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An Analysis of Defense Contractor Profit Margin Percentages

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AN ANALYSIS OF DEFENSE CONTRACTOR PROFIT MARGIN PERCENTAGES

THESIS

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Abstract

Profit earned by defense contractors is a controversial issue among government officials and the defense industry. It is recognized that profits earned by defense contractors are not strictly the product of the dynamics of a competitive market, but of federal profit statutes, contractual incentive schemes, the quality of government oversight, and in a market of less than full competition. As such, there is always concern of whether contractors are earning "excessive" profit – through policy or failed oversight. The purpose of this research is to investigate the question of reasonable profits from one particular angle – whether profit margins differ among two different categories of contractors, primes and sub-contractors. We assume rational behavior from contractors, and expect profit to rise where, broadly speaking, opportunity permits. Primes and subs face different opportunity. Principal-agent theory predicts sub-contractors may find opportunity to achieve higher profits. Asymmetric information theory predicts those with a special expertise in figuring out the complex DoD environment may earn higher profits. This study examine whether contractors may earn differential returns based on their distance from oversight, and their relative expertise toward others on projects. The study finds that sub-contractors, in the aggregate do not earn higher median profits than primes. However, it finds that expertise does appear to be a significant characteristic at a finer level of analysis. Expertise correlates with higher median profits. And, sub-contractors who exhibit this expertise earn higher median profits than both their primes and other sub-contractors.

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AN ANALYSIS OF DEFENSE CONTRACTOR PROFIT MARGIN PERCENTAGES

I. Introduction

1.1 Background

Profit earned by defense contractors is a controversial issue among government officials and the defense industry. Profit earned by defense contractors is of perennial concern because it is recognized that profits are not strictly the product of the dynamics of a competitive market but of federal profit statutes, contractual incentive schemes, the quality of government oversight, and in a market of less than full competition (Subpart 15-4 - Contract Pricing, n.d.). As such, there is always concern of whether contractors are earning more than necessary – through policy or failed oversight. Despite concerns, little research has been conducted using Department of Defense (DoD) data to analyze what variables drive defense contractor profit.

The debate over defense contractor profit is largely driven by the question of whether or not the defense industry derives "excessive profit" from government and DoD funded initiatives. Previous research has attempted to answer the subjective question of what excessive profit is, however, the conceptual trouble of defining "excessive" make it difficult to come to a consensus. Relevant profit metrics differ between companies and sectors. With no single accepted profit metric being used, research has yielded conflicting findings (Fisher, F. M., McGowan, J. J., 1983). This study skips the question of what is excessive, and instead aims to identify *conditions* in which defense contractors tend to earn higher profit margins. In doing so, it hopes to indirectly contribute to understanding when profit becomes unreasonable or problematic.

The concern about "excessive profit" remains the backdrop of the discussion, as it has been noted as influencing decisions. In testimony to the House of Representatives Committee, Pierre Chao, Senior Associate at the Center of Strategic and International Studies, emphasizes the economic and profit incentives embedded in the acquisition system create adverse results. He states, "Culturally, we have evolved to a point where we would rather pay $1 billion and 5% profit for a defense good, than $500 million and 20% profit"(Chao, 2013, p. 5). If so, the attempt to avoid profit, and the scrutiny it invites has biased DoD towards inefficient practices. Therefore, knowing if profit margins are reasonable could shift the bias towards a more overall effective means of managing programs.

In the same vein, the acquisition community has recently expressed concern over the profit earned by sub-contractors. In 2015, the Under Secretary of Defense, Acquisition, Technology, and Logistics (USD(AT&L)) found evidence to support this concern by comparing the median prime and sub-contractor profit margins on Major Defense Acquisition Programs (MDAPs) and subsystems (2001-2015). The study found that during both development and production, sub-contractors earned higher profit margins than primes. However, the USD(AT&L) study noted further analysis is required to understand these differences (USD(AT&L), 2015). The current study seeks to understand these differences and identify statistically significant profit drivers.

Rhea (2017) used contractor cost data on aircraft, missiles, and UAV commodities to further explore prime versus sub-contractor profit. Median profit percentage by phase, contract type, commodity, and service were used to determine differences. Rhea found neither contractor group to have a consistent advantage over the other. The current study readdresses the issue, and expands the scope of previous studies through the use of further commodities, an expanded data set, and a new methodology.

1.2 Problem Statement

The purpose of this research is to to investigate the question of reasonable profits from one particular angle – whether profit margins differ among two different categories of contractors, primes and sub-contractors. We assume rational behavior from contractors, and expect profit to rise where, broadly speaking, opportunity permits. Primes and subs face different opportunity. Principal-agent theory predicts sub-contractors may find opportunity to achieve higher profits. Asymmetric information theory predicts those with a special expertise in figuring out the complex DoD environment may earn higher profits. This study examine whether contractors may earn differential returns based on their distance from oversight, and their relative expertise toward others on projects.

1.3 Research Questions

This study will seek to answer several questions. First, do contractors derive higher profit margins in an environment characterized as being less scrutinized by government? In particular, do sub-contractors earn higher profit margins? The principal-agent theory predicts that – a sub might extract higher profits where in the prime as an agent is not incentivized to fully control sub-contractor costs (Eisenhardt, 1989)

Second, does contractor *expertise* in the DoD environment extract more profit? The study takes the magnitude of DoD contract dollars and number of contracts awarded as a proxy for contractor expertise. Third, does the *disparity* of expertise (expertise, as already defined) between primes and sub-contractors matter? There are two arrangements or "dyads" of big and small in practice ("expert" prime – "other" sub; "expert" prime – "expert" sub), which can be accurately analyzed. Asymmetric information theory suggests that in the first dyad, the primes "win," or earns higher profit compared to the sub. In the second (where there is no particular expertise advantage), the sub-contractor might earn high profits by exploiting regulations under less scrutiny. In particular, their expertise may allow them to exploit the opportunity of "pass through" and possibly even engage in strategic bargaining, whereby the agent of the prime is lax towards the secondary agent of the sub when they are equals – expecting similar lax treatment when the relationships are reversed.

1.4 Methodology

This study used Cost Data Summary Reports (CDSRs/1921s) to calculate the profit margins. CDSRs were pulled from the Defense Automated Cost Information Management System (DACIMS) on 28 June 2018. This dataset consisted of 1567 CDSRs (959 primes and 608 subs). The policy for the management of all acquisitions programs is established in the Department of Defense Instruction (DoDI) 5000.02. The DoDI 5000.02 requires both prime and subcontractors to submit CDSRs on all contracts valued over $50 million. Additionally, the Program Manager and/or the Deputy Director, Cost Assessment (DDCA) can require CDSRs for high-risk or high-technical-interest contracts priced between $20 million and $50 million (*Department of Defense Instruction 5000.02*, 2015).

JMP® Pro 13 was used to complete all the statistical analysis in this study. First, a comparison analysis examined the influence of expertise on profit margins. A comparison of prime and sub contractor profit margins was completed. Sample t-tests and Wilcoxon/Kruskal-Wallis tests were used to test for statistical significance when comparing the different groups of data.

Next, contingency table analysis was used to explore the hypothesis that "expert" contractors earn a higher profit regardless of the prime – sub dyad. The two dyads this study is concerned with are 'expert prime – expert sub' and 'expert prime – other sub.' The statistical significance of these dyads was tested using the Fisher's Exact Test. Odds ratios and confidence intervals were also reported. Finally, Ordinary Least Squares (OLS) regression was used identify profit drivers as well as determine which were most predictive. The regression model was created using the JMP®'s mixed stepwise OLS function.

1.5 Assumption/Limitations

This study only analyzes ACAT I programs and contracts that are 95-100% complete. The format of the CDSR has changed over the years with the two most recent versions being 2007 and 2011. These were the only versions of the CDSR that were able to be exported from DACIMS. Additionally, only development and production phase contracts were used in this study. Data from the CDSRs was used to calculate realized profit margins for primes and sub-contractors. This research assumes the data reported on the CDSRs is accurate.

1.6 Thesis Overview

This thesis consists of 5 chapters. Chapter 2 presents a review of the relevant literature, including economic theories, DoD profit regulations, and recent studies comparing profit within the defense industry. Chapter 3 outlines the methodology including data cleaning steps and creation of dummy and categorical variable necessary for the analysis techniques used. Chapter 4 presents the findings of the analysis and discusses them individually and as a group. Chapter 5 outlines the key findings from the analysis and presents some ideas for future research work.

II. Literature Review

2.1 Overview

The topic of profit earned by defense contractors is of perennial concern because it is recognized that profits are not the natural by-product of a competitive market, but rather something the government itself partially influences through its profit policy and contractual incentive schemes. The defense industry operates in an oligopolistic market structure where in a small number of large sellers dominate the market. Such high market concentration gives defense contractors unique bargaining power. Likewise, the government's position as a monopsonist gives it a unique power and a responsibility to provide adequate profit.

A 2018 study calculated the defense industry market concentration using data from the Defense Contract Action Data System (DCADS) Carril, R., Duggan, M, 2018). The calculation included all non-classified DoD contracts awarded from 1985-2001 that had a value of $25,000 or more. Figure 1 shows the change in the defense market concentration over time. The share of DoD contract dollars awarded to the five largest DoD contractors rose from 21.7 percent in 1990 to 31.3 percent in 2000. This higher concentration decreased competition creating an increase in sole source contracts. Despite the increased market concentration, the researchers found no evidence that it increased acquisition cost. The researchers suggests this could be due to the government's position as buyer as well as the long-term relationships formed Carril, R., Duggan, M, 2018). The 2018 study did not analyze the effect of this increased market share on defense contractor profit. However, it is widely recognized that there is a strong relationship between market share and return on investment (Furhan, 1972).

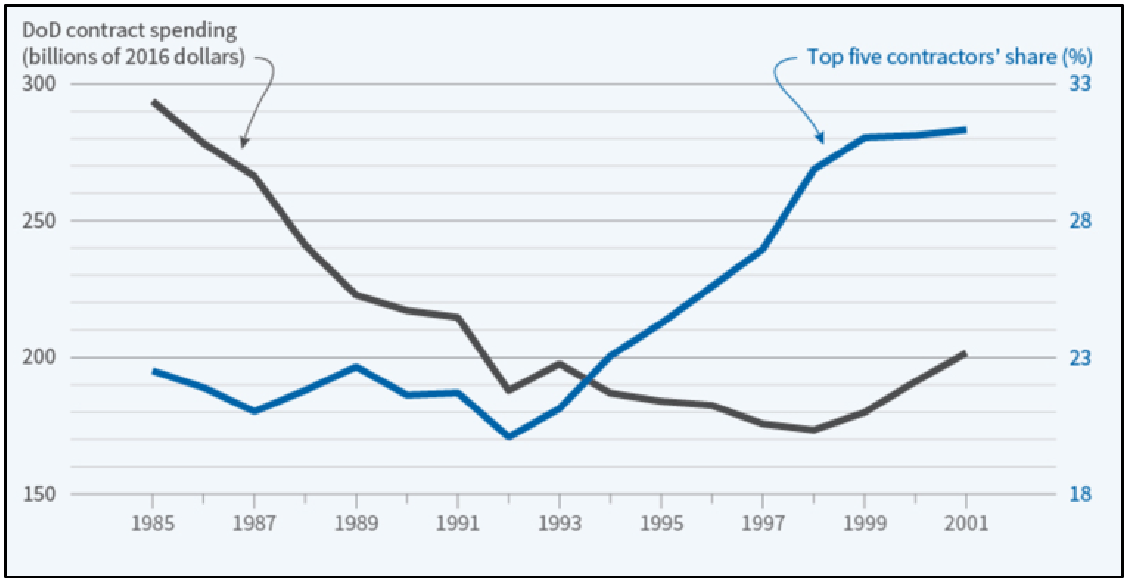


Figure 1. U.S. Defense Spending and Concentration (adapted from Carril, R., Duggan, M, 2018)

Unlike the competitive market where products are standardized and there are many choices, the defense industry often buys highly customized weapon systems that require a multi-year process. Demand is highly uncertain and is largely a function of the political environment. Prices are based primarily on a contractor's actual or anticipated costs using cost estimating methods rather than the market setting the price. The unique market structure of the defense industry makes it difficult to weigh in on whether the profit earned by defense contractors is appropriate relative to other industries.

A number of studies have nonetheless attempted to compare profit and make the subjective evaluation of what is "excessive" profit. Most have concluded at the aggregate there higher profits in the defense industry compared to other industries (Stigler & Friedland, 1971; Lichtenberg, 1992; Wang & San Miguel, 2012). This study will instead compare profit margins of different contractors *within* the defense industry and help to derive insights from that novel perspective. It is believed this lower level of aggregation permits a richer qiualitative discussion of what is reasonable.

This literature review has three areas of focus to form the hypothesis tested in Chapter 4. First, the economic theories that provide the framework for the empirical tests conducted in this study are reviewed. Second, we describe the uniqueness of the DoD regulations and acquisition process that relate to profit. Finally, this chapter reviews recent studies that compare profit margins within the defense industry.

2.2 Experiential Knowledge

The uniqueness of the defense industry requires a certain level of industry knowledge to operate in. There are two overarching types of knowledge, 'experiential knowledge' and 'objective knowledge' which differ in terms of the way each is acquired (Petersen, Pedersen, Sharma, 2003). Objective knowledge is acquired through standardized methods and market research (Petersen, Pedersen, Sharma, 2003). It is a technical knowledge easily codified and communicated. Experiential knowledge is acquired through carrying out activities (Petersen, Pedersen, Sharma, 2003). It is not as easily communicated or imitated. It becomes proprietary turning an initial advantage into an enduring market advantage.

Research on internationalization has focused on the role of experiential knowledge. Internationalization is the process of increasing involvement of enterprises in international markets (Petersen, Pedersen, Sharma, 2003). This research serves as a fair analogy for firms trying to figure out the uniqueness of the DoD market. And it suggests an important role for experiential knowledge for firms in new markets.

Johansen and Vahlne (1977) found that experiential knowledge is more valuable compared to objective knowledge and leads to firms taking steps towards opening new markets (Johanson and Vahlne, 1977). The current study does not distinguish between the two types, but rather derives from it the findings that time and breadth of experience can serve an important role for a firm in a highly unique market setting.

The defense industry is highly regulated and understanding the ends and out of the regulations requires experiential knowledge. With profit being negotiated through profit policies rather than the market determining profit, experience in negotiating with government contractors is likely highly beneficial.

2.3 Principal-Agent Theory

The principal-agent theory focuses on the relationship between one party (the principal) that employs another party (the agent) for work. One example of a principal-agent relationship is a buyer hiring a supplier. The buyer (principal) assigns duties, responsibilities, and decision-making authority to the supplier (agent) through contracts (Eisenhardt, 1989). The focus of the principal-agent theory is on determining the optimal contract between two parties such that the agent serves the principal's interests in their fullest in further negotiations with 3rd parties (Eisenhardt, 1989).

The relationship between the DoD and defense contractors can be interpreted as a principal-agent situation; therefore, the application of this theory should provide insight into defense contractor profit margins. For a given contract, it is usual for the DoD to interact with one defense contractor (prime). But, in order to complete a project these contractors will invoke the services of sub-contractors. The DoD (principal) relies on the prime contractor (agent) to not only deliver a product or service, but also efficiently manage sub-contractors (agents).

There are two overarching problems principal-agency theory is concerned with resolving. One problem is conflicting goals between the principal and agent, and the second is the problem of risk sharing (Eisenhardt, 1989). These two problems apply to the relationships within defense contracting. The government's goal is to acquire the best product or service for the lowest price; the goal of a defense contractor is to make the largest profit possible. This is self-evident. But if the prime takes action with sub-contractors in a manner that does not keep prices low for the DoD, then a principal-agent conflict arises. Negligence, ineptitude, and opportunism are all moral hazards an agent may display which ultimately harms the principal. The agent is not acting in good faith. Likewise, with risk-sharing, parties have their own view on the amount of risk they want to take on.

At the heart of the principal-agent problem is information asymmetry. Information asymmetry is where one party has more information or better information than the other creating an imbalance of power in a transaction. Agents have more knowledge in their specific field and not sharing this knowledge with the principal leads to information asymmetries. Moral hazard and opportunism arise. Moral hazard occurs when an agent has more information about his or her actions or intentions than the principal does, because the principal usually cannot completely monitor the agent. Opportunism is, "self-interest with guile" (Williamson, 1973 p. 317). Williamson further explains the two most common forms of opportunism. The first being the strategic disclosure of information. The second type is due to first-mover advantages, where the winner of original bids acquire experience which places them at a cost advantage compared to non-winners during future negotiations (Williamson, 1973).

Information asymmetry and the issues that arise from it are relevant to the defense industry. The DoD relies on the defense contractors to provide cost and price information that is used to build budgets and develop future cost estimates. Defense contractors have incentives to hide or exclude information to increase profits or win contract awards. For example, a prime could potentially submit a lower bid on a development contract to win the award knowing they will likely secure a sole source contact later for production. This increases its chances of earning higher profits over the long run.

A way to attempt to overcome the issue of information asymmetry is through screening. Screening is a technique used by one agent to extract otherwise private information from the other (Akerlof, 1978). The DoD employs this technique through regulations that increase oversight and require defense contractors to provide cost and price data. However, contractors also have means to gain information from the DoD. Some contractors gain more experience in the defense industry and may use their increased knowledge of expectations and behaviors of contracting officers over time to increase profit margins. The more experience a contractor has in the defense industry, the more they know they can use this experience to potentially derive higher profits.

Sharing many similarities with principal-agent theory is the transaction cost theory (Dahlman, 1979). Transaction costs include the costs of searching for information, bargaining, policing and enforcement (Dahlman, 1979). In his famous article, "Nature of the Firm," Coase (1937) argues that a firm will continue to expand until the marginal cost of expanding becomes greater than transaction costs. Once internal production costs exceed the market transaction costs, outsourcing tendencies arise (Coase, 1937). The DoD outsources where it is too much effort to organize the work internally and prime contractors do the same. But, with each outsourcing step more policing of agent behavior is required (Coase, 1937). Having fewer policing requirements of sub-contractors by the DoD, puts the responsibility on the incentive structure between the principal and agent. A concern in the DoD is whether the DoD has done enough here, or should it increase scrutiny of sub-contractors. If DoD incentives and oversight are deficient than we should expect primes with greater experience in the defense industry to have higher profit and more distant sub-contractors with greater experience in the industry to have even higher profits.

2.4 Profit Regulations

There are reasons to believe that the aforementioned forces may be at work. Profit earned by defense contractors must be addressed by the DoD at two critical times. The first is when a contract is being negotiated, and the second is after the contract is complete. The Federal Acquisitions Regulation (FAR) prescribes the cost and price negotiation policies and procedures for pricing negotiated contracts. The Defense Federal Acquisitions Regulation Supplement (DFARS) states contracting officers "shall use a structured approach for developing a pre-negotiation profit or fee objective on any negotiated contract action when certified cost or pricing data is obtained, except for cost-plus-award-fee contracts" (Subpart 15-4 - Contract Pricing, n.d.). The most common structured approach is the weighted guidelines method.

The weighted guidelines method focuses on four profit factors: performance risk, contract type risk, facilities capital, and cost efficiency (DFARS PGI 215.404-Profit, n.d.). The profit factor addresses the contractor's degree of risk in fulfilling contract requirements. The first of these factors, performance risk, initially consisted of three elements that contracting officers could assign a standard profit range of 2 to 6 percent:

1. Technical—the technical uncertainties of performance.
2. Management—the degree of management effort necessary to ensure the contract requirements are met.
3. Cost control—the contractor's efforts to reduce and control costs.

The weights of these 3 elements are determined by the contractor officer, but have been impacted also by legislation. In the National Defense Authorization Act for Fiscal Year 2000, Congress mandated that the DoD review it's profit guidelines. Specifically, Congress wanted the DoD to consider modifications to the performance risk factor. The focus was to increase incentives for contractors to produce complex and innovative new technology and weapons systems. This review resulted in technology incentives being added to the DoDs profit policy. The first change increased the weight contracting officers would likely assign to the technical performance risk element by combining the management and control element. The second change added a technology incentive to award contractors for innovation. These changes allowed contracting officers to assign and profit range of 6 to 10 percent as opposed to the standard range of 2 to 6 percent (GAO, 2001). The current study uses data entirely from this new era.

The second factor, contract type, focuses on the degree of cost risk accepted by the contractors under varying contract types. There are multiple contract types that generally fall into two categories: cost reimbursable contracts and fixed price contracts. Figure 2 depicts the inverse risk relationship for the most common types of contacts. Generally, contractors assume more risk with fixed contracts compared to cost contracts.

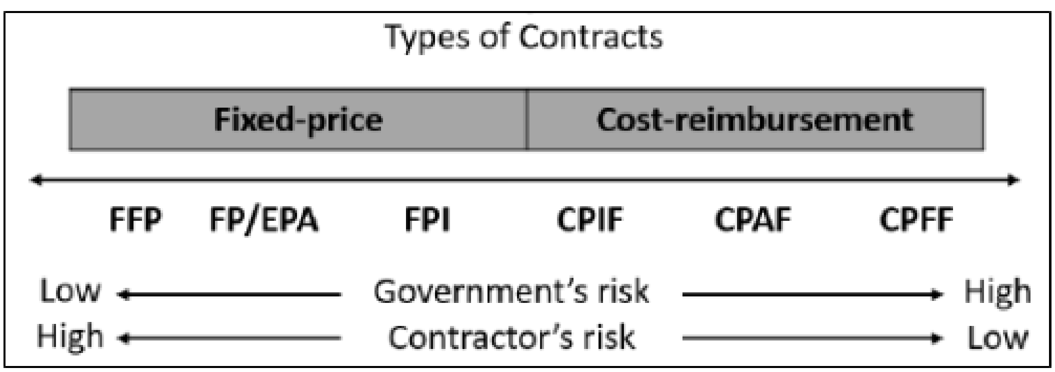


Figure 2. Types of Contracts by Risk (DAU, 2018)

Table 1 provides the normal value and designated range for profit percentages based on contract type. Generally speaking, contractors are awarded higher profit as they assume more contract type risk. Firm-fixed price contracts with no financing, being the most risky for the contractor, have the highest profit percent. Whereas cost-plus contacts, being less risky to the contractor, have the lowest profit percent. This creates an incentive for contractors to negotiate for a firm-fixed contract when they know their risk is low in attempt to earn higher profit margins (DFARS PGI 215.404-Profit, n.d.).

Table 1. Contract Type Profit (%) (adapted from DFARS PGI 215.404-Profit, n.d.)

Contract Type	Normal Value (%)	Designated Range (%)
Firm-fixed-Price, no financing	5	4 - 6
Firm-fixed-price, with performance-based payments	4	2.5 - 5.5
Firm-fixed-price, with progress payments	3	2 - 4
Fixed-price incentive, no financing	2	0.5 - 3.5
Fixed-price incentive, with progress payments	1	0 - 2
Cost-plus-incentive-fee	1	0 - 2
Cost-plus-fixed-fee	0.5	0 - 1

The third factor, facilities capital, rewards contractors for capital investments in facilities that benefit the DoD. It is calculated by applying cost-of-money rate to the facilities capital employed (DFARS PGI 215.404-Profit, n.d.). The final factor, the cost efficiency factor, provides contractors with incentives to reduce cost. The contracting officer can increase the pre-negotiated profit objective by 4 percent of the total objective cost (DFARS PGI 215.404-Profit, n.d.). Criteria used for this adjustment include prior contract cost reductions achieved, reduction of excess facilities, contractor's process improvements that reduce costs, and subcontractor cost reductions.

Statutory Limitations

The FAR also addresses the statutory limitations imposed by 10 U.S.C an 2306(d) and 41 U.S.C. 25(b). These limitations, identified in Table 2, apply to cost-plus-fixed fee contracts and only prime contractors.

Table 2. Statutory Limitations (FAR 15.404, n.d.)

Type of Contract	Fee Limitation
Experimental, developmental, or research work performed under a cost-plus-fixed-fee contract	15% of estimated contract cost, excluding fee
All other cost-plus-fixed-fee contracts	10% of estimated contract cost, excluding fee

Pass-Through Charges

These profit guidelines primarily apply to prime contractors. Profit for subcontractors is a growing concern that Congress has attempted to increase oversight. Pass-through charges are defined as overhead costs or profit passed to the Government by contractors adding no or negligible value over work done by lower-tier contractors (FAR 52.215, n.d.) Starting with the Post-Katrina Emergency Reform Act of 2006, Congress has been trying to eliminate "excessive" pass through charges. The Post-Katrina Emergency Reform Act of 2006 introduced limitations on tiering of subcontractors after allegation that lower-tier subcontractors were grossly overpaid during the reconstruction following the hurricane. This was primarily due to tiering of subcontractors by four to five levels creating excessive pass-through charges (Congress, 2007).

The 2007 National Defense Authorization (NDAA) also introduced provisions regarding pass-through charges. The 2007 NDAA introduced the requirement that independent estimate of costs of the future combat systems shall address pass-trough charges by the lead systems integrator and its major subcontractors (109th Congress, 2007). Following the 2009 NDAA, the FAR was amended to disallow excessive pass-through charges and requires contractors to provide a detailed proposal if they intend to subcontract more than 70 percent of the total cost of work (FAR 52.215, n.d.). Not only is the U.S. government cracking down on pass-through charges, but it is holding contractors accountable. In 2012, Lockheed Martin Corp. agreed to pay $15.8 million to the U.S government to settle allegations that they passed on inflated costs of tools by their subcontractor Tools & Metals Inc. (TMI) (Seper, 2012).

The DoD's complex system to determine profit and the updating and adjusting of policy make it difficult for contractors to navigate. The DoD environment differs greatly from the free market and requires distinct expertise to understand. Therefore, it seems entirely reasonable for contractors with more expertise in the DoD environment to earn higher profit.

2.5 Profit Studies of DoD

Since 2013 the office of the Under Secretary of Defense (USD) for Acquisitions, Technology, and Logistics (USD(AT&L)) has reported on the performance of the Defense Acquisitions. A study in the 2015 report compared first-tier sub-contractor final profit margins (fraction of price going to fee or profit) with their associated prime contractors on the same program during development and production. The subs analyzed were large-scale and did not provide commercial items. The analysis concluded that sub-contractors earned higher margins in both production and development.

During development, the sub-contractors earned a median profit margin percentage of 8.3% whereas primes only earned a median of 6.2%. The difference was much larger during production, with sub-contractors earning 16.3% and primes only earning 9% (USD(AT&L),2015). However, these findings are not compelling as the study used weighted averages. This means it took the unusual approach of combining two variables, size and profit, corrupting the view of profit. Furthermore, no statistical testing was completed to determine of the medians were statistically different. Nonetheless, this study provides a motive for the current study. It also captures the sentiment shared by some that sub-contractors may earn “excessive” profit.

A 2017 study by Rhea followed up on the USD(AT&L) study and compared profit percentages between prime and sub-contractor for aircraft, missiles, and unmanned aerial vehicles (UAVs). Rhea employed a more rigorous approach. He used contractor cost data to see if one contractor group had an advantage over the other regarding profit. Table 3 summarizes the results of Rhea’s study. It is important to note that statistical tests were not conducted to determine if the observed difference in means and medians are statistically significant. This study does yield the findings that there is no substantial significance; meaning most of the means and medians are very close together. At the aggregate the profit margin for prime contractors was found to be 14.3% and for subcontractors it was 14.6% (Rhea, 2017).

Table 3. Profit Margin Results (adpated from Rhea, 2017)

Variable	**Sample Size (Prime/Sub)**	**Median (Prime/Sub)**	**Mean (Prime/Sub)**	**Std Dev (Prime/Sub)**
Aggregate	389 / 276	14.3% / 14.6%	15.6% / 14.6%	9.6% / 13.5%
Dev	37 / 19	8.3% / 6.7%	9.1% / 5.0%	10.5% / 13.6%
Prod	352 / 257	15.0% / 15.1%	16.3% / 15.3%	9.3% / 13.3%
Cost	51 / 39	9.0% / 13.0%	10.4% / 12.5%	6.7% / 5.3%
Fixed	247 / 219	16.6% / 15.5%	17.5% / 15.1%	10.5% / 14.8%
Other	91 / 18	12.9% / 11.2%	13.3% / 13.2%	6.7% / 8.4%
Aircraft	288 / 241	14.7% / 14.2%	16.0% / 14.3%	9.2% / 14.1%
Missiles	69 / 28	13.6% / 17.6%	14.6% / 17.7%	11.5% / 8.2%
UAV	32 / 7	12.3% / 16.3%	14.2% / 13.4%	8.8% / 6.7%
Air Force	75 / 16	12.0% / 16.1%	12.7% / 12.5%	7.3% / 14.5%
Army	107 / 61	16.7% / 13.5%	18.4% / 12.4%	9.1% / 18.2%
Navy	200 / 115	14.5% / 16.0%	15.4% /17.4%	10.4% / 11.9%

Breaking out the aggregate revealed potential differences, but it is important to note that nothing is systematic. In his comparison of median profit margins by acquisition phase, Rhea found that prime contractors may have higher margins in development. In a comparison by contract type, sub-contractors may have higher profit margins compared to cost contracts. In a comparison by service, the results are varied (Rhea, 2017). These finding do not corroborate the 2015 USD(AT&L) study. It is important to note that Rhea did not weight the values as the previous study did (Rhea, 2017). With mixed finding between the two studies and the absence of statistical testing, further analysis is warranted.

2.6 Questions Derived

From this literature review several questions follow. First, do contractors derive higher profit margins in an environment characterized as being less scrutinized by government? In particular, do sub-contractors earn higher profit margins? The principal-agent theory predicts that – a sub might extract higher profits where in the prime as an agent is not incentivized to fully control sub-contractor costs (Eisenhardt, 1989) Second, does contractor *expertise* in the DoD environment extract more profit? The study takes the magnitude of DoD contract dollars and number of contracts awarded as a proxy for contractor expertise. Third, does the *disparity* of expertise (expertise, as already defined) between primes and sub-contractors matter? There are two arrangements or "dyads" of big and small in practice ("expert" prime – "other" sub; "expert" prime – "expert" sub), which can be accurately analyzed. Asymmetric information theory suggests that in the first dyad, the primes "win," or earns higher profit compared to the sub. In the second (where there is no particular expertise advantage), the sub-contractor might earn high profits by exploiting regulations under less scrutiny. In particular, their expertise may allow them to exploit the opportunity of "pass through" and possibly even engage in strategic bargaining, whereby the agent of the prime is lax towards the secondary agent of the sub when they are equals – expecting similar lax treatment when the relationships are reversed.

III. Methodology

3.1 Overview

Chapter 3 provides the methodology to examine profit margin percentages between primes and subcontractors for ACAT I Major Defense Acquisitions Programs (MDAP). This section will provide the source of the data, the calculations used for this study, and describe the data cleaning process. This section will also explain the statistical process used to perform the analysis in Chapter 4.

3.2 Data

The data used for this research was extracted on 28 June 2018 from the Defense Automated Cost Information System (DACIMS). DACIMS is part of the Cost Assessment Data Enterprise (CADE). CADE is the central repository for all ACAT I Contractor Cost Data Reports (CCDRs). There are four types of CCDRs: Cost Data Summary Report (CDSR/1921), Function Cost Report (1921-1), Progress Curve Report (1921-2), and Contractor Business Data Report (1921-3).

The DoDI 5000.02 requires both prime and subcontractors to submit CDSRs on all contracts valued over $50 million. Additionally, the Program Manager and/or the Deputy Director, Cost Assessment (DDCA) can require CDSRs for high-risk or high-technical-interest contracts priced between $20 million and $50 million (USD (AT&L), 2015). For CDSR purposes, the term "contract" (or "subcontract") may refer to a standalone contract, to a specific task or delivery order, to a contract line item number, or to a series of line item numbers within a contract (DodDI 5000.02, n.d.).

There are three types of CDSRs: Initial Reports, Interim Reports, and Final Reports. The current study only analyzed "Final" CDSRs for ACAT I development and production contracts at the summary level (WBS 1). Final Reports are intended to capture all or substantially all actual contract costs. A Final Report is required as of the last day of the month when at least 95% of the contract cost have been incurred and the final end item has been accepted by the government (Data item description "Cost Data Summary Report", 2011). For this research, the data was exported from DACIMS by running a query for all "Final" CDSRs. In the original dataset, there were 2032 CDSRs (1187 prime and 780 subs).

3.3 Calculations

The following calculations were performed on the original 2032 CCDRs before the data cleaning process. For each contract, the percent complete and profit margin percentage was calculated.

Percent Complete

The percent complete formula was used to ensure only contracts that were at least 95% complete were used in the analysis. Percent complete was calculated using Equation 1.

$$\%Complete = \frac{Subtotal\ Cost + G\&A\ (to\ date)}{Subtotal\ Costs + G\&A + UB\ (at\ Completion)} \tag{1}$$

Where

- Subtotal costs: "Total cost provided by the highest level WBS Reporting Element" (Data item description "Cost Data Summary Report", 2011)

- General & Administrative(G&A): "Indirect expenses related to overall management and administration of the contractor's business unit" (Data item description "Cost Data Summary Report", 2011)

- Undistributed Budget (UB): "Portion of the budget applicable to program effort that has not yet been allocated to control account budgets" (Data item description "Cost Data Summary Report", 2011)

Profit Margin Percentage

There are two ways to refer to contractor profit, either as "profit" or as "fee." Typically, "fee" is the amount contractors receive on cost-reimbursable contracts and "profit" is what contractors receive on fixed-type contracts. This research will refer to both terms as "profit." Equation 2 was used to calculate the profit margin for cost and other types of contracts. Since only contracts that were greater than 95% complete were analyzed, 99% of the dataset no UB remaining and 83% had no MR.

$$Profit\ Margin\% = \frac{Profit}{Subtotal\ Costs + G\&A + UB\ + MR} \tag{2}$$

Where

- Management Reserve: "Total allocated budget that is held back for management control and risk purposes at the total contract level" (Data item description "Cost Data Summary Report", 2011)

3.4 Data Cleaning

Table 4 shows the data cleaning process used for this research. The original dataset consisted of 2032 CDSRs, 1187 primes, and 780 subs. There were also CDSRs for which the contractor type was unknown. All unknown contractor types in the final dataset were manually reviewed in DACIMS to determine whether the contractor was a prime or sub. Equation 1 was used to calculate the percent complete and CDSRs that were not 95% complete were excluded. CDSRs for which were missing the profit or for which the profit margin was greater than 100% were removed because it was believed these were errors.

Next, duplicates were identified and the older version of the duplicate was removed. Since this study was only concerned with the development and production phases, Operations & Support (O&S) contracts were removed. Additionally, CDSRs that could not be identified as either development or production contracts were also removed. Lastly, if a period of performance date was missing and could not be determined by locating the CDSR manually in DACIMS, the CDSR was removed

A sample t-test was completed to compare the means between CDSRs that were 100% complete to CDSRs that were less than 100% complete. This was due to concern that contractors could potentially greatly influence profit in the last 5% of a contract. A level of significance (α) of 0.05 was used for this test. The null hypothesis for this test is that the means are equal and the alternative is that they are different. We failed to reject the null hypothesis. The final usable dataset consisted of 77% of the original data pull (959 primes and 608 subs).

Table 4. Dataset Exclusions

Criteria	**Affected CDSRs**	**Affected Prime**	**Affected Sub**	**Affected Unknown**
Initial Data Pull (Final Reports)	2032	1187	780	67
Exclusion 1: $<$ 95% complete	128	80	36	12
Exclusion 2: Missing Profit	138	29	86	23
Exclusion 3: $>$ 100% Profit	15	0	1	14
Exclusion 4: Duplicates	80	47	29	4
Exclusion 5: O&S Contract	72	51	8	13
Exclusion 6: Missing Phase	20	12	8	1
Exclusion 7: Missing PoP	14	7	4	0
Final Dataset	**1567**	**959**	**608**	**0**

Expertise Cohort

The data contains 72 different contractors, ranging in experience levels across 25 years from 1 contract to 177 contacts and from \$2.5 million to \$61.5 billion. It is credible that experience level varies greatly. There is no literature which identifies a # or \$ threshold to develop a study of cohorts, but it seems reasonable that the data itself would reveal such cohorts. In the current study, several methods were applied to identify cohorts within the data, which will be discussed below. Not all datasets may reveal such clear cohorts, and thus this method may not be generalizable, but the method does further the discussion of how longevity and scope of contractual experience might be important aspects of experiential knowledge, and worth further exploration of alternative methods.

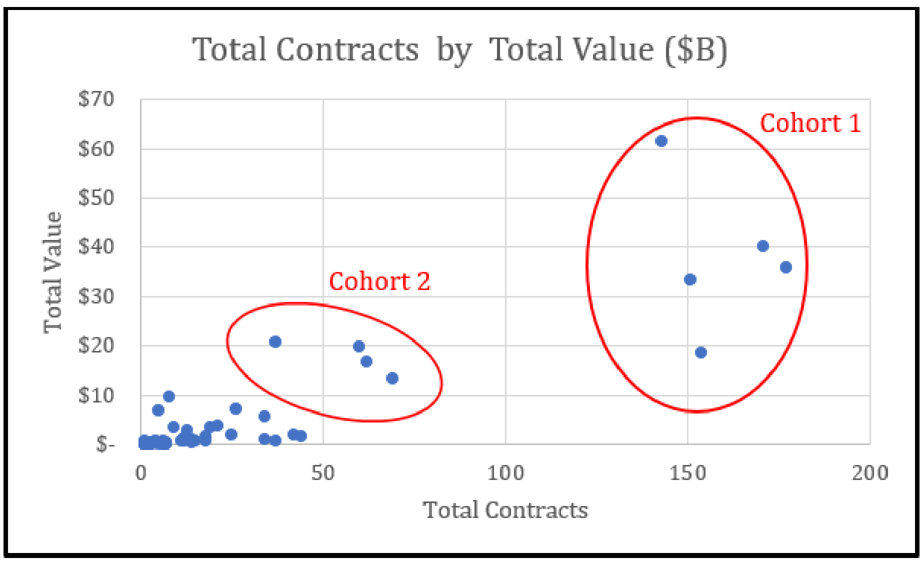


Figure 3. Scatter plot Identifying "Expertise" Cohort

This study uses the total magnitude of DoD contract dollars and the number of contracts awarded as a proxy for the level of contractor expertise in the DoD environment. As an initial assessment of the data, the total value [1] of the contracts

[1]Costs were escalated to Constant Year (CY) 2018\$ based on the period of performance start year using the aerospace Producer Price Index (PPI)

and the number of contracts in the given dataset was calculated for each of the 72 unique contractors. A plot of the number of contracts awarded vs total contract value, shown in Figure 3, provided a visual identification of 3 potential cohorts.

OLS Regression was used to determine if cohort 2 was statistically similar to cohort 1 or not. A model was created using the JMP®'s mixed stepwise OLS function. Cohort 1 and 2 were both statistically significant and reacted similar.[2] Cohort 1 has slightly stronger associations to profit, which one would expect. Contractors in both cohort 1 and 2 were deemed to have higher expertise operating in the DoD environment. Both cohort 1 and 2 were coded as "expert" since they have considerably more contracts and a higher total value compared to the remaining contractors. It should be noted that the term "expert" denotes a higher level of experience in the DoD environment and does not imply other contractors are "novices." It instead implies the "other" cohort of contractors lack a significant level of unique expertise that comes with a breadth and depth of work in this unique market. Table 5 provides the total number of contracts and the total value of the contracts for the contractors deemed to be in the "expert" cohort.

Table 5. Expert Cohort

Contractor Name	Count	Total $B
Contractor A	142	$61.5
Contractor B	171	$40.1
Contractor C	177	$35.2
Contractor D	150	$33.5
Contractor E	37	$21.6
Contractor F	59	$20.1
Contractor G	154	$19.2
Contractor H	62	$16.0
Contractor I	69	$13.3

[2] OLS regression parameter estimates are provided in Appendix A

Experience cannot be internalized instantaneously into expertise. Missing from operational knowledge is longevity. To determine if the experience, as defined, captures longevity, the data was evaluated across time. Table 6 shows the number of contracts/value($M) by year for each of the contractors in the "expert" cohort as well as the next 10 contractors.[3] A pattern is visible with the "expert" cohort (Contractors A-I) having a larger number and value of contracts over the entire dataset compared to the next 10 contractors. From this analysis there is credible support that the cohort is distinct.

Table 6. # Contracts/Dollars across time

	1992-01	**2002-04**	**2005-07**	**2008-10**	**2011-13**	**2014-17**
Ctr A	4/$5.6	16/$6.8	27/$6.1	49/$24.7	38/$15.0	8/$3.3
Ctr B	5/$7.1	7/$3.0	33/$10.3	56/$8.7	62/$11.0	8/$0.02
Ctr C	2/$1.4	9/$15.0	12/$3.7	56/$8.5	58/$5.4	40/$1.2
Ctr D	1/$1.7	6/$3.3	29/$8.4	49/$10.1	53/$9.0	12/$1.0
Ctr E	2/$4.9	3/$0.1	8/$2.0	16/$9.4	7/$2.6	1/$1.0
Ctr F			22/$10.8	1/$0.03	12/$3.6	24/$5.6
Ctr G		7/$2.4	27/$3.2	51/$6.7	51/$5.6	18/$1.3
Ctr H	4/$4.2	6/$0.1	14/$1.9	19/$5.6	17/$4.1	2/$0.1
Ctr I	1/$1.0	3/$0.6	13/$3.2	21/$6.9	21/$1.5	10/$0.1
Ctr J			4/$1.6	2/$2.1	2/$1.5	
Ctr K				13/$5.5	7/$0.6	6/$1.0
Ctr L	2/$3.8	3/$3.0				
Ctr M			4/$5.7	9/$0.1	24/$4.6	
Ctr N				6/$1.2	15/$2.4	
Ctr O			3/$0.1	4/$1.7	2/$1.3	
Ctr P				4/$0.1	16/$0.3	17/$0.3
Ctr Q	3/$0.04		4/$0.1	16/$0.5	11/$0.3	
Ctr R		1/$0.07	6/$0.3	20/$0.6	12/$0.6	5/$.07
Ctr S		1/$0.3	2/$0.2	13/$0.7	18/0.6	8/$0.1

[3]Ranked by total contract value

3.5 Comparison Analysis

The comparison analysis examines the influence of the DoD's regulations as well as contractor expertise on profit percentage. In both cases, the means and/or medians of primes and subs were compared. In terms of regulatory impact, it is theorized that the profit of primes is largely a by-product of DoD regulations and government scrutiny. Further it is theorized that the profit of subs is derived by a less regulated environment. As such, in the age-old question of "excessive profit," if subs earn higher profit-margins, it might be called "excessive" or need to be controlled.

The assumption of constant variance must first be tested to determine which statistical tests are appropriate for the comparison analysis. The Levene's test was used to assess the equality of variance for the contractor groups (Prime/Sub and Expert/Other) (Levene, 1961). The null hypothesis is that the population variances are equal. A level of significance (α) of 0.05 was used for this test. The null hypothesis was rejected for both contractor groups, and further statistical tests assumed unequal variance.

Sample t-tests and Wilcoxon/Kruskal-Wallis tests were used to test for statistical significance when comparing different groups of data. The sample t-test assumes a normal distribution and compares the means between two groups to determine if there is a statistical significance between the two population means. The null hypothesis is that the two groups are equal and the alternative is that the two groups are different.

The Wilcoxon/Kruskal-Wallis test compares the medians and does not assume normal distribution. The Wilcoxon/Kruskal-Wallis test is a rank sum test which means it combines all the observations and ranks the data 1 to N ignoring group membership. Then, the test calculates the rank averages within each variable which calculates the test statistic. The null hypothesis is that the medians between the two groups are equal and the alternative is that the medians are different. A level of significance (α) of 0.05 was used for both tests when used in this study.

3.6 Contingency Table Analysis

A more in depth variation of the expertise hypothesis examines the manifestation of higher profit regardless of the prime – sub dyad. Figure 5 shows the two dyads of prime and sub this study is concerned with. Contingency table analysis was used to explore the hypothesis that dyads of prime and sub influence profit. Contingency analysis explores the distribution of a categorical variable Y across the levels of a second categorical variable X. The results will allow us to show how expertise may have varied impact based on the dyad.

The question is: who earned a higher profit margin on a given contract? A simple test is a ratio of prime to sub. The ratios of prime to sub-contractor profit margin was calculated by taking the mean and median profit margin for the prime contractors on a given contract and dividing it by the corresponding sub-contractors final profit margin. If the ratio was greater than 1, the prime earned a higher profit margin than the sub-contractor on the given contract number.

JMP® was used to complete the contingency analysis for this research. The analysis results include a mosaic plot, frequency counts, proportions, and tests for statistical significance.

A subset of the prior dataset was used for this analysis. Only contracts that had at least one prime and corresponding sub were paired into dyads. Two ratios were created for each of the 346 sub-contractors identified. While the prime contractor was the same for each of the 83 unique contract numbers, there could be multiple prime CDSRs linked to the same contract number. Therefore, a ratio was calculated using the mean and median profit margin for the prime contractor in the cases where there was more than one CDSR.

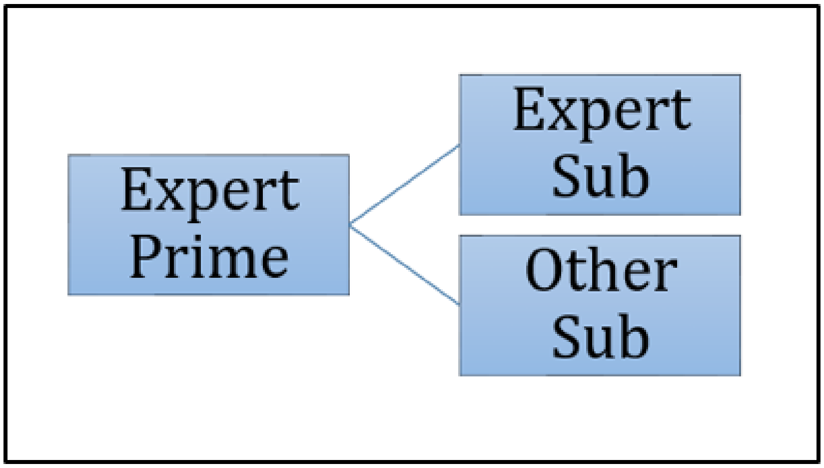


Figure 4. Contractor Dyads

This ratio was converted to a categorical variable where a value of greater than one indicated the prime contractor's profit margin was higher than the sub's. For the analysis, this was denoted by a '1' value. If the opposite was true (i.e. ratio <1 (sub-contractor earning higher profit)), a '0' was used. In a similar way, the two dyads were converted to categorical variables. A value of '1' was used for dyads in which both contractors (prime and sub) were "experts" and '0' if both (prime and sub) contractors were not. This, therefore, created two different contingency tables.

The Fisher's Exact Test was used to test the statistical significance of the dyads (Figure 5). This test assumes all observations are independent and presents a conditional exact inference. An exact inference does not rely on assumptions that parameters hold true through infinity, but is an exact calculation of a p-value given the data presented (Agresti, 1992). This research only uses the 1-tailed hypothesis test to determine whether or not the dyads significantly effect the ratio of a prime's profit margin to it's corresponding sub's profit margin.

An Odds Ratio (OR) can also be calculated using contingency tables. The OR is the ratio of the odds of an event occurring in one group to the odds of the same event occurring in another group. This research predicts which contracting group (prime or sub) earns a higher profit margin given the different dyads. To calculate OR, first calculate the odds of a prime earning a higher a profit margin given (x) variable. Next, calculate the odds of a prime earning a higher profit margin given the same (x) variable is missing. Finally, divide the odds of step one by the odds of step two.

3.7 OLS Regression

Ordinary Least Squares (OLS) regression was used to expand the analysis and determine if the proxy of expertise would appear predictive when analyzed with other potential profit drivers. The dependent variable used to identify profit drivers as well as determine which were most predictive was profit margin percentage. The explanatory variables used in the regression model are shown in Table 7. Three periods of performance (PoP ≤ 1, PoP ≤ 2, PoP ≤ 3) were also tested for statistical significance. The model was created using the JMP®'s mixed stepwise OLS function. A level of significance was set to 0.05 to determine the predictive ability of the explanatory variables in Table 7. The model was also tested for normality, constant variance, multicollinearity, and outliers.

Table 7. Categorical Variables used in OLS Regression

Contractor Expertise	Service	Contract Type	Life-cycle Phase	Platform
Expert	Air Force	Fixed Price	Development	Aircraft
Other	Army	Cost Plus	Production	Electronic/ Automated System
	Navy	Mixed/Other		Missile
				Ordnance
				Ship
				Space
				Surface Vehicle
				UAV

3.8 Summary

Chapter 3 discussed the methodology used to examine profit margin percentages between primes and subcontractors for ACAT I Major Defense Acquisitions Programs (MDAP). This section provided the source of the data, the profit margin calculations, and described the data cleaning process. This section finally explained the statistical process used to perform the analysis in Chapter 4.

IV. Analysis

4.1 Overview

Chapter 4 presents the analysis and results for this study. First, descriptive statistics associated with the dataset shown in Table 4 are presented. Next, we use comparison analysis via t-test and Wilcoxon/ Kruskal-Wallis test to determine if there is a statistically significant difference between prime and sub-contractor profit and expertise cohorts. We then present the results of the contingency analysis used to statistically examine the dyads of prime and sub. Finally, we present the results of the OLS regression model used to identify profit drivers.

4.2 Comparison Analysis

The comparison analysis examines the influence of the DoD's regulations as well as expertise on profit margin percentage. To better understand the influence of regulations, a comparison of prime and sub-contractor profit margins was completed. Means and medians were determined for primes and sub-contractor profit margins. Sample t-tests and Wilcoxon/Kruskal-Wallis tests were used to test for statistical significance when comparing prime and sub-contractor profit margins. The null hypothesis for both tests is that the two groups are equal. The significance (α) used was 0.05.

Table 8 organizes the means and medians of the variables analyzed for easy comparison. The total aggregates are the in the first line. Further lines break down the aggregate. The hypothesis tests with a p-value less than 0.05 were found to be statistically significant and are highlighted in Table 8.[1] The "expert" cohort was most significant with a p-value of less than 0.0001 for both the t-test and Wilcoxon/Kruskal-Wallis test. Subsequent analysis focuses on the "expert" variable.

[1] Appendix B includes descriptive statistics by commodity

Table 8. Comparison Results

Variable	Sample Size (Prime/Sub)	Median (Prime/Sub)	Mean (Prime/Sub)	Std Dev (Prime/Sub)
Aggregate	959 / 608	12.3% / 13.8%	13.9% / 15.0%	12.7% / 13.9%
Dev	147 / 72	8.0% / 7.7%	4.5% / 7.1%	12.8% / 12.7%
Prod	812 / 536	13.6% / 14.8%	15.6% / 16.0%	11.9% / 13.6%
Cost	213 / 103	9.5% / 10.2%	9.6% / 13.9%	4.6% / 12.8%
Fixed	559 / 409	15.3% / 15.3%	15.5% / 15.7%	14.6% / 15.1%
Other	187 /96	12.1% / 12.6%	13.8% / 12.8%	11.6% / 7.0%
Air Force	164 / 42	13.1% / 12.3%	17.5% / 11.4%	15.0% / 15.0%
Army	383 / 154	11.5% / 11.2%	13.5% / 12.5%	13.6% / 14.8%
Navy	412 / 413	12.6% / 14.4%	12.8% / 16.3%	10.2% / 13.3%
Expert Ctr	719 / 302	13.0% / 15.2%	14.6% / 17.8%	10.2% / 11.9%
Other Ctr	240 / 306	10.1% / 11.6%	11.7% / 12.0%	17.9% / 14.8%

Table 9 focuses on the last two lines of Table 8, the "expert" cohort and "other" cohort of contractors. Table 9 allows for a horizontical and vertical comparison. There is a statistically significant difference between "expert" primes' and "expert" sub-contractors' profit margins. The sub-contractor earning a higher profit margin in this case.[2] Additionally, there is a statistically significant difference between the "expert" cohort and "other". Experts earn higher profit margins regardless of whether they are operating as a prime or sub-contractor. The null hypothesis is accepted when comparing the "other" contractors by prime and sub-contractor, meaning there is not a statistical difference in their profit margins.

Table 9. Interactions Hypothesis Tests

	Prime: Mean	Sub: Mean	T-test	Wilcoxon/ Kruskal-Wallis
Expert	14.6%	17.8%	<0.0001*	<0.0001*
Other	11.7%	12.0%	0.7877	0.3258
T-Test	0.0155	<0.0001*		
Wilcoxon/ Kruskal-Wallis	<0.0001*	<0.0001*		

[2] Tests with p-values less than 0.05 are statistically significant

These results suggest that the economic theories reviewed in Chapter 2 are relevant to this discussion. While a number of theories could be applied, the two most relevant are principal-agent and transactional cost theories. Applying these theories, we can begin to explain the findings in Table 9 which we explore further in the next section. Experts have more information surrounding the operations of the defence industry and the DoD's complex regulations. They can therefore exploit this information to lower their transactional costs and increase their profit margins. The opposite holds true for less experienced contractors who do not have the same resources and knowledge of the DoD environment. Their transactional costs are likely higher which reduces their profit margins.

As suggested in Chapter 2, information asymmetry, which is connected to contractor profit margin, can be reduced by screening and regulation. This allows the DoD to monitor and regulate profit earned by primes. Conversely, for subcontractors, Table 9 shows a larger change in the mean profit earned between the expert cohort of contractors and others. This may be a result of both information asymmetry and negotiating power. Expert subcontractors are likely able to exploit the lower levels of DoD regulation which gives a more free-market style condition under which profit is determined. Moreover, they retain their low transaction costs compared to less-expert contractors which increases their profit margin.

What Table 9 cannot show is how expertise may correlate with profit when the "other" contractor in a prime-sub relationship does not have expertise. Using a subset of the data, we explore how relationships influence profit. The concerned dyads are shown in Figure 5 and are analyzed using contingency analysis in the Section 4.3

4.3 Contingency Analysis

Contingency analysis goes one level deeper to test if expertise allows for advantages relative to non-expertise. The comparison analysis already identified that "expert" subs do a lot better than "other' subs. Expertise could potentially allow one contractor to take advantage over the other in a dyad of prime and sub. Figure 5 provides the two dyads of prime and sub this study is concerned with. The ratios calculated in Chapter 3 were used for this analysis. Two ratios were created, one using the mean profit margin of prime contractor on a given contract and one using the median. The results for both ratios were the same.

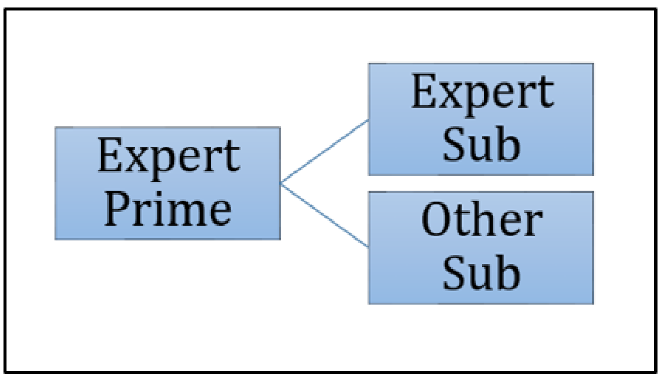


Figure 5. Contractor Dyads

The comparison analysis suggests that the prime contractor will earn a higher profit margin when paired with a sub not identified in the "expert" cohort as shown in Table 8. The mosaic plot for the dyad of expert prime - other sub is displayed by Figure 6. The contingency table analysis concludes that the prime earned a higher profit margin compared to the sub 60% of the time. The Fisher's Exact Test finds that the profit margin difference is statistically significant with a right tail p-value <0.0001. A right tail test indicates that the probability of a prime contractor earning higher profit margin percentage, compared to its corresponding sub-contractor, is greater for that dyad.

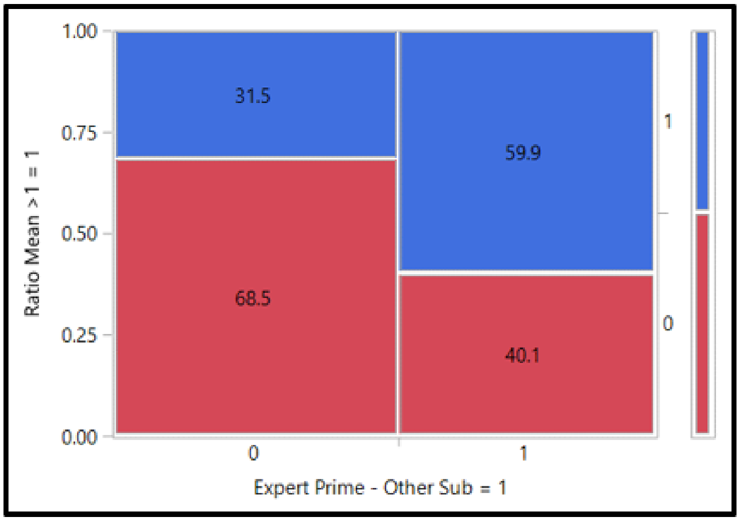


Figure 6. Contingency Table (Expert Prime - Other Sub)

Figure 7 displays the mosaic plot of the dyad of expert prime - expert sub. The analysis concludes that for 67% of the contracts analyzed the sub-contractor earned a higher profit margin percentage. The Fisher's test finds statistically significant left tail with a p-value of 0.0017. A left tail significance in this case indicates the probability of a sub-contractor earning a higher profit margin percentage than a prime is greater for this dyad. This finding is the opposite of the previous dyad analyzed.

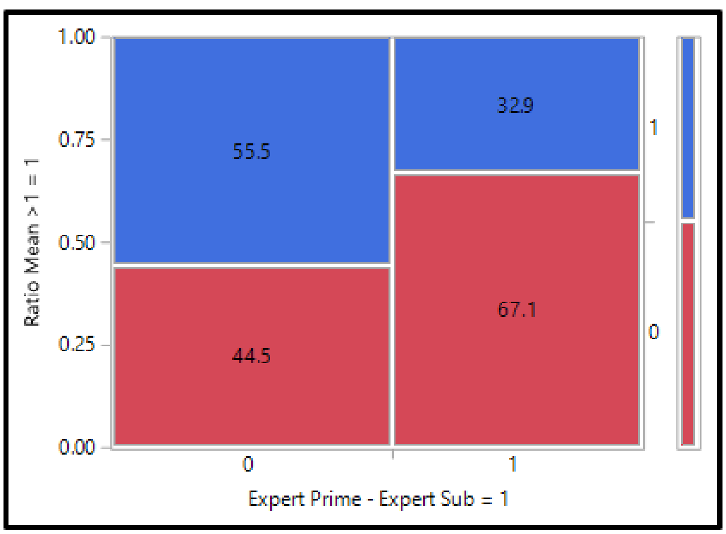


Figure 7. Contingency Table (Expert Prime - Expert Sub)

As previously described in Chapter 3, the odds ratio calculates the probability of an event occurring in one dyad and the same event occurring in the other dyad. The result of this analysis shows that the probability of a prime earning a higher profit margin percentage compared to the sub is 3.2 times greater for the expert prime - other sub dyad. Similarly, for the expert prime - expert sub dyad, the odds ratio of a prime earning more than a sub is 0.4. If the inverse of this value is calculated, the odds of a subcontractor earning higher profit percentage is approximately 2.5 times greater than a prime for this dyads. This agrees with the comparison analysis that expert sub-contractors are likely to earn higher profit margins due to regulation and information asymmetry.

The 95% confidence intervals for both odds ratios are shown in Table 10. The confidence intervals are relatively tight which indicates the odds ratios are stable. This means that there is a 95% probability that the confidence intervals contain the true odds ratio.

Table 10. Odds Ratio Confidence Intervals

Dyad	Odds Ratio	Lower 95%	Upper 95%
Expert Prime - Other Sub	3.2	2.1	5.0
Expert Prime - Expert Sub	0.4	0.3	0.6

4.4 OLS Regression

The focus of this study is to better understand the effect of a contractors' expertise and government control on defense contractor profit. However, it is understood that there are many other variables that effect profit beyond what is included in this analysis. Table 8 already reveals this to be true by comparing prime and subs. This portion of the research sought to identify potential drivers of Profit% by using

Ordinary Least Squares (OLS) Regression.

The explanatory variables shown in Table 7 were analyzed as profit margin predictors. The model was created using the JMP®'s mixed stepwise OLS function. A level of significance was set to 0.05 to determine the predictive ability of the explanatory variables in Table 7. The R^2 value for the model was 0.13 with seven statistically significant variables. This suggests that there are many different drivers for profit beyond the variables detailed in Table 7. These include macro-economic factors relating to contractor business environment, negotiation techniques and program specific drivers. The standard beta value output from the OLS regression model can be used to compare the strength of the independent variable. The following sections discuss the results of the created OLS model.

The standard beta coefficient compares the strength of the independent variables to the explanatory variables. The greater the number the stronger the effect on Profit percentage. The two most predictive variables were found to be program phase and contractor expertise as shown in Table 11. Production contracts and expert contractors also statistically earning higher profit. Previous research has identified that production contracts typically earn higher profit percentages compared to development contracts as discussed in Chapter 2. The positive standard beta coefficients support this finding.

Table 11. Model VIF Scores and Standard Beta Coefficients

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta	VIF
Intercept	0.0248791	0.010028	2.48	0.0132*	0	.
Space	0.0623217	0.014814	4.21	<.0001*	0.101733	1.0458252
Surface Vehicles	-0.039564	0.010463	-3.78	0.0002*	-0.09433	1.1128872
Ship	-0.036622	0.012807	-2.86	0.0043*	-0.06877	1.0341481
Expert	0.0477245	0.006866	6.95	<.0001*	0.173883	1.1192512
Fixed	0.0197792	0.00713	2.77	0.0056*	0.073497	1.2551213
POP<=1	-0.019747	0.008704	-2.27	0.0234*	-0.05591	1.0861065
Prod	0.094723	0.009591	9.88	<.0001*	0.251148	1.1563987

The standard beta coefficient indicates that the second strongest explanatory variable found, in this model, was the “Expert” variable. Expert contractors therefore are predicted to earn higher profit percentages. This is supported by the analysis of the literature presented in chapter 2 and is the focus of this thesis. A noticeably missing variable from the OLS model is prime vs sub. This matches the findings of the comparison analysis, at the aggregate level there is little difference between prime and sub-contractor profit margins.

The positive standard beta coefficient for fixed contracts is explained by the DoD’s profit policy reviewed in Chapter 2. Firm fixed contracts have the potential to earn a higher profit margin due to the potential for higher risk to the contractor. Only three commodities were found to be statistically significant with only Space contracts having a positive standard beta coefficient and being the third strongest explanatory variable.

Table 11 shows, in certain cases, a negative standard beta value. This indicates that profit percentage is likely to decrease where this explanatory variable is present. For example, when the period of performance of a contract is less than or equal to one year the profit margin is likely reduced. A key oversight of the OLS regression model is the dyad of prime and sub. This limitation is explored in the contingency analysis in section 4.3.

A series of further tests substantiate the accuracy and applicability of the OLS regression model. These tests are used to detect:

- Input assumptions for the model
- Multicollinearity
- Overly influential data points
- Outliers

The Shapiro-Wilks goodness of fit test was used test the assumption of normality and the Breusch-Pagan test was used to test the assumption of constant variance for the model. Based on the p-values, both tests failed statistically. However, after reviewing the graphs associated with each tests, the statistical tests were considered to be a "soft fail." [3] Figure 8 shows that the residuals appear to be normally distributed and Figure 9 shows the residuals versus predicted plot appears to have constant variance. Since the model created was only used to identify drivers of the explanatory variables, these test were not a major concern.

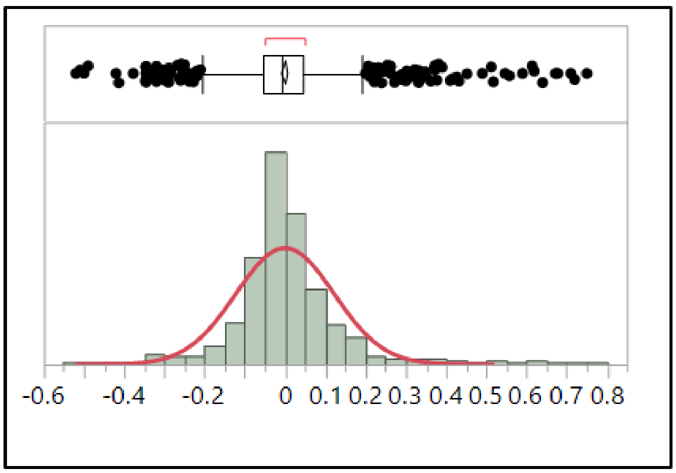


Figure 8. Histogram of Residuals

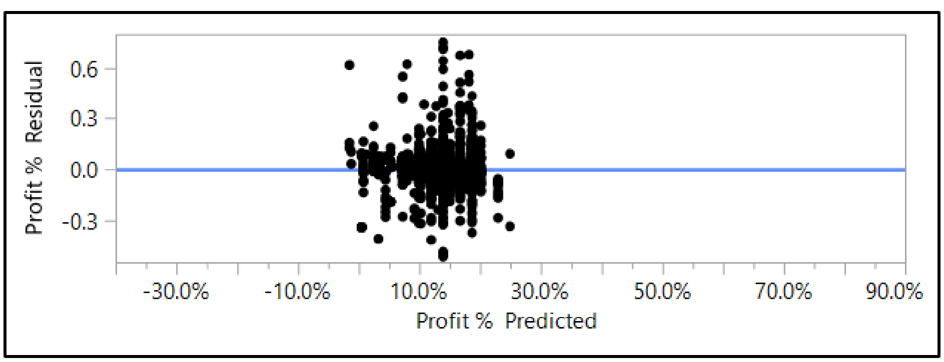


Figure 9. Residuals by Predicted Plot

[3] A soft fail can be described as one where the p-value indicates a failed test, however a plot of the data shows a normal distribution or constant variance

VIF scores are used to identify multicollinearity (correlation between predictors) within regression analysis. VIF scores that are above 5 suggest there is linear dependency between two ore more independent variables and therefore should be removed from the model. The VIF scores for the independent variables in this this analysis were all below 5 (shown in Table 11).

The Cook's Distance detects overly influential data points that could possible skew the results. Typically, if a Cook's D value is greater than 0.5, the data point(s) are justified for removal. No points were removed from the Cook's Distance plot shown in Figure 10.

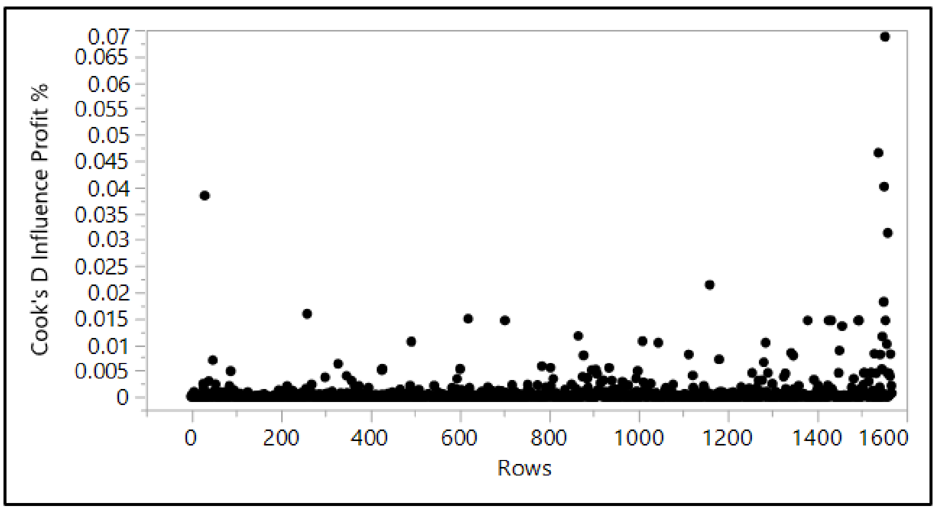


Figure 10. Cook's Distance Plot

A histogram of the studentized residuals identifies potential outliers in the data. The status quo for this analysis is 3 standard deviations above or below the normal distribution's mean of zero. Figure 11 shows the histogram for the studentized residuals for this analysis. Since there are many variables that potentially effect profit, it was assumed that there would be outliers and they were not removed. 97.5% of the data fell within 3 standard deviations.

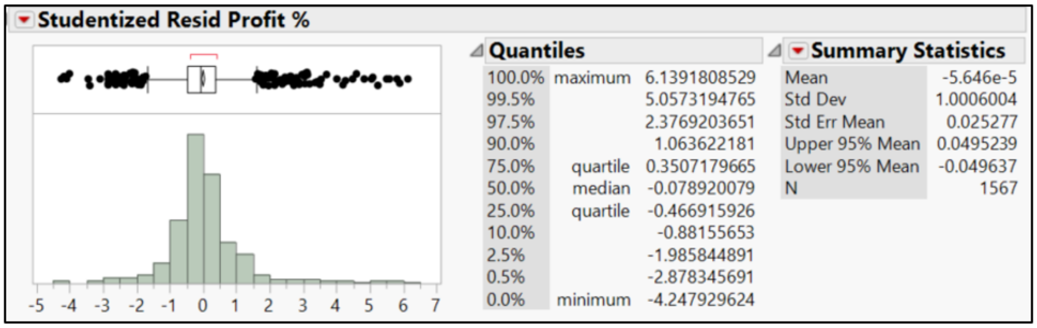


Figure 11. Studentized Residuals

4.5 Sensitivity Analysis

It might be argued that the experts earn higher profit margins because they are merely doing larger contracts. A at the median size of the contract for each cohort of contractors (expert and other) confirms that experts do have larger contracts. The results provided in Table 12 show that at the aggregate the median contract size for “expert” contractors is $58M larger compared to “other” contractors. The results are similar when the aggregate is broken down by prime and sub-contractors.

Table 12. Median Contract Size

Variable	Expert	Other
Aggregate	$98M	$40M
Prime	$114M	$79M
Sub	$81M	$26M

But, what is the relationship between contract size and profit margin? We can do a rough test. It must be rough because because contract size would appear on both sides of the OLS equation (showing up in the denominator of profit margin). Because of this any slope produced would be uncertain. Nonetheless, running it for a broad overview reveals that, in the aggregate, there is no relationship between contract size and profit anyway. Applying the same test to subsets offers no challenge to our interpretation. The test was applied to the “expert” cohort of contractors, the "other" cohort, primes, and subs, and then the further subset of expert-subs. The "other" cohort nearly shows a relationship, with a p-value of 0.0532, but its slope is negative and the R-square minimal. If we can tentatively enter this as evidence, it is evidence that further supports our finding, revealing that size appears to tend toward a negative correlation with profit instead of a positive. The expert-subs has a more convincing negative relationship, though failing a test of normality. As such, we can confidently conclude that the higher profit margin we observe among the expert contractors in our original test is not a product of the scope of the projects they are involved.

It also might be argued that the designation of the cohort is arbitrary and that there is merely a continuum of expertise from little to a lot. To test that counter-hypothesis, we ran two parallel OLS Regression tests using the two components of our variable of expertise, total dollar amount of contracts for a given contractor, and total number of contracts for a given contractor. We regressed each to the median profit each earned from all those dollars and contracts, respectively. We found no statistically significant correlation between these components and profits across the whole database. Total dollars does not correlate to a contractor's median profit. Nor does the total number for contracts.[4]

4.6 Summary

At the aggregate level profit percentage is more consistent for prime contractors than subs as shown by the standard deviation. When the data is analyzed by contract type, commodity and other variables, patterns can be seen in the data. Further analysis of these by comparison analysis, contingency table analysis, and OLS regression shows statistical significance of some of these variables.

[4]Results of these statistical tests can be found in Appendix C

The comparison analysis shows little difference in profit percentages between prime and sub contractors at the aggregate level. When the expertise factor is introduced, a statistically significant difference is seen. This further reinforces the importance of contractor expertise and its influence on profit percentage.

The contingency analysis shows the importance of relationships between prime and sub-contractors and DoD regulation. The number of expert contractors is small, therefore, there is a small number of possible expert prime and expert sub contractor combinations (i.e. dyad 2). Over time, relationships between these contractors strengthens. This decreases issues arising from information asymmetry and, given the small contractor numbers, promotes collective bargaining, as discussed in Chapter 2.

OLS regression shows that a number of explanatory variables can predict profit percentage. The most predictive variables were found to be program phase and contractor expertise. The program phase finding is consistent with previous research identified in Chapter 2.

Sub-contractors are not as scrutinized, by the government, as prime contractors, however, this analysis indicates that prime contractors should potentially screen sub-contractor costs. This may prove difficult to implement give the aforementioned relationships between expert prime and expert sub-contractors.

V. Conclusions and Future Research

"The directors of such companies, however, being the managers rather of other people's money than of their own, it cannot well be expected that they should watch over it with the same anxious vigilance with which the partners in a private copartnery frequently watch over their own" - Adam Smith, Wealth of Nations (1776) p. 408

5.1 Conclusion

This research set out to better understand the conditions where in defense contractor profit margins may be higher. A general argument would be that sub-contractors potentially earn higher profit margins compared to primes. A review of economic theories and market concentration suggests that contractor expertise in the DoD environment influences profit earned, and that we should specifically look at "expert" sub-contractors. This study uses the magnitude of DoD contract dollars and the number of contracts awarded as a proxy for expertise.

Government control was analyzed by comparing prime and sub-contractor profit margins. Regulations dictate that primes are more scrutinized than subs, suggesting that subs are in a better position to earn higher profit margins. The study shows that the expertise proxy is a statistically significant variable in determining profit margin for ACAT I programs. DoD regulations, largely controlling the prime contractor, have a distinct influence on and reduce the variation of profit margin percent. This potentially indicates the profit policy and purpose of the regulations is successful. Sub-contractor profit margin display larger variation, as would be expected, owing to less scrutiny, potential exploitation of information asymmetry and competitive market conditions. Relationships are analyzed through contingency analysis using dyads of prime and sub. This analysis found both dyads analyzed (expert prime –

other sub and expert prime – expert sub) to be statistically significant and showed the probability of a prime contractor earning a higher profit margin is greater when the sub is not characterized as an expert. The opposite was found to be true when both contractors were characterized as experts. Regardless of an experts role (prime or sub), they always command a higher profit margin than contractors not characterized as expert. This effect statistically increased when the expert is a sub-contractor and therefore subjected to less regulatory scrutiny.

OLS regression identified a number of explanatory variable as being predictive of profit margins. The two most predictive variables were found to be program phase and contractor expertise. It was noticeable that at the aggregate level, the variable of prime and sub was not a predictive variable.

Ultimately, the purpose of business is to return a profit to its shareholders. The DoD must recognize this and understand that profit can be a driver of innovation and increase the quality of a good or service provide to it. As stated at the beginning of this thesis, defining "excessive" profit is difficult. Among other things, profit is the result of good business practice and innovative product. Therefore, the higher profits commanded by the "expert" cohort of contractors, as identified in this study, may be warranted. Areas of further analysis are identified in the next section.

5.2 Future Research

This research only used CDSRs which could be exported from DACIMS and used a limited number of variables for analysis. Future research could manually collect data from the system which may enable more variables to be analyzed. Variables such as contract type and program phase can be further decomposed for more detailed analysis. An analysis of the negotiated profit, compared to the realized profit will shed more light on the true value of expertise. Additionally, examining performance metrics such as costs and schedule variance can help determine if higher profit is warranted.

Profit margins were not analyzed in regards to period of performance start and end date and the change in profit margin over the years. Future research should examine this and highlight trends related to this. An interesting analysis could focus on the effect of mergers and acquisitions within the defense industry, macro-economic factors such as interest rates, domestic GDP and stock market performance and political environmental variables such as DoD budget.

Further exploration of the relationships between prime and sub contractors is required to understand why the effects, shown in this study, are occurring. Moreover, an understanding of the root-causes of these identified effects is required. This will help determine if pass-through regulations should be reviewed or if expert sub-contractor charges are deserving of their increased profit.

A limitation of this study is the understanding of labor flow-down among contractors. It is unknown if prime contractors are simply sub-contracting to another expert and therefore acting as a project manager. The ultimate effect of this may be that the DoD pays profit twice. An analysis of this should examine the proportion of labor to management charges. Currently sub-contractor charges are built within a prime's costs and invisible to the DoD unless the total sub-contracted value is over 70% of the contract value. This is a recent addition (2013) to the Federal Acquisition Regulation which requires additional justification for such pass-through charges. Therefore a study comparing pre- and post- 2013 contractor dyad profit margins could provide insight into the success of this new addition and the proportion of labor to management charges.

Appendix A. OLS Regression - Cohort Analysis

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta	VIF
Intercept	0.0268728	0.010177	2.64	0.0084*	0	.
Space=1	0.0612601	0.014826	4.13	<.0001*	0.1	1.0481619
Surface Vehicles=1	-0.039672	0.01074	-3.69	0.0002*	-0.09459	1.1735624
Ship=1	-0.038506	0.012848	-3.00	0.0028*	-0.0723	1.0415547
Prod=1	0.0932295	0.009527	9.79	<.0001*	0.247188	1.1419964
Cohort 1	0.0506922	0.007237	7.00	<.0001*	0.193798	1.369762
Cohort 2	0.0366718	0.009906	3.70	0.0002*	0.098697	1.2719962
Fixed=1	0.0219422	0.007163	3.06	0.0022*	0.081534	1.2676986
POP<=2	-0.016063	0.007094	-2.26	0.0237*	-0.05688	1.1294011

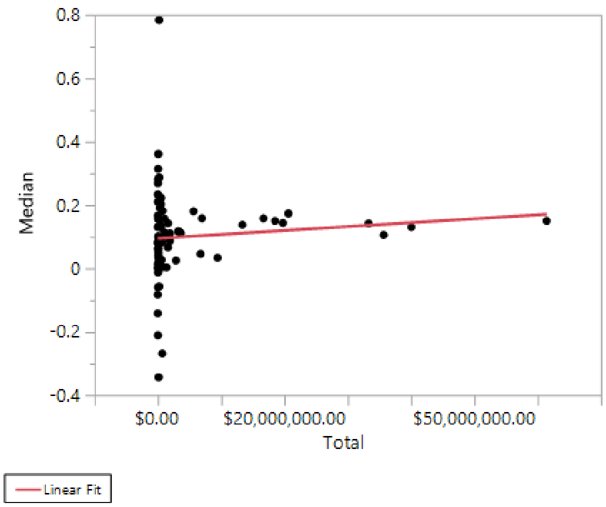
Appendix B. Descriptive Statistics

Table 13. Descriptive Statistics by Commodity

Variable	Sample Size (Prime/Sub)	Median (Prime/Sub)	Mean (Prime/Sub)	Std Dev (Prime/Sub)
Aircraft	365 / 443	14.7% / 14.2%	16.1% / 15.3%	10.4% / 14.5%
Electronic/ Automated	129 / 45	8.8% / 8.0%	11.3% / 7.5%	14.0% / 6.3%
Missiles	104 / 45	13.0% / 15.6%	15.5% / 17.9%	12.4% / 10.7%
Ordnance	8 / 14	12.4% / 20.5%	10.2% / 19.3%	5.3% / 7.4%
Ship	83 / 18	12.2% / 9.6%	10.8% / 12.3%	9.5% / 14.3%
Space	58 / 17	16.7% / 11.4%	20.1% / 14.1%	17.0% / 11.5%
Surface Vehicle	164 / 7	10.0% / 21.0%	9.4% / 19.8%	14.8% / 20.0%
System of System	2 / 7	10.6% / 19.1%	10.6% / 19.6%	2.4% / 15.6%
UAV	46 / 12	12.3% / 14.5%	13.9% / 12.6%	8.7% / 5.4%

Appendix C. Sensitivity Analysis

Bivariate Fit of Median Profit by Total $ Value



Linear Fit

Median = 0.0945465 + 1.24e-9*Total

Summary of Fit

RSquare	0.008573
RSquare Adj	-0.00539
Root Mean Square Error	0.143636
Mean of Response	0.100025
Observations (or Sum Wgts)	73

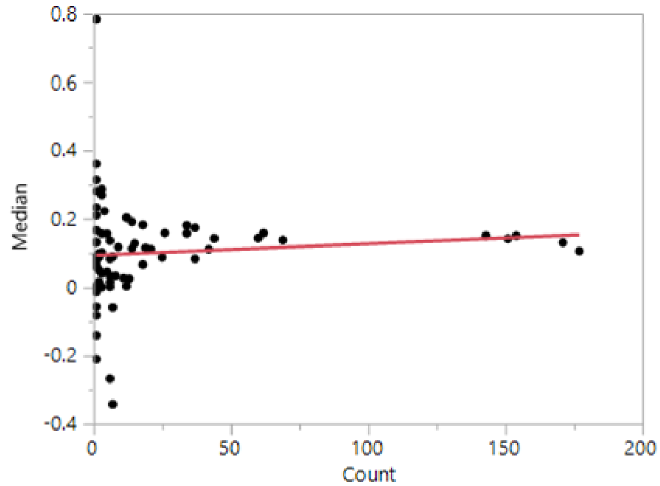
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.0126658	0.012666	0.6139
Error	71	1.4648132	0.020631	**Prob > F**
C. Total	72	1.4774790		0.4359

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0945465	0.018207	5.19	<.0001*
Total	1.24e-9	1.583e-9	0.78	0.4359

Bivariate Fit of Median by # of Contracts



Linear Fit

Median = 0.092735 + 0.000339* Count

Summary of Fit

RSquare	0.00928
RSquare Adj	-0.00467
Root Mean Square Error	0.143584
Mean of Response	0.100025
Observations (or Sum Wgts)	73

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.0137116	0.013712	0.6651
Error	71	1.4637674	0.020616	**Prob > F**
C. Total	72	1.4774790		0.4175

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.092735	0.019035	4.87	<.0001*
Count	0.000339	0.000416	0.82	0.4175

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14. ABSTRACT
Profit earned by defense contractors is a controversial issue among government officials and the defense industry. It is recognized that profits earned by defense contractors are not strictly the product of the dynamics of a competitive market but of federal profit statutes, contractual incentive schemes, the quality of government oversight, and in a market of less than full competition. As such, there is always concern of whether contractors are earning "excessive" profit – through policy or failed oversight. The purpose of this research is to investigate the question of reasonable profits from one particular angle – whether profit margins differ among two different categories of contractors, primes and sub-contractors. The study finds that sub-contractors, in the aggregate do not earn higher median profits than primes. However, it finds that expertise does appear to be a significant characteristic at a finer level of analysis. Expertise correlates with higher median profits. And, sub-contractors who exhibit this expertise earn higher median profits than both their primes and other sub-contractors.

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