets. Funding instability contributed to an increase in contract cost overruns of $13.4 billion since 1970.

- War is correlated with decreases in Cost-Plus contract cost overruns and increases in Production cost overruns. This could illustrate the impact of nearly completed weapons modifications being pushed into production early at the onset of war.

- Estimation error caused by unexpected inflation is not significantly correlated with cost overruns. If estimation error in cost estimates is a causal factor in contract cost overruns, it is likely the result of some other aspect of weapon system cost estimating.

- With the exception of DAWIA, acquisition reforms are correlated with a decrease in cost overruns of defense weapon systems. In particular, reforms resulting from the Nunn-McCurdy Act of 1982, the Packard Commission Recommendations of 1986 and the Federal Acquisition Streamlining Act (FASA) of 1994 resulted in savings of almost $124 billion since 1982. Yet, the biggest implication of this finding is not the correlation of one specific reform with contract cost overruns but the consistency with which the acquisition reforms did matter and did act to reduce cost overruns in defense weapon systems.

Recommendations for Future Research

This research has created an empirical model that has laid the foundation for further study of the causes of cost overruns in defense weapon systems. Without a doubt, there are other factors related to weapon system costs that were not modeled in this study. For example, in his confirmation hearing, Air Force Chief of Staff, General Michael Mosely said that acquisition corps manning decreases may have contributed to weapon system cost growth. That data could easily be added to the model created in this thesis. Also, other importance events such as the formation of the Air Force Materiel Command in the early 1990's could be modeled. Finally, the research linking cost overruns and schedule delay is inconclusive. A model that incorporated schedule as an independent variable explaining cost overruns or a model that treated schedule as the dependent variable and cost overruns as an independent variable would also advance the current level of research.

Appendix A. Summary of DAES Data

Air Force

Program Name	Number of Contract Entries
A-10	38
ACM	82
Advanced Extremely High Frequency Satellite (AEHF)	10
AFATDS	2
Airborne Laser (ABL)	23
ALCM	91
AMRAAM (AIM-120A)	175
ASAT	83
ATS	29
B-1 CMUP-DSUP	2
B-1B	432
B-1B CMUP	62
B-2A	15
C-130 Avionics Modernization Program ((C-130 AMP)	2
C-17A	291
CMU	115
CSRL	23
DMSP	176
DSCS III A&B	65
DSP	294
E-3 AWACS RSIP	73
E-3A Hawkeye	125
E-4 (AABNCP)	34
EF-111A	35
EJS	13
F/A-22 raptor	91
F-15	221
F-16	270
GBS	17
GLCM	58
Global Hawk Unmanned aerial Vehicle	2
Inertial Upper Stage	29
IR Maverick	58
I-S/A AMPE	13
JDAM	30
JGL Tacit Rainbow	27
Joint air to surface Standoff Missile (JASSM)	16
Joint Primary training aircraft (JPATS) (T-45)	88
Joint Tactical Information Distribution System	36
JSIPS CIGSS	22
JSTARS	181
KC-135R	53
MARK XV IFF	33
MAVERICK (LASER)	12
MILSTAR	49
Minuteman III Guidance replacement Program (MMIII GRP)	90
Minuteman III Propulsion replacement program (MMII PRP)	53
MP RTIP	4
National Polar Orbiting operational; environmental	28
Navistar Global Positioning system (GPS) II Modern	306
OTH-B (Radar)	52
Peacekeeper	868
PLSS	25
Rail Garrison	48
Sensor Fused Weapon	83
Small ICBM	234
SMART-T	20
Space based infra red surveillance system (SBIRS)	37
SRAM T AGM 131A/B	17
T-46A	34
Titan IV	91

Army

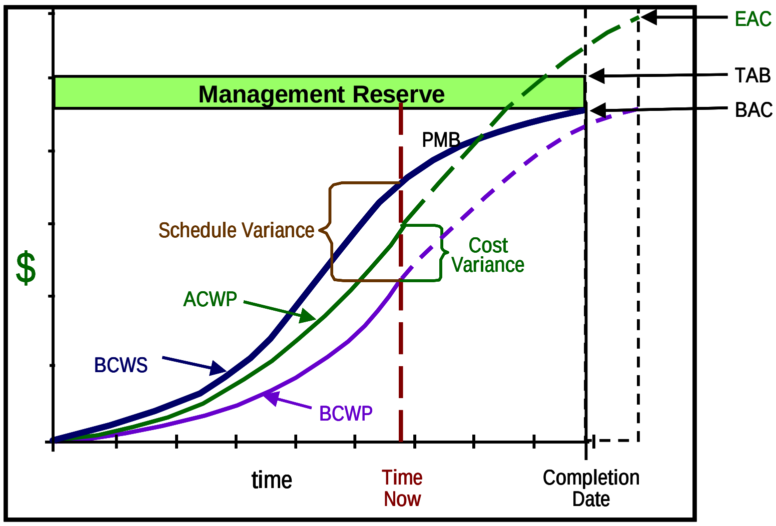
Program Name	Number of Contract Entries
ABRAMS Tank M1/M1A1	78
ADDS	68
Advanced Threat Infrared Countermeasures / Common Missile Wa	25
AFATDS (ATCCS)	49
AH-64 Apache	195
AHIP Kiowa Warrior	14
AN/TTC-39	28
Army TACMS	65
ASAS (ATCCS) Block IIB III	49
ATACMS BLK II	104
BFVS A3 Upgrade	29
BFVS M2 M3 (Bradley Fighting Vehicle	129
CH-47 Improved Cargo Helicopter (CH-47F)	13
CH-47D Chinook	46
CHEYENNE	18
Comanche Reconnaissance Attack Helicopter (RAH-66)	102
COPPERHEAD	39
CRUSADER	27
CSSCS	21
FAAD C2I	64
FAAD NLOS Fiber Optic Guided-Missile	7
FBCB2	19
GMLRS Upgrade Missile	13
IAV (Stryker)	6
Javelin	71
JSTARS Common Ground Station (CGS)	26
LANCE	13
Laser Hellfire	119
Longbow Apache FCR	73
Longbow Hellfire	21
M1A2 Abrams Upgrade	10
MCS IV	25
MLRS	82
MLRS-TGW	57
PATRIOT	270
Patriot PAC-3	142
PERSHING II	97
ROLAND	32
RPV (AQUILA)	68
SADARM	87
SCAMP	10
SGT YORK GUN (DIVAD)	31
SINCGARS	38
SOTAS	17
STINGER	126
STINGER RMP	56
TACFIRE	7
TACIT RAINBOW (JGL)	3
TOW 2	19
UH-60A/L Black Hawk	135

Navy

Program Name	Number of Contract Entries
5-Inch GUIDED PROJECTILE	13
A-12	9
AAAM	16
advanced amphibious assault vehicle (AAAV)	20
Aim-9X Short range air to air missile	35
AN/BSY-1	76
AN/BSY-2	26
AN/SQQ-89	206
AN-APG-79 Active Electronically Scanned Array Radar	2
AOE 6	73
ASPJ (AN/ALQ-165)	45
AV-8B Harrier II	28
C/MH-53E	55
CAPTOR (MK 60 MINE)	84
CG 47 Aegis Cruiser	243
Cooperative Engagement Capability (CEC)	53
CVN 68	66
DD 963	7
DD(X) Destroyer	3
DDG 51	499
E-2C Computer Upgrade	63
EMSP	12
F/A-18 C/D	112
F/A-18 E/F Super Hornet	129
F-14D	35
F-35 Joint Strike Fighter (JSF)	6
FDS	60
FFG-7	271
Future Aircraft Carrier CVN 21	2
HARM (NAVY)	51
Harpoon A/R/UGM-84	24
Joint standoff weapon (JSOW)	61
JTIDS (NAVY)	23
LAMPS MKIII	74
LCAC	155
LHD-1	151
LPD-17	45
LSD 41 CARGO VAR	26
LSD 41 Class CV	24
MCM 1	37
MH-60R	76
MH-60S	9
MHC 51	112
MIDS-LVT	43
MK 48 ADCAP	46
MK 50 Torpedo	84
NATO PHM	20
Navy Area TMBD	70
NSSN New Attack Sub	167
P-7A	6
PHALANX CIWS (MK-15)	40
Phoenix (AIM-54C)	16
ROTHR	3
SEA LANCE	33
SEALIFT	123
SIDEWINDER (AIM-9L) (Navy)	24
SIDEWINDER (AIM-9M) (Navy)	1
SLAT (AQM-127A)	12
SM 2 (BLKS I-IV)	98
SPARROW (AIM-7M) (Navy)	28
SSDS	20
SSN 688 Attack Sub	261
SURTASS	9
T-45TS	21
TACTAS	2
Tactical Tomahawk Missile	14
T-AGOS	20
T-AO 187 OILER	26
Tomahawk R/UGM-109	338
TRIDENT II MSL	392
TRIDENT II SUB	157
TRIDENT SUB	72
USMC H-1 Upgrades	17
V-22 Joint services advanced vertical lift aircraft	210
Virginia Class Sub SSN 774	84

Appendix B. Earned Value Management Gold Card

Earned Value Management
'Gold Card'
Defense Acquisition University



VARIANCES Favorable is Positive, Unfavorable is Negative

Cost Variance	CV	= BCWP – ACWP	CV % = (CV / BCWP) * 100
Schedule Variance	SV	= BCWP – BCWS	SV % = (SV / BCWS) * 100
Variance at Completion	VAC	= BAC – EAC	

PERFORMANCE INDICES Favorable is > 1.0, Unfavorable is < 1.0

Cost Efficiency	CPI	= BCWP / ACWP
Schedule Efficiency	SPI	= BCWP / BCWS

OVERALL STATUS

% Schedule = ($BCWS_{CUM}$ / BAC) * 100

% Complete = ($BCWP_{CUM}$ / BAC) * 100

% Spent = ($ACWP_{CUM}$ / BAC) * 100

ESTIMATE AT COMPLETION #

EAC = Actuals to Date + [(Remaining Work) / (Efficiency Factor)]

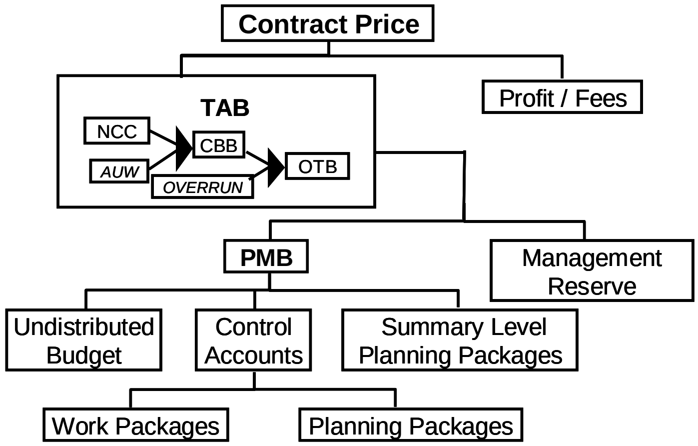
EAC_{CPI} = $ACWP_{CUM}$ + [(BAC – $BCWP_{CUM}$) / CPI_{CUM}] = **BAC / CPI_{CUM}**

$EAC_{Composite}$ = $ACWP_{CUM}$ + [(BAC – $BCWP_{CUM}$) / (CPI_{CUM} * SPI_{CUM})]

TO COMPLETE PERFORMANCE INDEX (TCPI) #

$TCPI_{EAC}$ = Work Remaining / Cost Remaining = (BAC – $BCWP_{CUM}$) / (EAC – $ACWP_{CUM}$)

To Determine Either TCPI or EAC; You May Replace BAC with TAB



TERMINOLOGY

NCC	Negotiated Contract Cost	Contract price less profit / fee(s)
AUW	Authorized Unpriced Work	Work contractually approved, but not yet negotiated / definitized
CBB	Contract Budget Base	Sum of NCC and AUW
OTB	Over Target Baseline	Sum of CBB and recognized overrun
TAB	Total Allocated Budget	Sum of all budgets for work on contract = NCC, CBB, or OTB
BAC	Budget At Completion	Total budget for total contract thru any given level
PMB	Performance Measurement Baseline	Contract time-phased budget plan
MR	Management Reserve	Budget withheld by Ktr PM for unknowns / risk management
UB	Undistributed Budget	Broadly defined activities not yet distributed to CAs
CA	Control Account	Lowest CWBS element assigned to a single focal point to plan & control scope / schedule / budget
WP	Work Package	Near-term, detail-planned activities within a CA
PP	Planning Package	Far-term CA activities not yet defined into WPs
BCWS	Budgeted Cost for Work Scheduled	Value of work planned to be accomplished = PLANNED VALUE
BCWP	Budgeted Cost for Work Performed	Value of work accomplished = EARNED VALUE
ACWP	Actual Cost of Work Performed	Cost of work accomplished = ACTUAL COST
EAC	Estimate At Completion	Estimate of total cost for total contract thru any given level; may be generated by Ktr, PMO, DCMA, etc. = $EAC_{Ktr / PMO / DCMA}$
LRE	Latest Revised Estimate	Ktr's EAC or EAC_{Ktr}
SLPP	Summary Level Planning Package	Far-term activities not yet defined into CAs
TCPI	To Complete Performance Index	Efficiency needed from 'time now' to achieve an EAC

EVM POLICY: DoDI 5000.2, Table E3.T2 . EVMS in accordance with ANSI/EIA-748 is required for cost or incentive contracts, subcontracts, intra-government work agreements, & other agreements valued ≥ $20M (Then-Yr $). EVMS contracts > $50M (TY $) require that the EVM system be formally validated by the cognizant contracting officer. Additional Guidance in Defense Acquisition Guidebook and the Earned Value Management Implementation Guide (EVMIG). EVMS is discouraged on Firm-Fixed Price, Level of Effort, & Time & Material efforts regardless of dollar value.

EVM CONTRACTING REQUIREMENTS:

DFAR Clauses - 252.242-7001 for solicitations and 252.242-7002 for solicitations and contracts
Contract Performance Report – DI-MGMT-81466A * 5 Formats (WBS, Organization, Baseline, Staffing & Explanation)
Integrated Master Schedule – DI-MGMT-81650 *
Integrated Baseline Review (IBR) - Mandatory for all EVMS contracts > $20M
* See the EVMIG for CPR and IMS tailoring guidance.

EVM Home Page = https://acc.dau.mil/evm
DAU POC: (703) 805-5259 (DSN 655)
eMail Address: EVM@dau.mil
Revised February 2006

Appendix C: Budget Summary

All budget figures represent Total Obligation Authority as reported in various tables from Chapter 6 of the DoD Greenbook which is published annually in support of the Presidents Budget submission. Budget data is in millions of fiscal year 2006 dollars.

Air Force

	Total Budget	Procurement Budget	R&D Budget
1970	$129,730	$33,797	$13,748
1971	$118,941	$29,995	$12,057
1972	$113,724	$27,466	$11,955
1973	$108,816	$25,968	$12,029
1974	$99,936	$22,018	$10,803
1975	$94,940	$20,823	$10,459
1976	$96,459	$23,905	$10,637
1977	$97,424	$26,797	$10,371
1978	$95,686	$27,338	$10,636
1979	$93,302	$25,974	$10,058
1980	$96,997	$27,696	$10,452
1981	$108,721	$32,815	$13,584
1982	$123,096	$42,368	$15,960
1983	$133,487	$46,369	$18,301
1984	$149,387	$57,168	$20,303
1985	$164,097	$61,309	$21,103
1986	$156,943	$55,108	$20,574
1987	$152,567	$49,538	$22,606
1988	$143,145	$39,810	$21,898
1989	$144,126	$42,158	$20,368
1990	$138,110	$39,922	$18,268
1991	$127,982	$31,457	$15,460
1992	$115,768	$29,448	$16,529
1993	$107,506	$26,339	$15,860
1994	$99,669	$21,028	$14,849
1995	$97,027	$18,674	$13,885
1996	$95,324	$19,279	$14,688
1997	$91,830	$16,481	$16,271
1998	$93,314	$17,402	$16,328
1999	$96,398	$20,438	$15,493
2000	$97,171	$20,928	$16,117
2001	$101,578	$24,147	$15,630
2002	$110,319	$25,446	$15,642

Army

	Total Budget	Procurement Budget	R&D Budget
1970	$132,886	$19,015	$7,524
1971	$117,812	$13,735	$7,285
1972	$106,780	$13,518	$7,476
1973	$95,341	$10,131	$7,427
1974	$87,998	$8,296	$6,921
1975	$82,551	$7,550	$5,894
1976	$84,450	$8,524	$5,971
1977	$87,321	$11,183	$6,323
1978	$87,721	$12,966	$6,285
1979	$89,084	$13,882	$6,124
1980	$89,570	$13,514	$6,020
1981	$99,022	$19,688	$6,104
1982	$108,720	$24,373	$6,720
1983	$113,588	$26,269	$6,972
1984	$117,055	$27,056	$7,244
1985	$132,560	$28,305	$7,213
1986	$130,756	$25,907	$7,584
1987	$129,806	$22,600	$7,583
1988	$126,861	$21,116	$7,234
1989	$125,362	$19,795	$7,571
1990	$122,939	$18,142	$7,560
1991	$135,699	$14,100	$7,640
1992	$110,042	$10,772	$8,476
1993	$95,176	$9,012	$7,824
1994	$88,265	$8,291	$6,939
1995	$87,214	$7,895	$6,804
1996	$86,866	$8,827	$5,915
1997	$84,023	$9,297	$6,006
1998	$80,839	$8,366	$5,984
1999	$84,673	$10,690	$5,893
2000	$86,636	$11,609	$6,054
2001	$89,864	$13,003	$6,987
2002	$95,810	$12,532	$7,673

Navy

	Total Budget	Procurement Budget	R&D Budget
1970	$119,405	$32,208	$10,596
1971	$108,200	$29,644	$9,796
1972	$109,139	$33,418	$10,169
1973	$106,588	$31,868	$10,023
1974	$105,046	$29,749	$9,762
1975	$99,978	$25,779	$9,857
1976	$103,677	$28,486	$9,956
1977	$109,586	$33,271	$10,404
1978	$111,114	$34,533	$10,365
1979	$109,235	$32,202	$9,949
1980	$110,160	$31,807	$9,248
1981	$119,993	$37,168	$9,358
1982	$132,101	$44,672	$10,264
1983	$146,238	$54,471	$10,345
1984	$144,987	$48,852	$12,480
1985	$162,118	$49,280	$14,313
1986	$158,825	$47,959	$14,652
1987	$157,168	$47,596	$13,908
1988	$162,419	$52,196	$13,691
1989	$151,264	$43,183	$12,872
1990	$147,769	$43,732	$11,635
1991	$145,155	$38,970	$10,275
1992	$127,247	$31,278	$10,769
1993	$117,676	$25,641	$11,267
1994	$104,782	$19,079	$10,033
1995	$103,239	$20,402	$10,327
1996	$102,170	$18,342	$9,991
1997	$99,815	$19,865	$9,164
1998	$100,323	$22,324	$9,073
1999	$101,767	$23,288	$10,248
2000	$103,789	$26,149	$10,174
2001	$109,238	$29,204	$10,578
2002	$112,525	$26,525	$12,352

Appendix D. Model Lag Structure Results

Budget Variables	**AIC**			
Lag	**Fixed-Price**	**Cost-Plus**	**Production**	**R&D**
0	**412.83**	286.941	344.1723	349.9155
1	425.61	285.1438	342.4186	353.5846
2	421.95	**278.5705**	343.8825	**350.0317**
3	423.40	286.9981	**339.0549**	352.0559
4	424.20	286.1704	343.6701	352.14
5	425.40	285.064	339.9242	353.6565
6	425.40	287.0761	342.2523	353.0675
7	426.13	288.4477	343.2183	353.5141

Nunn-McCurdy	**AIC**			
Lag	**Fixed-Price**	**Cost-Plus**	**Production**	**R&D**
0	**412.83**	286.94	**344.17**	349.92
1	417.26	289.80	356.09	349.83
2	417.27	**288.15**	357.38	349.89
3	415.30	291.14	355.70	**347.92**
4	417.30	290.33	357.74	349.15
5	416.98	290.11	357.65	349.39
6	415.54	289.30	357.45	348.78
7	415.30	291.82	355.70	**347.92**

Packard	**AIC**			
Lag	**Fixed-Price**	**Cost-Plus**	**Production**	**R&D**
0	**412.83**	286.94	344.17	349.92
1	415.51	286.67	343.30	348.97
2	414.08	287.11	344.73	**343.31**
3	415.14	286.55	344.96	348.75
4	414.64	287.33	**340.24**	350.53
5	415.00	284.64	344.47	350.02
6	414.46	281.96	344.96	350.79
7	414.25	**276.36**	345.13	350.45

DAWIA	AIC			
Lag	**Fixed-Price**	**Cost-Plus**	**Production**	**R&D**
0	412.83	**286.94**	**344.17**	**349.92**
1	417.74	289.80	345.85	360.26
2	**410.75**	288.15	348.71	360.37
3	422.10	291.14	348.29	359.79
4	423.43	290.33	346.49	358.36
5	424.55	290.11	345.33	355.73
6	424.25	289.30	347.55	353.58
7	424.90	291.82	348.34	359.85

FASA	AIC			
Lag	**Fixed-Price**	**Cost-Plus**	**Production**	**R&D**
0	**412.83**	286.94	344.17	286.94
1	427.78	283.05	**340.05**	283.05
2	423.41	**282.84**	345.22	**282.84**
3	428.84	286.82	347.81	286.82
4	426.76	287.50	341.61	287.50
5	429.39	287.25	347.49	287.25
6	429.30	287.73	347.81	287.73
7	429.02	285.41	347.02	285.41

Appendix E. Test for Stationarity of the Dependent Variable

The dependent variable in panel regression must be stationary to prevent spurious regression. This is tested by the Augmented Dickey-Fuller Test for a unit root. Since the p-value for the Augmented Dickey-Fuller test is less than α =.10 for each model, we can reject the null hypothesis that the variable is non-stationary and conclude that the data comes from a stationary process.

Fixed Price Contracts (Overrunpercentfp100)					
Dickey-Fuller test for Unit Root					
			Z(t) has t-distribution		
	Number of Obs	**Test Statistic**	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)-Air Force	28	-2.0300	-2.4790	-1.7060	-1.3150
p-value for Z(t) =		**0.0263**			
Z(t)-Army	27	-2.8650	-2.4850	-1.7080	-1.3160
p-value for Z(t) =		**0.0000**			
Z(t)-Navy	26	-4.3710	-2.4920	-1.7110	-1.3180
p-value for Z(t) =		**0.0001**			

Cost-Plus Contracts (Overrunpercentcp100)					
Dickey-Fuller test for Unit Root					
			Z(t) has t-distribution		
	Number of Obs	**Test Statistic**	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)-Air Force	32	-2.7250	-2.4570	-1.6970	-1.3100
p-value for Z(t) =		**0.0053**			
Z(t)-Army	30	-3.9080		-1.7010	-1.3130
p-value for Z(t) =		**0.0003**			
Z(t)-Navy	27	-2.5370	-2.4850	-1.7080	-1.3160
p-value for Z(t) =		**0.0089**			

Production Contracts (Overrunpercentproc100)					
Dickey-Fuller test for Unit Root					
			Z(t) has t-distribution		
	Number of Obs	**Test Statistic**	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)-Air Force	27	-1.6630	-2.4850	-1.7080	-1.3160
p-value for Z(t) =		**0.0544**			
Z(t)-Army	23	-2.7130	-2.5180	-1.7210	-1.3230
p-value for Z(t) =		**0.0065**			
Z(t)-Navy	24	-2.9650	-2.5080	-1.7170	-1.3210
p-value for Z(t) =		**0.0036**			

Research and Development Contracts (Overrunpercentrd100)					
Dickey-Fuller test for Unit Root					
			Z(t) has t-distribution		
	Number of Obs	**Test Statistic**	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)-Air Force	32	-1.3640	-2.4570	-1.6970	-1.3100
p-value for Z(t) =		**0.0914**			
Z(t)-Army	30	-4.1010	-2.4670	-1.7010	-1.3130
p-value for Z(t) =		**0.0002**			
Z(t)-Navy	27	-1.4530	-2.4850	-1.7080	-1.3160
p-value for Z(t) =		**0.0793**			

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Vita

Captain James P. Smirnoff was born in San Diego, California. He graduated from Walkersville High School in Walkersville, Maryland and enrolled in college at Virginia Tech in 1995. He graduated with a Bachelor of Arts in Economics in 1999 and was assigned to Wright-Patterson Air Force Base where he worked as a Financial Manager for the F-16 System Program Office until 2002. From 2002 until 2004, he was assigned to the Wright-Patterson Air Force Base Financial Services Office. During that time he also spent six months deployed to Southwest Asia as Comptroller of the 384th Air Expeditionary Wing in support of Operation Enduring Freedom and Operation Iraqi Freedom. In August of 2004, Capt Smirnoff entered the Cost Analysis Master's Program at the Air Force Institute of Technology's School of Engineering and Management. Upon graduation, Captain Smirnoff will be assigned as a Cost Analyst in the Space and Missile Center, Los Angeles Air Force Base, California.

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14. ABSTRACT
Cost overruns in weapon system purchases have plagued the Department of Defense (DoD) throughout its history and have resulted in schedule delays and potentially reduced combat capability. This thesis created an empirical model that begins to explain those cost overruns. The model describes how changes in defense budgets, consolidation of the defense industry, acquisition reform, war, and cost estimating error are related to cost overruns.

The cost performance of 186 major weapon system programs managed by the Air Force, Army, and Navy from 1970 to 2002 was described using a panel regression model. This research found that funding instability resulting from changing levels of defense budgets accounted for an increase of over $13.3 billion in weapon system costs since 1970. This research also found that the defense industry consolidation of the 1990's did not result in significant savings to the DoD. Finally, this research found that contrary to past studies, several acquisition reforms are correlated with a decrease in weapon system cost overruns. In particular, reforms resulting from the Nunn-McCurdy Act of 1982, the Packard Commission Recommendations of 1986 and the Federal Acquisition Streamlining Act (FASA) of 1994 resulted in savings of almost $124 billion since 1982.

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