Cost Growth Above Inflation (CGAI) in Operating and Support (O&S) Costs in Raw Materials for Air Force Aircraft

THESIS

Gregory J. Ferry, Captain, USAF

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

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THESIS

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Gregory J. Ferry, BS

Captain, USAF

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Gregory J. Ferry, BS
Captain, USAF

Approved:

Edward D. White, PhD, USAF (Chairman) Date

Jonathan D. Ritschel, Lt Col, PhD, USAF (Member) Date

Samuel A.Wright, PhD, USAF (Member) Date

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Abstract

Cost growth above inflation (CGAI) is the cost growth that exists after adjusting for the effects of currency inflation over time. The time value of money would suggest the increase in Operating and Support (O&S) costs over time would only be affected by inflation. In essence, every year aircraft need to be maintained at the same level and O&S costs should not change, assuming the same level of requirements. If CGAI exists in O&S there will be a large inaccuracy in the total life cycle cost (LCC) of weapon systems and an inaccurate budget put in place. An inaccurate estimate of O&S costs lead to budgeting problems and creates future budget issues.

This study begins an exploration of CGAI and attempts to measure the relationship of the cost growth to unaccounted increases in raw material cost. Specifically, an evaluation CGAI through an analysis of raw material costs from a period of 2000 to 2012 for Air Force aircraft. Raw material costs ideally should only be affected by inflation, and thus any cost growth beyond inflation indicates a problem. A better understanding of inflation-adjusted cost growth provides understanding why O&S cost continues to increase beyond the rate of inflation.

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Dedicated to my friends and family

Acknowledgments

First, I could not have done this without the love and support of my friends and family. Second, I would like to thank my advisor Dr. White for guiding me through this long and arduous process. I would next like to thank my mentor in the process Dr. Wright for his guidance and support during this endeavor. Lastly, I would like to thank LtCol Ritschel for superb encouragement and leadership.

Gregory J. Ferry

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Cost Growth Above Inflation (CGAI) in Operating and Support (O&S) Costs in Raw Materials for Air Force Aircraft

I. Introduction

Background

The Department of Defense (DoD) ensures a level of national security and safety for the American people by maintaining current weapon systems and funding development of future weapon systems. Recent Congressional limitations on the national defense budget coupled with ever increasing defense costs have created a difficult financial environment to ensure the defense readiness and security of our nation. Thorough planning and prioritization of resources in the face of a declining budget is just as crucial to our national defense as the weapons. As Admiral Mullens, the Chairmen of the Joint Chiefs of Staff stated, “continually increasing debt is the biggest threat we have to our national security.” (O’Keefe, 2011).

To force a reduction of deficit spending, the US Congress passed the Budget Control Act of 2011. The act calls for a committee to produce legislation providing a deficit reduction in the Congressional Budget in the amount of $1.2 trillion, and if no plan is successfully drafted the DoD will incur approximately half of the cuts. According to the Secretary of Defense, Leon Panetta, maximum sequestration of the defense budget would result in cuts of roughly $100 billion a year and force a mass reduction in the size of the military (O’Keefe, 2011).

The wary fiscal environment and the unknown future of the defense budget put a renewed importance on presenting accurate total life cycle costs (LCC) for weapon systems. LCC are the “cradle to grave” costs of a weapon system and are crucial for decision makers (Office of Secretary of Defense, 2003). In order to formulate a national defense strategy the decision makers must know the level of capabilities that can be afforded. The LCC cost estimates help to set the guideline for future costs and set the foundation for shaping the affordability of the national defense's future capability. The inaccuracy of LCC cost estimates affects the implementation of our defense strategy and hinders the execution of our forces. The largest portion of LCC come from operating and support (O&S) costs; history indicates O&S account for 70% or more of the total life cycle cost (GAO, 2000).

O&S encompasses all program costs from the time of initial system deployment through the end of operation. This includes all sustainment costs for a weapon system, which include operating, maintaining and supporting a fielded system (DoD CAIG, 2007). With over 70% of LCC accounted for in O&S there is great importance in ensuring O&S estimates accurately model raw material demand, personnel requirements, facilities, training, configuration management, engineering support, reliability growth and maintenance costs. Decision makers must be confident the LCC costs are accurate when planning future defense strategies because they often have to balance cost with capability.

Once a weapon's system O&S budget is estimated for the initial rollout of a program, future costs are extrapolated by adjusting for currency inflation. Audits evaluating O&S budget allocations have illustrated that this method is under-predicting future O&S costs. From 1996 to 2011 O&S costs rose by 6% per year, 4.3% greater than general inflation (SAF FMCC/FMBP, 2012). Cost growth above inflation (CGAI) is the cost growth that exists after adjusting for the effects of currency inflation over time. The time value of money would suggest the increase in O&S costs over time would only be affected by inflation. In essence, every year aircraft need to be maintained at the same level and O&S costs should not change, assuming the same level of requirements.

If CGAI exists in O&S there will be a large inaccuracy in the total LCC of weapon systems and an inaccurate budget put in place. An inaccurate estimate of O&S costs lead to budgeting problems and creates future budget issues. If future budgets are not accurately put in place there is a potential decision makers will have to cancel funding on programs in order to pay for O&S costs of current programs. Increasing O&S costs are must-pay bills and could force the DoD to reduce research and development (R&D) efforts in order to pay for the current fleet.

The Air Force Total Ownership Cost (AFTOC) is a data warehouse, which is fed by fourteen sources (Kunc, 2008). One of the financial sources feeding AFTOC is the Standard Base Supply System (SBSS). SBSS is "a computerized system to account for supplies and equipment at the base level" (USAF Supply Manual, 2012). AFTOC contains actual costs of all major Air Force weapons systems, and is used to help satisfy congressional reporting of O&S costs (Kunc, 2008). This study uses AFTOC to collect actual cost data. By using AFTOC, fed by SBSS, the database allows for evaluation of O&S costs of weapon platforms at the line replaceable unit (LRU) level. The evaluation of CGAI takes place at the LRU level for Air Force aircraft. The data set from AFTOC contains 32,765 unique national item identification numbers (NIINs). The data set provides a complete base level inventory of purchases for 103 different Air Force aircraft.

Problem

The Congressional Budget Committees rely on accurate cost estimates from the Air Force to determine budget allocations and prioritize DoD capability expenditures. As O&S costs increase beyond inflation the estimates are not accurately predicting budget requirements for current programs. The ability to accurately show the LCC cost of program greatly relies on the accuracy of the O&S estimate. If cost estimators fail to adjust for CGAI, senior leaders and decision makers will inadequately allocate resources.

There are several potential areas where there may be CGAI. Potential areas where CGAI may exist include: raw materials, operational requirements, aircraft age, workforce skills, maintenance practices, military compensation, civilian compensation, and fuel costs. This research looks at the raw material costs, and the accuracy of the inflation indices. Specifically, we evaluate CGAI through an analysis of raw material costs from a period of 2000 to 2012 for Air Force aircraft. Raw material costs ideally should only be affected by inflation, and thus any cost growth beyond inflation indicates a problem.

The Office of the Secretary of Defense (OSD) has emphasized that a better understanding of spending on equipment, including raw materials, "would aid the Congress and DoD officials in understanding the role that equipment costs play in driving total spending" (US Congressional Budget Office, 2001). The current uncertainty surrounding the existence of cost escalation of raw materials requires new research to quantitatively measure the effect of this cost growth. By analyzing a large inventory of LRU cost variations over a period of time, the influence of product specific trends are minimized and a general change in raw material cost can be estimated. This fundamental exploration of changing prices will aid understanding and defining CGAI and allow for a uniform method of O&S cost estimating to be developed.

Purpose of this Study

This study explores CGAI and attempts to measure the relationship of the cost growth to unaccounted increases in raw material cost. The efforts in this thesis aim to answer the following questions:

1) Are raw material costs a source of CGAI?
2) Do the DoD inflation indices accurately account for inflation?
3) Should an adjustment factor be applied to raw material costs?

Under tighter financial restrictions the DoD will require greater accuracy of O&S cost estimates. Today’s acquisitions involve a significant future financial commitment and the DoD needs to ensure the future commitments are accurately being estimated (GAO, 2012). Raw materials, or equipment, are a vital component of O&S and fundamental to the cost to operate weapon systems. Exploring the influence of raw materials in O&S costs, and the existence of rising cost over time is crucial to identifying where CGAI exist. This thesis attempts to identify if raw materials costs are increasing beyond the rate of inflation and the accuracy of O&S inflation indices. Identifying if raw materials are generating cost growth above inflation helps decision makers now appropriately budget for the increasing costs. This also is crucial to portfolio analysis and it could change decisions on continuing further development versus modernization.

Study Process

The study process begins with background information on what CGAI is and how it is measured. A clear understanding of the different ways O&S cost growth and the effects of inflation are evaluated. A better understanding of inflation-adjusted cost growth provides the ability to begin applying the effects of raw material and inflation indices on increasing O&S costs. Raw material is a key component to understanding why O&S cost continues to increase beyond the rate of inflation.

This thesis is divided into five chapters. Chapter I provides background on the importance of weapon systems cost estimation in relation to Air Force and DoD budgets. Chapter II presents a more detailed background of previous O&S cost estimating and CGAI. Past research is analyzed and dissected allowing the reader to gain a historical perspective and establishing a plan on new ways to examine the problem. This literature review leads to Chapter III where the methodology of the research is made clear. The methodology will provide the framework to be followed in conducting the research on CGAI. In Chapter IV the results of the research are presented to the reader. Chapter V provides a summary and conclusion of the research analysis, along with recommendation for future research.

II. Literature Review

Chapter Overview

This chapter explores the historical existence of cost growth above inflation for O&S costs of the DoD. Measuring cost growth is traditionally done as a ratio of an early LCC estimate to the current estimate or the actual final cost of a program (Arena, Leonard, Murray, & Younossi, 2006). Inadequacies in O&S estimates led to a General Accounting Office (GAO) investigation into the accuracy of O&S estimates. This report found that "estimated weapon system O&S costs are often inconsistent and sometimes unreliable, limiting visibility needed for effective oversight of these costs" (GAO, 2012). The necessity to provide consistency in O&S cost estimates requires a more thorough understanding and application of cost growth above inflation.

This discussion begins with an exploration of reports and studies that examine the existence of cost growth above inflation. Studies have shown the existence of an inflation-adjusted cost growth in DoD weapons programs, but have not identified the root cause. After examining cost growth above inflation the discussion moves to the factors that cause non-inflation growth in O&S.

Next, the research on inflation indexes used within the DoD and the resultant accuracy in estimation is evaluated. It is critical to examine how the DoD adjusts for inflation to accurately interpret the CGAI. Following is a breakdown of the different methods for accounting for cost growth above inflation in O&S estimates. Following the discussion of previous research is a brief conclusion of the literature review.

Cost Growth Above Inflation

Inflation

To begin to comprehend the nuances involved in cost growth above inflation requires a careful look at inflation. Inflation is an economic phenomenon that explains the increasing price of goods and services over time (Blanchard, 2000). This phenomenon can easily be mistaken as cost growth, but a careful differentiation should be made. It makes sense the cost to operate and maintain weapon systems, specifically aircraft, will cost more in the future because of the price of the goods and services on which the O&S costs are based rise with inflation. This issue is not worrisome to estimators and decision makers, as long as the increasing prices are following the anticipated change in inflation. The increasing prices to maintain and operate aircraft become troublesome when the cost growth exceeds that of the rate of inflation. The growth experienced after accounting for the effects of inflation will be defined as the cost growth above inflation.

Cost Growth

The discussion of cost growth in weapons acquisitions is not a new or recent development. The desire to garner a more comprehensive understanding of defense acquisition, and specifically cost estimating, is evident from more than 130 studies and commissions that were accomplished since World War II (DoD, 2009). Of those studies, dozens relate to the accuracy of cost estimating (Ryan, et al, 2012). The collective goal of all of these studies is to try and eliminate the error in cost estimates and underreporting of expected expenditures. A RAND study exploring the sources of cost growth succinctly defined cost growth as, “the ratio of a weapon system’s current estimate of cost to that of some earlier estimate” (Hough, 1992). For the purposes of this study cost growth will similarly be defined; however, instead of estimates we will be dealing with actual cost totals reported to the GAO.

CGAI

Mistakenly, authors use CGAI to suggest a failure in cost estimating to accurately anticipate increasing costs caused from inflation. CGAI instead suggests something within the original estimate is increasing at a rate beyond the anticipated inflation for the item. It is premature to assume the inability to accurately predict cost growth is due to inflation estimator error or faulty use of the DoD inflation indices. In fact, the unexplained cost growth above inflation may imply the requirements, or resources, of operating and maintaining aircraft increases over the entire life cycle of the program.

In 2001, The United States Congressional Budget Office (CBO) investigated the existence of cost growth above inflation. The Congressional study called for a look at the increasing cost of maintenance to aircraft. In the study the CBO found the appearance of cost growth above inflation. More specifically, the study found evidence that the cost to maintain aircraft was increasing each year, even after adjusting for inflation (US Congressional Budget Office, 2001). The CBO study looked at the increasing sustainment costs using two different methods. The study expressly looked at the rising costs in Operation and Maintenance (O&M). O&M is one of the components that comprise the overarching O&S costs. Besides O&M, O&S costs include military personal costs (MILPERS), but no disposal costs (DAU, 2012). The study found cost growth above inflation in O&M of 1 to 3 percent, per year (US Congressional Budget Office, 2001). The CBO did not provide any comments to the root cause of the rise in cost above the rate of general inflation. The study used both the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) to pull O&S data, and the Air Force's AFTOC system. The study only looked at major defense acquisition programs (MDAP), and both findings were statistically significant.

The Office of the Secretary of Defense (OSD) also looked into the existence of increasing cost to maintain existing DoD weapon systems. The OSD Cost Assessment and Program Evaluation (CAPE) performed a study investigating increasing costs. The study found CGAI to be between 2-3% on DoD weapons systems (Anderson, 2012). The study used the DoD deflators to calculate how much annual growth was seen in DoD weapon systems after adjusting for inflation. This study compared the percentage of cost growth in O&S over time, versus the percentage of growth in inflation over the same period. However, it fails to identify the root causes for this cost growth. Without digging into the actual expenditures in O&S cost there is little insight into the contributing factors of CGAI.

Raw Materials

There are many different parts that make up maintenance costs of an airplane. The foundation of sustaining an aircraft is ensuring the aircraft has properly maintained parts. The raw materials used in the maintenance process are a source of O&S costs. The Congressional Budget Office estimates that nine percent of the total O&M budget is spent on replacement equipment, which equates to $9.6 billion annually (US Congressional Budget Office, 2001). Raw materials make up the parts on the aircraft that ensure it is operational and ready for it's mission. Individual aircraft parts may seem trivial, but these raw materials make up a substantial portion of total maintenance costs. Approximately 20 percent of total O&M spending is comprised of raw materials (US Congressional Budget Office, 2001). The same Congressional study went on to state, "O&M spending for most types of equipment has not risen in the past decade" (US Congressional Budget Office, 2001). The declarative statement by the Congressional Budget Office is not backed up with any calculations, or citations. Evaluation of National Item Identification Numbers (NIINs) with part specific information aids in either confirming or disproving the declaration. Raw materials provide a unique ability to identify changing costs over time because the numbers used are the actual purchased price of the materials.

The raw materials used on aircraft do not change over time and are identified with a nine digit NIIN. Table 1 depicts NIIN 004424412, a butterfly valve, used on the C-5. Tracking individual NIIN costs over time allows for insight of price changes. Using the example of NIIN 004424412, the average unit NIIN price for the part is plotted over time and is depicted in Figure 1.

Ideally, price changes in the cost of the NIINs will track with inflation. If the NIIN cost growth tracks with inflation then there is no additional cost growth above inflation; however if the costs of the NIINs are increasing at a more rapid rate than inflation, then that suggests evidence of CGAI.

Table 1 NIIN Example

NIIN	Description	Airframe
004424412	Butterfly Valve	C-5A

The government agencies are interested in understanding how the cost of raw materials is changing over time. The quest for better understanding of the changing prices in raw materials became intensified when the Senate Budget Committee asked the CBO to analyze defense spending and the extent materials are affecting the growth (US Congressional Budget Office, 2001). The CBO study went on to explain, “there are few sources of data on those cost[s] for individual pieces of equipment” (US Congressional Budget Office, 2001). The lack of insight into the actual cost of equipment and parts highlights the need for further analysis of specific parts.

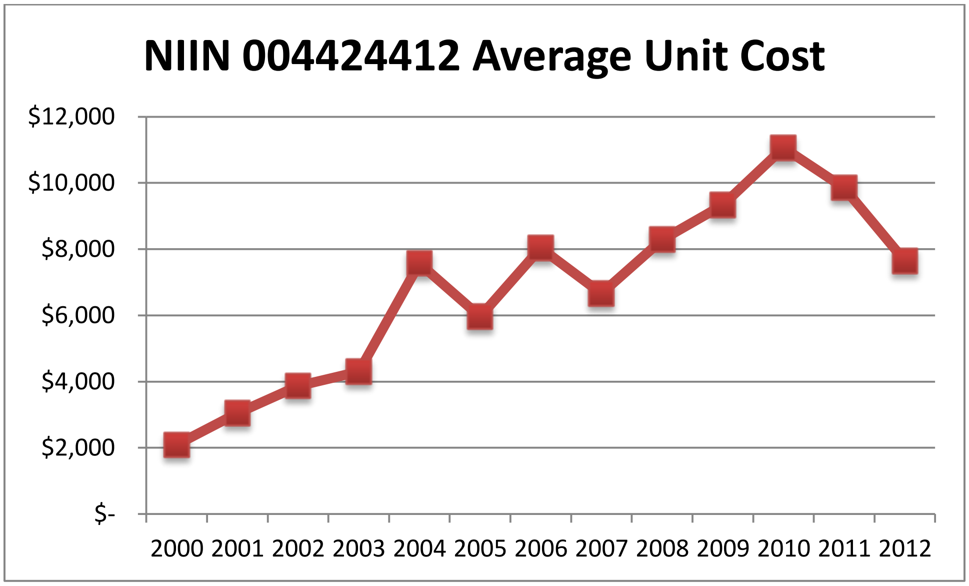


Figure 1 NIIN 004424412 Average Unit Cost Over Time in Then-Year Dollars

This study attempts to provide greater insight into the actual equipment cost over time, and to examine one potential cause of CGAI. To look at the cost of equipment over time the research breaks down cost per part, per year, by NIIN. This will provide insight into the actual cost of parts over time.

Inflation Indices

As discussed earlier, inflation is the general rise in prices for goods and services over time. The DoD uses inflation indices to estimate and adjust for future costs of products. For instance, the DoD would use inflation indices to forecast the future costs of raw materials based on the rising prices caused by inflation. A unique quality about the DoD's indices is that it is an attempt to predict future escalation in prices, opposed to inflation adjustments for social security and retirement pay which focus on prior information (Military Reform Caucus, 1985). Proper implementation of inflation indices is key to normalizing cost data for changes in currency value. Proper application of inflation indices ensures the effects of inflation are not influencing the cost growth.

To ensure the DoD has a proper understanding of the inflation indices the 2009 Weapon System Acquisition Reform Act (WSARA) requires the CAPE to "…periodically assess and update the cost (or inflation) indexes used by the Department to ensure that such indexes have a sound basis and meet the Department's needs for realistic cost estimation" (Horozitz, 2012). Improperly adjusting for effects of inflation create an incomplete computation of cost growth and can either underestimate or overestimate the amount of true cost growth (Arena, et al, 1994).

There are two major uses of DoD inflation indexes; estimating in then-year (TY) dollars for future budget requirement and calculating real system cost growth. The latter is often used in identifying Nunn-McCurdy breaches and thresholds (Horozitz, 2012). Nunn-McCurdy thresholds are designed to trigger action when average procurement unit cost goes beyond 25 percent of the current estimate, or 50 percent of the original estimate (DAU, 2010). In order to accurately predict the "most likely or expected full costs" when budgeting for future costs program managers encourage the use of program-specific information (Horozitz, 2012). These inflation indexes can differ from OMB's indexes because the estimators for the program may choose other indices they believe may more accurately predict the future growth. These factors could be developed at the program level and be used to help to reduce the risk of systematically under-funding programs.

Price indexes are intended to adjust for inflation, solely capturing the change in price at a certain level of function. The index should not capture a change in product quality, or enhanced/reduced functionality (Horozitz, 2012). This is key to ensuring the goal of capturing only real CGAI, and not the artificial growth caused by inflation or by changes in the product.

There is still great uncertainty in how to best capture inflation in DoD programs. The DoD Financial Management Regulation (FMR) provides conflicting guidance on how to account for inflation. First, the FMR states the estimate should "reflect the most likely or expected full costs," while the next paragraph states the "price level changes will be based on data provided by OUSD (Comptroller)" (DoD Financial Management Regulation, 2008).

Calculating the inflation indices to be used in O&M estimating is not a task handled solely by one organization. Rather, after gathering economic data, OMB works together with U.S. Department of Treasury, and the President's Council of Economic Advisors (CEA) to develop the "Troika" forecast (Wise & Cochran, 2006). The Troika model is a six-year economic forecast, including the projected inflation rates (Wise & Cochran, 2006). The development of the DoD inflation rates combines input from several different sources to help in creating the inflation indices to be used in O&S estimating. Figure 2 illustrates the process.

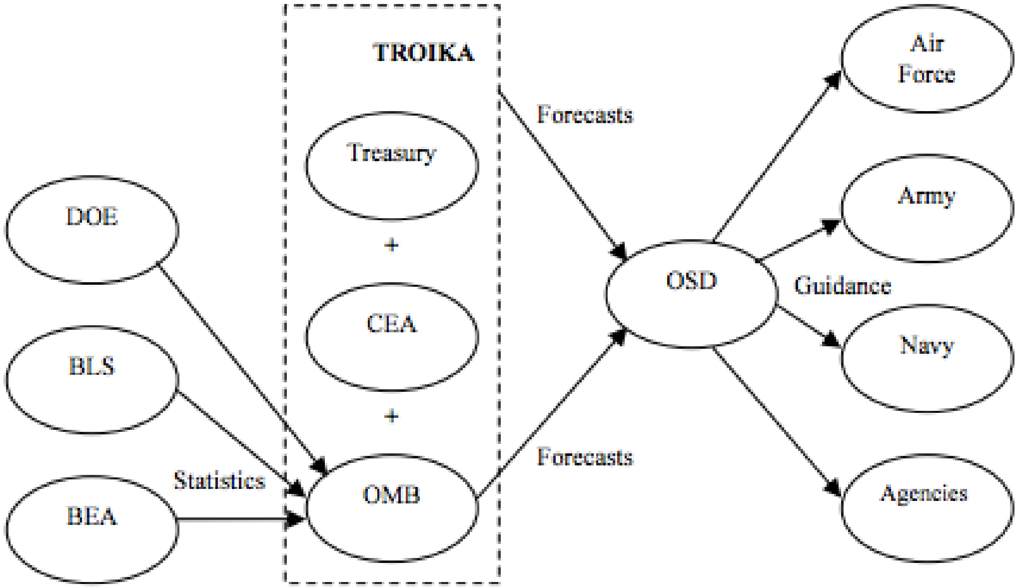


Figure 2 Troika Inflation Model

Using this input the OUSD(C) uses weighted averages of the five OMB indexes to create annual price indexes by DoD appropriation-level. The price indexes handed down by the OUSD(C) are distributed to DoD Components via guidance memo (Horozitz

2012). The weighted averages calculation is illustrated in Equation 1 using data provided in Table 2, which shows the values used for calculating the indices.

Table 2 Composition of Appropriation-Level Inflation Deflators

Appropriation (FY10 Outlay)	MilPay	CivPay	Fuel	Medical	Other Purchases
Military Personnel ($155.0B)	61%			8%	31%
O&M ($279.7B)		30%	5%	12%	53%
Procurement ($147.2B)					100%
RDT&E ($79.3B)		11%	<1%		89%
Military Construction ($23.8B)		5%			95%
Family Housing ($3.3B)		4%	1%		95%

Table 2 shows the process for FY 2010 budget. For instance, 5 percent of total DoD spending on O&M was for fuel. The calculation of the index is as follows:

Equation 1 Index Calculation for O&M

$$O\&M\ Index = (Civ\ Pay)0.30 + (Fuel)0.05 + (Medical)0.12 + (Other\ Purchases)0.53$$

It should be noted that a significant amount of total spending is grouped into the "other purchases" category. The "other purchases" category is simply defined as anything else that does not fall into the other four categories (Horozitz, 2012). If the category is not specifically assigned then the single price index is used for all other spending (Horozitz, 2012). This means that "other purchases" heavily weight the O&M deflators. Each service then uses the deflators provided by OUSD to produce guidance on recommended inflation indices.

Aging Aircraft Factors

The average age of the Air Force fleet continues to increase, with an average age of over 20 years. The steady rise in aircraft age began after WWII and continues to increase. Figure 3 depicts the escalating average aircraft age since WWII.

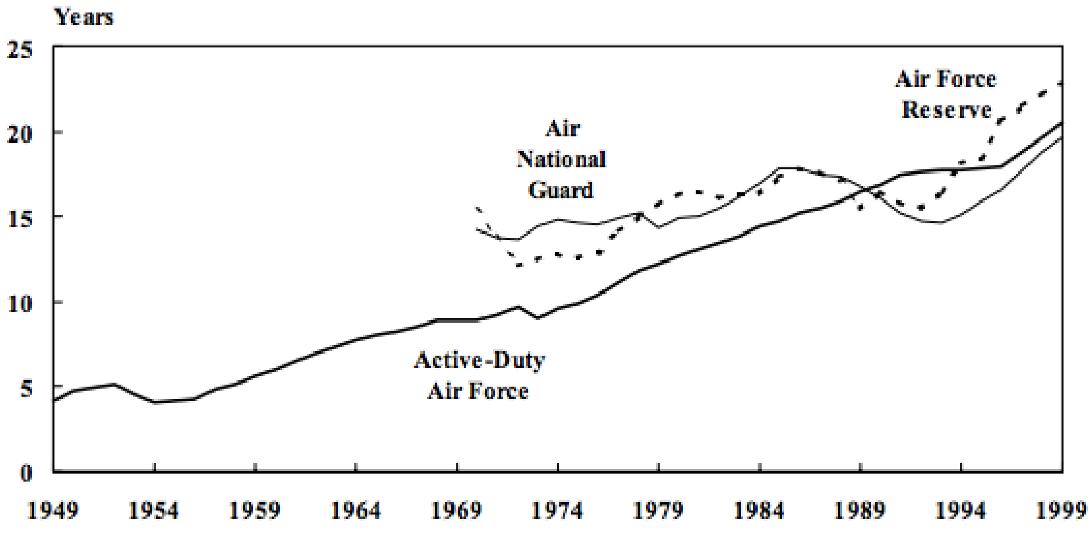


Figure 3 Air Force Average Aircraft Age (CBO, 2001)

Many factors must be accounted for when examining the cost of aging aircraft. According to the National Research Council, aging aircraft maintenance provides less stability and may in fact be less predictable (National Research Council, 1997). The unpredictability added by aging aircraft maintenance costs makes it necessary to examine the factors that can be accounted for in the O&S estimates.

Age is not the only factor requiring examination when attempting to find the effects on age for an aircraft. For instance, included within O&S cost estimates are the operating and maintenance (O&M) personnel costs. The personnel costs is another component that adds to the overarching O&S costs. The personnel costs could indicate an increasing cost in personnel above the cost of inflation because the wages aren't being adjusted for inflation. Similarly, the cost of goods required in maintenance may be increasing faster than inflation and indicating an escalation in cost above inflation, when in fact the incorrect inflation index for the goods may have been used.

In addition to the cost of goods and personnel there are other aging factors that need examination. For example, a report released by the US CBO found that "Fatigue, corrosion, and obsolete parts explain why many analysts expect failure rate, maintenance actions, and associated costs to rise as equipment becomes older" (US Congressional Budget Office, 2001). The CBO study does not cite these factors as the sole reason for increasing cost to maintain aircraft, but merely as a potential cause. The study concludes that if these factors are the cause of rising costs to maintain aircraft then there are benefits to the early retirement of aircraft.

There are also factors that may falsely adjust the cost to maintain an aircraft that are not due to age at all. For instance, changes in operation tempo, or war, may increase the cost to maintain an aircraft and a source of cost growth above inflation (Greenfield and Persselin, 2003). The last decade has experienced an increased operations tempo making it even more difficult to distinguish if the aging aircraft are the cause of CGAI, or the increased stress on the aircraft.

O&S Estimates

The preferred methodology estimation technique for effects of age on cost is not uniformly accepted; several methods are currently in use. Currently, the three methods that are being conducted to test for the affects of age on aircraft are studies based on average ages and aircraft types over time, studies based on pooled average ages and aircraft types over time, and studies based on data for individual aircraft (US Congressional Budget Office, 2001).

According to the US Congressional Budget Office the most credible method for analyzing the effects of age are the studies that directly attribute the cost to individual aircraft (US Congressional Budget Office, 2001). The benefit of these studies is the ability to remove extraneous factors and look at only the cost to maintain the specific aircraft over a period of time. The studies involving average ages and aircraft types over time are easier to calculate, but less credible. The limiting factors in these studies are the changing accounting and data collection techniques (US Congressional Budget Office, 2001). The last study type uses pooled average ages and aircraft over time. The benefit of this method is the large amount of data and ability to distinguish between aging effects and other factors. However, the method makes broad assumptions that all aircraft experience aging effects in the same manner (US Congressional Budget Office, 2001).

According to the 2007 O&S Cost Estimating Guide, there is little guidance on how to adjust for inflation, or future cost of the program. The guide merely states, “The indices used to adjust for inflation should be specified and documented.” (DoD CAIG, 2007). This lack of insight and consistency in estimating for O&S has led to the need to identify if CGAI exists. The implementation of O&S inflation indices rests heavily on the responsibility of estimators.

Conclusion

Costs in O&S continue to rise beyond the rates of inflation. There are several explanations for the rationale behind the increasing costs in O&S. Cost growth above inflation may stem from the use of inaccurate indices, or unexpected changes in inflation. One of the difficulties in creating O&S estimates is the reliance on indices that are predicting an unknown rate of growth. O&S cost growth stemming from inflation indices not accurately capturing the proper rate of growth is not truly cost growth, but rather, growth due to inflation.

As aircraft age research indicates the resources required to operate and maintain also increases. If indeed an aging factor is affecting O&S costs, then more research needs to be conducted to help analysts account for age in the estimation process. For instance, personnel cost, fatigue, corrosion, obsolete parts and operations tempo need to be taken into account during the O&S estimation process. In order to accurately understand the age effects the other factors must be accounted for appropriately.

This literature review shows the importance placed on creating accurate O&S estimates by the DoD. The importance is increasing as today’s acquisitions are committing the government to large future obligations in O&S. To best estimate future O&S costs it is crucial to understand if currently cost growth above inflation exists. While studies have shown that there is an increasing cost, above the rate of inflation, to maintain Air Force aircraft there has not been a study of the cost of raw materials. With raw materials making up over $9.1 billion in spending annually it will be beneficial to the DoD to find if this is a source of CGAI.

III. Methodology

Chapter Overview

This chapter outlines the methods and procedures for evaluating the existence of cost growth above inflation in raw materials by examining NIIN costs. The section also goes into the source of the NIIN data, along with identifying limiting factors of the data. Setting up the framework and methods that will be used in the analysis of the raw materials is a significant portion of this chapter. The methodology and guidance set forth here will ensure the analysis is complete and accurate.

Data Source

The data for this study are obtained from the AFTOC system. The AFTOC system collects historical Operating and Support costs for Air Force weapons systems. The O&S costs reported in AFTOC are comprised of both direct costs for programs, along with some indirect costs. Depending on the weapons system in question, the database can include historical costs up to 25 years old (Kunc, 2008).

Initially, AFTOC was used to identify Major Defense Acquisition Programs (MDAP), or Acquisition Category (ACAT) I programs (Kunc, 2008). The system identifies the MDAP programs based on total dollar value of the program. AFTOC strives to provide routine, timely visibility into costs by providing information on all major weapon systems, including components (Kunc, 2008). The benefit of the AFTOC system is the ability to provide information on all appropriations and across all MAJCOMs.

The major benefit of AFTOC data is the numbers are historical, thus only actual costs incurred by the program. Often estimators face uncertainty trying to predict and understand future costs, but using historical cost aids in the evaluation and validity of the analysis. The AFTOC warehouse combines data from 14 different sources to populate the historical costs, which include the base supply costs from SBSS (Kunc, 2008). The advantage of SBSS supplying data to AFTOC is the materiel accounting consists of both item and financial records (USAF Supply Guide, 2012). Using a historical perspective in analyzing raw materials allows the data to be analyzed longitudinally. This longitudinal approach to calculating the changing costs of raw materials provides a unique perspective. AFTOC allows for a rare ability of comparing actual cost trends to inflation indices because of the use of actual costs.

Longitudinal Evaluation

This study will evaluate Air Force aircraft base supply actuals for fiscal years 2000 through 2012. The ability to plot and track NIIN prices across time allows for an evaluation of the changing prices for raw materials. There have many upgrades and changes to the AFTOC system since its inception. There were several rollouts and phases in the late 1990s that revamped AFTOC. During the phases new data was added to the system to include a wider range of systems, all appropriations, all MAJOCOMs and part identification numbers. The last significant change to AFTOC's base supply data occurred in 1999, and for that reason the data in this research is being limited to data from 2000 through 2012. Using data since the most recent significant rollout helps to ensure the accuracy and validity of the data being analyzed.

A major benefit of focusing on the data longitudinally is the ability to track the changing prices by NIIN over years. In addition, evaluating a twelve-year span takes away the focus of total ownership cost (TOC), and directs the focus to the changing prices of materials. Focusing on the bottom-line cost of the program can sidetrack decision makers from the intended focus of the changing costs in materials over time, which is the sole focus of this research.

Data Selection

AFTOC is a warehouse of historical costs and information for all ACAT I programs. The varied set of systems, platforms and programs can initially be intimidating because of the overwhelming amount of data. The first step is to narrow the focus of the study to ensure the evaluation data is usable. The data selection criteria begin with devising criteria to sort the data.

The sorting of data begins by setting selection criteria for the data that will be evaluated. The first decision is to only include Air Force aircraft. The decision to use only aircraft stems from the desire to have the platforms as homogeneous as possible to help eliminate other outside forces that may be affecting the cost of raw materials. The cost of raw materials between aircraft, spacecraft, and electronic systems may prove to be so dissimilar that it would deter from the analysis.

There is a desire to compile similar systems for comparison to provide a more concise evaluation. Dissimilar systems may have a greater affect on the changing cost of parts than merely the escalation of cost over time. This study limits the analysis to Air Force aircraft in order to narrow the study. By not limiting the selection to certain aircraft platforms also allows for evaluation of parts enterprise-wide. Included in the data are 103 Air Force aircraft platforms. There are so many aircraft platform because AFTOC breaks up certain aircraft types into many variants. Table 3 lists the different variants of the C-5. For the purpose of this study the different aircraft variants are treated as separate airframes.

Table 3 C-5 Variants

C-5 Variants
C-5
C-5A
C-5B
C-5C
C-5M

Many NIINs evaluated in the study are used on multiple platforms and are not exclusive to a particular platform. An enterprise-wide evaluation of aircraft NIINs provides a unique ability to eliminate the effects one particular airframe may have on the cost of parts.

AFTOC Data

AFTOC allows for O&S actual costs to be broken down by weapon system and fiscal year (DAU, 2012). The AFTOC data evaluates the supply-side actual costs of the parts. The parts are identified by a unique, nine digit NIIN. In addition, the AFTOC data provides a description of each NIIN. The description is an easy reference to identify parts, and it helps the user to gain more insight into each NIIN. For instance, from Table 4 the description of NIIN 005969637 is “wheel landing gear.”

The AFTOC data also identifies the airframe the part was used for, and in what fiscal year. Perhaps the most important information given by AFTOC for each NIIN is the total demand quantity and total demand cost for the NIIN for each airframe in each fiscal year. The ability to evaluate the actual costs of the parts is the foundation for identifying how a NIIN's price is changes over time. An example of the data from the A-10 is shown in Table 4:

Table 4 A-10 AFTOC Data

FY	Aircraft	NIIN	NIIN Description	Quantity	Cost
2000	A-10	005917353	SERVOCYLINDER	1	13,379.10
2000	A-10	005969637	WHEEL, LANDING GEAR	28	19,284.37
2000	A-10	006054570	SUPPORT,STRUCTURAL COMPONENT	1	3,346.58
2000	A-10	008625524	BRUSH ASSEMBLY,PROP	1	1,183.19
2000	A-10	009141329	WHEEL,LANDING GEAR	2	2,416.26
2000	A-10	009611971	TRANSMITTER,ANGLE OF ATTACK	1	2,215.99
2000	A-10	010030909	VALVE,EMERGENCY,BRAKE,LANDING	1	2,085.28
2000	A-10	010042738	INDICATOR,RATE OF FLOW	1	461.27
2000	A-10	010110502	CIRCUIT CARD ASSEMBLY	1	9,650.54
2000	A-10	010121938	NAVIGATION SET,TACAN	1	2,776.48
2000	A-10	010129154	SERVOCYLINDER	1	10,334.31
2000	A-10	010213681	GYROSCOPE,DISPLACEMENT	2	31,943.12

The ability to evaluate the actual price per part, by fiscal year, allows the examination of actual costs. By looking at actual costs over time, analyzing the effects of inflation is possible and permits the analysis of CGAI caused by raw materials.

Data Limitations

AFTOC

AFTOC reports and allows analysis of historical costs for Air Force weapons systems, but there are limitations to the system and the data involved. The limitations are not terminal, but they require consideration on accounting for them. AFTOC provides an annual summary of the total supply demand quantities and total cost. The data is not broken down into individual purchase prices of the NIINs. Without providing individual purchase prices of each NIIN the individual cost of items will have to be calculated. The benefit of finding an individual purchase price is it normalizes the quantity and provides a unit-to-unit comparison. The method used to normalize for quantity will be discussed later.

AFTOC reports the total NIIN cost for each fiscal year in then-year (TY) dollars. The cost is reported in TY dollars because that is the total actual cost for the NIINs and reflects the cost incurred by the government at the time of the purchase. Depicting the costs in then-year costs provides the ability to apply DoD deflators and examine the costs in the same base year (BY).

The benefit of transforming the TY costs to BY costs is the ability to evaluate the DoD deflators. If the DoD deflators were correct, all the BY costs for a particular item would be equal. This is because the only reason raw materials should cost more is because of inflation. Ideally, the only difference between the cost of a part purchased one year from now, and the same part purchased today should be the rise due to inflation. Figure 4 illustrates what should be expected if quantities did not change and inflation was the only growth in the cost of the same part year to year, and in the same BY. In this situation there is a horizontal line that represents the same quantity and price over time.

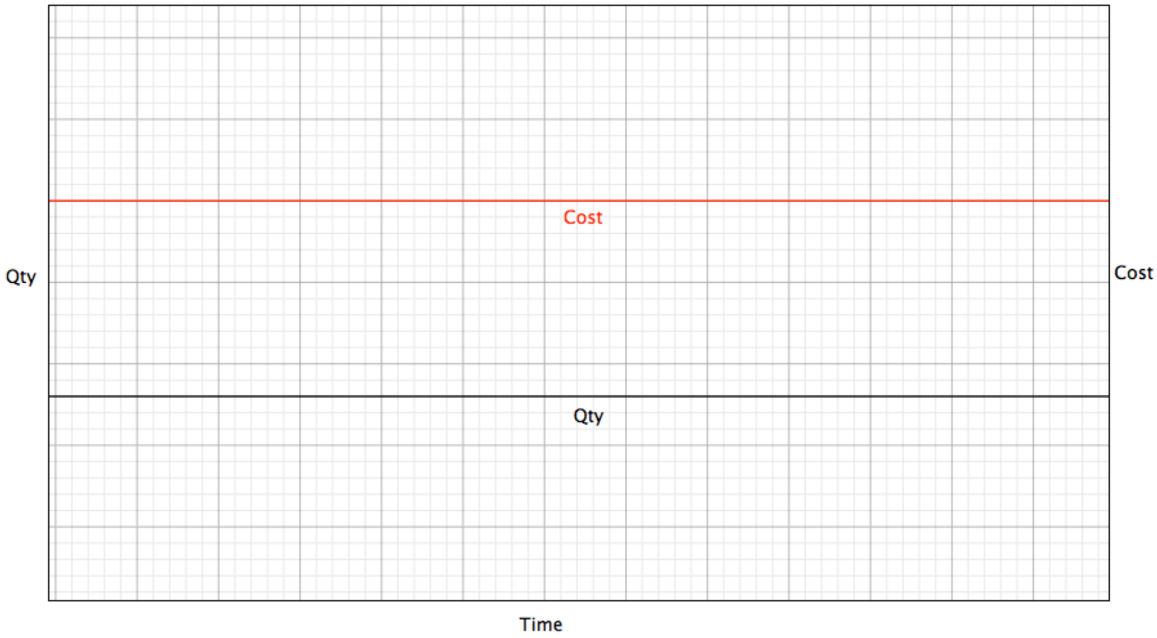


Figure 4 No Cost Growth Above Inflation

If CGAI did exist in the raw material of parts, then it would be expected that cost could increase over time, even when in the same base year. The widening gap between cost and quantity represents CGAI. Figure 5 illustrates a graphical representation of the existence of CGAI. If CGAI is present and quantity is constant, then the unit cost of each NIIN would increase over time. When both the cost and quantity line are horizontal there is not CGAI present.

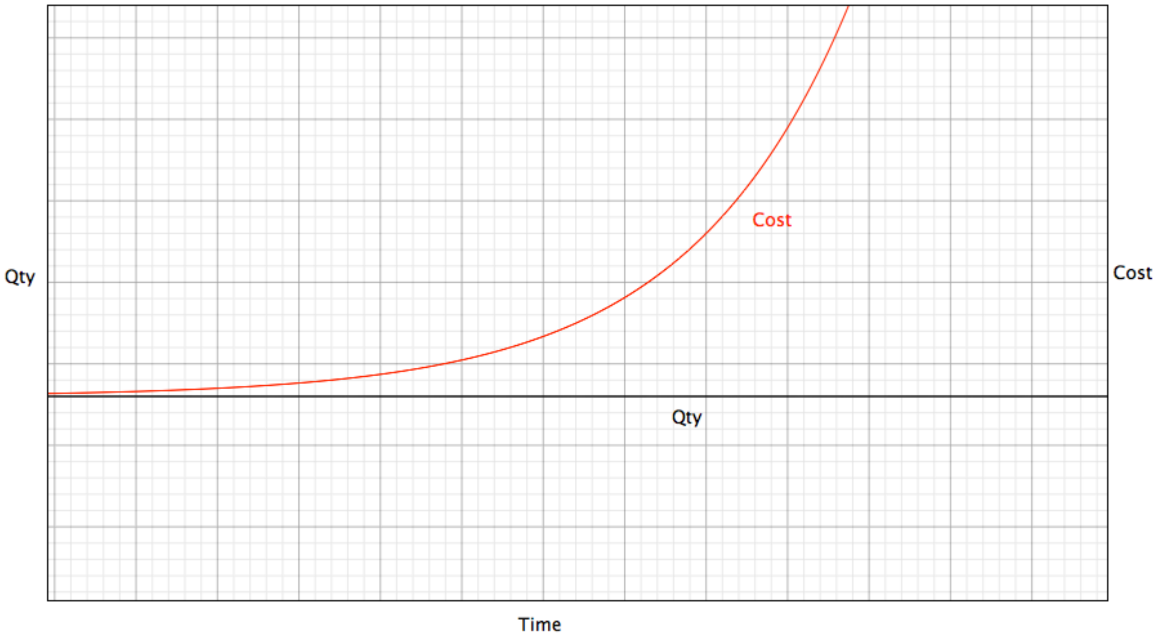


Figure 5 Cost Growth Above Inflation

AFTOC data will be able to provide actual part costs over time to see if after adjusting for inflation, if the cost of parts is increasing beyond the rate of inflation. An upward trend in cost per part by fiscal year, insinuates the existence of CGAI in aircraft parts. CGAI in parts would provide one reason why O&S costs are increasing faster than inflation.

NIIN

Analyzing all NIINs for all Air Force aircraft produced 668,145 records on 103 different Air Force aircrafts. Combining like NIINs in the same fiscal year provides a result of 32,765 unique NIINs. The data provided a plethora of data points and many avenues for evaluation. To ensure the data was analyzed appropriately not all NIINs were included in the analysis. There were two requirements for inclusion into the final NIIN data set. The NIIN must have a purchase quantity greater than one, and the NIIN had to be purchased in at least two fiscal years. These requirements for inclusion into the final data set ensure at least two points are included per NIIN so that a regression could be performed. Again, the data only included Air Force aircraft base level raw materials from fiscal years 2000 through 2012.

The final data set included 23,473 unique NIINs. NIINs used for analysis are limited to only NIINs with at least two positive purchase costs for fiscal years 2000 through 2012 . The criteria are established because several NIINs had negative costs. A negative quantity, and resulting negative price, occurs when the Air Force returns a sale (USAF Supply Guide, 2012). A return of sale can occur if the item was purchased for an off-base customer, or if there is a surplus. Table 5 breaks down the number of fiscal years NIINs are purchased. For instance, 5,144 NIINs were purchased in all 13 fiscal years (2000-2012), while only 3,663 NIINs were only purchased in two fiscal years.

Table 5 Number of FYs NIINs Purchased

Number of Years Ordered	Number of NIINS
13	5144
12	1264
11	996
10	949
9	1215
8	1177
7	1274
6	1562
5	1671
4	1998
3	2560
2	3663
1	7143

Limiting used NIINs to only positive purchase costs in the fiscal year ensured the data was complete and structured for proper analysis. Using the qualification criteria of the NIINs limited the evaluation to 23,473 NIINs, or 71.64 percent of the original data. NIIN 012461643, electronic synthesizer, appeared to have an abnormally large purchase price in fiscal year 2006, but was still included in the analysis. The reason for inclusion was the item was not returned within the following six fiscal years, and it is still an actual cost.

Measuring Raw Material Costs

The identification of O&S costs increasing beyond inflation can be illustrated in different ways. The focus of this study is on the changing prices by NIIN over time. There are two ways to measure O&S part costs: costs by airframe, and costs by NIIN. There are benefits to looking at the data in both forms, along with drawbacks.

Examining the total O&S part costs by airframe allows for easy understanding if certain total airframe parts cost is increasing each year. Looking at aircraft part costs over time allows the ability to see if trends across different airframes (i.e. bombers, cargo and fighters) are affected in the same general trend. While general trends can be examined between airframes, there is a lack of insight in the cost of the parts. For instance, one airframe may be demanding a specific part more often because of an increased operations tempo. A potential way to account for an increasing operations tempo is to normalize for flight hours. The increasing frequency of use of the aircraft would be the root cause of the growth, and not rise in prices of the parts beyond inflation.

To see if the costs of individual parts are increasing above the rate of inflation, it would be best to examine the cost per part, by fiscal year. This would allow the ability to compare the average price of parts, per fiscal year, over time. This method allows the ability to see if the general trends in parts are increasing above inflation. In addition, to identifying a general trend in CGAI, it also allows the identification of part-specific CGAI. This method allows insight into which specific parts are experiencing CGAI. Again, this may not paint a complete picture of the root cause of CGAI, but it can begin to fill in the gaps.

Identifying NIIN Cost Growth

To find out if individual NIINs are experiencing CGAI enterprise-wide there are several steps that must take place. This section will outline the steps necessary to evaluate and confirm the existence of CGAI in raw materials by exploring changes in individual NIINs. For the purpose of this paper raw materials cost are equivalent to equipment costs.

Average Unit NIIN Cost (AUNC)

The first step in studying the change in cost of NIINs over time is by adjusting for differing quantities across fiscal years. Differing quantities of NIINs across fiscal years inaccurately portrays the change in cost over time. Furthermore, because AFTOC does not provide the individual prices of the NIINs an adjustment is required. Equation 2 demonstrates the method for calculating the average unit NIIN cost for each year.

Equation 2 Average Unit NIIN Cost

$$Average\ Unit\ NIIN\ Cost = \frac{Total\ NIIN\ Cost}{Total\ NIIN\ Quantity}$$

The analysis will focus on the changing average unit NIIN cost over time. The AUNC is the basis for the upcoming analysis. Using a unit cost removes quantity uncertainty from the analysis and allows for an accurate comparison of the changing cost.

Base-Year (BY) 2012

The analysis is identifying if there is CGAI in raw materials for Air Force aircraft. The benefit of comparing the AUNC in the same BY is the effect of inflation has been removed. By removing the effects of inflation any escalating cost in raw materials is CGAI.

Table 6 DoD O&M Deflators

Fiscal Year	DoD O&M Deflator
2000	80.72
2001	81.86
2002	82.7
2003	84.04
2004	86.12
2005	88.64
2006	91.08
2007	93.28
2008	94.99
2009	96.1
2010	97.15
2011	98.5
2012	100

The DoD O&M inflation indices are used to put all AUNC into BY 2012. Table 6 lists the DoD deflator values used in putting all data into 2012 BY. Appendix A provides a table of DoD deflators for all appropriations.

AUNC Standardization

To continue the process of analyzing the presence of CGAI process in raw materials it is beneficial to standardize the AUNC. The standardization of the AUNC helps ensure equal weights of all the inputs in the data set. The NIINs in the data set vary in both quantity and cost. We have standarized by unit, and now we need to standarzie by cost.

To standardize the AUNC the first step is to calculate the mean for each NIIN from 2000 to 2012. The next step in the standardization process is to calculate the standard deviation for each NIIN for all the data between 2000 and 2012. Once the mean and standard deviation are calculated the process of standardization can begin. Now, subtracting the mean and dividing by the standard deviation transforms each AUNC. The result is a standardized average unit cost for each NIIN. The standardized data will aid in evaluation and is beneficial to the next step in the process.

Regression

Now that the AUNC are all in base-year 2012 dollars, and standardized, the process of identifying the cost trends begins. A linear regression is performed on all 23,473 NIINs in the data set. The linear regression plots a best-fit linear line through all the data points for each fiscal year for each NIIN. The data points for each NIIN represent the AUNC for every fiscal year the NIIN was purchased. Using Equation 3 fiscal year is the independent variable (x) and standardized AUNC is the dependent variable (y).

Equation 3 Regression Equation

$$y = \beta_0 + \beta_1 x + \varepsilon$$

This equation is calculating the slope (β_1) from the regression. The slope of the equation represents the trend of the NIIN's cost growth. A positive number represents growth over time and the presence of CGAI. A negative value means the costs are decreasing over time, and a zero slope depicts no cost growth above inflation in the NIIN.

Confidence Interval (CI)

The next step involves creating a confidence interval for β_1. A 95 percent confidence interval is created using the slopes found during the regression. We use all 23,473 NIIN slopes for this confidence interval. When creating this confidence interval it is crucial to identify if zero is represented within the interval. If zero is represented in the data interval then there is no evidence of cost growth above inflation at 95 percent confidence.

Summary

The evaluation of how the cost of materials are changing over time and being affected by inflation is crucial to better understanding CGAI. This section laid out the sources and limitations of the data, along with selection criteria. Ensuring potential deficiencies in the data are identified early and a process for dealing with them allows for insurance the process will not be dictated by deficiencies in the data. This step is key when evaluating NIIN costs that are changing over time.

Next, this section laid out the methodology for using the data to determine if the cost of raw materials is changing over time at a greater rate than inflation. The methodology began with an explanation of the techniques and methods that are used in analyzing the raw material data to ensure proper analysis. The methodology outlined in this section will be used in the proceeding chapter to identify the presence of CGAI in Air Force NIINs.

IV. Analysis and Results

Chapter Overview

This chapter presents the results of the analysis identifying the existence of cost growth above inflation in Air Force aircraft materials. First, this chapter explores the calculation of the average cost growth. Second, the discussion leads into the analysis of regression of the 23,473 NIINs. Third, the results of the confidence interval for the raw materials are discussed. Parlaying on this information the interpretation of the results from the analysis is discussed. Using all of these components the results provide a comprehensive analysis of Cost Growth Above Inflation in raw materials for Air Force aircraft.

In order to establish the existence of Cost Growth Above Inflation we must show the trend in AUNC over time. A positive slope illustrates the existence of CGAI, and no cost growth equates to a slope of zero (horizontal line). If the slope is positive it means DoD inflation indices are not accurately anticipating inflation.

Average Unit NIIN Cost

It cannot be assumed throughout a fiscal year parts are purchased at the same price. The data does not provide enough insight into individual purchases, so there is a need for a common comparison across NIINs. Many NIINs are used across multiple platforms and throughout multiple fiscal years, so it is imperative to combine all NIINs in each fiscal year. Again, the combining of like NIINs produced 32,765 unique NIINs purchased in fiscal years 2000 to 2012.

The first step in creating an AUNC is summing the total cost of each NIIN during each fiscal year. Next, the total demand quantities for each NIIN are summed for each fiscal year. Table 7 illustrates an example of combining total NIIN costs and total NIIN quantities for fiscal year 2000 for several different NIINs.

Table 7 Calculating Total Demand Quantities and Cost

FY	NIIN	Total Quantity Sum	Total Cost Sum
2000	12816849	19	$9,797
2000	12818470	1	$3,793
2000	12818580	17	$55,480
2000	12818661	10	$8,105
2000	12820281	18	$123,925
2000	12821028	5	$134,106
2000	12821029	3	$8,401
2000	12822882	18	$85,030
2000	12823595	5	$40,052
2000	12823673	6	$7,828
2000	12823674	61	$733,591
2000	12823686	94	$96,540
2000	12823689	1	$21,231
2000	12823703	30	$173,039
2000	12824202	47	$14,633
2000	12824323	47	$263,476
2000	12825330	1	$3,889

It does not matter which platform the NIINs were ordered for because this analysis is enterprise-wide and is focusing on the change in cost of raw materials.

The average unit NIIN, equation 2 in chapter III, cost equation is applied to every NIIN, for every fiscal year. The AUNC allows for a comparison of changes in then-year costs across fiscal years and between NIINs. Using the data from Table 7, and the AUNC equation the AUNC is calculated and is depicted in Table 8. This step is performed for every NIIN for every fiscal year in the data set.

Table 8 Calculating Then-Year AUNC

FY	NIIN	Total Quantity Sum	Total Cost Sum	AUNC
2000	12816849	19	$9,797	$516
2000	12818470	1	$3,793	$3,793
2000	12818580	17	$55,480	$3,264
2000	12818661	10	$8,105	$811
2000	12820281	18	$123,925	$6,885
2000	12821028	5	$134,106	$26,821
2000	12821029	3	$8,401	$2,800
2000	12822882	18	$85,030	$4,724
2000	12823595	5	$40,052	$8,010
2000	12823673	6	$7,828	$1,305
2000	12823674	61	$733,591	$12,026
2000	12823686	94	$96,540	$1,027
2000	12823689	1	$21,231	$21,231
2000	12823703	30	$173,039	$5,768
2000	12824202	47	$14,633	$311
2000	12824323	47	$263,476	$5,606
2000	12825330	1	$3,889	$3,889

Base-Year 2012 Dollars

Now that every NIIN has an AUNC for every fiscal year the DoD deflators must be applied. Using the DoD O&M deflators the AUNC for each NIIN are converted to base-year 2012 dollars. Converting the AUNC to base year 2012 requires dividing AUNC by the given deflator value. Again, this is done for every NIIN, in each fiscal year, so we can compare all AUNCs in the same base-year. An example of converting the AUNC in Table 8 to base-year 2012 is shown in Table 9.

Table 9 Calculating Base-Year 2012 AUNC

FY	NIIN	AUNC	Deflator	Base 2012 AUNC
2000	12816849	$516	80.72	$639
2000	12818470	$3,793	80.72	$4,699
2000	12818580	$3,264	80.72	$4,043
2000	12818661	$811	80.72	$1,004

2000	12820281	$6,885	80.72	$8,529
2000	12821028	$26,821	80.72	$33,227
2000	12821029	$2,800	80.72	$3,469
2000	12822882	$4,724	80.72	$5,852
2000	12823595	$8,010	80.72	$9,924
2000	12823673	$1,305	80.72	$1,616
2000	12823674	$12,026	80.72	$14,899
2000	12823686	$1,027	80.72	$1,272
2000	12823689	$21,231	80.72	$26,302
2000	12823703	$5,768	80.72	$7,146
2000	12824202	$311	80.72	$386
2000	12824323	$5,606	80.72	$6,945
2000	12825330	$3,889	80.72	$4,818

Besides calculating the AUNC in base-year 2012 dollars for each NIIN for each fiscal year, we are able to plot a frequency graph of AUNC. Figure 6 is a frequency plot of the AUNC for all NIINs. This frequency histogram helps to identify the majority of the AUNC costs are, relative to each other. It is evident from the histogram that there is skewing in the data set. It appears there are more raw materials with low AUNCs. As the AUNC increases there tends to be fewer and fewer NIINs.

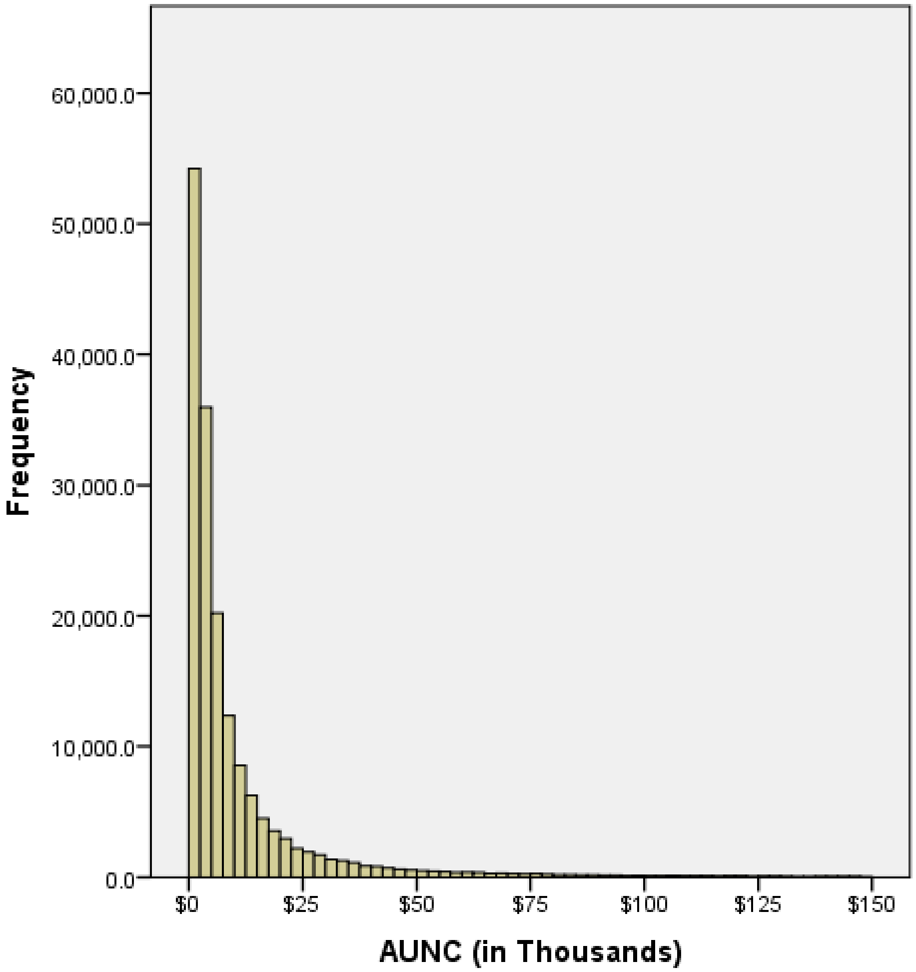


Figure 6 AUNC Frequency Graph

Standardization

With all the AUNC in base-year 2012 dollars the data can be transformed and standardized. Using SPSS and Excel™ the process of standardizing the AUNC is possible. First, the mean for each AUNC was calculated for years 2000 through 2012. The next step is calculating the standard deviation for each NIIN for all the 13 years of data points in fiscal years 2000 through 2012. Now, all the components required in standardizing the AUNC in BY 2012 are calculated and can be put together. By subtracting the mean from the AUNC and dividing it by the standard deviation the data is transformed into a standardized AUNC. Again, this step is performed for each NIIN in the data set. Using the previous examples, Table 10 illustrates the process of standardizing the AUNC. The standardized AUNC is a result of first subtracting the mean from “Base 2012 AUNC” and dividing the result by the standard deviation. The outcome is a standardized AUNC.

FY	NIIN	Base 2012 AUNC	Mean	Std Deviation	Standardized AUNC
2000	12816849	$639	1097.429028	325.9277656	-1.407184879
2000	12818470	$4,699	4687.256922	1251.456783	0.009351057
2000	12818580	$4,043	8043.742245	8855.354724	-0.451785061
2000	12818661	$1,004	6451.985646	4979.121157	-1.094148398
2000	12820281	$8,529	10825.14776	3466.347688	-0.662371523
2000	12821028	$33,227	36544.07808	30112.91452	-0.110139627
2000	12821029	$3,469	28442.5332	20910.14158	-1.19431728
2000	12822882	$5,852	17497.16883	8578.896989	-1.35739782
2000	12823595	$9,924	6484.847779	1831.425715	1.877684152
2000	12823673	$1,616	15830.03697	19337.74326	-0.735026104
2000	12823674	$14,899	7231.316778	3759.999052	2.039148547
2000	12823686	$1,272	2405.753945	2494.22378	-0.454421881
2000	12823689	$26,302	9312.849137	14713.1965	1.154690116
2000	12823703	$7,146	18678.44159	7183.254394	-1.605510444
2000	12824202	$386	372.3633074	97.49599068	0.136829828
2000	12824323	$6,945	16109.86868	6827.76213	-1.342318978
2000	12825330	$4,818	6459.396665	2321.442404	-0.707106781

Regression

Now that each NIIN is in the same base-year dollars (BY 2012) and standardized the regression of each NIIN is performed. Using the Statistical Package for the Social Sciences (SPSS) tool a linear regression for each NIIN is performed. This analysis plots the standardized AUNC of each NIIN as the dependent variable over time (independent variable). After plotting each data point SPSS calculates a best-fit linear line through the points. By fitting a line through the point a slope is calculated. The slope represents the presence, or absence, of cost growth above inflation for each individual NIIN. A positive slope represents an upward trend in base-year cost, and thus CGAI. Each year the cost of raw materials is increasing more than the DoD indices predict. An example of the commands used to create a linear regression in SPSS is provided in Appendix B. Performing a regression on each NIIN provides an output of 23,473 slopes.

Confidence Interval

Using the estimated slopes calculated from the linear regressions we are able to calculate a confidence interval for the entire data set. First, we calculate some descriptive statistics from the set of slopes. Table 10 provides a summary of some of the meaningful statistics calculated from all of the slopes.

Table 10 Slope Descriptive Statistics

Max Slope	8.49
Min Slope	-7.78
Mean Slope	1.07
Median Slope	1.33
Std Dev	1.97

Using the information provided in Table 10 it is evident there is slight negative skewness in the slope. When the mean is less than the slope there is negative skewness in the distribution. Figure 7 illustrates a frequency histogram of all the slopes. The slight negative skewness is seen in the histogram, along with the relatively normal distribution shape.

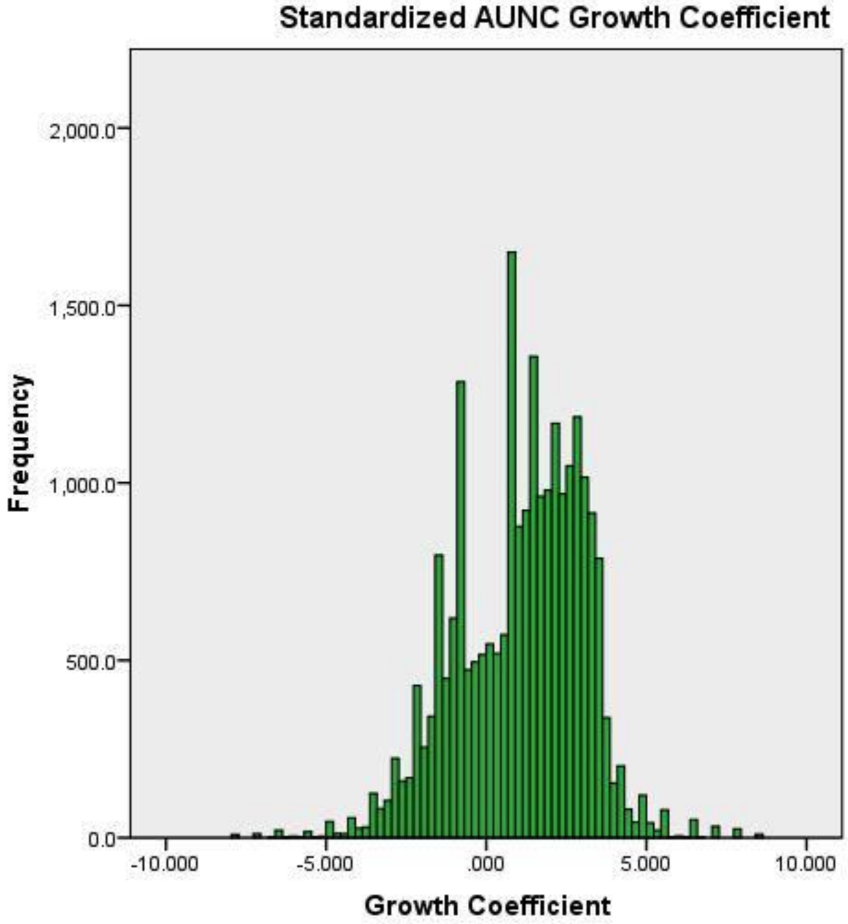


Figure 7 Standardized AUNC Growth Coefficient

The information in Table 10 also allows us to calculate a confidence interval. For the purposes of this study we will calculate at 95 percent confidence interval for the true slope of all the NIINs. Table 11 provides the information we will use in creating a 95 percent confidence interval.

Table 11 Confidence Interval Information

Description	Data
α (significance level)	.05
Standard Deviation	1.969591206
Sample Size	23,473

Using this data we are able to calculate the confidence interval using Excel. From Excel we determine that the 95 percent confidence interval is (1.05,1.09). This interval tells us that at the 95 percent confidence level zero is not included in the data set. Since zero is not included in the confidence interval there is a positive trend in the slopes from the data set. This means there is evidence to suggest at the 95 percent confidence level there is CGAI in the raw material costs for Air Force Aircraft.

Modified Data Set

The previous results used all data whre there were at least two data points. This means that as long as each NIIN was purchased in more than one fiscal year the data was included. This allowed for a linear regression to be performed on the AUNC for each fiscal year. After completing the analysis on the two or more data points the same analysis was run on only NIINs purchased in four or more fiscal years. The analysis is run the exactly same way, but now with 15,252 NIINs (compared to the full data set which had 23,473 NIINs). The increased requirements did lower the data set by 8,223 NIINs by focusing on NIINs with purchases in at least four fiscal years, the regression lines may be more stable in comparison to just two or three data points.

When only looking at four or more fiscal year purchases for each NIIN an interesting result is found. Previously, when the frequency histogram was drawn for the cost growths the resulting histogram resembled a normal distribution with a slightly negative skew. Now, when examining at least four fiscal years the graph changes significantly. The resulting analysis shows there are no points that have a negative cost growth coefficient. This means none of the 15,252 parts cost less over time. Figure 8 clearly depicts the different shape of the growth coefficient frequencies. There are now no negative slopes and a smaller standard deviation.

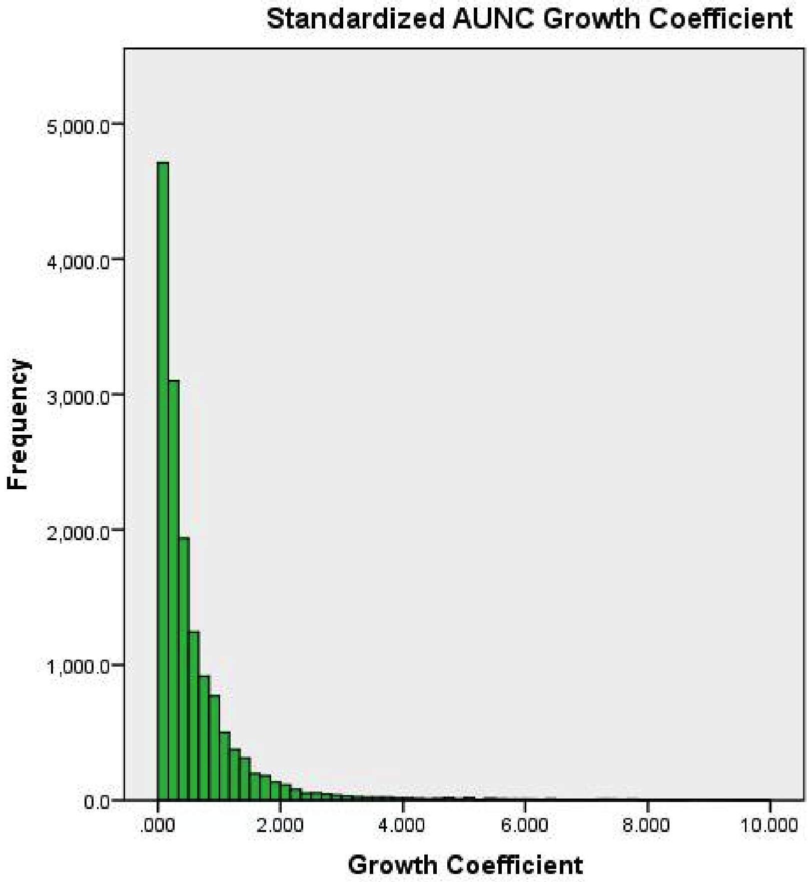


Figure 8 Standardized AUNC Growth Coefficient with Four or More Fiscal Years

Two points were removed during the analysis of the data. The two points cost growth coefficients were 20,000 times greater than the nearest cost growth coefficient. The mean of the data set was 26.99 before the two NIINs were removed, and 0.702 once the two points were removed. Table 12 shows a comparison of the results before and after the outliers were removed from the data set. Note the large decrease in mean by removing two data points, or 0.015 percent of the data set.

Table 12 Four or More Fiscal Years: Descriptive Statistics

With Outliers		Without Outliers	
Max Slope	200690	Max Slope	85.702023
Min Slope	0.000182876	Min Slope	0.000183
Mean Slope	26.99287582	Mean Slope	0.702
Median Slope	0.320531693	Median Slope	0.320
Std Deviation	2295.754762	Std Deviation	1.839806704

Using the data without outliers from Table 12 we are able to construct a new confidence interval. The new 95 percent confidence interval is (0.673, 0.731), and once again zero is not included in the confidence interval. Zero not being in the confidence interval again illustrates the existence of CGAI in raw materials, but this time with a more refined data set.

Creating an Adjustment

Using the results from the regression it is evident there is CGAI in raw materials. To overcome the presence of CGAI it is beneficial to have an adjustment factor. This adjustment factor benefits both analysts and decision makers. By using an adjustment factor it helps to ensure the O&S estimates are as accurate as possible and most accurately depict the future operating environment.

The process of the identifying an adjustment factor began by drawing from literature review. From this process several different sources concluded that it appeared aging aircraft cost 1-3 percent more each year to operate. The first step was adding a constant adjustment factor to the DoD deflator to apply to raw material O&S estimates. A constant three percent adjustment factor was added to each fiscal year for 2000-2012. This adjustment is intended to account for the current CGAI existence in raw materials.

Using the data set containing data from NIINs with purchases in four or more fiscal years, a new cost growth is constructed. The process is the same as done before, but now when converting the AUNC to BY 2012 an additional three percent adjustment is added to the conversion. The process continues as before with calculating the mean and standard deviation for each NIIN in order to standardize the AUNC. With the newly standardized AUNC (with an additional deflator) a linear regression is performed. Again, the slopes from the linear regression represent the growth coefficient for the raw materials.

Now, with a new set of raw material growth coefficients a frequency histogram is constructed. Figure 9 illustrates the new histogram of the growth coefficients for NIINs purchased in four or more fiscal years. Clearly, the additional adjustment to the deflator has moved the data. Previously, all the growth coefficients were positive and showed a sharp positive skew to the right of zero. Now, the data is centered on zero and contains both positive and negative growth.

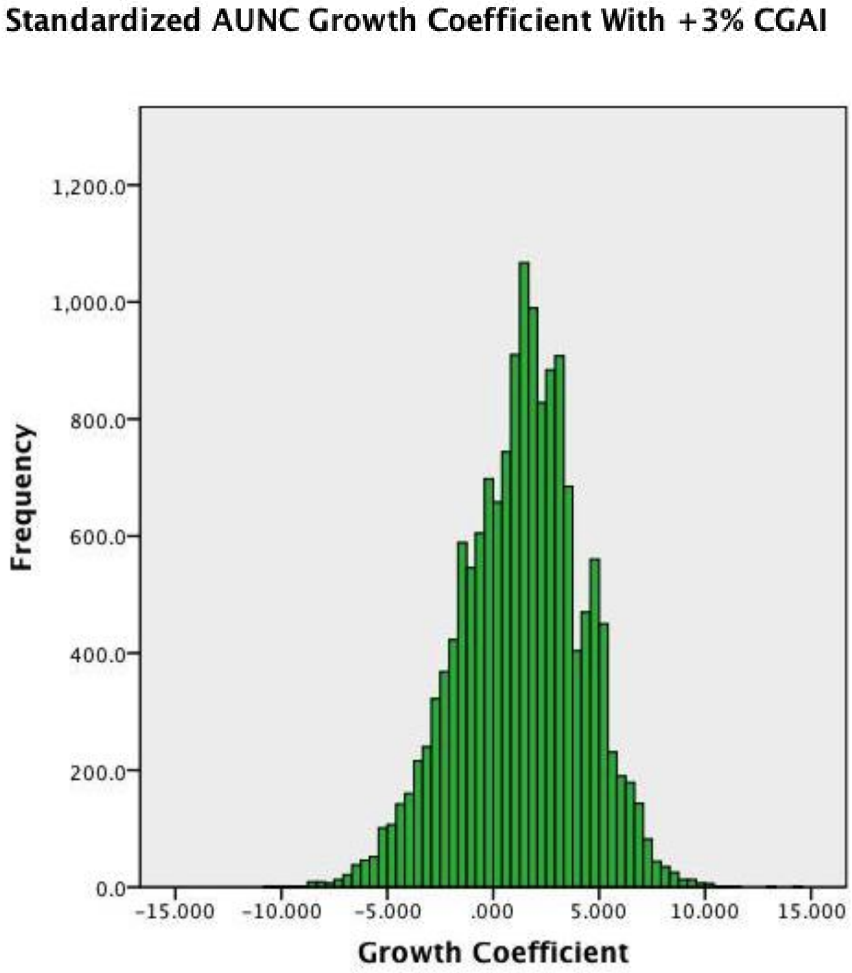


Figure 9 Cost Growth Coefficient Frequency Histogram With Adjustment

The cost growth coefficients' outputs received from the regression allow for an analysis of the data. Table 13 provides a summary of some of the key descriptive statistics from the output. With the three percent adjustment factor added to the DoD deflator the mean of the slope is closer to zero. In addition, using the data in Table 13 a new 95 percent confidence interval is constructed and is (-.00411, .02111). This new confidence interval now includes zero and this means the adjusted values would not show CGAI.

Table 13 Growth Coefficients with Adjustment Descriptive Statistics

Max Slope	11.15
Min Slope	-9.24
Mean Slope	0.017
Median Slope	0.033
Std Deviation	1.33

This adjustment factor allows for increased accuracy enterprise-wide on the cost of raw materials and would be beneficial to “big-picture” decision-making. Individual parts may be less accurate, but enterprise-wide the accuracy is much closer to reality.

Conclusion

This chapter highlighted the key finding of the analysis of CGAI. During the analysis there were different results depending on which data set was used in the analysis; however, there is systematic evidence of CGAI in the raw material costs. To further validate the belief of CGAI in raw materials the data set was rerun using new admission requirements. Using the more stringent requirements for inclusion the data again illustrated CGAI, and this time without any negative growth in any of the parts. This analysis led to the development of an adjustment factor to apply to the DoD deflators. By applying a constant adjustment to the AUNC a distribution was created. In the new distribution it was centered on zero, and at the 95 percent confidence contained zero and reflected no CGAI. Using the results from this analysis the next chapter will summarize the conclusions of this thesis.

V. Conclusions and Recommendations

Chapter Overview

This thesis ventured into the uncertainty surrounding cost growth above inflation by examining the increasing costs of parts in Air Force aircraft. The information garnered about CGAI will be the basis to guiding future research and exploration into escalating aircraft O&S costs. This chapter reviews the key findings and limitations of the thesis, along with recommendations and future research.

Discussion of Results

This thesis set out to answer the following research questions:

1) Are raw material costs a source of CGAI?
2) Do the DoD inflation indices accurately account for inflation?
3) Should an adjustment factor be applied to raw material costs?

This study explored CGAI and attempted to measure the relationship of cost growth to unaccounted increases in raw material cost. Specifically, we evaluated CGAI through an analysis of raw material costs from a period of 2000 to 2012 for Air Force aircraft. If CGAI exists in O&S there will be a large inaccuracy in the total life cycle cost (LCC) of weapon systems and an inaccurate budget put in place. An inaccurate estimate of O&S costs lead to budgeting problems and creates future budget issues.

The research concluded raw materials for Air Force aircraft are a source of CGAI. The presence of CGAI indicates the cost of raw materials are increasing at a greater rate than the DoD predicted and is leading to cost growth. Furthermore, the DoD deflators are not accurately capturing the increasing cost of parts over time and require an adjustment.

By adjusting the DoD deflators at a constant three percent rate allows for a statistically significant finding of no cost growth above inflation when applied enterprise-wide.

Significance of Research

The ability to analyze actual costs of raw materials over time provided a unique ability to compare actuals and evaluate any change. By using actual costs and standardizing for units and cost provided the ability to focus on actual cost growth for raw materials. Using the DoD deflators allowed for analysis of CGAI in raw materials. The analysis of raw material parts had not previously been performed and provided new insight into the accuracy of current DoD inflation indices.

The research showed using actual raw material cost via AFTOC there is CGAI in raw materials. The evidence was confirmed by performing an analysis on 23,473 NIINs actual costs during fiscal years 2000-2012. The presence of CGAI in materials was confirmed when the analysis was rerun using a data set containing NIINs purchased in four or more fiscal years. This new data set contained 15,252 NIINs and showed no evidence of negative cost growth in any NIINs.

The evidence of CGAI in raw materials suggest current DoD inflation indices are not accounting for the rising cost of raw materials over time and need reevaluation. Using an adjustment factor allowed for a more accurate representation of the rising cost of aircraft raw materials at an enterprise-level. With improved accuracy on forecasting rising prices of raw materials allows for more precise O&S cost estimating and improved information for decision makers. The evidence of CGAI in raw materials for Air Force aircraft also highlighted a need for future research of CGAI in other areas.

Recommendations for Future Research

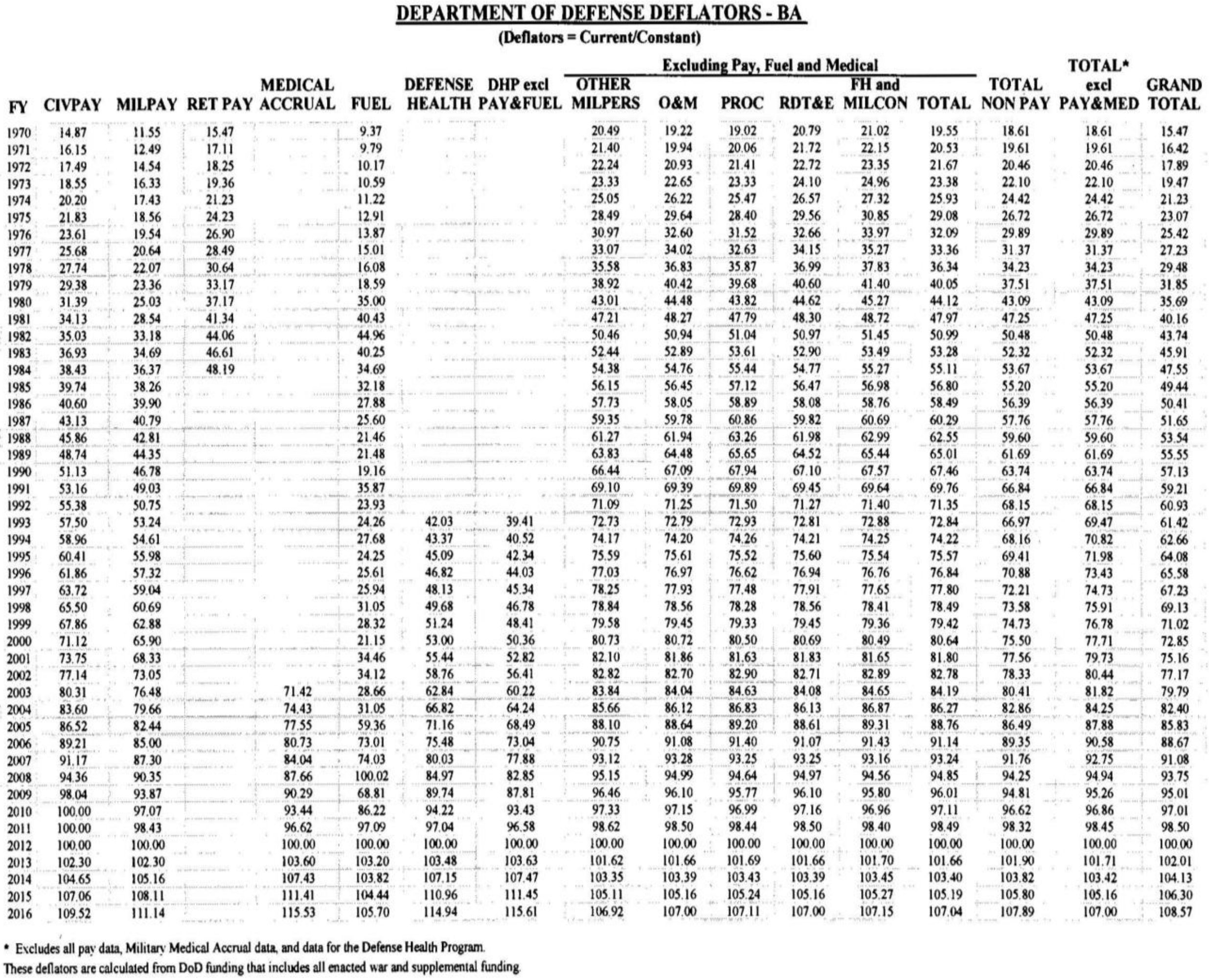
There are several areas where further research can provide useful information. The first area of future research pertains to more analysis of CGAI in raw materials. In addition to examining base supply information from SBSS it would be beneficial to examine contractor support costs. This analysis would require further insight into contractor logistic support contracts and contractor part usage. In addition, further research could be done on fine-tuning an adjustment factor for raw materials to apply to DoD deflators. Potentially each NIIN could create an adjustment factor in order to provide more insight at the lowest level.

The next area of future research is the presence of CGAI in other areas. In addition to raw materials there should be analysis on CGAI in personnel costs. With rising healthcare and personnel costs this could be a contributing factor to rising O&S costs. An analysis would need to be done into all facets of O&S and find if there is CGAI.

Lastly, future research can also be done on the DoD inflation indices. It would beneficial to examine the implementation of the DoD inflation indices by the different services. Each of the military services uses the DoD inflation rates differently and a more universal approach could provide further insight into other causes of CGAI.

All of the proposed future research will challenge the current practices within the cost estimating community. By challenging the current practices future efforts may lead to more insightful analysis of causes of both CGAI and increasing O&S costs. With improved accuracy, techniques and knowledge the DoD will better be able to handle future challenges and fiscal uncertainty.

Appendix A Department of Defense Deflators



DEPARTMENT OF DEFENSE DEFLATORS - BA

(Deflators = Current/Constant)

								Excluding Pay, Fuel and Medical							TOTAL*	
FY	CIVPAY	MILPAY	RET PAY	MEDICAL ACCRUAL	FUEL	DEFENSE HEALTH	DHP excl PAY&FUEL	OTHER MILPERS	O&M	PROC	RDT&E	FH and MILCON	TOTAL	TOTAL NON PAY	excl PAY&MED	GRAND TOTAL
1970	14.87	11.55	15.47		9.37			20.49	19.22	19.02	20.79	21.02	19.55	18.61	18.61	15.47
1971	16.15	12.49	17.11		9.79			21.40	19.94	20.06	21.72	22.15	20.53	19.61	19.61	16.42
1972	17.49	14.54	18.25		10.17			22.24	20.93	21.41	22.72	23.35	21.67	20.46	20.46	17.89
1973	18.55	16.33	19.36		10.59			23.33	22.65	23.33	24.10	24.96	23.38	22.10	22.10	19.47
1974	20.20	17.43	21.23		11.22			25.05	26.22	25.47	26.57	27.32	25.93	24.42	24.42	21.23
1975	21.83	18.56	24.23		12.91			28.49	29.64	28.40	29.56	30.85	29.08	26.72	26.72	23.07
1976	23.61	19.54	26.90		13.87			30.97	32.60	31.52	32.66	33.97	32.09	29.89	29.89	25.42
1977	25.68	20.64	28.49		15.01			33.07	34.02	32.63	34.15	35.27	33.36	31.37	31.37	27.23
1978	27.74	22.07	30.64		16.08			35.58	36.83	35.87	36.99	37.83	36.34	34.23	34.23	29.48
1979	29.38	23.36	33.17		18.59			38.92	40.42	39.68	40.60	41.40	40.05	37.51	37.51	31.85
1980	31.39	25.03	37.17		35.00			43.01	44.48	43.82	44.62	45.27	44.12	43.09	43.09	35.69
1981	34.13	28.54	41.34		40.43			47.21	48.27	47.79	48.30	48.72	47.97	47.25	47.25	40.16
1982	35.03	33.18	44.06		44.96			50.46	50.94	51.04	50.97	51.45	50.99	50.48	50.48	43.74
1983	36.93	34.69	46.61		40.25			52.44	52.89	53.61	52.90	53.49	53.28	52.32	52.32	45.91
1984	38.43	36.37	48.19		34.69			54.38	54.76	55.44	54.77	55.27	55.11	53.67	53.67	47.55
1985	39.74	38.26			32.18			56.15	56.45	57.12	56.47	56.98	56.80	55.20	55.20	49.44
1986	40.60	39.90			27.88			57.73	58.05	58.89	58.08	58.76	58.49	56.39	56.39	50.41
1987	43.13	40.79			25.60			59.35	59.78	60.86	59.82	60.69	60.29	57.76	57.76	51.65
1988	45.86	42.81			21.46			61.27	61.94	63.26	61.98	62.99	62.55	59.60	59.60	53.54
1989	48.74	44.35			21.48			63.83	64.48	65.65	64.52	65.44	65.01	61.69	61.69	55.55
1990	51.13	46.78			19.16			66.44	67.09	67.94	67.10	67.57	67.46	63.74	63.74	57.13
1991	53.16	49.03			35.87			69.10	69.39	69.89	69.45	69.64	69.76	66.84	66.84	59.21
1992	55.38	50.75			23.93			71.09	71.25	71.50	71.27	71.40	71.35	68.15	68.15	60.93
1993	57.50	53.24			24.26	42.03	39.41	72.73	72.79	72.93	72.81	72.88	72.84	66.97	69.47	61.42
1994	58.96	54.61			27.68	43.37	40.52	74.17	74.20	74.26	74.21	74.25	74.22	68.16	70.82	62.66
1995	60.41	55.98			24.25	45.09	42.34	75.59	75.61	75.52	75.60	75.54	75.57	69.41	71.98	64.08
1996	61.86	57.32			25.61	46.82	44.03	77.03	76.97	76.62	76.94	76.76	76.84	70.88	73.43	65.58
1997	63.72	59.04			25.94	48.13	45.34	78.25	77.93	77.48	77.91	77.65	77.80	72.21	74.73	67.23
1998	65.50	60.69			31.05	49.68	46.78	78.84	78.56	78.28	78.56	78.41	78.49	73.58	75.91	69.13
1999	67.86	62.88			28.32	51.24	48.41	79.58	79.45	79.33	79.45	79.36	79.42	74.73	76.78	71.02
2000	71.12	65.90			21.15	53.00	50.36	80.73	80.72	80.50	80.69	80.49	80.64	75.50	77.71	72.85
2001	73.75	68.33			34.46	55.44	52.82	82.10	81.86	81.63	81.83	81.65	81.80	77.56	79.73	75.16
2002	77.14	73.05			34.12	58.76	56.41	82.82	82.70	82.90	82.71	82.89	82.78	78.33	80.44	77.17
2003	80.31	76.48		71.42	28.66	62.84	60.22	83.84	84.04	84.63	84.08	84.65	84.19	80.41	81.82	79.79
2004	83.60	79.66		74.43	31.05	66.82	64.24	85.66	86.12	86.83	86.13	86.87	86.27	82.86	84.25	82.40
2005	86.52	82.44		77.55	59.36	71.16	68.49	88.10	88.64	89.20	88.61	89.31	88.76	86.49	87.88	85.83
2006	89.21	85.00		80.73	73.01	75.48	73.04	90.75	91.08	91.40	91.07	91.43	91.14	89.35	90.58	88.67
2007	91.17	87.30		84.04	74.03	80.03	77.88	93.12	93.28	93.25	93.25	93.16	93.24	91.76	92.75	91.08
2008	94.36	90.35		87.66	100.02	84.97	82.85	95.15	94.99	94.64	94.97	94.56	94.85	94.25	94.94	93.75
2009	98.04	93.87		90.29	68.81	89.74	87.81	96.46	96.10	95.77	96.10	95.80	96.01	94.81	95.26	95.01
2010	100.00	97.07		93.44	86.22	94.22	93.43	97.33	97.15	96.99	97.16	96.96	97.11	96.62	96.86	97.01
2011	100.00	98.43		96.62	97.09	97.04	96.58	98.62	98.50	98.44	98.50	98.40	98.49	98.32	98.45	98.50
2012	100.00	100.00		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2013	102.30	102.30		103.60	103.20	103.48	103.63	101.62	101.66	101.69	101.66	101.70	101.66	101.90	101.71	102.01
2014	104.65	105.16		107.43	103.82	107.15	107.47	103.35	103.39	103.43	103.39	103.45	103.40	103.82	103.42	104.13
2015	107.06	108.11		111.41	104.44	110.96	111.45	105.11	105.16	105.24	105.16	105.27	105.19	105.80	105.16	106.30
2016	109.52	111.14		115.53	105.70	114.94	115.61	106.92	107.00	107.11	107.00	107.15	107.04	107.89	107.00	108.57

* Excludes all pay data, Military Medical Accrual data, and data for the Defense Health Program.

These deflators are calculated from DoD funding that includes all enacted war and supplemental funding.

Appendix B SPSS Regression Commands

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  /QUALIFIER='"'
  /ARRANGEMENT=DELIMITED
  /FIRSTCASE=2
  /IMPORTCASE=ALL
  /VARIABLES=
  FY F4.0
  NIIN F6.0
  Total Demand F7.2
  Total_Demand_Cost F10.2
  Filter A6
  ANUC F8.2
  Deflator F5.2
  AdjustedANUC F8.2.
DATASET NAME DataSet1 WINDOW=FRONT.
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COMPUTE filter_$=(Filter = "#N/A").
VARIABLE LABELS filter_$ 'Filter = "#N/A" (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
SORT CASES  BY NIIN.
SPLIT FILE LAYERED BY NIIN.
REGRESSION
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  /MISSING LISTWISE
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  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FY
  /METHOD=ENTER AdjustedANUC.
```

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14. ABSTRACT

Cost growth above inflation (CGAI) is the cost growth that exists after adjusting for the effects of currency inflation over time. The time value of money would suggest the increase in Operating and Support (O&S) costs over time would only be affected by inflation. In essence, every year aircraft need to be maintained at the same level and O&S costs should not change, assuming the same level of requirements. If CGAI exists in O&S there will be a large inaccuracy in the total life cycle cost (LCC) of weapon systems and an inaccurate budget put in place. An inaccurate estimate of O&S costs lead to budgeting problems and creates future budget issues. This study begins an exploration of CGAI and attempts to measure the relationship of the cost growth to unaccounted increases in raw material cost. Specifically, we evaluate CGAI through an analysis of raw material costs from a period of 2000 to 2012 for Air Force aircraft. Raw material costs ideally should only be affected by inflation, and thus any cost growth beyond inflation indicates a problem. A better understanding of inflation-adjusted cost growth provides understanding why O&S cost continues to increase beyond the rate of inflation.

15. SUBJECT TERMS
Cost Growth Above Inflation, Aging, Operating and Support

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