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**THE IMPACT OF HUMAN CAPITAL ON THE COST OF AIR FORCE  
ACQUISITION PROGRAMS**

THESIS

Jeffrey C. Feuring, Captain, USAF

AFIT/GCA/ENV/07-M5

**DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY**

***AIR FORCE INSTITUTE OF TECHNOLOGY***

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**Wright-Patterson Air Force Base, Ohio**

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AFIT/GCA/ENV/07-M5

THE IMPACT OF HUMAN CAPITAL ON THE COST OF AIR FORCE  
ACQUISITION PROGRAMS

THESIS

Presented to the Faculty

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science (Cost Analysis)

Jeffrey C. Feuring, BS

Captain, USAF

March 2007

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ACQUISITION PROGRAMS

Jeffrey C. Feuring, BS  
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### **Abstract**

Previous studies have established a link between Human Capital and performance both at the firm and the individual level. These studies have shown that performance can be improved with additional personnel and/or higher education levels. This study attempts to build on this relationship by using the Cobb-Douglas Production function to relate inputs to outputs. The inputs to the function are the number of cost analysts positions, military and civilian, and an education variable for the number of master's degrees in the field. The measure of output is the average cost overrun of Air Force contracts. A time series regression was conducted while controlling for other economic factors such as budgetary fluctuations and inflation. The results show positive effects of human capital on performance. Other policy implications of the study are the importance of budgetary stability, inflation predictions and the Defense Acquisition Workforce Improvement Act (DAWIA).

## Table of Contents

|   | Page |
|---|------|
| Abstract.....                               | iv   |
| List of Figures.....                        | vii  |
| List of Tables.....                         | viii |
| I. INTRODUCTION.....                        | 1    |
| General Issue.....                          | 1    |
| Chapter Summary.....                        | 5    |
| II. LITERATURE REVIEW.....                  | 6    |
| Past Research on Cost Variance.....         | 6    |
| Past Research on Human Capital.....         | 7    |
| <i>Numbers of Personnel</i> .....           | 8    |
| <i>Education Levels of Personnel</i> .....  | 9    |
| <i>Individual Level of Analysis</i> .....   | 9    |
| <i>Firm Level of Analysis</i> .....         | 10   |
| <i>Indirect Benefits of Education</i> ..... | 11   |
| Chapter Summary.....                        | 11   |
| III. METHOD.....                            | 12   |
| Measuring Contract Performance.....         | 12   |
| Data and Variables.....                     | 14   |
| <i>Dependent Variable</i> .....             | 14   |
| <i>Independent Variables</i> .....          | 14   |
| <i>Control Variables</i> .....              | 15   |
| Model.....                                  | 16   |
| Chapter Summary.....                        | 18   |
| IV. RESULTS.....                            | 19   |
| Pre-Specification Tests.....                | 20   |
| Post-Specification Tests.....               | 22   |
| Regression Results.....                     | 23   |
| V. DISCUSSION.....                          | 28   |

|                          | Page |
|--------------------------|------|
| Future Research .....    | 28   |
| Research Conclusion..... | 30   |
| Appendix A.....          | 31   |
| Appendix B.....          | 32   |
| Appendix C.....          | 33   |
| References.....          | 34   |
| Vita .....               | 37   |



## List of Figures

| Figure   | Page |
|--|------|
| Figure 1: NASA Earned Value Management (2006).....               | 13   |
| Figure 2: Cost Overruns vs. Military and Civilian Analysts ..... | 19   |
| Figure 3: Variance of Residuals.....                             | 32   |
| Figure 4: Error term distribution.....                           | 33   |

## List of Tables

| Table   | Page |
|---|------|
| Table 1: Summary Statistics .....                                     | 20   |
| Table 2: Lag Structure Determination .....                            | 21   |
| Table 3: Time-Series Regression Results .....                         | 24   |
| Table 4: Associated Dollar Amounts for Significant Coefficients ..... | 26   |
| Table 5: Variance Inflation Factor .....                              | 31   |

# THE IMPACT OF HUMAN CAPITAL ON THE COST OF AIR FORCE ACQUISITION PROGRAMS

## I. INTRODUCTION

The primary purpose of this research was to determine if there is a relationship between the number of cost analysts, their education and training levels and the cost variance of Air Force contracts. In this study, the cost variance measurement was the amount of cost overruns. The research looked at both officers and civilians within the cost analysis career field.

### General Issue

One of the ongoing struggles within the Department of Defense (DoD) Acquisition community is how to produce weapon systems within specified budgets. There have been several studies conducted to determine the actual amount of cost variance that has occurred within DoD acquisition systems. Depending on the time period analyzed and the type of variance used in determining a cost difference, these studies found that costs have increased by an average of 8% to 40% (Jacques S. Gansler 1989; Jeffrey A. Drezner, Jeanne M. Jarvaise, Ron Hess, Daniel M. Norton, and Paul G. Hough 1993; David S. Christensen and James A. Gordon 1998; William J. Swank, Paul A. Alfieri, Charles K. Gailey III, and Raymond W. Reig 2000; James Smirnoff 2006). Typically, the increased costs results in a request for additional funds, but in extreme cases, inaccurate estimates can lead to program cancellations, and the loss of billions of dollars, as was the case for the A-12, a controversial program that was cancelled due to overly optimistic estimates (Christensen 1994).

Because of the amount of money involved with DoD projects, multi-billions of dollars, this issue has received significant attention from senior leaders in the DoD, and the legislative and executive branches of government. As such, various reform measures have been instituted over the past 40 years. The empirical studies on the effectiveness of these reforms have found mixed results. Drezner (1993) looked at 197 acquisition programs from 1960 to 1990 and found no improvement in cost variance due to the reforms. In addition, David S. Christensen, David A. Searle and Caisse Vickery (1999) found that one of the biggest reform measures, the Packard Commission, had no impact on cost variance. Smirnoff (2006), however, found that when controlling for such macro-economic factors as annual procurement budget, research and development budget, and unexpected inflation, some of the reforms have been effective at controlling costs.

There have been several studies to date which have attempted to explain where cost variance primarily occurs and why cost estimates are inaccurate, with the goal of instituting meaningful reforms. These studies have determined that cost variance is primarily influenced by the characteristics of the program (program size, stage of the program, urgency, degree of testing, and production rate) and the characteristics of the weapon system (technological maturity, difficulty of technology, type of commodity, and performance characteristics) (Vince Sipple, Edward White and Michael Greiner 2004). These studies do not provide a policy lever that can be used to reduce cost variance. They only identify the characteristics of programs that experience an increase in cost; as a result, it is difficult for policy makers to use these findings to prevent the unexpected increase in the cost of weapon systems. More needs to be done on these earlier reports to make them useful for decision makers.

One such factor which could influence cost variance and could provide a tool for policy usage is the quality of the estimates. The idea that cost overruns are attributed to an error in the initial cost estimates was suggested by Christensen, Searle and Vickery (1999) and Jeffrey Drezner, Jean Jarvaise, Ron Hess, Daniel Norton, and Paul Hough (1993). Christensen, Searle and Vickery (1999) noted that cost realism is a problem in cost estimation. In addition, Bobby J. Pannel (1994) indicated that most of the estimation errors are in the estimation of production costs. Pannel identified estimation errors as those which are not attributable to any program decisions made in the production stage.

While these studies simply identify the problem, some private sector studies go deeper into the issue. Even though these studies are not specific to DoD cost estimating, a general cost estimating analogy can be drawn. The two types of studies are those relating the number of personnel to performance (Xi Li 2002) and those relating human capital to performance (Gary Becker 1964; Anne Bartel 1994; Lisa Lynch and Sandra Black 1995; Alan Krueger and Cecilia Rouse 1998). These studies concluded that the performance of the firm (Bartel 1994 used net sales) and of the individual (Krueger and Rouse 1998 used performance awards, job upgrades, job bids and job attendance) can be improved with more personnel or higher education levels. In addition, two studies (Lynch and Black 1995; J.H. Bishop 1994) found that education produces indirect benefits such as innovativeness and the ability to better adapt to new tasks and technologies.

Smirnoff (2006) evaluated the effect of the Defense Acquisition Workforce Improvement Act of 1990 (DAWIA) which mandated certain education and training requirements for acquisition personnel. In his model, he found that this act actually had a positive correlation with cost overruns, meaning the establishment of this act correlated

with more cost overruns. This seems counterintuitive; so this variable was also added to this study to see if different results are produced with a different analysis technique.

With the exception of Smirnoff (2006), these studies suggest estimation error, or the performance of Air Force cost estimators, could be improved by either increasing the amount of personnel or by providing more education to those already employed. If estimation errors are reduced, this may lead to fewer cost overruns for the Air Force. However, the current state of the Air Force makes this difficult. According to the Air Force Cost Analysis Agency, Air Force cost analysis resources are down 60% (300 positions) since 1994, while the total AF positions are down 13% (Thomas Dupre 2005). In addition, the Air Force cost field has experienced cuts, even while other services are increasing their cost analysis personnel; Naval Air Systems Command (NAVAIR) cost personnel have increased 91% since 1992 and NASA cost personnel have increased 250% (Dupre 2005). Concurrently, among the DoD, the Air Force is historically the poorest performer when it comes to cost growth. During the development stage, the Air Force experienced a 78% increase in cost overruns, compared with 58% for the DoD (Dupre 2005), and its not getting any better. The Air Force is expecting a 76% growth in costs over the life of programs currently in procurement (Dupre 2005). The current feeling in the Air Force Cost Analysis Agency is that the reason the Air Force is doing poorly compared with the other services is because of a lack of cost personnel (Dupre 2005).

The FY06 National Defense Authorization Act – House Armed Services Committee Report has directed the Air Force to correct the situation and for the Secretary of the Air Force to take steps necessary to correct the problems in cost analysis (Dupre

2005). The Secretary of the Air Force reasoned that an immediate fix to the cost overrun problem is to increase the number of cost analysts in the Air Force. The Air Force has been approved to add 50 more personnel to the career field. This study will attempt to determine if adding more personnel will indeed fix the problem or if the cost analysis career field is already at a suitable strength level.

The rest of this study will be organized as follows; chapter 2 provides a review of the literature related to this field of study, chapter 3 uses this literature and develops a method for analyzing the relationship between cost overruns and human capital, chapter 4 provides the results of the analysis with a discussion of the significant findings, and finally, chapter 5 provides additional discussion on the topic and provides areas for future research.

## II. LITERATURE REVIEW

The purpose of this research was to determine whether or not a relationship exists between the number of AF cost analysts, both military and civilian, investments in human capital, and AF contract cost variances. In order to give a background of the topic, this chapter provides an overview of the previous research that has been conducted in this area.

### Cost Variance

There are two methods that measure cost variance, which is a cost increase or decrease in a program, namely, cost growth and cost overruns. We'll reserve discussion of the specifics of each for the end of the chapter; however, Vince Sipple, Edward White, and Michael Greiner (2004) published a study which synthesized all research on cost variance to date. In the article, the authors summarized studies from the Ballistic Missile Defense Organization Study in 2000, a 1993 RAND study, a NAVAIR study in 2001, a study by Christensen and Templin in 2000, a study by Henry Eskew in 2000, an Institute for Defense Analysis (IDA) study in 1994, and a 2001 RAND study. In their review, Sipple, White and Greiner (2004) noted that while these studies only identify where cost variance occurs, they are the starting point to identify a model that allows cost variance to be predicted and controlled.

Estimation error is one factor that has been highlighted, almost as an afterthought, in several studies. The Office of the Secretary of Defense Cost Analysis Improvement Group (OSD CAIG 2001) did an extensive examination of the causes of cost variances. In this examination, the underlying reasons seemed to result from either decisions or mistakes that were made regarding the program. Decisions that drove variances included



requirement changes, schedule changes, and changes in acquisition strategy. Estimation mistakes included assumption or estimation changes, schedule slips not attributable to technical problems and any other changes not made as a result of a discretionary decision. In sum, the OSD attributed more than half of cost variance to errors.

Christensen, Searle and Vickery (1999) focused on the idea of errors or mistakes when they concluded the costs are not only underestimated initially, but all subsequent estimates of the final program cost are underestimated. The authors attribute this to estimation error or other causal factors not identified. Pannel (1994) suggested some of those additional factors, indicating that the majority of estimation errors are due to errors in the production cost estimations. These errors in the estimation of production costs arise because of method errors, omissions, schedule slips attributable to technical problems, weight growth, and inadequately scoped engineering and software development efforts (Pannel 1994). Sipple, White, and Greiner (2004) diverged from this type of thinking by suggesting that costs might be controlled with additional manpower and training.

### Human Capital

The idea that human capital can affect performance is something that has been explored in the private sector. Richard Blundell, Lorraine Dearden, Costas Meghir, and Barbara Sianesi (1999) state there are three components to human capital: “early ability (whether acquired or innate); qualifications and knowledge acquired through formal education; and skills, competencies and expertise acquired through training on the job” (p. 2). They go on to assert that investing in human capital is the same as investing in other capital assets. An up-front fee is incurred for the tuition, loss of wages, or training

fees but a return on investment is expected (Blundell, Dearden, Meghir, Sianesi 1999). Specifically, this study found that education and training have an important impact on the individual, firm and economy. Past findings do support the sequence of relationships that are hypothesized. That is, studies have related the number of personnel to performance (Li 2002; James Shaw and Jeff Weekley 1985). Others have conducted studies to determine how much return can be expected from investing in training or education (Bishop 1994; Krueger and Rouse 1998; Bartel 1989, 1994; Lynch and Black 1995)

#### *Numbers of Personnel*

Several studies have concluded that the number of personnel making the estimation can have a positive effect on the quality of the estimation. In analyzing the performance of stock analysts, Li (2002), for instance, found the analysts' predictive power began to decline as their coverage exceeded 12-13 stocks. At some point if a worker takes on too much work, his or her performance begins to decline. The analyst does not have time to conduct a thorough review of the stocks and their estimates become inaccurate. The same could be true with a military cost analyst. If a military cost analyst is working on a large program that requires several estimates, he might not be able to conduct as comprehensive review as possible and could produce results which are less accurate. In addition, there are other factors involved with being overworked. Shaw and Weekley (1985) conducted an experimental study in which they gave subjects word puzzles to solve in order to determine the effects of overload and underload situations. In their study, they measured perceived pressure, self-esteem, task enjoyment, resentment, anxiety, depression, hostility, and performance and found overload situations caused the subjects to feel more pressure, have less task enjoyment and feel more depressed (Shaw

and Weekly 1985). If this sort of situation were to be prolonged, you would expect it to have a negative effect on performance.

### *Education Levels of Personnel*

Performance cannot be improved by simply adding more personnel. It is also important that the right people are doing the job with the right skill set and education levels. There have been numerous private sector studies on human capital and the performance of firms. Becker (1964), in his pioneering work on human capital, stated the most important investments in human capital are education and training. In the years since, there have been two types of studies which relate education and training to performance: those at the individual level and those at the firm level.

### *Individual Level of Analysis*

At the individual level, Bishop (1994) used data from the National Federation of Independent Business survey to look at the impact of training on newly hired employees. The results of the study found training raises productivity by 16%, where productivity was measured subjectively with a survey that asked employers to rate the productivity of the new employees. However, as noted by Lynch and Black (1995), this method is a subjective measure of performance and is not comparable across firms or within firms.

Krueger and Rouse (1998) measured performance objectively by using data from records from both a service and manufacturing company, that were supplemented with subjective measures. They found training was positively correlated with the occurrence of job bids, upgrades, performance awards, and job attendance across industries. This could make the argument that higher education levels could lead to better performance, or in this case better cost estimations and lower cost overruns.

### *Firm Level of Analysis*

Other studies have looked at the effect of training and education on the performance at the firm or organizational level. Bartel (1994) uses the Cobb-Douglas production function to estimate the impact of employee training. Her effort was an early attempt to address the gap in the literature on the effects of training and productivity at the firm or organizational level, because most of the prior research on this topic was done at the individual level. She found that organizations that were operating below the expected productivity increased their productivity after establishing training programs. These findings were echoed by Lynch and Black (1995).

Lynch and Black (1995), again applying the Cobb-Douglas Production function, used data from the National Center on the Educational Quality of the Workforce and confirmed the influence of capital investments on organizational level outcomes. Specifically, they found that a 10% increase in the average education levels of employees resulted in an 8.5% increase in productivity in manufacturing and 12.7% in non-manufacturing firms.

Bartel (1989) used a survey on human resource management and measures of financial performance to determine a correlation between training and productivity. She concluded training increases productivity by 16%; however, the low 6% survey response rate could place the actual productivity rate at a different number. Also, another problem with Bartel's 1989 study is that most firms used in her study were multiple establishment firms. The measure of output, financial performance, was for the firm as a whole and not the specific locations. Based on this study, there could be a problem with correlating

training, which is an input at the specific locations, to output, which is a measure of the entire firm's performance (Lynch and Black 1995).

### *Indirect Benefits of Education*

In addition, the studies of education show there are indirect benefits to education. Workers with higher education levels can learn how to learn (Lynch and Black 1995), can adapt to new tasks and technologies, and are more innovative (Bishop 1994). Specifically, Bishop (1994) found that the number of years schooled increased an innovation measure by 7.8%.

### Summary

This chapter showed there is a historical link between human capital and performance of both the individual and the firm. The next chapter will use this link to build a model to test the relationship between Air Force cost analysis human capital and cost overruns.

### III. METHOD

In order to deal with some of the shortcomings in the literature linking human capital to performance, this study will use an organizational level of analysis and an objective measure of performance. The method of analysis will be the Cobb-Douglas production function similar to Bartel (1994). In addition, the performance measure will be the amount of cost variance per year. Following is a description of how this cost variance will be captured.

#### Measuring Contract Performance

The performance of contracts is determined by various factors such as its schedule and whether or not the final product met the requirements of the customer. One performance factor which receives a lot of scrutiny is cost. There are two methods that measure a cost increase or decrease in a program, namely, cost growth and cost overrun. Cost growth is calculated by subtracting the initial estimate from the final program cost, while a cost overrun is computed by subtracting the budgeted cost of work performed (including budget changes) from the actual cost of work performed (Christensen and Gordon 1998). This is also consistent with the definition provided by the Earned Value Management System (Earned Value Management 2006). The appropriate measure (i.e., cost growth or overrun) varies based on the researcher's purpose. When attempting to identify errors in estimation, a cost overrun is the better measurement. Factors which are out of the program's control, such as funding instabilities and changes in the scope of a requirement, can lead to cost growth but not to cost overruns (Christensen and Gordon 1998). The final budget, which is used in the cost overrun calculation, is a better

measure of how well a program's budget was estimated. Figure 1 captures the overall cost variance computation (Earned Value Management 2006)

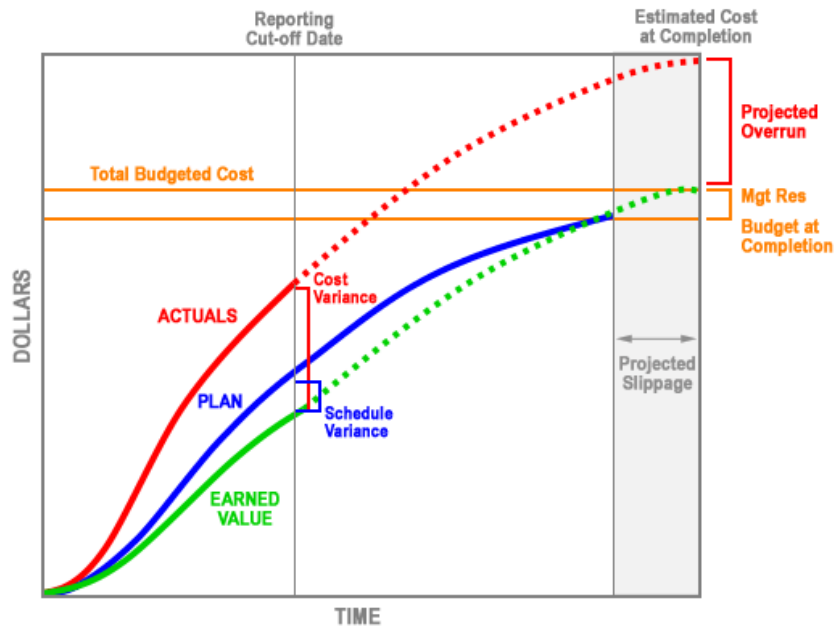


Figure 1: NASA Earned Value Management (2006)

The actuals line, also known as the Actual Cost of Work Performed (ACWP) reflects the amount spent to date, or the amount paid to the contractor. The plan line, also called the Budgeted Cost of Work Scheduled (BCWS), is the planned expenditures, or the budget of the contract. The earned value line is the Budgeted Cost of Work Performed (BCWP) and is the value of completed work. The value of the completed work is what takes into account requirement and budget changes. A cost variance is computed as the difference between the ACWP and the BCWP. In other words, it is the difference between what has been spent and what has actually been accomplished. Because this measurement takes into account the budgeted amount (program changes and changes in quantity) the cost variance is equivalent to a cost overrun. Cost growth, on the other hand, would be the difference between the ACWP line and the initial budget (not

shown on the graph). This form of measuring cost variance would not take into account re-baselines of the budget or quantity changes, and so it is not a good measure of estimation accuracy.

## Data and Variables

### *Dependent Variable*

To conduct this study, data was collected on the average cost overruns of Air Force weapon systems per year from 1970 to 2006 using Earned Value Management data (EVMS) from the Defense Acquisition Executive Summary (DAES). The amount of overrun for each weapon system will be consolidated by year to give the average cost overrun for that year in percentage terms (Earned Value Management 2006):

$$\%Overrun = \frac{(ACWP - BCWP)}{(BCWP)} * 100 \quad (1)$$

### *Independent Variables*

Personnel numbers and education levels were collected from the Air Force Personnel Center, the agency responsible for maintaining personnel records for each occupational Air Force specialty. The numbers represent those identified as cost analysts, using a specific occupational code within the Air Force personnel system (officers having the Air Force duty occupational code 65W). Because there is no Cost Analysis career field for civilians, an estimate has to be made as to the actual numbers that are performing cost analysis duties. The civilians in cost analysis come from two career fields, Occupational Series 501, Financial Management and Program, and 1515, Operations Research. Not all civilians in these occupational series perform cost duties, so we eliminated all but those civilians funded within the Program Element Code (PEC)



72806K, Acquisition. It can be assumed that civilians in this PEC who are in the 501 series and 1515 series are doing work related to cost analysis. This method was crosschecked with the current civilian cost analysts manning levels on record at the Air Force Cost Analysis Agency and produced similar results.

Similar to the work done by Smirnoff (2006), a dummy variable for training was added. Starting in 1994, the dummy variable captures the effects when all the provisions of the DAWIA Act of 1990 were put in place (William J. Perry 1995). Smirnoff (2006) found a positive correlation of this act on cost overruns. This research will determine if this same finding holds true using a Cobb-Douglas function.

#### *Control Variables*

In order to account for other factors which could contribute to the amount of cost overruns per year, control variables were added to the model. The Air Force Research and Development budget per year was added as a technological proxy. One of the common criticisms of inaccurate estimates is that new weapon systems are becoming more complex and thus are more difficult to estimate. If this is the case, more complex systems with higher technologies will require more Research and Development funds. Of course, if the number of R&D programs is increased, this would also cause the R&D budget to increase. So there could be some error in using this variable as a proxy for technology level.

Another factor to control for is the amount of analytical work which is outsourced to private contractors. Trying to determine the actual amount of contractors who are currently doing cost estimates is a difficult task, let alone trying to find out numbers from previous years. In order to estimate this and provide a proxy for the effects of contractor

work, a raw number for the total number of people doing defense related work in private industry was added to the model. This provides a trend for the amount of analytical work that was outsourced per year. Given that this is an estimate, this introduces the possibility for errors in the estimation.

Because this research is dealing with estimation error, unexpected inflation is another control variable we added to the model. Because of the large amounts of dollars being expended, minor changes in the actual amount of inflation can have large effects on overruns.

The last two control variables are the total budget and the procurement budget of the Air Force. These last two control variables should account for any budget fluctuations that may constrain programs and cause them to be delayed, and consequently become over budget.

#### Model

The basic Cobb-Douglas Production function is given by: (Charles Cobb and Paul Douglas 1928).

$$Q = AK^{\beta}L^{\gamma} \quad (2)$$

Where Q is a measure of output, A is a technological parameter, K is capital, and L is labor. The model suggests that as more capital or more labor is added to an organization, the output increases. This model was adapted by simply adding another input variable, education (Lynch and Black 1995).

$$Q = K^{\beta}L^{\gamma}E^{\lambda} \quad (3)$$

In this study, Q is the amount of cost overruns, K represents the capital of the defense industries, L is reported labor, and E is education. L is simply the number of personnel in

the cost analysis career field, E is the education level of the personnel in this field.

Finally, we conducted a log-log transformation on equation (3) to linearize the functional form for ease of estimation.

$$\ln Q = \beta \ln k + \gamma \ln L + \lambda \ln E + \alpha X + \varepsilon \quad (4)$$

The natural log was not conducted on the budget, DAWIA and unexpected inflation variables due to the existence of observations with negative or zero values. As such, a semi-log interpretation will be made on these variables. The additional variable X is added to represent the vector of control variables. In the Cobb-Douglas Function, output can be many things but in this study it will be assumed that output is equal to cost overruns. Bartel (1994) used net sales as a proxy for output. A cost overrun is similar to a negative “net sale” for the Air Force, it takes away funds from other projects. It is also assumed that the capital of the defense industries, specifically, the Industrial Production of the Defense Industries, will be a good proxy for K, since this study is looking at contracts. These contracts are undertaken by the defense industries using in large part, their own capital, not the Air Force’s capital. The use of Industrial Production data is a standard proxy capital in the literature.

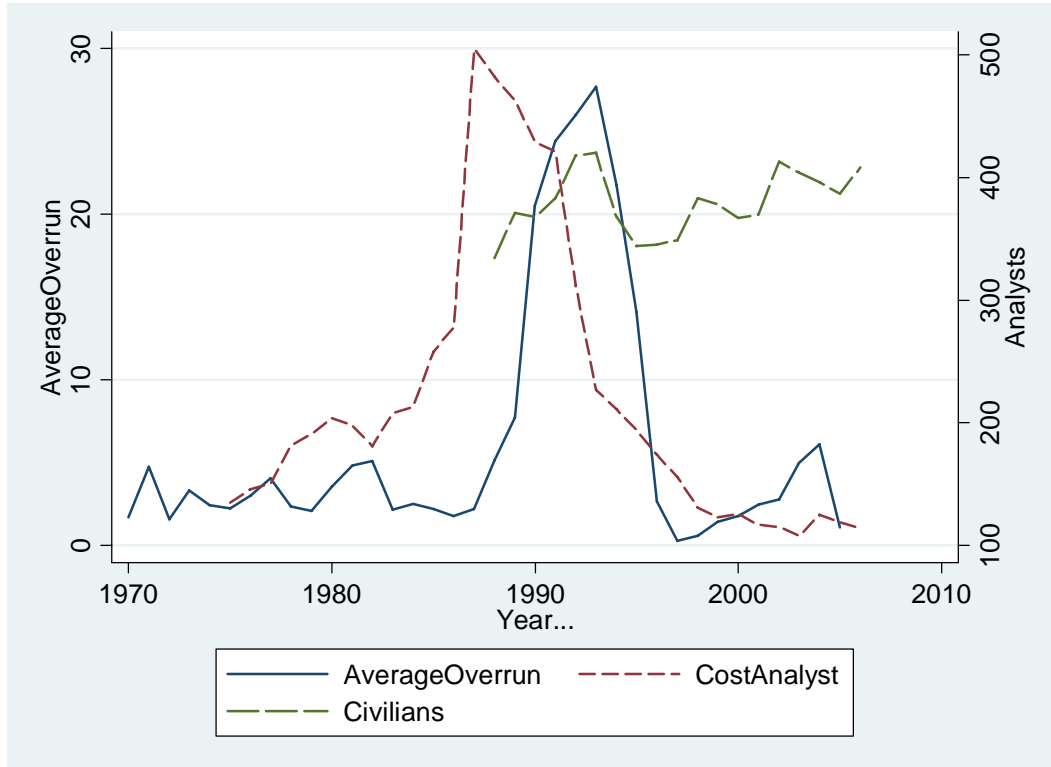
While there is a technological parameter in the equation, in some studies using the Cobb-Douglas production function, this is omitted. When a log transformation is conducted on the Cobb-Douglas function, the technological parameter, A, becomes the intercept in a linear equation. Since this study is only looking at the relationship between personnel, education, and cost overruns, which is the slope of the Cobb-Douglas function, the technological parameter will be given a value of 1, with no loss of generality.

## Summary

This chapter provided a review of the model to be used in the analysis, how it was derived, the variables being considered, why they are important and how they were collected. In the next chapter, the results of the analysis will be presented.

## IV. RESULTS

To begin, the key parameters of the analysis, cost overruns and military and civilian analysts were plotted against time, to get a visual representation of the data. Due to the range of the civilian data, this study ranged from 1988 through 2005.



**Figure 2: Cost Overruns vs. Military and Civilian Analysts**

Below are the summary statistics of the database. The mean cost overrun is 9.79% with a range of 0.284% to 25.71%. The number of military and civilian analyst range from 487 to 834 with a mean of 589. The percentage of MA/MS degrees averaged at 47% and ranged from 41.5% to 53.5%. This information will be used later in the chapter in the interpretation of the significant coefficients.

| Variable                   | Obs | Mean    | Std. Dev. | Min    | Max     |
|----------------------------|-----|---------|-----------|--------|---------|
| Overrun Percent            | 17  | 9.79    | 10.17     | 0.284  | 27.716  |
| AF Budget Change (Lag 2)   | 17  | -0.01   | 0.08      | -0.095 | 0.228   |
| R&D Budget Change (Lag 2)  | 17  | 0.003   | 0.10      | -0.154 | 0.287   |
| Procurement Change (Lag 2) | 17  | -0.001  | 0.14      | -0.212 | 0.322   |
| Percent MA/MS              | 17  | 47.00   | 3.32      | 41.487 | 53.541  |
| Capital                    | 17  | 112.26  | 16.29     | 90.100 | 148.500 |
| Number of Analysts         | 17  | 589.12  | 122.87    | 487    | 834     |
| AFIT Grads (Lag 1)         | 17  | 11.29   | 3.16      | 6      | 17      |
| Unexpected Inflation       | 17  | 0.0002  | 0.005     | -0.010 | 0.010   |
| Defense Employment         | 17  | 2777.94 | 540.22    | 2180   | 3850    |
| DAWIA                      | 17  | 0.71    | 0.47      | 0      | 1       |

**Table 1: Summary Statistics**

### Pre-Estimation Specification Tests

In order to conduct a time-series regression analysis, both the dependent and independent variables must be stationary. Any trends or drifts in the variables can lead to a spurious regression and faulty conclusions. If two non-stationary variables that have no relationship (for example height of a tree and GDP) are regressed on each other, it will appear as if the height of the tree is affecting GDP. The common procedure for ensuring stationarity is to first test for it using the Augmented Dickey-Fuller test. If the variable is found to be non stationary, the variable is replaced with the change in that variable from one year to the next, called the first difference. Using this procedure, the dependent variable, Number of Analysts, Education, Defense Employment and Capital variables required a first difference to become stationary.

The next step was to determine the lag lengths of the independent variables. The theory behind lags is that the presence of an independent variable may not be felt until later time periods in the dependent variable. To determine the appropriate lag length, each independent variable was regressed on the dependent variable with the results of the Akaike Information Criteria (AIC) and adjusted R squared shown in table 2. Because

adding an additional lag decreases the amount of useable observations and therefore causes the AIC to decrease, the AIC was divided by the number of observations to give the variance per observation; this was crosschecked with the R<sup>2</sup> value of the regression. In all cases, the AIC was minimized when the R<sup>2</sup> was maximized, except for the capital variable. As such, this lag was defaulted to a no year lag. The minimum AIC of the procurement variable occurred at the second lag with an R<sup>2</sup> of close to 0.00. Lag 0 and lag 3 of this variable also had an R<sup>2</sup> of close to zero. As such, the second lag was chosen in order to be consistent with the other budget variables. All variables, with the exception of AFIT Graduates which had a lag of 1, and the budget variables, which had a lag of 2, were maximized at no lags. The 2 year lag on the budget changes is to be expected. When budgets change, schedules and requirements consequently change to free up additional funds. As a result, an immediate effect probably would not be felt. It is reasonable to assume that the true effects of a budget change will not occur until later years.

|            | Cost Analysts |             | AFIT Grads         |              | Capital              |              | DAWIA             |             | AF Budget Change    |               |
|------------|---------------|-------------|--------------------|--------------|----------------------|--------------|-------------------|-------------|---------------------|---------------|
|            | AIC           | R2          | AIC                | R2           | AIC                  | R2           | AIC               | R2          | AIC                 | R2            |
| No Lag     | <b>2.71</b>   | <b>0.08</b> | 2.61               | -0.04        | 2.32                 | <b>-0.02</b> | <b>2.29</b>       | <b>0.03</b> | 2.33                | 0.00          |
| One Lag    | 2.80          | 0.00        | <b>2.48</b>        | <b>0.14</b>  | 2.30                 | -0.03        | 2.37              | 0.03        | 2.32                | -0.02         |
| Two Lags   | 2.91          | -0.06       | 2.63               | 0.05         | 2.30                 | -0.03        | 2.36              | 0.00        | <b>2.23</b>         | <b>0.04</b>   |
| Three Lags | 2.89          | -0.06       | 2.78               | -0.05        | 2.33                 | -0.03        | 2.37              | -0.03       | 2.28                | -0.02         |
| Four Lags  | 2.93          | -0.02       | 2.84               | -0.02        | 2.37                 | -0.04        | 2.35              | -0.01       | 2.27                | 0.03          |
| Five Lags  | 2.96          | 0.03        | 2.86               | -0.05        | 2.40                 | -0.04        | 2.40              | -0.03       | 2.28                | 0.04          |
|            | Education     |             | Defense Employment |              | Unexpected Inflation |              | R&D Budget Change |             | Proc. Budget Change |               |
|            | AIC           | R2          | AIC                | R2           | AIC                  | R2           | AIC               | R2          | AIC                 | R2            |
| No Lag     | <b>2.55</b>   | <b>0.22</b> | <b>2.33</b>        | <b>-0.02</b> | <b>2.28</b>          | <b>0.00</b>  | 2.33              | -0.01       | 2.32                | 0.008         |
| One Lag    | 2.73          | 0.07        | 2.37               | -0.03        | 2.33                 | -0.03        | 2.40              | -0.01       | 2.33                | -0.03         |
| Two Lags   | 2.78          | 0.07        | 2.40               | -0.03        | 2.35                 | -0.03        | <b>2.24</b>       | <b>0.02</b> | <b>2.27</b>         | <b>-0.006</b> |
| Three Lags | 2.90          | -0.06       | 2.43               | -0.04        | 2.37                 | -0.01        | 2.27              | 0.00        | 2.27                | -0.002        |
| Four Lags  | 2.93          | -0.02       | 2.46               | -0.04        | 2.41                 | -0.05        | 2.32              | -0.02       | 2.32                | -0.03         |
| Five Lags  | 2.95          | 0.04        | 2.48               | -0.02        | 2.41                 | -0.01        | 2.36              | -0.03       | 2.34                | -0.01         |

**Table 2: Lag Structure Determination**

## Post-Estimation Specification Tests

With the configuration of the dependent and independent variables determined, the next step was to perform diagnostic checks of the model. Tests for multi-collinearity, heteroskedasticity, auto-correlation, cointegration, normal distribution of the error terms and omitted variable bias were conducted.

To test for multi-collinearity, the Variance Inflation Factor (VIF) was calculated, see Appendix A. The mean VIF for the variables in the model was 3.79. Ideally, this value would be below 10 to ensure that no collinearity was present, so this model is within the safe zone for not having multi-collinearity.

In order to test for heteroskedasticity, two methods were used; a visual inspection as well as an empirical test of the data. To empirically test for heteroskedasticity, the Breusch-Pagan/Cook-Weisberg test was used. With a p-value of 0.4672, it is not possible to reject the null hypothesis that heteroskedasticity is present. For a visual inspection of the residuals, see Appendix B.

To test for auto-correlation of the residuals, the Durbin Watson's d-statistics and the Durbin's alternative test for autocorrelation were used. The d-statistic was 2.36. With 17 observations and 10 variables, the d-statistic should be between 0.197 and 3.184 in order to not be auto-correlated. As such, the d-statistic was within the safe zone. The alternative test for autocorrelation yielded a  $\text{prob} > \chi^2$  of 0.287, with the null being no autocorrelation, so it is not possible to reject that there is no autocorrelation present.

The next test was to ensure there was no cointegration of the error terms. Even though the variables are stationary or made stationary by first differencing, the combination of the variables could be creating a non-stationary process. The Augmented



Dickey Fuller test was conducted on the residuals to ensure they are stationary. The result was a test statistic of -6.65, with a 1% critical value of -3.75, giving a p-value of 0.000. Therefore, we can be assured that the residuals are stationary.

The last test is to ensure that the error terms are normally distributed. To test for this, two different tests were conducted; a visual inspection, and an empirical test. The visual inspection of the residuals, located in Appendix C, shows that the error terms appear to fairly normally distributed. The Shapiro-Wilk test revealed that the degree of skewness and kurtosis were significant to the 0.422 and 0.382 level respectively, with a joint prob>chi2 of 0.4549, not enough to conclude that the residuals are not normally distributed.

The Ramsey RESET test was used to test for omitted variable bias and for misspecification of the model. With a prob>chi2, it is not possible to reject the null hypothesis that the model has no omitted variables. In addition, exogeneity was not considered an issue since this model is derived from the theoretical relationship of the Cobb-Douglas Production Function.

## Results

The results, with the required specification changes based on the above diagnostic tests, are displayed in table 3 below:

Number of obs = **17**  
R-squared **0.8365**  
Adjusted R-squared **0.5639**

| 1st Diff ln (Cost Overrun Percentage)     | Coef.         | Std. Err.    | t            | P> t         |
|---|---------------|--------------|--------------|--------------|
| Proc. Budget Change (Lag 2)               | <b>2.86</b>   | <b>2.41</b>  | <b>1.19</b>  | <b>0.281</b> |
| R&D Budget Change (Lag 2)                 | <b>3.23</b>   | <b>2.86</b>  | <b>1.13</b>  | <b>0.302</b> |
| Total Budget Change (Lag 2)**             | <b>-17.62</b> | <b>5.41</b>  | <b>-3.25</b> | <b>0.017</b> |
| 1st Diff ln (Education)*                  | <b>-9.64</b>  | <b>4.53</b>  | <b>-2.13</b> | <b>0.077</b> |
| Ln (AFIT Grads) lag 1                     | <b>-0.50</b>  | <b>0.84</b>  | <b>-0.6</b>  | <b>0.572</b> |
| 1st Diff ln (Capital)                     | <b>6.56</b>   | <b>3.78</b>  | <b>1.73</b>  | <b>0.134</b> |
| 1st Diff ln (Military/Civilian Analysts)* | <b>-10.06</b> | <b>4.86</b>  | <b>-2.07</b> | <b>0.084</b> |
| DAWIA***                                  | <b>-2.21</b>  | <b>0.54</b>  | <b>-4.1</b>  | <b>0.006</b> |
| 1st Diff ln (Defense Employment)**        | <b>12.56</b>  | <b>4.46</b>  | <b>2.82</b>  | <b>0.030</b> |
| Unexpected Inflation                      | <b>108.34</b> | <b>62.31</b> | <b>1.74</b>  | <b>0.133</b> |
| cons                                      | <b>2.37</b>   | <b>1.95</b>  | <b>1.21</b>  | <b>0.270</b> |

Notes

- \*Significant to the 10% level
- \*\*Significant to the 5% level
- \*\*\*Significant to the 1% level

**Table 3: Time-Series Regression Results**

According to the results, total budget change, education, number of analysts DAWIA and Defense Employment are all significantly correlated with the amount of cost overruns in a given year.

The results show that adding more analysts is correlated with a reduction in cost overruns. Specifically, for every 1% the number of military analysts is increased, the cost overrun percentage decreases by 10%. On average, there are 597 cost analysts in the AF and a 10% contract cost overrun occurs. If the amount of military analysts is increased by 1%, or 6 analysts, the percentage of cost overruns could be expected to decrease by  $(10 \times 1) = 1.0$ .

Increasing the number of MA/MS degrees is also correlated with a reduction in cost overruns. For every 1% the percentage of MA/MS degrees is increased, cost overruns drop by 0.0964%. On average, there are 46.7%, or 279, analysts with a MA/MS degree. If this number is increased by 1%, or 3 more MA/MS degrees, cost overruns

would decrease by  $(10 \times 0.00096) = 0.0096$ . Adding 30 more MA/MS degrees could decrease overruns by 0.096.

The Air Force total budget was also a significant contributor to overruns. According to the results, for every 1% the total budget is increases, the amount of cost overruns would decrease by 0.176%. On average, with a 10% cost overrun, adding 1% to the budget could decrease the amount of overruns by  $(10 \times 0.00176) = 0.0176$ . This makes a strong case for the importance of budget stability in acquisition programs.

The proxy for defense contractors, defense employment, was also significant. However, it had the opposite sign that would be expected. The coefficient indicates that if the amount of defense employees is increased by 1000, overruns would actually increase by 12.5%. This seems counterintuitive. A possible explanation is that this variable is also acting as a size variable. As the Air Force gets bigger, we incur more overruns. It could be that the Air Force has become too large and has entered into an area of diseconomies of scale. This fact could also be seen in the capital variable. Even though this variable was not significant, it had a positive sign as well indicating that as the Air Force gets bigger, more overruns follow.

The last significant variable was the Defense Acquisition Workforce Improvement Act. This variable had a coefficient of -2.21. Because this is a dummy variable, transforming this into a meaningful number requires the use of the equation (Patricia A. Champ, Kevin J. Boyle and Thomas C. Brown 2003)

$$g = (e^{\beta} - 1) * 100$$

Where  $g$  is the percentage effect of the dependent variable, and  $\beta$  is the coefficient of the variable. The resulting percentage effect DAWIA has on cost overruns is 8.9%. This

would mean, on average with a cost overrun percentage of 10%, the occurrence of DAWIA has dropped cost overruns by 0.89. This is counter to other studies that found a positive relationship between DAWIA and overruns. It could be that when controlling for human capital factors, DAWIA has actually helped to reduce the amount of overruns.

The unexpected inflation variable is also worth mentioning. This variable was marginally significant to the 0.13 level. However, the sign of the variable was positive, as you would expect, indicating that as the amount of unexpected inflation increases, cost overruns increase. The magnitude of the variable indicated that if unexpected inflation increased by 1%, the amount of overruns increase by approximately 1%, almost a 1 to 1 ratio.

Some of the magnitudes of the coefficients seem relatively small but when you consider the amount of money that is involved, the values are fairly significant. Table 4 below summarizes the significant variables and puts them into perspective in terms of the dollar amounts that are involved.

---

|                         |                |
|-------------------------|----------------|
| Procurement Budget 2006 | \$32.6B        |
| R&D Budget 2006         | <u>\$21.1B</u> |
| Total                   | \$53.7B        |
| 10% Average Overrun     | <u>0.1</u>     |
| Total Overruns          | \$5.37B        |

|                                  | <u>Percentage Effect</u> | <u>Dollar Amount</u>   |
|----------------------------------|--------------------------|------------------------|
| Add 3 degrees                    | 0.10%                    | \$5,155,200.00         |
| Add 6 Analysts                   | 0.10%                    | \$5,370,000.00         |
| Subtract 1000 Defense Employees  | 0.13%                    | \$6,981,000.00         |
| Add 1% to Budget                 | 0.17%                    | \$9,129,000.00         |
| Decrease Unexpected Inflation 1% | <u>0.10%</u>             | <u>\$5,370,000.00</u>  |
| Total percent decrease           | 0.60%                    | <b>\$32,005,200.00</b> |

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**Table 4: Associated Dollar Amounts for Significant Coefficients**

Given that the 2006 Air Force procurement budget was \$32.6B and the R&D budget was \$21.1B, for a total of \$53.7B, and overruns average 10% per year, there is an overrun of \$5.37B per year. Multiplying this number by the associated percentage effects of the significant coefficients, the column on the right shows how much money is involved with these changes. It can be seen that by making these changes, the Air Force could either save or more accurately budget for approximately \$32B dollars. It is yet to be determined if this is an actual savings or just money that would be more accurately predicted. More discussion of this will follow in the next chapter.

## V. DISCUSSION

An area of future research could be to optimize the number of cost analysts and their education levels based on the cost of acquiring new personnel, sending them to school, giving them training and finally enough experience to become productive workers. Taking this cost into account and comparing it to the expected decrease in cost overruns, a better decision can be made as to whether or not the Air Force will ultimately do better with more analysts. This is because a decrease in overruns may or may not coincide with an actual saving. The results show that adding more analysts can decrease the amount of overruns. However, this could just indicate that we are better able to estimate the cost of the weapon system and therefore would not incur any overruns. The cost of the weapon system remains the same; we just better predicted the price. The greatest benefit would occur in correctly forecasting budgets and allocating resources. It was seen that budget fluctuations have a significant effect on overruns. If we can more accurately budget resources, we can subsequently maintain stable budgets for acquisition programs and could then possibly save money.

Also, the number of observations in the study was relatively low, only 17. One way to increase the number of observations is to incorporate the other services into the study. This would greatly enhance the credibility of the results. We suspect that the same results will hold if the other services are added since it appears the same relationship exists; it was seen that the other services are building up their cost analysis manpower and at the same time they are experiencing less overruns than the Air Force.

The effect of budget fluctuations is another area that needs further study. Even though the coefficient on the Total Budget variable was negative, it may not be cost

effective for the Air Force to increase its budget in hopes of making up the difference from decreased overruns. The coefficient on this variable implies that by increasing the total budget by 1%, the amount of cost overruns will decrease by 0.17%. The total budget of the Air Force is roughly \$120B, increasing this by 1% would cost the Air Force \$1.2B. Overruns are typically in the area of \$5.3B per year. If the total budget is increased by 1%, it would be expected that overruns would decrease by 0.17% or \$9.1M. This would end up costing the Air Force \$1.19B. Of course, the reverse is also true. If the Air Force cuts the budget by 1%, the difference would be a savings of \$1.19B.

More research is needed into this area to fully understand the implications of budget changes, the resulting cost overruns, and the potential savings that could occur. A more micro view is probably needed. Looking at the programs individually and looking to see if the program had a decrease in their budget, what did that do to their overruns? Did the program continue spending at the previous rate and end up overrunning at the same amount that they were cut? In which case, there would be no savings. Did the program tighten up and spend more prudently and end up overrunning less than they were cut? This would result in an overall net savings. Or in the last scenario, did the program end up overrunning more than they were cut because schedules were slipped and requirements were delayed. In this case, the cut in funds actually ended up costing the Air Force money.

Also, the total budget variable should be looked at more closely. This variable was significant, however the other budget variables, procurement and R&D, were not. These are the variables that you would expect to have an effect on overruns since the acquisition programs are funded with these appropriations. Is it because procurement and

R&D alone do not have an effect on overruns but the two together do? If not, what is it about the total budget that is correlated with overruns? Is it the MILCOM, O&M, or MILPERS portions? If this is the case, causation couldn't be inferred because these appropriations do not fund acquisition programs.

In conclusion, this research set out to determine if there is a relationship between human capital and cost overruns. Based on previous literature, it was seen that a historical link has been established between performance levels, number of personnel and education levels. Using the lessons learned from these studies and the theoretical relationship of inputs to outputs in the form of the Cobb-Douglas function, an analysis was conducted relating Air Force cost analysts to contract cost overruns. From this analysis, it was seen that there is a significant relationship between the number of analysts, their education levels and the amount of cost overruns that occur. Depending on the cost of acquiring new personnel and the cost of sending them to school, it is possible that the Air Force could garner significant savings by adding more analysts with higher education levels. Other policy implications from the study are the importance of maintaining stable budgets and of accurately predicting inflation. In addition, the DAWIA act was seen to have a decreasing effect on overruns.

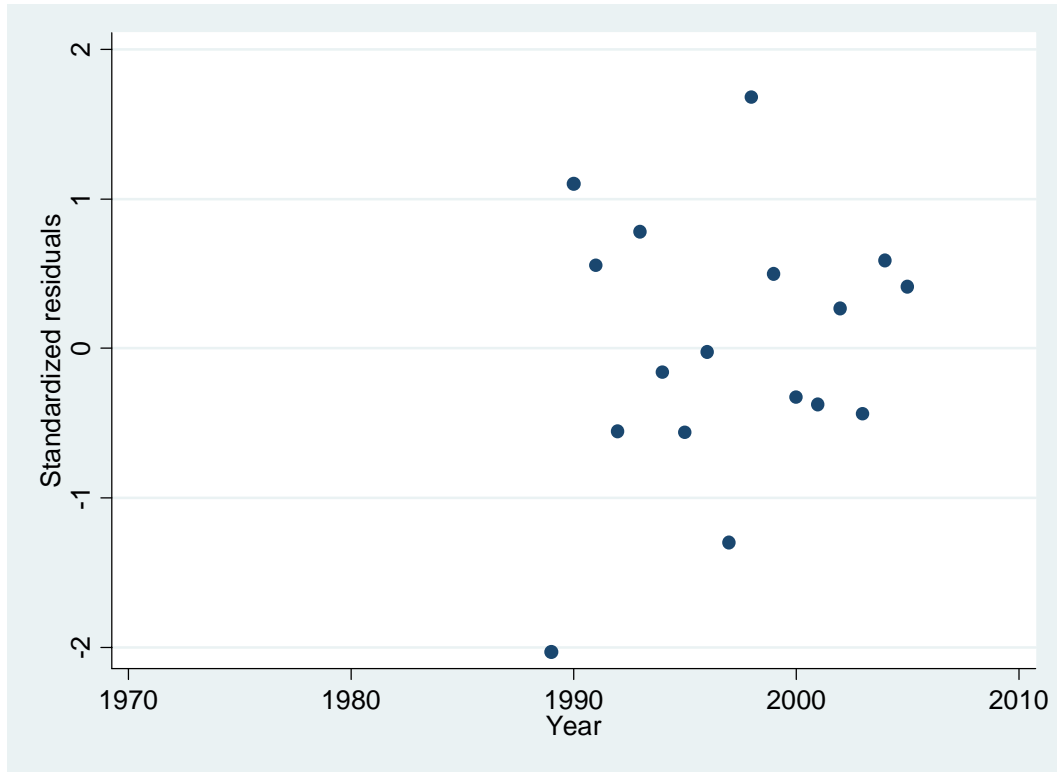


## Appendix A: Variance Inflation Factor

| Variable                           | VIF  |
|------------------------------------|------|
| ln (Mil/Civ Analysts)              | 7.46 |
| DAWIA                              | 5.36 |
| ln (capital)                       | 4.71 |
| Total Budget Change (2 Lags)       | 4.53 |
| ln (Defense Employment)            | 3.61 |
| ln (Mil/Civ Education)             | 2.71 |
| Procurement Budget Change (2 Lags) | 2.68 |
| ln (AFIT Grads)                    | 2.48 |
| R&D Budget Change (2 Lags)         | 2.23 |
| Unexpected Inflation               | 2.13 |
| Mean VIF                           | 3.79 |

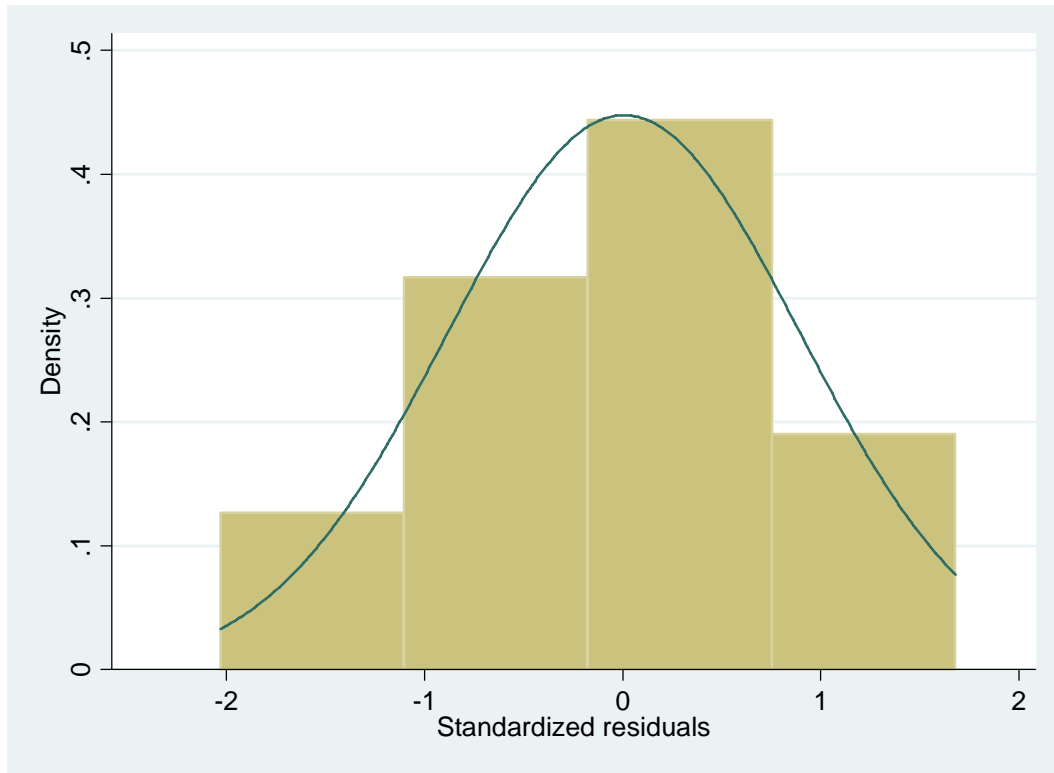
**Table 5: Variance Inflation Factor**

## Appendix B: Variance of Residuals



**Figure 3: Variance of Residuals**

### Appendix C: Distribution of the Error Terms



**Figure 4: Error term distribution**

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## Vita

Capt Jeffrey Feuring graduated from Wentzville High School in Wentzville, Missouri in 1997 and was accepted into the United States Air Force Academy class of 2001. After graduating from the Air Force Academy, Capt Feuring entered the Finance career field and was stationed at Hurlburt Field, Florida. Assigned to the 16<sup>th</sup> Comptroller Squadron, Capt Feuring worked as Deputy Budget Officer, Budget Officer, Deputy Financial Service Officer and Deputy Disbursing Officer. In 2004, Capt Feuring deployed to various units in the Middle East as an auditor for a deployed comptroller cell within SOCOM. After leaving Hurlburt Field, Capt Feuring was accepted to the Air Force Institute of Technology and is currently working on obtaining a master's degree in Cost Analysis. After graduation, Capt Feuring will be assigned to the FMC division at Los Angeles Air Force Base, California.

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| 14. ABSTRACT<br><br>Previous studies have established a link between Human Capital and performance both at the firm and the individual level. These studies have shown that performance can be improved with additional personnel and/or higher education levels. This study attempts to build on this relationship by using the Cobb-Douglas Production function to relate inputs to outputs. The inputs to the function are the number of cost analysts positions, military and civilian, and an education variable for the number of master's degrees in the field. The measure of output is the average cost overrun of Air Force contracts. A time series regression was conducted while controlling for other economic factors such as budgetary fluctuations and inflation. The results show positive effects of Human Capital on performance. Other policy implications of the study are the importance of budgetary stability, inflation predictions and the Defense Acquisition Workforce Improvement Act (DAWIA). |             |                                   |   |   |  |
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