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Abstract

Contracts that are fixed-price provide the benefit of cost control and certainty; however, they are less likely to succeed when uncertainty exists regarding other contract requirements. Their use remains contentious in certain areas of acquisition, such as development, and existing acquisition literature largely fails to provide empirical foundations that would guide contracting officers in choosing between fixed-price and cost-based mechanisms. This study seeks to illuminate this debate by testing several hypotheses regarding relationships between contract characteristics and fixed-price contract outputs. Here, outputs is measured across four dependent variables, in the form of contract characteristics relevant to the risks and potential benefits of fixed-price contracts:

- Number of offers received for competed contracts,
- Number of change orders per contract,
- Extent to which change orders raised the contracts' cost ceiling (ceiling breaches), and
- Whether the contract was terminated.

The study team has created a dataset, populated by completed, publicly reported DoD contract data from FY2007–FY2013 to address this research question. The study finds that fixed-price contracts are more likely to face termination but are not systematically more likely to receive fewer bids or experience more change orders or ceiling breaches than cost-based contracts. Of the circumstances tested, longer-duration contracts proved most consistently challenging to fixed-price contracts. To support future research, the analytical data and processing code used by the study team for this analysis are posted on the CSISdefense GitHub repository.[1]

[1] See GitHub CSISdefense/Fixed-Price, https://github.com/CSISdefense/Fixed-price.

1.1. Contents

Figures

1.2. Introduction

Signaled by President Obama's 2009 Memorandum on Government Contracting and subsequent policy implementation issued by the Office of Management and Budget (OMB)[2], there is presently a policy preference, at the margins, for the use of fixed-price contracts over cost-based[3] contracts. Driven by both external budget pressures and cost overruns associated with certain high-profile acquisition programs, fixed-price contracts are seen as a mechanism to control costs. As such, there have been recent regulatory changes targeting and restricting the general use of cost-based contracts. For example, the 2009 National Defense Authorization Act, Sec. 864, contained provisions related to the management and use of cost-based contracts.[4] Most notably, it increased the documentation required to justify the use of cost-reimbursement contracts. Better Buying Power 1.0, an acquisition reform effort designed to prioritize affordability in the defense acquisition system, included a provision to increase the use of Fixed-Price Incentive (Firm Target) contracts. The U.S. government also passed the Federal Acquisition Regulation (FAR), which included in Part 16.103 further parameters and guidelines for contracts other than firm fixed-price.

However, Federal Acquisition Regulations are quite clear in that fixed-price contracts are not a one-size-fits-all solution for the entirety of the defense acquisition system. These contracts can present significant downsides when misused and can have a negative impact on the military. Frank Kendall, the current Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)), frequently cites the failed development of the A-12 as an example of the misuse of fixed-price contracts.[5] When describing the problems of fixed-price development contracts, Secretary Kendall stated, "We got no flexibility under the contract vehicle [fixed-price] to go in and make adjustments . . . we threw away a fair amount of money, we didn't get anything."[6] Following this argument, many acquisition officials have argued that fixed-price contracts should be used in well-defined situations in which they can realistically provide greater cost certainty.

If fixed-price contracts are not always the superior contract type, under what circumstances should they be employed? The study team seeks to answer this question by analyzing Department of Defense (DoD) contracting records available from the Federal Procurement Data System (FPDS). By comparing FPDS records for fixed-price and cost-based contracts, this research measures the outputs of both pricing

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[2] Office of Federal Procurement Policy, "Memorandum for Chief Acquisition Officers, Senior Procurement Executives, Subject: Increasing Competition and Structuring Contracts for the Best Results,"2009.

[3] This study defines cost-based contracts as those that include cost-reimbursement contracts as well as hybrid types, like time, materials, and labor hours.

[4] Duncan Hunter National Defense Authorization Act for Fiscal Year 2009, Pub. L. 110-417, 122 Stat. (2008): 4364.

[5] The A-12 was a proposed all-weather, carrier-based stealth bomber for the Navy and Marine Corps. The program was canceled after questions about the program's ability to accomplish its basic requirements emerged. After being ordered to repay the government almost $1.3 billion in development costs, the two manufacturers, General Dynamics and McDonnell Douglas [later acquired by Boeing], sued the government arguing wrongful termination. In 2014, Boeing and General Dynamics settled the 23-year-old lawsuit by agreeing for each company to give the government $200 million in products and services. See Jen DiMascio, "A-12 Avenger Suit Reconciled, At Last," *Aviation Week,* February 3, 2014, http://aviationweek.com/awin/12-avenger-suit-reconciled-last.

[6] U.S. Department of Defense, "DOD News Briefing on Better Buying Power 2.0 with Deputy Secretary Carter and Under Secretary Kendall from the Pentagon," http://www.defense.gov/transcripts/transcript.aspx?transcriptid=5148; Michael Hoffman, "Are Fixed-Price Contracts a Fad," *DoD Buzz,* March 15, 2013, http://www.dodbuzz.com/2013/03/15/are-fixed-price-contracts-a-fad/.

mechanisms under a range of circumstances. While FPDS does not directly and explicitly measure performance, the study team has extracted four key outcome metrics:

- Number of offers received
- Number of change orders
- Extent of ceiling breach
- Partial or complete contract termination

While any of these outcomes can occur in individual cases without being a direct result of selecting a fixed-price contract, the study team set out to determine if the probability of one of these outcomes occurring is significantly related to the choice of contract type when looked at across a very wide sample set. Analysis of the four listed outcome variables allows for testing hypotheses on the possible drawbacks of fixed-price contracts. These hypotheses focus on five different contract characteristics that available literature argues offer a relative advantage to either fixed-price or cost-based contracts: large R&D contracts, Major Defense Acquisition Programs (MDAPs), long-duration contracts, competed contracts, and large software contracts.

The pendulum of shifting DoD preferences between fixed-price and cost-based contracting cannot, and likely should not, be stilled via empirical analysis. These historical shifts reflect changing priorities and not just an attempt to move toward an ideal defense acquisition system. The existence of these tradeoffs is affirmed by the results found in the paper—that is, cost-based contracts suffer as many ceiling breaches as fixed-price contracts, but fixed-price contracts are more likely to be terminated than their cost-based counterparts. This paper seeks to empower policymakers and contracting officers when making the choice between fixed-price and cost-based by providing an enumeration of past outcomes across a range of circumstances. For this reason, the study team chose to focus on hypotheses and controls that are both straightforward to measure and will reliably be known by the contracting officer before the decision is made as to whether a contract will be fixed-price and cost-based.

This paper is divided into six sections, starting with this introduction. The second section is a literature review that surveys the history and present fixed-price contract policies. The literature review goes on to summarize the academic research and policy documents that were the source of this study's hypotheses and controls. The third section describes the study's methodology and dataset, elaborating on the paper's four dependent variables. The fourth section describes how the study team categorized the key variables and studied their interaction through the use of a Bayesian network.

The fifth section, Results, constitutes the bulk of the paper. It has six subsections, starting with a review of the population of the nearly 6 million defense contracts included in this study across the four dependent variables discussed above, followed by a similar treatment of each of the five hypotheses and control variables. The sixth section, Conclusions, uses the results from the previous section to draw out trends across the different hypotheses.

This study will hopefully leave many researchers and experts curious enough to further investigate the results or test their own theories using the dataset produced for this project. The study team abides by reproducible research principles, and the processing code and resulting dataset are therefore available online via the CSISdefense account on the GitHub website. The fixed-price repository under this account represents a seventh section of this report and a point to launch from for future research.

1.3. Literature Review

Since the emergence of the U.S. defense industrial base, a continuous policy debate has been waged on the proper allocation of risk between the government and the vendor, as well as the role of profits in the management of the defense industry. This debate has often focused on whether defense vendors' profit margins have been too large or too small, and whether contractors have been exposed to too much or too little risk for their profits. Historically, these debates have focused on the role of fixed-price and cost-based contracts in defense acquisition. Some view industry profit margins to be too large, arguing that cost-based contracts allow contractors to make their profit without regard to the quality of their performance, or even that contractors may earn higher profits at lesser levels of performance. Opponents of this argument insist that defense contractor profit margins are either less than or in line with non-defense manufacturing industries, and that the choice of contract type usually makes little or no difference to ultimate government cost. This literature review examines the historic cyclical preference for fixed-price contracts in this context, followed by a review of the literature discussing under what circumstances specific contract types are best applied.

Following the end of World War I, there was a general prohibition placed on cost-plus contracting after fears were raised that industry had made too much profit off of public funds.[7] In the build-up to World War II, these restrictions were largely lifted, as the primary concern was no longer to address war profiteering but to ensure the military had arms and munitions critical to success in the theater. While limiting profits was no longer the top concern, there remained a requirement to govern the management of the defense acquisition sphere in order to restrict cost growth. In particular, government officials sought to introduce fixed-price contracts into the airplane-production industry, to balance profits and risks for both the government and industry. However, as RAF historian Sebastian Ritchie notes, the British were able to introduce fixed-price contracts into the aircraft-manufacturing base while the United States was largely unable to do so.[8] He noted that the U.S. aircraft industry,

> *Refused to accept the financial risks inherent in fixing prices without far greater security than they had received in the past. They sought contractual protection against unanticipated increases in labor and raw material costs; they refused to accept financial liability for late deliveries; and they insisted on the right to renegotiate the price of any additional orders placed by the government.*[9]

Following the end of World War II, cost-plus contracts remained the predominant contract type. However, as DoD placed a larger emphasis to push technology forward, the newer development programs exhibited large cost growth. For example, in the 1950s the average aircraft program saw 220 percent cost growth over its baseline.[10] In response to this cost growth, fixed-price contracts became

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[7] Sebastian Ritchie, "The Price of Air Power: Technological Change, Industrial Policy, and Military Aircraft Contracts in the Era of British Rearmament, 1935–39," *The Business History Review,* Vol. 71 No. 1 (Spring, 1997), 82–111, http://www.jstor.org/stable/3116330. Ritchie describes the detailed history of how the British developed a fixed-price contracting landscape. The British were able to introduce fixed-price because of mixed industry opposition to them, fixed-price contracts offered industry the possibility of higher profits, and the advantages of industry in contract negotiations.

[8] Ibid.

[9] Ibid.

[10] Defense Business Board, "Report to the Secretary of Defense: Best Business Practices for Fixed-Price Contracting," *Report FY10-03*, January 2010, 5,

more appealing for developmental work in an effort to control costs. Despite this, these programs continued to exhibit significant cost growth as a result of "inaccurate cost estimates, technological unknowns, inflexible contract modification mechanisms, and inflation."[11]

In the 1970s, the Department abandoned this preference for fixed-price contracts with the establishment of its new guidance, DOD Directive 5000.1. This new guidance stated a policy preference favoring the use of cost-based development. This change did not last due to complaints about cost growth. The pendulum swung away from the use of cost-plus contracts in development and back to fixed-price contracts by the 1980s. The Defense Business Board's critique of the era once again noted that fixed-price contracts were "plagued by inaccurate cost estimates, technological unknowns, changing requirements."[12] By the 1990s, preference had swung back to the use of cost-plus contracts in development, before a shift back towards fixed-price exemplified in the Office of Management and Budget guidance issued in 2009.

1.4. Fixed-Price Guiding Principles

Formal Definition of Fixed-Price Contracts

Because the focus of this paper is on the outputs of fixed-price contracts, the term needs further illustration. A fixed-price contract suggests a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. And according to provisions in FAR, a firm-fixed-price contract is suitable for acquiring commercial items (see Parts 2 and 12) or for acquiring other supplies or services on the basis of reasonably definite functional or detailed specifications (see Part 11) when the contracting officer can establish fair and reasonable prices at the outset. But, as is succinctly noted in DoD's "Performance of the Defense Acquisition System, 2014 Annual Report" (iii–vi): "Prices on fixed-price contracts are only 'fixed' if the contractual work content and deliverables remain fixed; such contracts can be (and often are) easily modified to handle unexpected technology gaps, engineering issues or shifting threats, leading to cost growth. At times, fixed-price vehicles can be virtually indistinguishable from cost plus vehicles, as was the case with the Air Force's canceled Expeditionary Combat Support System (ECSS)."

This DoD definition of "fixed-price contract" guides our understanding of fixed-price contracts in the framework of this study. The study team chose to include not just firm-fixed-price contracts, but also the range of variants such as fixed-price award fee or fixed-price economic price adjustment, which respectively include bonuses for the quality of the end product and allow for variable payments based on changing commodity prices. The study team chose to exclude fixed-price level of effort contracts, at the suggestion of an expert, because they share too many traits with cost-based contracts. For this study, cost-based contracts include both the range of cost-reimbursable contracts, labor hours contracts, and time and materials contracts. With the preference for fixed-price or cost-plus contracts changing periodically over the past 60 years, have general guiding principles emerged on the use of fixed-price contracts? While there are multiple answers to this question, literature is largely aligned with five principles elucidated by Secretary Kendall: firm requirements, the availability of qualified suppliers, low technical risk in the program, the ability of the vendor to absorb overruns, and the existence of an

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http://dbb.defense.gov/Portals/35/Documents/Reports/2010/FY10-3_Best_Business_Practices_Fixed_Price_Contracting.pdf.

[11] Ibid.

[12] Ibid, 6.

adequate business case in the event of overruns.[13] The existence of these conditions in a company's bid does not guarantee better performance, but it does provide an analysis framework for the contracting officer in making his or her determination of contract type:

- **Firm Requirements:** The government must have a clear understanding of what it is asking vendors to build, confidence that the necessary conditions exist, and a commitment to acquiring said project.
- **Availability of Qualified Suppliers:** The firms bidding on the contract have a demonstrated history in performing the proposed type of work, allowing them to make rational bids and ensure successful program execution.
- **Low Technical Risk:** The major research and development has already occurred within the program or other programs. At the date of contract signing, there are no unresolved design issues, risks associated with integration, external interfaces are well designed, and no major known risk appears in the testing phase.
- **Ability of the Vendor to Absorb Overruns:** If overruns occur, the winning vendor must have a demonstrated ability to deliver the product despite any overruns.
- **Adequate Business Case If Overruns Occur:** There must be a demonstrated business case for vendors to continue performing work in the event that overruns occur.

1.5. Under What Other Criteria Does the Literature Suggest That Fixed-Price Contracts Are Best Applied?

Analysis of the literature suggests that there are situations, often specific instances of the general principles, in which a fixed-price or cost-plus contract may provide greater utility. The situations identified by the study team are not mutually exclusive nor exhaustive, and any contract may encounter multiple situations or none. Identified situations, which proved critical in the selection of controls and hypotheses for testing, included:

- Large research and development contracts
- Major defense acquisition programs and other complex projects
- Long-duration contracts
- Competition in the bidding process
- Large software projects

The study has also chosen control variables which may influence contract performance irrespective of fixed-price or cost-based mechanism.

- Contracts for aircraft development and manufacturing
- Undefinitized Contract Actions
- Contract Vehicle

The last controls were driven by a variation in reporting mechanisms rather than because of the literature review. Based on the study team's past reports and regular consultation with experts, the variation in types of contracts reported competition is one of keen interest. Different vehicles report competition in different ways, and this control is included to hedge against the possibility that

[13] Frank Kendall, "Use of Fixed-Price Incentive Firm (FPIF) Contracts in Development and Production," *Defense AT&L*: March–April 2013, http://www.acq.osd.mil/fo/docs/Kendall%20Use%20of%20Fixed-Price%20Incentive%20Firm%20(FPIF).pdf.

differences between fixed-price and cost-based contracts are just an artifact of the reporting system used.

Large R&D Contracts

Analysis of academic literature on auction models and historical evidence suggest that a relationship between poor outputs and fixed-price contracts for large R&D projects may exist. In *Managerial and Decision Economics,* Rajeev Goel found that in research and development (R&D) contracts, when the outcome of research is uncertain, among other determinations, "the principal [government] prefers a cost-plus contract in cases of projects with large R&D outlays and higher innovation benefits, but would prefer a fixed-price contract when the number of is increasing."[14] This suggests that for large R&D contracts, cost-plus is preferable unless multiple bidding vendors exist.

Major Defense Acquisition Programs and Other Complex Projects

Major Defense Acquisition Programs (MDAP) are the most complex defense acquisition programs within the DoD acquisition portfolio.[15] These programs in particular have been the most significant source of cost growth within DoD. 2011 analysis by the Government Accountability Office (GAO) found that MDAPs active at the time were projected to exceed their initial cost estimates by $402 billion. As such, the recent movement toward fixed-price contracts has been couched in a debate on the importance of limiting MDAP cost growth.

Within the literature, there exists a debate on the proper use of fixed-price and cost-plus contracts for complex projects. Researchers Patrick Bajari and Steven Tadelis found that "cost-plus contracts are preferred to fixed-price contracts when a project is more complex."[16] Furthermore, Chong Wang and Joseph G. San Miguel support this argument, asserting that the use of fixed-price contracts for MDAPs incurs certain disadvantages, notably that a fixed-price may entail higher, rather than lower, costs to the government.[17] This notion that fixed-price contracts are not ideally suited for MDAPs is further supported by Karer W. Tyson et al. Their research found that programs in development conducted under fixed-price contracts experience higher cost growth than those not conducted under fixed-price.[18]

However, other research has concluded that there are no significant differences between fixed-price and cost-plus contract outputs. Research by the Institute for Defense Analyses in 2009 found that the differences in cost growth between fixed-price and cost-plus contracts were not statistically significant.[19]

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[14] Rajeev K. Goel, "On Contracting for Uncertain R&D," *Managerial and Decision Economics*, Vol. 20, Issue 2, March 1999, 104.

[15] MDAP is defined as those programs that are either (1) designated by the Secretary of Defense as an MDAP or (2) "Estimated by the Secretary of Defense to require an eventual total expenditure for research, development, test, and evaluation of more than $300,000,000 (based on fiscal year 1990 constant dollars) or an eventual total expenditure for procurement, including all planned increments or spirals, of more than $1,800,000,000 (based on fiscal year 1990 constant dollars)." Source: Title 10 Code § 2430—Major Defense Acquisition Program Defined.

[16] Patrick Bajari and Steven Tadelis, "Incentives versus transaction costs: a theory of procurement contracts," *RAND Journal of Economics* Vol. 342, No. 3, Autumn 2001, 387–407.

[17] Chong Wang and Joseph G. San Miguel, "Are Cost-Plus Defense Contracts (Justifiably) Falling Out of Favor?," *Journal of Governmental & Nonprofit Accounting,* Volume 2, 2013, 1–15.

[18] Karen W. Tyson, J. Richard Nelson, Neang I. Om, and Paul R. Palmer, "Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness," Institute for Defense Analyses, IDA Paper P-2201, 1989, F-19–F-20, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA212538.

[19] Scott A. Arnold et al., "Defense Department Profit and Contract Finance and Their Effects on Contract and Contractor Performance" (Alexandria, VA: Institute for Defense Analyses, 2009), 56, http://www.acq.osd.mil/mibp/docs/ida_paper_p-4284_revised.pdf.

This argument is supported by the Office of the USD (AT&L) in *Performance of the Defense Acquisition System: 2013 Annual Report.* Analyzing 433 MDAP programs between 1970 and 2011, the report found that when controlling for work content, aircraft contracts, and undefinitized contract actions (UCA), "the type of contract used in each case did not result in a statistically significant difference in cost growth."[20] This contrary evidence in the literature on the role of MDAPs and contract type merits further analysis.

Long-Duration Contracts

Academic literature on best contract management practices has argued that shorter contracts are preferable to long-term contracts for simpler actions, whereas long-term contracts are preferred for more complex, uncertain projects or projects requiring significant capital investment.[21]

The data suggest that long-duration contracts are more susceptible to cost growth in the defense marketplace. A 2006 RAND study on historical cost growth for completed weapon systems found that "programs with longer duration had greater cost growth."[22] The current USD (AT&L) Frank Kendall identified long-duration contracts as a potential explanation for differences between negotiated and actual outcomes, stating, "there may be times (e.g., multiyear contracts) where the period of performance is long enough that it places too much uncertainty and risk on either party."[23]

Availability of Competition

Evidence suggests that when competition is available during the bid process, the government's preference for fixed-price or cost-plus contracts changes. Research in the Autumn 1986 *RAND Journal of Economics* by R. Preston McAfee and John McMillan supports this argument on a relationship between competition and contract-type outputs. Their research suggests that the use of cost-plus contracting is less efficient when multiple bidders exist. In *Bidding for Contracts: A Principal Agent Analysis*, they argue that "fixed-price contracts should be used much less frequently than they currently are and that cost-plus contracts should not be used if there is more than one bidder."[24] These conclusions are supported by the research of Rajeev Goel cited above. His research found that for large R&D contracts specifically, as the number of bidders increases, the principal agents' (government's) preference for fixed-price contracts increases.

Large Software Contracts

The academic literature suggests that software may be an opportunity to maximize fixed-price utility. In analysis of offshore software contracting, Anandasivam Gopal and Konduru Sivaramakrishnan found that a "vendor would prefer the FP contract for larger and longer projects with larger teams."[25] With a

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[20] Office of the Under Secretary of Defense, Acquisition, Technology and Logistics, "Performance of the Defense Acquisition System: 2013 Annual Report," 51.

[21] Oliver E. Williamson, *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting* (New York: Free Press, 1985); *The Mechanisms of Governance* (New York: Oxford University Press, 1996); Drew Fudenberg, Bengt Holmstrom, and Paul R. Milgrom, "Short-Term Contracts and Long-Term Agency Relationships," *Journal of Economic Theory* 51(1), 1990: 1–31.

[22] Mark V. Arena et al., "The Historical Cost Growth of Completed Weapon System Programs," xii, http://www.rand.org/content/dam/rand/pubs/technical_reports/2006/RAND_TR343.pdf.

[23] http://www.acq.osd.mil/fo/docs/Kendall%20Use%20of%20Fixed-Price%20Incentive%20Firm%20(FPIF).pdf

[24] Goel, "On Contracting for Uncertain R&D."

[25] Anandasivam Gopal and Konduru Sivaramakrishnan, "On Vendor Preferences for Contract Types in Offshore Software Projects: The Case of Fixed-price vs. Time and Materials Contracts," *Information Systems Research,* Vol. 19, No. 2, June 2008, 202–20.

historical inability to conduct information technology projects in an optimal manner, this research suggests there may be an opportunity for increasing efficiency within DoD software contracting.[26]

Contracts for Aircraft Development and Manufacturing

Review of the literature suggests that aircraft contracts experience cost and schedule growth at rates beyond those of other major platforms. Analysis by the Office of the Under Secretary of Defense for Acquisition Technology and Logistics (USD(AT&L)) found that, when controlling for work content, aircraft, and undefinitized contract actions, there was no statistically significant connection between total cost growth and contract type. The research further found that aircraft contracts had an increase of 22 percentage points on the total cost growth of a contract. [27] Further research showed that U.S. Naval Air Systems Command (NAVAIR) was able to better control cost growth than its U.S. Air Force counterpart, the Aeronautical Systems Center (ASC). Whereas NAVAIR saw a 40 percent increase in aircraft contracting obligations, ASC total cost growth increased by 67 percent over a similar time period. Furthermore, the report found that the increase in total cost growth stemmed from work content and schedule growth.[28]

Undefinitized Contract Actions

The support in the literature for this control came exclusively from the 2013 State of the Defense Acquisition report.[29] However, UCAs also risk confounding the analysis because key contract characteristics may be decided after the contract has already been signed. However, because the subsequent analysis excludes unlabeled and inconsistently labeled contracts, that confusion is already largely avoided. Nonetheless, by separating out these contracts, the study team separately examines that part of the sample most likely to defy the team's assumptions about the contracting process.

1.6. Methodology and Dataset

The research in this study employs multiple methods. First, the study team conducted a literature review to identify what other studies on contract type have found.[30] This literature review assisted in identifying variables, controls, and hypotheses.

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[26] A 2012 audit found that six DoD software modernization projects were 110 percent over budget and had suffered schedule delays of up to 12 years. See Sean Reilly, "At DoD, 6 IT Projects, $8 billion over budget," *Federal Times,* July 23, 2012, http://archive.federaltimes.com/article/20120723/DEPARTMENTS01/307230001/At-DoD-6-projects-8-billion-over-budget.

[27] Office of the Under Secretary of Defense, Acquisition, Technology and Logistics, "Performance of the Defense Acquisition System: 2013 Annual Report," June 28, 2013, 43–44, https://acc.dau.mil/adl/en-US/658966/file/73116/Report%20on%20the%20Performance%20of%20the%20Def%20Acq%20System.pdf.

[28] Ibid., 91.

[29] Ibid.

[30] The literature search was carried out through databases of monographs, edited volumes, books, and journal articles with special attention to leading sources on acquisition and contracting such as the following publications: *Journal of Public Procurement*; *Administrative Theory and Praxis*; *Law and Society Review*; *American Political Science Review*; *Public Administration Review*; *Journal of Public Administration Research and Theory*; *The Government Contractor*; *Quarterly Journal of Economics*; *Public Administration*; *Public Management Review and Administration and Society*. In addition, the study team reviewed contracting-related research material from government and legislative agencies such as publications by agencies as diverse as Congressional Research Service (CSR); Defense Acquisition University (DAU); The Naval Postgraduate School (NPS); United States Government Accountability Office (GAO), Department of Defense (DoD); and Office of Management and Budget (OMB). The study team also leaned on pertinent dissertations and other available acquisition literature.

The second portion of the study worked with the Federal Procurement Data System (FPDS) to summarize each of these variables by dividing their possible values into a manageable number of bins. By limiting each variable to typically two to four possible states, the study team was better able to understand the evidence and to identify and clean up or remove anomalies in the data. As part of this process, the study team created a Bayesian network of probabilistic relationships between already identified evidence variables. This Bayesian Network model eased efforts by the study team to examine connections between the variables. The related machine learning process indicated which parts of the evidence were strongly connected and provided means and opportunity for the study team to explicate the sequencing of the contracting officer's decision-making when soliciting a grant. By sharing how this model is derived, the study team hopes to contribute to evidence-based approaches to analysis of fixed-price contracts by other researchers as well as to identify policy implications for practitioners.

Third, the paper directly analyzes the seven years of Department of Defense contract transactions collected and categorized in the second step. The study team had initially planned to directly use the Bayesian model for this step of the process as well. However, a challenge emerged because several of the hypotheses and control variables are focused on a proportionally tiny portion of the contract sample. Bayesian models do not function well if there are any paths that have a 100 percent chance or a zero percent chance of being true. However, in some cases there simply were not contracts that fulfilled all possible combinations of the criteria, for example, there were no R&D cost-based contracts with ceilings over $75 million that were terminated during the study. Bayesian networks employ a smoothing process to manage the zero percent and 100 percent cases, but unfortunately that process changed the outcomes sufficiently that they often no longer passed a chi-squared test for similarity to the raw data.

Benefiting from the data categorization and already completed for as a prerequisite for the Bayesian network, the study team instead tested the categorized tabular contract data directly to produce the graphs and analysis displayed in the results section. The project compares the outputs of fixed-price and cost-based contracts across a range of characteristics that typically would be known to the contracting officer before the contract was signed. The four dependent variables derived through this process will be discussed in greater detail in section 1.9 Study Dataset and Contract Output Measures.

Addressing the question of when fixed-price contracts are most effective is only a portion of the public purpose of this project. The data that undergird this investigation originate from FPDS and are thus open source and touch on a wide range of government contracting questions. With its approach, the study team simultaneously addresses two of the issues that have bedeviled a wider and more effective use of FPDS by academic, government, and industry researchers: (1) the difficulty of accessing relevant and complete data from this database and (2) the problem of deriving contract outputs from FPDS.

As a source for data, the FPDS is not easy to use. Some of the challenges associated with using the FPDS relate to specific problems associated with the ways the data are collated as well as broader policy issues that impact the maintenance of this database.[31] The various web tools associated with FPDS, at this stage of their development and deployment, do allow retrieval of small contract samples and

[31] This issue has recently figured prominently in the press publications. Carol Leonnig raises concerns about federal contracts and the instruments used to implement them. Carol D. Leonnig, "Government Counted Big Firms as Small," *Washington Post*, October 22, 2008, http://www.washingtonpost.com/wp-dyn/content/article/2008/10/21/AR2008102102989.html. The Defense-Industrial Initiatives Group at CSIS has been tracking and analyzing some of these issues, especially as they relate to the service contracting industry. See, for example, Guy Ben-Ari and Greg Sanders, "Defense Industrial Initiatives Current Issues: Small Businesses," CSIS, 2010, http://csis.org/files/media/csis/pubs/081022_diig_small_business.pdf.

addressing questions that can be answered using a small number of fields. However, research going beyond those constraints present often prohibitive challenges to researchers without the time and resources to undertake a significant database effort.

To arrive at useful data attributes like "complete," "relevant," and "contract outputs," the study team developed methodologies to process the data in FPDS. To establish the attribute "relevant," the study team had to comb through, isolate, and eventually combine multiple fields in FPDS. "Contract outputs" required creating a methodology that aggregates transactions at the contract level so as to yield "terminations" and "ceiling breaches." Finally, though it is easy enough to look at small samples of contracts in FPDS, the sheer number of entries and the volume of transactions are a block to "complete" management of the millions of DoD contracts. To mitigate the data-extraction challenge that FPDS poses, the study team will provides samples and datasets that have already been cleaned. The nature of this resulting dataset is discussed in the next section.

1.7. Study Dataset and Contract Output Measures

The dataset for this study consists of DoD contracts reported in FPDS that were initially signed no earlier than FY2007 and completed by FY2013. Notable exclusions include classified contracts not mandated to be reported in FPDS, contracts funded but not managed by DoD, and Defense Commissary Agency contracts that have not been reported in recent years.[32] To enable comparisons, the dataset is not limited to fixed-price contracts.

Determining when contracts are completed is the most challenging portion of compiling the dataset. Contracts closed out or terminated by the end of FY2013 are included even if their current completion dates run into the next fiscal year. However, many contracts in FPDS and in the sample are never marked as closed out or terminated in the Reason for Modification field. In these cases, completion status is based on the current completion date of the most recent transaction in FPDS. This method could accidentally include contracts that have not reached their ultimate conclusion dates and are merely dormant. However, the FY2013 sample end date means that any such contracts would have to be inactive for an entire fiscal year, which is unlikely.

FPDS raw data are available in bulk from USAspending.gov starting in FY2000. However, data quality steadily improves over that decade and a half, particularly in the commonly referenced fields of interest to this study. In most cases, unlabeled rates topped out at 5 to 10 percent. The critical exceptions are the Base and All Options and Base and Exercised Options fields, which report contract ceilings. Prior to FY2007, these fields are blank for the majority of contracts. When that field is not available, calculating the extent of ceiling breaches is impossible. In addition, this study classifies contract size by original ceiling and not total obligations because the latter figure is dependent on contract performance.

Because a key dependent and independent variable are not available prior to FY2007, the study team chose to set FY2007 as the start date rather than risk sample bias by including only those earlier contracts that were properly labeled. This restriction poses a significant limitation in that no contracts of more than seven years in duration can be included and five-year contracts are only in the study period if they started by October 1, 2007, or were closed out early.

[32] These exclusions are common with other Defense-Industrial Initiatives Group work. See "Methodology" for more details: http://csis.org/program/methodology.

The dependent variables, as well as the other study variables, are available through the project's GitHub page.[33] The entire dataset includes nearly 6 million contracts, and as a result the study team will also provide smaller samples as a more accessible starting point.

The largest sampling challenge is that approximately two-thirds of the contracts have a total obligated value less than $25,000 but these contracts represent only about 3 percent of the obligations for the period. The Bayesian model described more fully later in this paper is calculated using the complete dataset but includes a variable differentiating by original contract ceiling, which is intentionally constructed to ease study of larger contracts.

This approach addresses two of the largest obstacles to wider use of FPDS within the government, academia, and industry. First, the two official portals, USAspending.gov and the FPDS web-tool, both perform a critical service in giving access to contract transaction in aggregate or detailed form. However, for many researchers the relevant unit of analysis is contracts and not transactions. Both websites can be used to access the full records of individual contracts, but due to data inconsistencies and bulk download restrictions, they are not well suited to larger sample studies.

The limitations of the data in raw form can be overcome by downloading the complete data feeds via the data tab of USAspending.gov, but with each year accounting for multiple gigabytes, this represents a high barrier to entry for researchers who lack the tools or training for large dataset work. This challenge is further increased by the often-arcane nature of the data fields and the need to undertake cleanup and refer to multiple columns to get to data of interest. This first challenge is attested to by the regular calls the study team receives from other researchers seeking to use FPDS.

The second obstacle is that FPDS almost exclusively measures contract inputs but not performance outputs. Measures of contract performance do exist in other databases, but they are largely inaccessible without, at very least, an official government purpose or permit. This project takes a step toward overcoming that problem through the four dependent variables referenced earlier in this section: number of offers, change orders, ceiling breaches, and terminations. These variables were chosen due to their relevance to fixed-price contracting and availability, but they are also applicable to a wider range of research questions. Due to their importance and broader reference, this paper will discuss each of the four in detail in a subsequent section.

Number of Offers for Competed Contracts

Whether or not a contract is competed is an unusual output in that it happens at the start of the period of performance. However, the number of offers for competed contracts also reveals information about the request for proposals. A solicitation that only has a single respondent indicates some combination of three factors: thinness in the underlying market; a failure to notify or give adequate response time to potential competitors; or a contract that is unappealing to vendors. That final point is of interest to this study. Fixed-price contracts transfer risk to vendors, and if vendors perceive a greater risk than the government is willing to pay for, fewer vendors may be willing to bid.

The focus on the number of offers also has a basis in the regulation known as the Single Offer rule (DFARS 215.371), which addresses competitive acquisitions in which only one offer is received. This rule was rewritten in 2012 to add a policy section that shifts emphasis away from an analysis of whether the circumstances described at FAR 15.403-1 (c)(1)(ii) (determining adequate price competition) are present, to whether statutory requirements for obtaining certified cost or pricing data are met and if the

[33] See GitHub CSISdefense/Fixed-Price, https://github.com/CSISdefense/Fixed-price/tree/master/Data.

price is fair and reasonable. The revised rule also emphasizes the need to extend the period of solicitation when only one offer is received, to see whether a longer response period can elicit additional bids.

Essentially, the new standard suggests that if you cannot get two bidders, you must evaluate whether proceeding forward with one bid can be done while protecting the interests of the government. The heightened scrutiny applied to single-offer competition as part of the DoD Better Buying Power Initiative suggests that using this condition as a variable in the model can provide an indication that a fixed-price contract involves too much risk on the vendor side, and as such has not attracted multiple offers from potentially capable vendors.

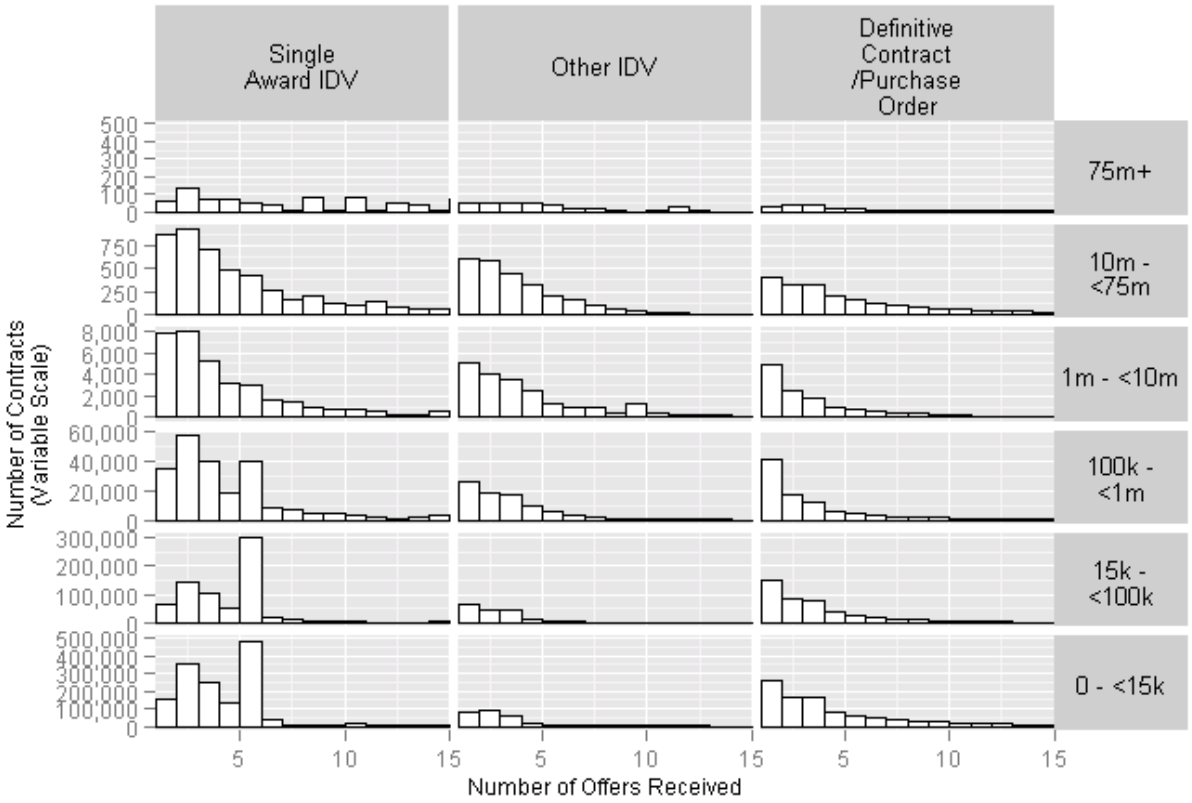
Non-competed contracts are not included in this analysis because the choice of whether or not to compete is based on factors that are already known before the choice between fixed-price and cost-based contract is made. For example, when a sole-source award is justified based on there being "only one source," that rationale refers to the total number of potential vendors and not the number of interested vendors. As a result sole-source awards are excluded from graphs on single-offer competition, along with the analysis at the end of this piece. While multiple variables are used to judge whether a contract has been completed, only one, the Number of Offers Received, is necessary to determine how many vendors really did submit an offer.

Whether a contract is competed is calculated largely by using the same approach as in prior CSIS studies.[34] This method emulates the official DoD methodology to the fullest extent possible when using raw data downloads rather than the FPDS web tool. In the vast majority of cases, competitive status is classified for the entirety of the contract duration. Thus, if a contract had a duration of three years and was competed in the first year, it qualifies as competed for the entire duration. This also extends to single-award indefinite delivery contracts, which are classified based on whether the original vehicle was competed rather than consistently treated as only receiving an offer from the single awardee. The number of offers received is calculated with the same methods.

Figure 1.7-1 shows the distribution of contracts by number of offers, faceted by the initial contract ceiling and use of an indefinite delivery vehicle (IDV). While all six categories show a similar broad curve, higher- and lower-ceiled contracts do have clearly different patterns. There is a large spike at exactly five offers for those contracts with ceilings below $1 million. That spike is even more prominent for those with ceilings below $100 thousand. As is shown by comparing the columns of Figure 1.7-1, this phenomenon is entirely driven by Single-Award IDV contracts and, given the immediate drop off from five to six contracts, these data would be consistent with a widespread coding quirk or a deliberate if not necessarily regulatory target for contracting officers dealing with smaller IDVs contracts. On the other hand, because single-award IDVs always report the number of offers of the original contract, a smaller number of prolific contracts could also explain part of this story.

[34] See "Methodology": http://csis.org/program/methodology.

Figure 1.7-1 Number of Offers by Original Ceiling and Vehicle

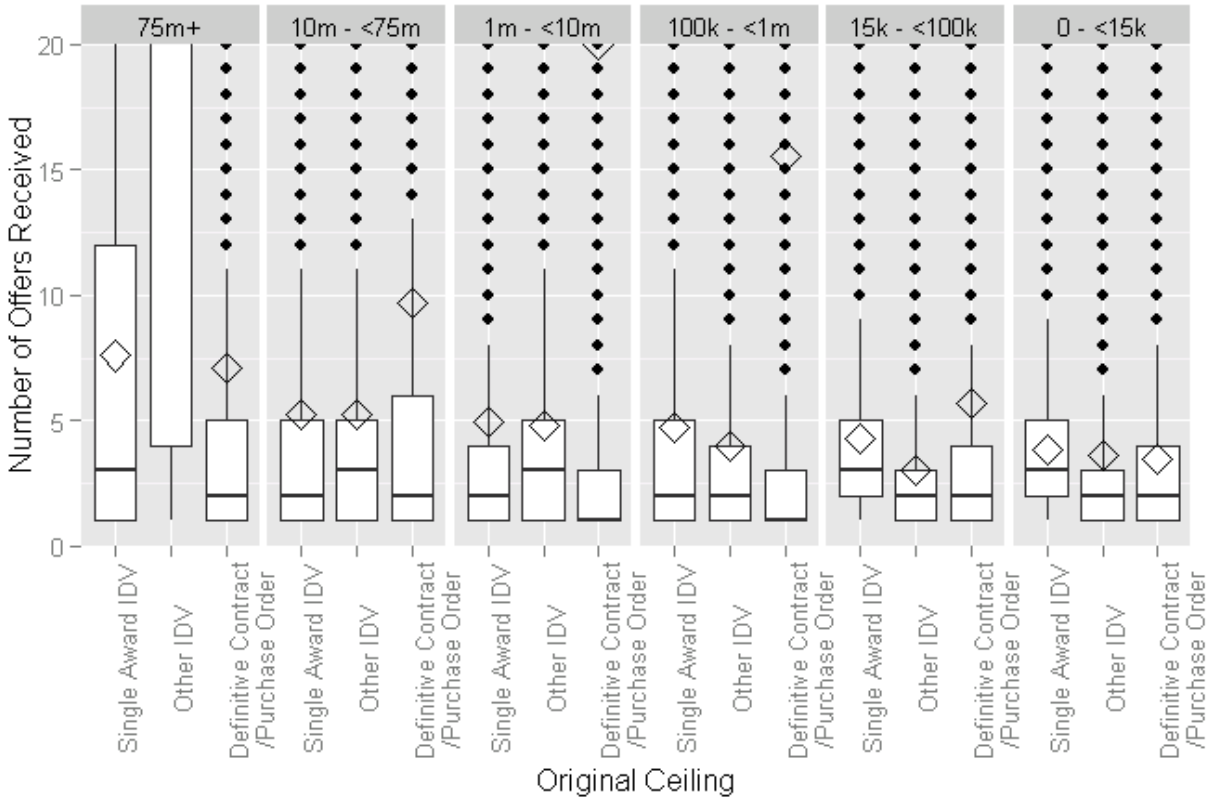


Source: FPDS, CSIS analysis.
Note: Contracts with more than 15 offers are excluded from the graph.

For Other IDVs and Definitive Contracts and Purchase Orders, single-offer competition is prominent in all categories and exceeds two offers for contracts with ceilings between $15 thousand and $75 million. The pattern is different for single award-IDVs. Single-offer competition is less common and, in proportional terms, is concentrated in contracts with original ceilings between $1 million and $75 million.

Figure 1.7-2 displays the data as a box-and-whisker plot instead. In this chart, the white rectangular box represents the values that fall between the 25th and 75th quartile. Thus, at least half of the contracts for each category have a value within the box. The thick solid horizontal line represents the median number of offers, and the black diamond the mean. This plot is cut off at 20 offers, and while these outliers are small in percentage terms, they do help ensure that the mean is consistently above the median. The most common median is two offers. Definitive Contracts/Purchase orders never exceed two contracts as a median, although both types of IDVs jockey for more offers depending on the ceiling category. A notable outlier is Other IDVs in the largest ceiling category, driven by a significant number of contracts that report exactly 253 offers, which is why the bar extends above the top of the graph. The trend is different when examining means rather than medians. With the exception of the Other IDV oddity, the highest means are found for definitive contracts/purchase orders between $100 thousand and $10 million.

Figure 1.7-2 Box Plot of Number of Offers Received by Ceiling and IDV



Source: FPDS, CSIS analysis.
Note: Contracts with more than 20 offers are excluded from the graph. The mean number of offers for IDV contracts with ceilings of $75 million or higher is 136.6, and the median is 253; neither is depicted on this graph.

When looking at all three vehicle types, the highest number of offers consistently comes with original ceilings above $10 million. While this category does not always have the highest averages, the 75th percentile frequently includes five or more offers, and the black bars above each rectangle that show the range of non-outlier contracts are also the highest. This means at least a quarter of all contracts with original ceilings above $10 million receives more than five offers, regardless of vehicle. This would be consistent with middle-tier contracts sometimes attracting fewer offers when they are unappealing or overly fitted for a single vendor. However, once contracts ceilings rise above the $10 million threshold, vendors appear to be generally more willing to bid even though potential risks are, in absolute terms, greater.

As the above summary indicates, the number of offers received varies considerably, depending on the characteristics of the contract. For definitive contracts and purchase orders, competition is highest at the extremes and lowest for most contracts with original ceilings between $100 thousand and $10 million. Similarly, between $1 million and $10 million is the only ceiling category where less than a quarter of Single Award IDVs receives five offers or more. For Other IDVs, vendors are most hesitant to bid below the $100 thousand mark. The oddest standouts are the high averages in several categories, but this is an area where the lower granularity used in the data sample will prevent possibly distorting effects. All contracts with five or more offers are lumped together in one category.

To see more details on the construction of the number of offers, visit Contract_Competition.md on the project's CSISdefense/Fixed-price GitHub page.[35] Summary charts are included in the parallel CSIS report on Competition, which is also in the conference proceedings.

Change Orders and Ceiling Breaches

Change orders are not as severe an indicator of trouble as terminations, which is described in more detail below. A change order might result from a contract being adapted to a changing environment or to take further advantage of a successful innovation. Even when a change order indicates a mistake, it often may not be on the vendor's side. Instead, elevated requirements mandated by the government can add expensive new tasks to the contract. The affordability of fixed-price contracting comes, in part, from its simplicity and inflexibility. Thus, when fixed-price contracts are subjected to a large number of change orders, whether prompted by government or vendor actions, they can be considered an indication that a different form of pricing may have been more affordable.

Similar to contract terminations, change orders are reported in the Reason for Modification field. There are two values that this study counts as change orders: "Change Order" and "Definitize Change Order." For the remainder of this report, contracts with at least one change order are called Changed Contracts.

There are also multiple modifications captured in FPDS that this current study will not investigate as change orders. These include:

- Additional work (new agreement, FAR part 6 applies)
- Supplemental agreement for work within scope
- Exercise an option
- Definitize letter contract

The Number of Change Orders refers to the number of FPDS transactions for a given contract that lists one of the two change order categories as their Reason for Modification. The vast majority of contracts do not receive change orders, but changed contracts are still far more common than terminations.

This paper calls when the total potential cost of a contract increases due to a change order a ceiling breach. In Federal acquisition, the government usually sets a "cost-ceiling" of contracts that limits the total amount of funds it may obligate on a single contract. This maximum cost-ceiling can serve as a target for vendors looking to maximize their revenue under a contract. However, cost-ceilings can be raised, meaning that they do not represent true maximums. When work under a contract is set to exceed the contract ceiling for any reason, the government is forced to breach these cost-ceilings. "Ceiling Breaches" represent output indicators, because they indicate that either the real cost of a contract or its true scope of work was not fully understood at the time of contract award.

This study uses changes in the Base and All Options Value Amount as a way of tracking the potential cost of change orders. The Base and All Options Value Amount refers to the ceiling of contract costs if all available options were exercised. The alternative ceiling measure, Base and Exercised Value Amount, is not used because contracts are often specified such that the bulk of the eventually executed contract, in dollar terms, is treated as options. In these cases, the all-inclusive value provides a better baseline for tracking growth.

[35] See Greg Sanders, "DoD Fixed-Price Study: Procedural Competition Classification," GitHub, January 13, 2015, https://github.com/CSISdefense/Fixed-price/blob/master/Contract_Competition.md.

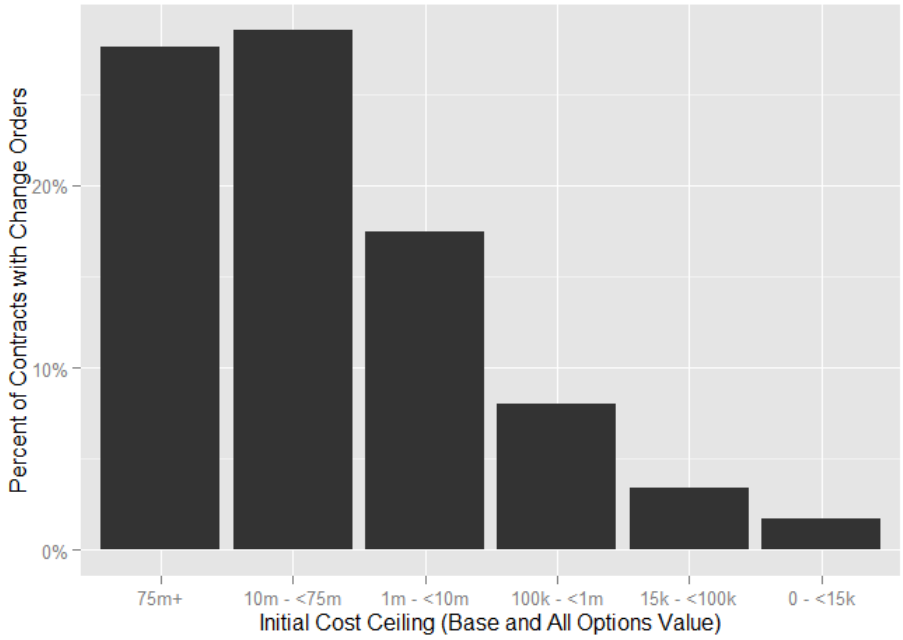
The Obligated Amount refers to the actual amount paid to vendors. This study team does not use this value for the analysis because spending for change orders is not necessarily front-loaded. For example, a change to a contract in May 2010 could easily result in payments from May 2010 through August 2013.

The Extent of Ceiling Breach is calculated as follows:

$$Extent\ of\ Ceiling\ Breach = \frac{Base\ \&\ All\ Options\ Value\ Increases\ from\ Change\ Order\ Modifications}{Base\ \&\ All\ Options\ Value\ Amount\ for\ Original, Unmodified\ Transaction}$$

Figure 1.7-3 shows the percentage of change orders broken down by original ceiling. From this, we can tell that change orders are most prevalent in contracts with higher cost ceilings. Over 25 percent of contracts in the two highest original ceiling categories ($10 million or more) experienced a change order. On the other hand, contracts with cost-ceilings of $15 thousand or less only had change orders in about 2 percent of contracts.

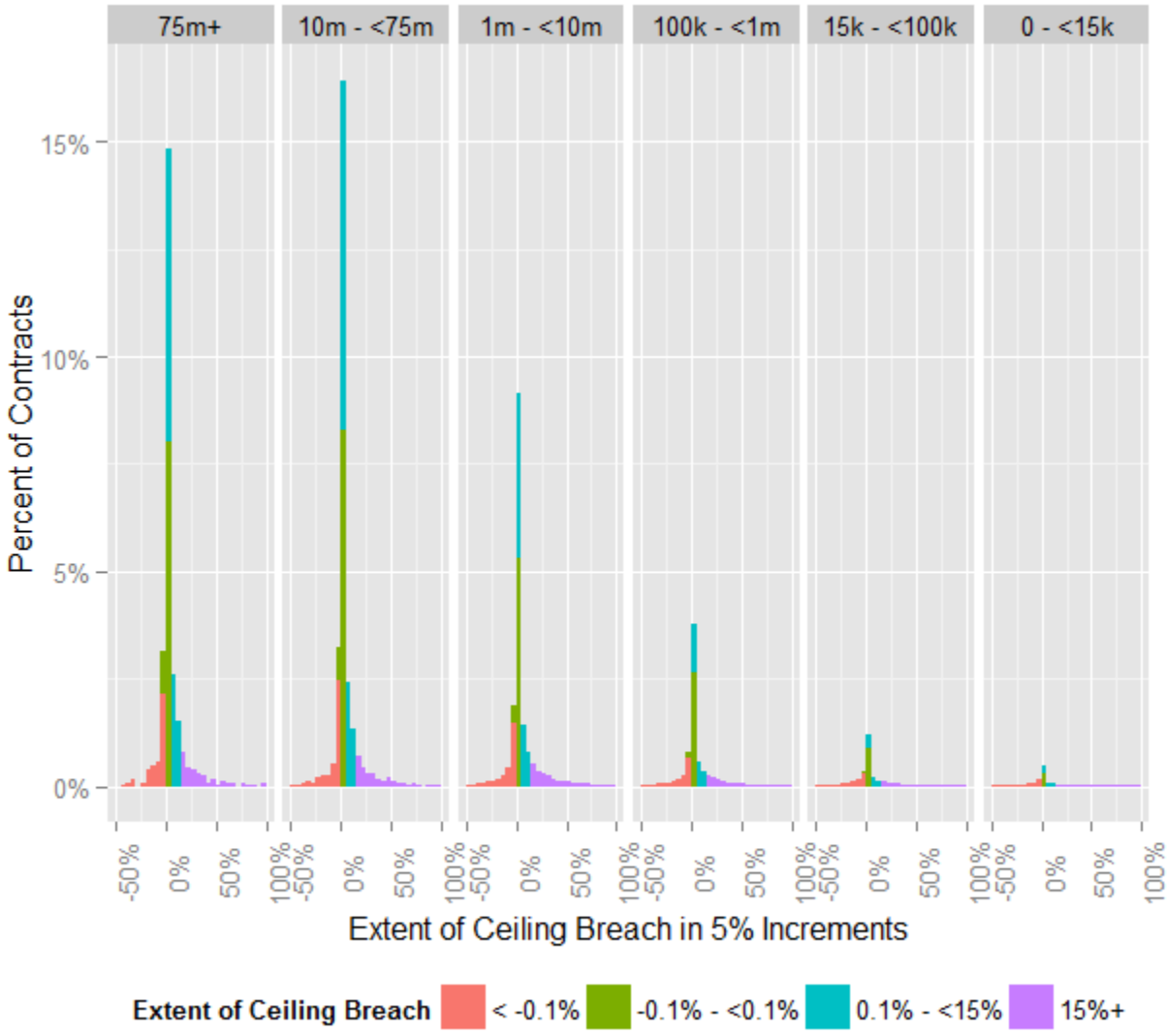
Figure 1.7-3 Percentage of Contracts with Change Orders by Original Ceiling



Source: FPDS; CSIS Analysis

Figure 1.7-4 breaks down the effects of change orders on changing a contract's cost ceiling. Percentages cited in the figure are of contracts within that original ceiling category. For contracts worth $10 million or more, roughly 9 percent of contracts did not significantly alter their original cost ceiling, as shown in the green bar. When lumped together with ceiling breaches of zero percent to 5 percent, this bin is consistently the most prominent for each original ceiling category. For both of the higher-ceiling categories, roughly 15 percent of contracts had a positive change order-related ceiling change percentage, which qualifies as a ceiling breach. For both categories, more than 3 percent of contracts grew by 15 percent or more, and a concentrated amount of change orders increased the ceiling by 25 percent or more, with some increases measuring close to 100 percent.

Figure 1.7-4 Ceiling-Breach Percentage by Original Ceiling



Source: FPDS; CSIS Analysis

For contracts worth $1 million to $10 million, the trend was similar. About 17 percent of contracts experienced a change order, and over half (9 percent of total) of those contracts experienced a ceiling breach. Less than 3 percent of contracts experienced growth above 15 percent, and the percentages reach their lowest level above 75 percent.

As cost ceilings reduce, change orders and ceiling breaches become rarer. The distribution also begins to flatten out; for those with original cost ceilings below $100 thousand, negative changes to ceilings are more common than non-changes. Similarly, growth of 15 percent or more is more prevalent than the smaller contract breach category. However, as noted above, this number is comparatively small overall and only accounts for 2 percent of contracts with change orders, thus resulting in far less of a financial impact than those contracts with higher original cost-ceilings.

To see more details on the construction of the change orders and ceiling breaches, visit Contract_ChangeOrders.md on the project's CSISdefense/Fixed-price GitHub page.[36]

Terminations

Abruptly ending a contract through termination is a challenging endeavor for the government. While the government is able to terminate its obligations through special clauses called "termination clauses," in practice the costs and inconveniences of this approach are significant. The proximate cause of the termination may not be vendor performance but instead a drastic change in government needs, the failure of a related contract, or the cancellation of the entire program. However, in all three cases the government has the option of simply paying out currently exercised options and stopping further payments. Thus, even if the source of the failure was outside the contract, a termination indicates that the contract was unable to adapt to changing circumstances.

Critically, the greatest vulnerability of fixed-price contracting will result in a termination: too much risk is placed on the vendor, and they fail beyond the point at which adjusting the contract could turn things around. In this instance, the government may lose any resources it has already invested, as well as pay a significant cost, in the form of time, to start the project over.

Contract termination is determined through the Reason for Modification field in FPDS. A contract is considered terminated if it has at least one modification with the following values:

- "Terminate for Default (complete or partial)"
- "Terminate for Cause"
- "Terminate for Convenience (complete or partial)"
- "Legal Contract Cancellation"

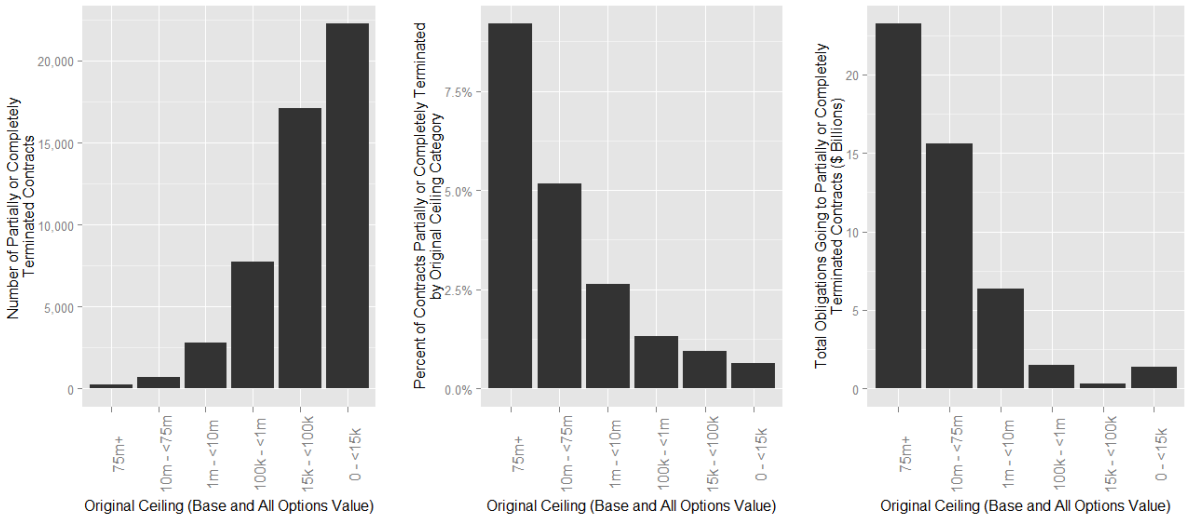
These four categories and the "Close Out" category are used to mark a contract as closed. As discussed above, many contracts well past their current completion date never have a transaction marking them as closed; however, a termination is an active measure that mandates reporting, unlike the natural end of a contract, which can go unremarked.

The four different values of contract termination provide useful granularity, but for reasons just discussed, even a partial termination for convenience indicates that something has likely gone awry. Thus, given the already low number of terminations, the study team treats a contract as either terminated or not, rather than subdividing by type.

Overall, the data demonstrate that the majority of contracts that are terminated had lower original ceilings (Figure 1.7-5). Over 20,000 terminated contracts fell under an original ceiling of $15 thousand. The count of contract termination gradually decreases as the contract size increases. Contracts with an original cost ceiling of $75 million or more saw the least amount of terminated contracts by number.

[36] Sanders, "DoD Fixed-Price Study: Procedural Competition Classification."

Figure 1.7-5 Contract Terminations by Original Ceiling



Source: FPDS; CSIS Analysis

However, these data do not take into account the number of overall contracts in each category. A more complete representation is the comparison of contracts terminated by percentage of total contracts in an original ceiling category. When calculated as such, the data show that those contracts with higher original ceilings have a higher percentage of complete or partial terminations than those with lower original ceilings. Contracts with original ceilings of $75 million or more were partially or completely terminated over 9 percent of the time.

On the other hand, despite accounting for the highest number of overall terminations, those contracts with partial or complete terminations under $15 thousand account for less than 1 percent of contracts in this original ceiling category. This shows that, with a higher percentage of partial or complete contract terminations occurring for higher original ceiling categories, the total obligated value of these terminated contracts is much higher. As a result, the impact of terminations on contracts with higher ceilings is much greater and results in significantly larger financial impact.

To see more details on terminations, visit Contract_Terminations.md on the project's CSISdefense/Fixed-Price GitHub page.[37]

1.8. Bayesian Network Model Building

A variety of statistical techniques is appropriate for inferential analysis on when fixed-price contracts perform best according to the contract output metrics. The study team chose a Bayesian network approach for three key reasons. First, this approach scales well to large datasets, such as the nearly 6 million defense contracts completed between FY2007 and FY2013. Traditionally, only a sample of such data would be available, but thanks to FPDS and modern computing it is possible to analyze the entire population. Second, while a Bayesian network approach and other similar techniques can be used for prediction, it is particularly well suited to understanding how the different pieces of evidence are interrelated. Because this project seeks to provide a starting point for future research, enhancing

[37] Ibid.

understanding of the model's causal logic is more important than creating a model that optimizes the ability to predict outcomes.

Finally, the knowledge engineering process used with Bayesian models—building connections between evidence, called whitelists and blacklists, and the subsequent model queries—is well suited to CSIS's strength in accessing acquisition domain experts and data scientists.

The model is built in the open-source statistical programming language R using two modules. The module BnLearn is used for the Bayesian network learning process, which turns the collected data into a directed graph that is acyclic, which is to say there are no loops.[38] The module gRain is used for the second part of the process, creating the conditional probability table and then querying the resulting multiples.[39] Both modules are also open source and the data as well as the processing and analytic programming code used to implement this process are available through the CSISdefense fixed-price GitHub repository.[40]

1.9. Description of Evidence

As with most statistical models, the first step with a Bayesian network is to gather, clean, and transform the data. Each piece of evidence was collected by first applying CSIS transaction-level lookup tables. Once the transaction-level data were categorized in SQL server, it was then collated into contract-wide values. The first step in this process was done using codebooks available at the lookup-tables repository of the CSISdefense GitHub account. The combination stage was done on a variable-by-variable basis and that process is covered in the fixed-price repository of the CSISdefense GitHub account. The last stage was conversion into evidence notes, each having between two and eight distinct states. The processing required for a Bayesian network increases exponentially with each new node of evidence.

Contract fundamentals:

These nodes of evidence are largely set by the needs of the relevant portion of the Department of Defense rather than chosen by the acquisition official. There are choices to be made within them, for example, whether to fill a need directly with a product or via a service provider. However, as a rule these nodes of evidence influence the contracting method and not vice versa.

Who (Component: Army/Navy/Air Force/Other DoD): Determined by the contracting office rather than the funding office. This will be referred to as "component" throughout this discussion.

What (Platform: Air/Land/Vessel/Electronics & Communications/Missiles and Space/Weapons and Ammunition/Facility-Related Services & Construction/Other): Determined by the combination of the claimant program code for the platform when available and otherwise via the product or service code. This will be referred to as "platform" throughout this discussion.

PSR (Product/Service/R&D): Determined by the product or service codes, with R&D management and support being treated as a service.

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[38] Marco Scutari, "Learning Bayesian Networks with the bnlearn R Package," *Journal of Statistical Software*, July 2010, Volume 35, Issue 3, 1–22, http://www.jstatsoft.org/v35/i03/paper.

[39] Søren Højsgaard, "Graphical Independence Networks with the gRain Package for R.," *Journal of Statistical Software*, March 19, 2014, Volume 46, Issue 10, 1–26, http://www.jstatsoft.org/v46/i10/. The *R Journal*.

[40] See GitHub CSISdefense/Fixed-Price, https://github.com/CSISdefense/Fixed-price.

Soft (Possible Software Eng./No Possible Software Eng.): A set of product or service codes specific to software engineering were identified and labeled by the study team. The criterion for selection of these fields was services that implied a high possibility of programming activity directly conducted in response to the contract. Products, electronics hardware services, and information technology services without an explicit software-related design component were excluded.

Intl (International: Just U.S./Some International): Based on the place of performance. Those contracts with any transactions in foreign countries are classified as "some international." Lookup tables are primarily used when imputing data is necessary due to a missing or malformed value in either the country or U.S. state place of performance fields.

Link (number of linked contracts: none/1–749/750+): This calculated column is the study team's first effort to account for the possibility of problems cascading from other related contracts. For those contracts without a system code, the value is set equal to the number of preexisting contracts in the same contracting office that share a Platform characterization (excluding the Facility-related Services and Construction (FRS&C) and other platforms). For those contracts with a system equipment code, the value is equal to the number of preexisting contracts sharing the system equipment code. This value is then supplemented with the number of contracts with the same platform and contracting office (with the exclusions discussed above) that are not labeled with any system or equipment code. This field will be referred to as "Interlinkages" throughout this discussion.

See the fixed-price repository of the CSISdefense GitHub account for processing code used for this calculation: https://github.com/CSISdefense/Fixed-price.

MDAP (Labeled MDAP/No Labeled MDAP): Labeled MDAPs are derived from the system equipment code in FPDS, although in a small number of cases they are supplemented by contracts that have been manually identified by the study team during prior projects. The term labeled MDAP is used because the field is known to have gaps.

Contract approach:

The contract approach refers to those contract characteristics chosen by the relevant acquisition officials in the pursuit of a successful outcome.

Comp (Competition: Comp. /No Comp.): Is determined using the standard CSIS methodology, with the critical exception that the number of offers received is treated as a separate piece of evidence.

Ceil (Ceiling: $15,000/$100,000/$1,000,000/$10,000,000/$75,000,0000): Refers to the original ceiling on total potential contract obligations. Is set by the initial Base and All Options Value for the contract. This value was chosen rather than the initial Base and Exercised Options Value because exercising options happens regularly during the course of an on-time and on-budget contract. For the results section of the paper, the lower two ceiling groups are combined creating a single category from $0 to $100 thousand.

Dur (Duration: One Day to <Two Months/Two Months to <Seven Months/Seven Months to <One Year/One Year to <Two Years/Two or More Years): Refers to the time span between the effective date of the contract and latest possible end date listed at contract signing, referred to as the initial ultimate duration.

FxCb (Fixed-price/Cost-based/Combination or Other): Fixed-price includes all forms of fixed-price contracting except fixed-price level of effort. That comparatively rare form has been described in meetings with DoD officials as exhibiting more properties of cost-based contracts.

Cost-base includes all forms of cost-plus contracts as well as time and materials and labor-hours contracts.

Combination or Other includes all remaining labeled contract pricing types, and those contracts that contain significant portions of multiple contract types or the combination contracting type.

UCA (Undefinitized Contract Action: UCA/Not UCA): This is identified in the undefinitized contract action, previously the letter contract, field in FPDS. It includes both letter contracts and other forms of undefinitized contract actions. One confounding factor discovered too late to correct is that contract modifications can also include undefinitized contract actions, which is a violation of this paper's principle of limiting study's independent variables to those known prior to the initiation of the contract.

Vehicle (Contract Vehicle: Single Award-IDV/Other IDV/Definitive & Purchase order): Indicates whether or not a contract is single award IDV or one of many other forms of Indefinite Delivery Vehicles (IDVs). This is a contracting approach in which a single root contract is used as a basis for multiple other contracts.

Contract outcomes:

These four variables are discussed in greater detail in section 1.9 Study Dataset and Contract Output Measures.

Offr (Number of Offers Received: 1, 2, 3–4, 5): Cases with no competition are categorized as only one offer, although for hypothesis-testing purposes, when this variable is discussed the sample is limited to competed contracts.

NChg (Number of Change Orders: 0, 1, 2, 3+): The number of change orders refers to the number of transactions for the contract that include a type of change order within the reason for modification field.

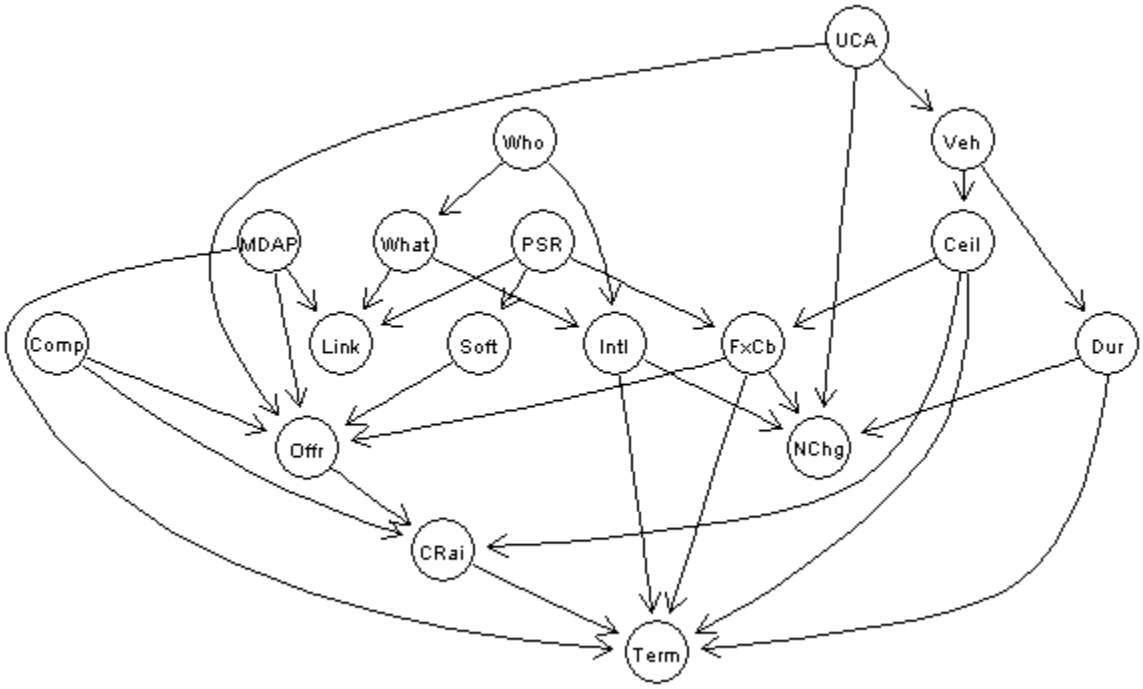
CRai (Ceiling Raising Change Orders, i.e., Extent of Ceiling Breach): <-0.01%, -0.01% to <0.01%, 0.01% to <15%, 15%+): Extent of Ceiling Breaches records changes to the Base and All Options values that happen as part of a change order in the reason for modification field. Other alterations to contract ceiling, such as those associated with new work, are not treated as breaches.

Term (Partial or Complete Terminations: Terminated/Not Terminated): A single termination entry in the reason for modification field is necessary and sufficient to categorize a contract as terminated.

1.10. The Whitelist of Mandatory Arcs between Pieces of Evidence

The whitelist is a collection of directed arcs between pieces of evidence that must be included in the final model whether or not the learning algorithm recommends them. Developing the whitelist was an iterative process. First, the team determined which pieces of evidence were most strongly linked and then, after seeing initial results, added further connections where the learning algorithm could not determine the flow of causality. Finally, the team compared different versions of the model created using variant algorithms and added those arcs that the study team deemed important but that were absent in some models or that were directly relevant to the study hypotheses. This process was first conducted with just the number of offers as a dependent variable, but then was repeated with the addition of change orders, ceiling breaches, and terminations as well as a number of hypothesis specific variables.

Figure 1.8-1 Whitelist of Arcs That Must Appear in the Bayesian Model



Source: FPDS; CSIS Analysis

In the graph, each circle is a piece of evidence or node. Each arrow is a directed arc, and the parent node influences the child node that the arrow points to. For example, there is an arc from the parent Component ("Who") node to the child Platform ("What") node because the different components buy different mixes of platforms. Thus if Component is “Army” then the Platform is substantially more likely to be “Land Vehicles” and less likely to be “Vessels.” So long as no loops are formed, each node can be linked to multiple or no other nodes, for example, Product/Service/R&D (PSR) influences both “Fixed-price or cost-based” and Interlinkages (“Link”) and “Number of offers received” (Offr) has arcs coming from competition, MDAP, software, and “Fixed-price or cost-based.”

Working from the bottom, “Terminations” has MDAP, Ceiling Breaches (“CRAI”), Ceiling, Duration, and “Fixed-price or cost-based” as parents—the first two driven by factors that raise the risk of cancellation because of external and internal factors respectively. Ceiling and Duration by comparison mean remaining cost may make terminations worth the high transaction cost for the government. Finally, “fixed-price or cost-based” is the study variable. Ceiling Breaches is influenced by Competition, Number of Offers, “Fixed-price or cost-based,” and Ceiling—the former two chosen in part to account for the effects of monopoly. “Number of offers received” has “Fixed-price or cost-based” and Competition, MDAP, UCA, and Software as its parents because the number of offers directly depends on whether a contract is competed and the other parents are the study variables, and thus the connection with the dependent variable is highly of interest. The number of change orders (“NChg”) draws from International, and has “Fixed-price or cost-based,” Duration, and UCA. These variables were all chosen because they influenced how much the contract would likely change from its starting condition and how easily it could adapt.

On the next level up, Interlinkages is a constructed variable, and Platform, MDAP, and PSR are used to create it. The contracting office also plays a role, but because there are many contracting offices in each military department, there is not as direct a connection between Component and Interllinkage. The arc from “Fixed-price or cost-based” to PSR was there from the start, as R&D contracts are classically the domain of cost-based pricing. The arc to the second parent of “Fixed-price or cost-based” ceiling was added near the end of the process because that connection appeared in some of the models and the literature provides multiple reasons that a contracting officer would consider ceiling when choosing between fixed-price and cost-based. Further analysis via cross-sectional graphs showed that after accounting for PSR, Ceiling appeared to have the strongest influence on “Fixed-price or cost-based.” Namely, contracts with high ceilings are notably more likely to be Cost-Based or Combination. Unlike these other arcs, the connection between the number of change orders and ceiling breaches is found by the machine learning process, so it was not made explicit.

International is influenced by component and platform, different parts of the military rely on contingency contracting in different ways relating to their mission, and similarly the choice whether to procure an item or service at home or abroad depends greatly on the nature of that item or service. Software is influence by Product/Service/R&D because it is a subset of services. Duration is influenced by Vehicle after the machine-learning algorithm could not decide the nature of the relationship. The study team chose to have Vehicle be the predominant influence for the same reasons as discussed above with Ceiling and Vehicle.

Platform (“What”) is influenced by Components in another straightforward connection as was covered in an earlier example. Vehicle (“Veh”) is a parent of Ceiling because the learning algorithm could not decide on the direction of the relationship, forcing the study team to explicitly define the relationship. The study team chose Vehicle as the parent because choosing an IDV can often mean choosing to break a goal into multiple lower-ceiled pieces, each with a small scope. Thus the Ceiling of a project can depend on whether or not the contracting officer feels an IDV is available and appropriate. The last two nodes, Intl and Duration, do not have any whitelist entries at this time. During model creation, the study team experimented with linking Duration to “Number of offers received,” but that caused the learning algorithm to reject the stronger connection between Ceiling and “Number of offers received.” The team chose to allow the algorithm-preferred arc to take precedence, in the absence of specific discussion in the literature and because an examination of a cross-sectional of Duration and “Number of offers received” did not show any obvious relationship. Vehicle’s parent is UCA because of constraints on the form a contract can take until it is definitized.

1.11. The Blacklist of Mandatory Arcs between Pieces of Evidence

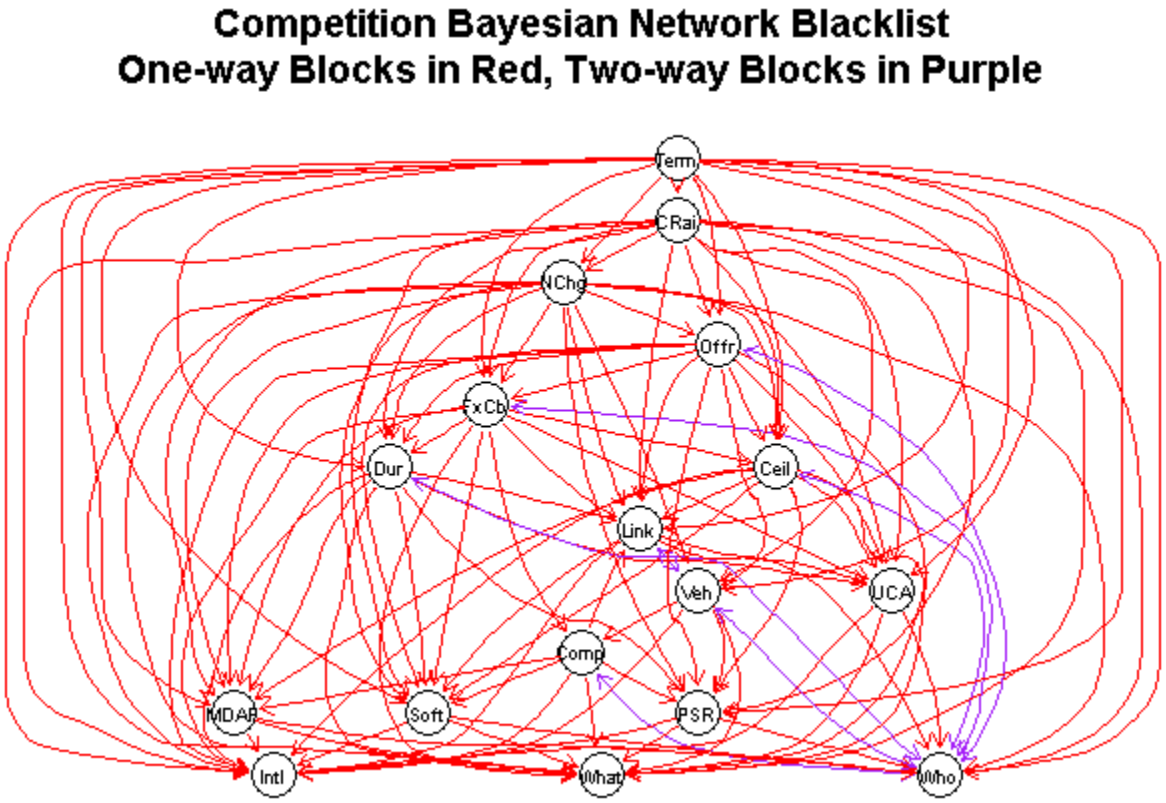
Blacklists are the inversion of whitelists: arcs that may never be included in the model regardless of the findings of the learning algorithm. Developing the blacklist was similarly an iterative process, although with one notable exception, most of the revisions were merely adding more arcs to the blacklist to correct for possibilities overlooked in prior iterations.

For Figure 1.8-2 the red lines indicate arcs that are not allowed. For example, the arrow from “Number of offers received” to Platform means that the number of offers cannot have a casual influence on what sort of platform is being bought. In many cases this is for straightforward causal reasons. The evidence regarding contract fundamental can influence the contracting approach, but not vice versa. This graph has many more arcs than the prior whitelist graph because it is straightforward for experts to establish which evidence factors are decided earlier along the timeline or take precedence over deciding other related factors. For example, the relevant acquisition official will typically first determine whether they

can compete a given contract and only then determine what vehicle or pricing mechanism would be appropriate.

The existence of a blacklist arrow does not mandate that there is a connection going the other direction. In fact, that is the point of the blacklist, to prevent spurious connections from being made without committing to an arc going in the opposite direction. For example, “Number of offers received” is blacklisted to every other piece of evidence in the model, because competition takes place only after the other factors are set in broad terms. However, as will be seen in the casual model, not every piece of evidence that can arc to “Number of offers received” does so.

Figure 1.8-2 Bayesian Network Blacklist



Source: FPDS; CSIS Analysis

In a smaller number of cases, the blacklist extends to arcs in both directions. This means that the two evidence nodes, connected with a purple arc and an arrow pointing in both directions, cannot be parents or children of each other. Most prominently the component node has purple arcs with six different nodes. The linked nodes occur later in the process, so they cannot influence the component that is paying for the contract. However, this study is also primarily concerned with how contracts are designed and not the organization that controls them, so the influence of component is limited to other contracting fundamentals. In the case of IDV and linked, this is because the causal link is difficult to adjudicate because of confounding factors. For contracting office and platform pairings that have IDVs available, the number of preexisting interlinked contracts will typically be higher. However, that reflects the omitted variable of whether there are active IDVs rather than a direct connection between the two evidence nods.

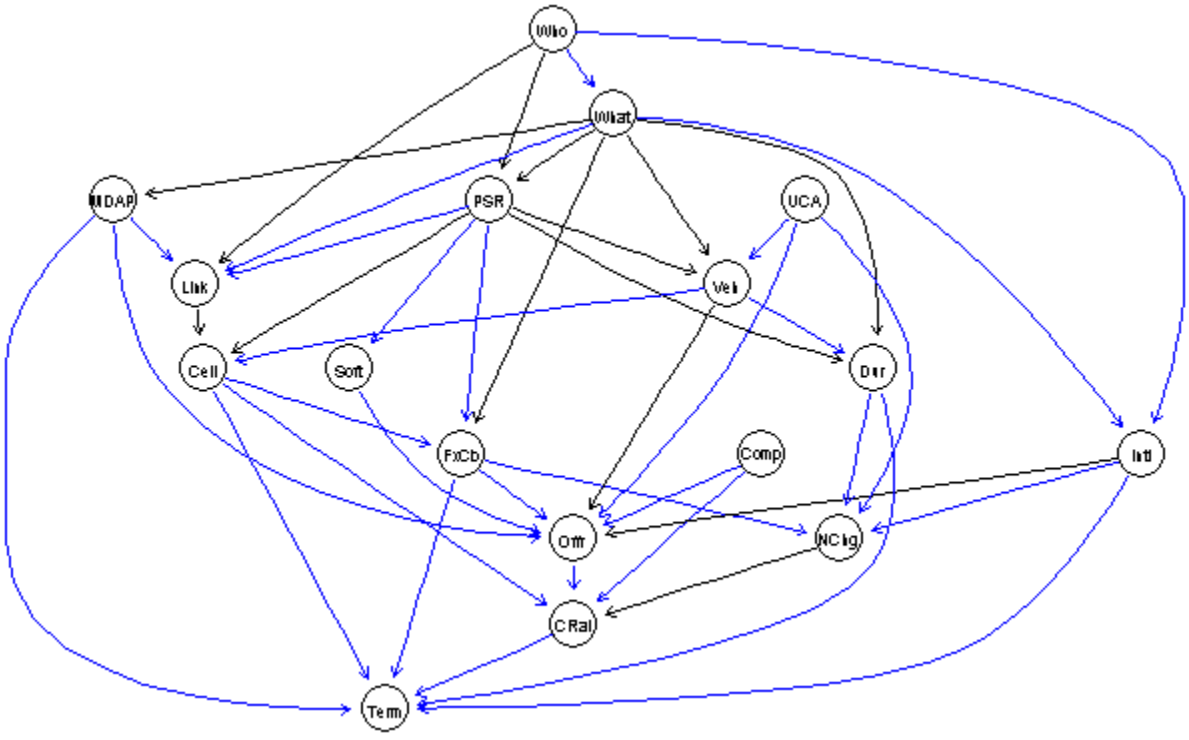
The Component evidence node has bidirectional blacklisted arcs with all of the contracting approach evidence nodes as well as with the “Number of offers received” outcome node. The study team chose to block these links because the literature review did not find a theoretical basis for the organization itself, rather than the characteristics of its contracts, being a key determiner for contract performance under fixed-price contracts. The remainder of the connections primarily reflect the casual ordering as interpreted by the study teams, with those nodes at the bottom occurring first in the process and those at the top representing contract outcome.

1.12. The Contract Outputs Bayesian Network

After the iterated whitelist and blacklist generation process, Figure 1.8-3 shows the ultimate result. In the figure, the blue arrows are those arcs that were mandated by whitelists. The majority of the remainders were not required by the model, but had their direction set by the blacklist as the opposite relations were disallowed.

The resulting Bayesian network shows connections in excess of those mandated by the model, particularly with regard to contract fundamentals. One critical point of note, “Fixed-price or cost-based," has no children that are not mandated by the whitelist. This may reflect the accuracy of whitelisted mandates but also suggests humility may be necessary regarding the influence of the study variable.

Figure 1.8-3 Bayesian Network



Source: FPDS; CSIS Analysis

1.13. Results

This study examines five hypotheses regarding when fixed-price or cost-based contracts deliver comparatively better performance. Because there are a variety of different factors that influence contract outcome, these hypotheses are tested over a range of control conditions. Both the controls and the hypotheses emerged from the academic and policy literature in Section 1.5. Each of the hypotheses is measured by comparing fixed-price contract performance with cost-based contract performance. Combination and mixed contracts are excluded from these measures to avoid further expanding an already daunting number of comparisons. Hypotheses are listed below.

1) Large R&D contracts that are cost-based perform better than Large R&D contracts that are fixed-price competed.

2) Major Defense Acquisition Programs (MDAPs) that are cost-based perform better than MDAPs that are fixed-price.

3) Contracts with a longer duration that are cost-based competed contracts perform better than longer-duration contracts that are fixed-price competed.

4) Fixed-price contracts with greater competition will perform better than fixed-price contracts that are not competed.

5) Large software projects that are fixed-price contracts perform better than software contracts that are cost-based competed contracts.

The performance metrics used to evaluate these hypotheses are reviewed in temporal order, competition first, followed by change orders, ceiling breaches, and then terminations.

Control Variables

Drawing from the findings of the literature review, the study team developed six different controls. The purpose of these controls is to highlight factors that could act has hidden variables that would not necessarily be even distributed between fixed-price and cost-based contracts. The most prominent of these is contract size. The distribution of contracts by size is asymptotic, the smallest two categories of contract ceilings [0–15k) and [15k–100k) are lumped together and account for the vast majority of all contracts but only about a fifth of contract obligations.[41] As a result, for all discussions of the hypotheses below, the results are cross-tabulated by the five different contract ceiling categories.

In addition to the breakdown by contract ceiling, five additional controls were separately applied. Note that these controls are neither mutually exclusive nor exhaustive. A contract may be included within multiple controls or within none.

Aircraft vs. Not Aircraft: Past research has found aircraft and drone contracts to be especially challenging. Aircraft includes Products, Services, and R&D dedicated and is reported in the Platform evidence node

[41] The first round of hypotheses and controls was formulated with a higher level of specificity that grew out of past CSIS work that focused on market share rather than number of contracts. For example, the study team considered a contracting threshold of $500 million in certain cases. This approach was subsequently rejected because while these large contracts do receive a significant market share, they represent a tiny fraction of cases. As the discussion of the results reveals, even the lower $75 million threshold often results in sample sizes too small to be evaluated by chi-squared tests.

UCA vs. Non UCAs: Also known as letter contracts, undefinitized contracts give broad leeway in determining the nature of the contracting arrangement after it is initially signed. This makes UCAs difficult to classify to begin with and has significant influence on performance.

Single Award IDVs/Other IDVs/Definitive Contracts and Purchase Orders (Def./Pur.): This control was identified based on CSIS's past work in this area. In policy terms, Single Award IDVs and other IDVs are different in a range of ways from definitive contracts and purchase orders. Single Award IDVs are available for only one vendor are classified as receiving the number of offers from when the overarching contract vehicle was first solicited. Other IDV types include a range of contract vehicles, but typically limit to a pool of prequalified vendors. They are reported in the IDV evidence node.

2+ Year Duration (2+ Year Dur.) /<2 Year Dur. Dur.: Contracts with longer durations are at greater risk for change orders and even termination because of the time that can pass between the signing of the contract and the final outcome. For this report, long duration means that at the time of signing, the contract allowed for a period of at least two years if all options were exercised. As is always true with the Duration node, the actual contract may take longer or shorter than was initially expected. This particular division is also included in hypothesis 3 and is removed from the list of controls for that hypothesis.

Comp. (Competition)/Not Comp.: The availability of competition reflects a broader industrial base and also the risk for monopolistic practices. However, the impact is not entirely salutary, as competed contracts can encourage overly optimistic bids. This variable is reported in the Competition node and does not distinguish between various types of competition and includes both single offer and multiple offer competition. Competition is covered by hypothesis 4 and is removed from the list of controls for that hypothesis.

1.14. The Study Population

This section provides a review of the entire set of 6 million defense contracts completed between 2007 and 2013. The trends in this population will, in subsequent sections, be compared to each of the hypotheses, in order to analyze how the characteristics discussed influence the relative performance of fixed-price and cost-based contracts.

Number of Offers

Figure 1.13-1, comprising two charts, examines the approximate average number of offers received for competed contracts. The study team chose to expand the discussion of single offer competition and look at the average number of offers received. The study team did perform the initial analysis on the extent of single offer competition alone and the results largely tracked with the average number of offers.

This dependent variable deals exclusively with competed contracts, because the evaluation of whether or not a contract can be available for competition typically precedes the choice to adopt a fixed-price or cost-based approach. As a result, whether or not a contract was available for competition in the first place is not dependent on the pricing mechanism chosen.

The upper chart in Figure 1.13-1 shows the approximate average number of offers for fixed-price and cost-based contracts. The true average number of offers is not available, because the study team separated the number of offers into four categories.

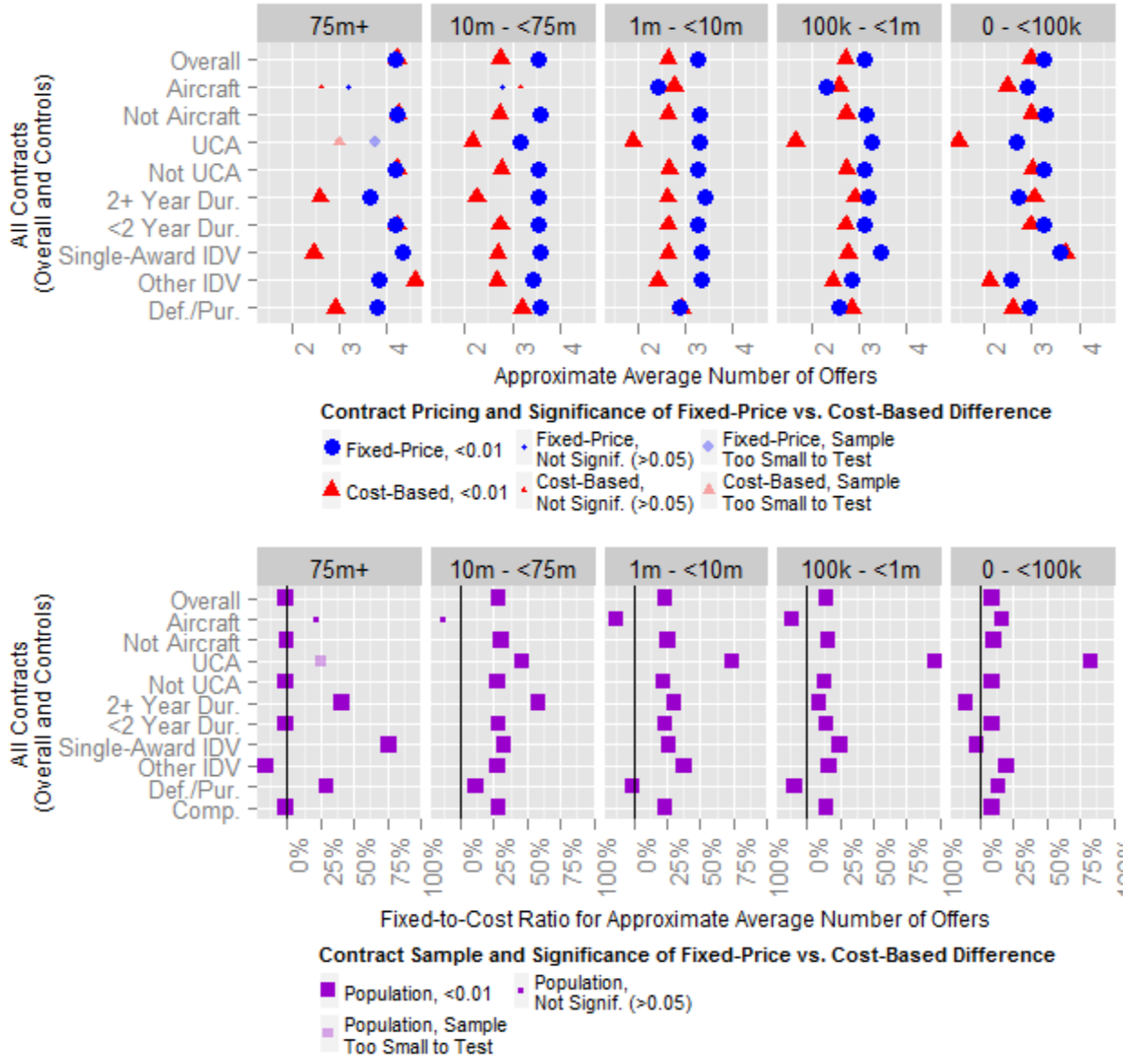
$$\boldsymbol{Approximate\ Average\ Number\ of\ Offers} = 1 * (\%\ of\ contracts\ receiving\ 1\ offer) + 2 * (\%\ of\ contracts\ receiving\ 2\ offers) + 3.5 * (\%\ of\ contracts\ receiving\ 3-4\ offers) + 5 * (\%\ of\ contracts\ receiving\ 5\ or\ more\ offers)$$

For the lower chart, the percent difference between fixed-price and cost-based contracts is examined.

$$\textbf{\textit{Fixed-to-Cost Ratio for Number of Offers}} = \frac{Approx.\,Average\,No.\,of\,Offers\,for\,Fixed\,Price\,Competed\,Contracts}{Approx.\,Average\,No.\,of\,Offers\,for\,Cost\text{-}Based\,Competed\,Contracts} - 1$$

This ratio is the percentage difference between the average number of offers for fixed-price and cost-based contracts. Thus a value of about zero percent (e.g., Overall [75m+]) means the fixed-price and cost-based averages are roughly equivalent. A value of about -12.5 percent (e.g., UCA [1m,10m)) means that fixed-price contracts receive an eighth fewer offers than comparable cost-based contracts.

Figure 1.13-1 Approximate Average Number of Offers for Competed Contracts, Fixed-Price vs. Cost-Based



Source: FPDS; CSIS Analysis

For competed contracts with original ceilings of less than $75 million, fixed-price contracts consistently receive more offers than cost-based contracts. In particular, outside of the largest categories, fixed-price UCAs receive nearly 50 to 100 percent more offers than their cost-based counterparts. There are exceptions where cost-based contracts prove more attractive to vendors, most prominently Aircraft,

which has original ceilings between $100 thousand and $10 million. For the contract with the highest original ceilings, cost-based has a small and inconsistent, though significant, lead. Even with controls in place, the composition of cost-based contracts differs from fixed-price contracts, so this should be taken as a strike against cost-based contracts in its own right. This trend persists across most hypotheses and suggests that, writ large, vendors have not been driven away by the greater inherent risk in fixed-price contracts.

Number of Change Orders and Ceiling Breaches

Unlike the study of number of offers or terminations, two different approaches to change orders are included because they tell slightly different stories. The first is simply the number of change orders, which does not necessarily indicate problems but is a basis for understanding the study variable extent of ceiling breaches. As with the average number of offers, the average number of change orders is an approximation:

$$\begin{aligned}\boldsymbol{Approximate\ Average\ Number\ of\ Change\ Orders}\\ &= 0 * (\%\ of\ contracts\ with\ 0\ change\ orders) + 1\\ &* (\%\ of\ contracts\ with\ 1\ change\ order)\\ &+ 2 * (\%\ of\ contracts\ with\ 2\ change\ orders) + 3\\ &* (\%\ of\ contracts\ receiving\ 3\ or\ more\ change\ orders\ )\end{aligned}$$

The calculation for the approximate average extent of ceiling breaches is slightly more complex. Because ceilings can be lowered at times, it also allows for the possibility of negative changes.

$$\begin{aligned}\boldsymbol{Approximate\ Average\ Extent\ of\ Ceiling\ Breaches}\\ &= -0.1\% * (\%\ of\ contracts\ with\ ceiling\ breaches < \text{-}0.1\%)\\ &+ 0 * (\%\ of\ contracts\ with\ ceiling\ breaches \geq\ \text{-}0.1\%\ and < 0.1\%) + 0.1\%\\ &* (\%\ of\ contracts\ with\ ceiling\ breaches \geq\ 0.1\%\ and < 15\%)\\ &+ 15\%\ * (\%\ of\ contracts\ with\ ceiling\ breaches \geq 15\%)\end{aligned}$$

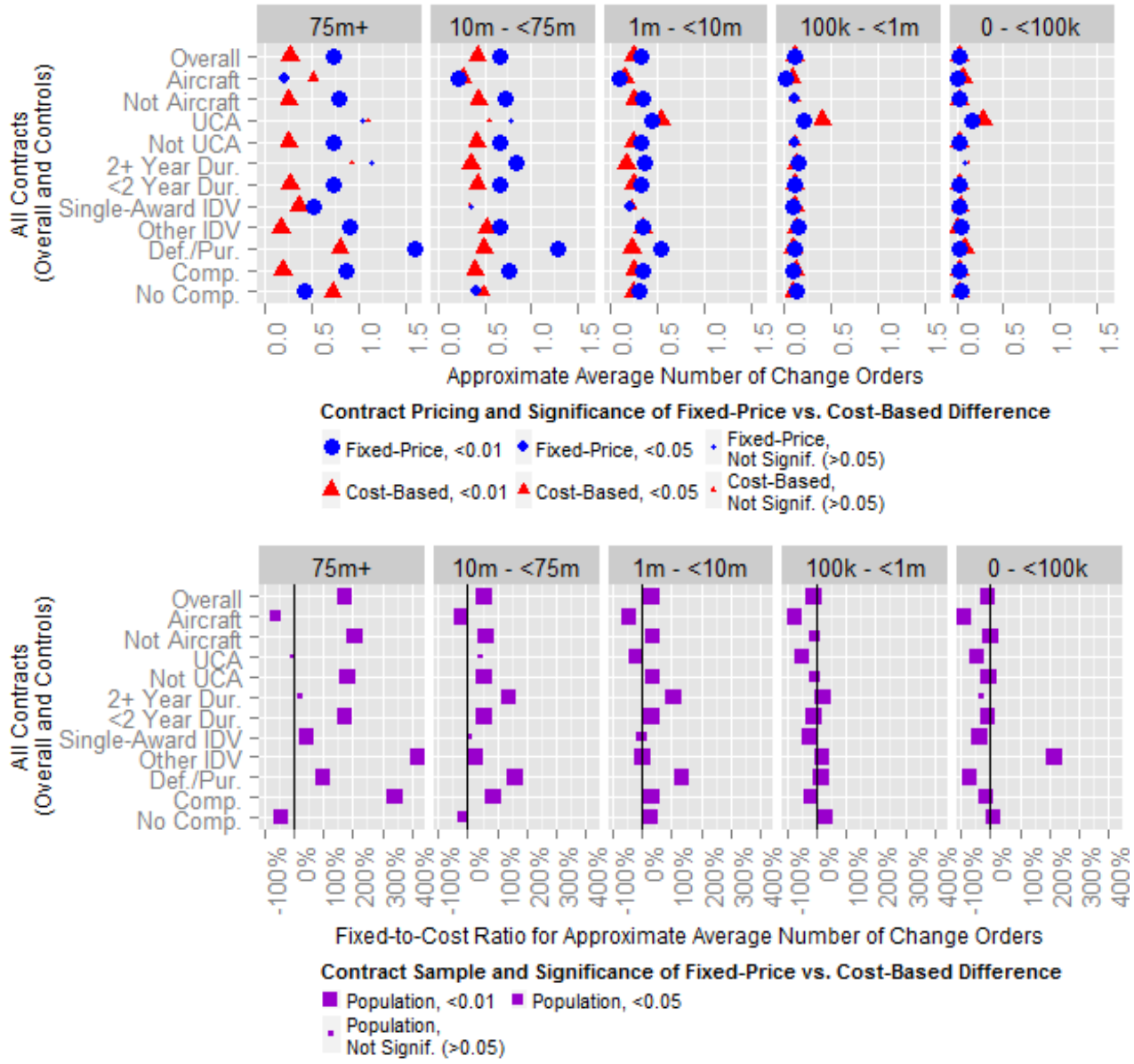
In the same manner as with competition, the percentage difference between fixed-price and cost-based is calculated for both variables.

$$\boldsymbol{Fixed\text{-}to\text{-}Cost\ Ratio\ for\ Approx.\ Average\ Number\ of\ Change\ Orders} = \frac{Approx.\ Average\ No.\ of\ Change\ Orders\ for\ Fixed\text{-}Price\ Contracts}{Approx.\ Average\ No.\ of\ Change\ Orders\ for\ Cost\text{-}Based\ Competed\ Contracts} - 1$$

$$\boldsymbol{Fixed\text{-}to\text{-}Cost\ Ratio\ for\ Approx.\ Average\ Extent\ of\ Ceiling\ Breaches} = \frac{Approx.\ Average\ Extent\ of\ Ceiling\ Breaches\ for\ Fixed\text{-}Price\ Contracts}{Approx.\ Average\ Extent\ of\ Breaches\ for\ Cost\text{-}Based\ Contracts} - 1$$

Critically, higher fixed-to-cost ratios now indicate less favorable outcomes for fixed-price contracts. This effectively reverses the spectrum for the lower chart in Figure 1.13-2: now, negative percentages indicate change orders, and their consequences are more prevalent in cost-based contracts. Positive percentages, on the other hand, indicate that change orders are more prevalent in fixed-price.

Figure 1.13-2 Approximate Average Number of Change Orders for All Contracts, Fixed-Price vs. Cost-Based

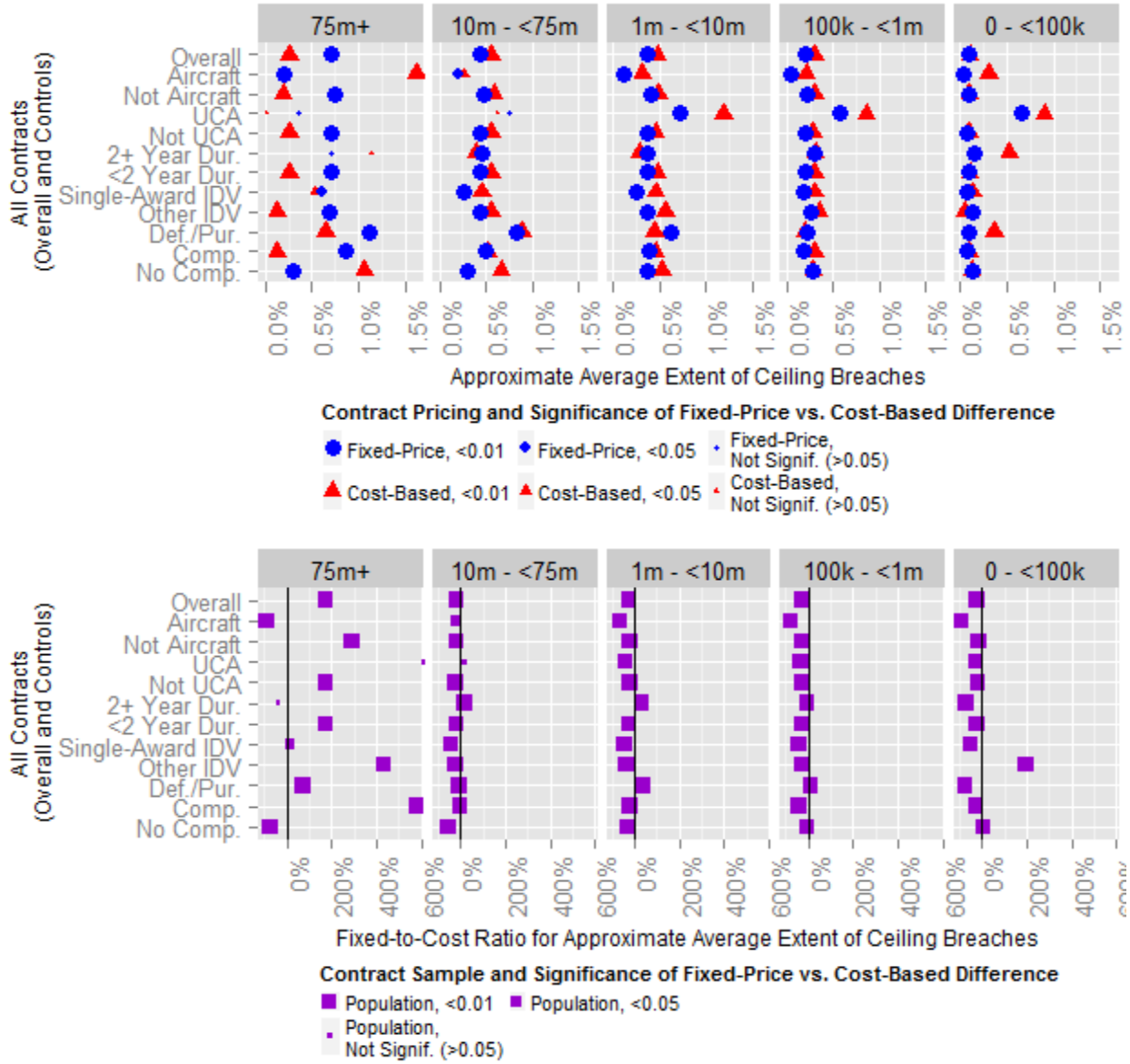


Source: FPDS; CSIS Analysis

In keeping with conventional wisdom, fixed-price contracts with original ceilings of over $1 million experienced more change orders on average than cost-based contracts. Specifically, for the largest and smallest contracts, change orders are two to four times as prevalent for fixed-price contracts. There are prominent exceptions: the fixed-to-cost ratios that showed fewer change orders were less prevalent for fixed-price contracts for aircraft and non-competed contracts with ceilings over $10 million.

Ceiling breaches tells a mixed story (Figure 1.13-3). For contracts with original ceilings of $75 million or more, fixed-price contracts on average experience a greater percentage of growth.[42] Aircraft, longer duration, and competed contracts are exceptions to this trend. Among contracts with original ceilings between $1 million and $75 million, cost-based contracts experience more growth on average. For the smallest contracts, cost-based contracts also tend toward more growth, but the difference is often negligible.

Figure 1.13-3 Approximate Average Extent of Ceiling Breaches



Source: FPDS; CSIS Analysis

[42] For the lower chart in Figure 5-3, the UCA value for $75 million or more is excluded because it indicates a ceiling breach of 3,460 percent. However, this constitutes a rise from 0.01 percent to 0.36 percent, a large relative jump but very small in absolute terms.

Terminations

The final dependent variable is the percentage of contracts that are partially or completely terminated, regardless of cause. The upper chart in Figure 1.13-4 simply reports that percentage. The lower chart, as with the prior variable, reports on how much more likely a fixed-price contract is to be terminated than a cost-based contract.

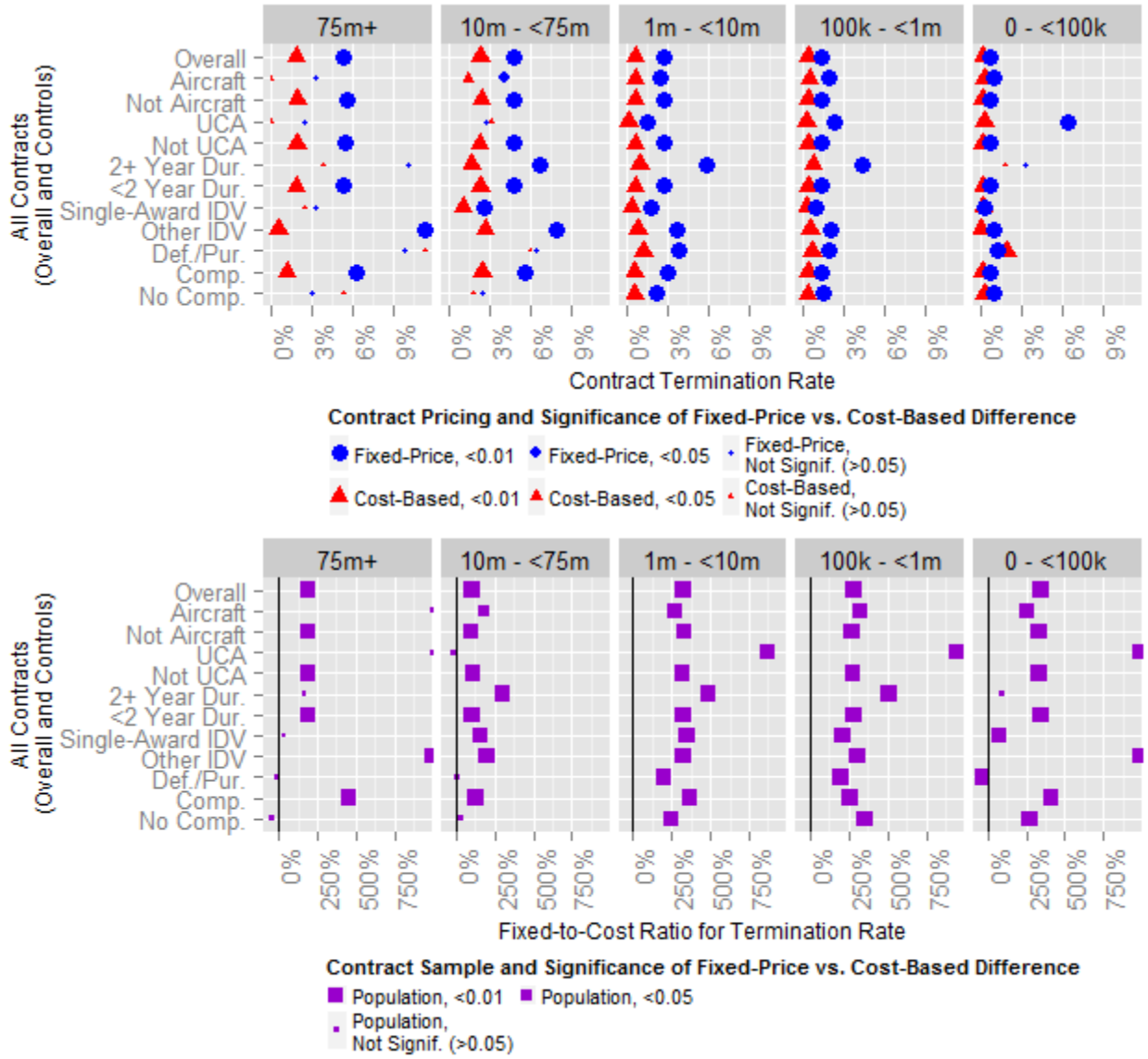
$$\boldsymbol{Fixed\text{-}Price\ to\ Cost\text{-}Based\ Ratio\ for\ Termination\ Rate} = \frac{\%\ of\ Fixed\ Price\ Contracts\ Terminated}{\%\ of\ Cost\text{-}Based\ Contacts\ Terminated} - 1$$

Thus, a fixed-to-cost ratio of around 500 percent (e.g., [75m+] no comp.) would mean fixed-price contracts would have a termination rate of five times that of the corresponding cost-based contracts. By comparison, a dot slightly on the negative side of the line (e.g., [0,100k], Def/Pur) shows that fixed-price contracts are slightly less likely to be canceled than cost-based contracts with the same control group and cost ceiling category.

The termination rate is low enough to, in many instances, produce outliers with 1,000 percent and greater differences between fixed-price and cost-based contracts.[43] In some cases there are no cancellations, which results in an infinte growth rate. For both outliers and those cases in which a rate cannot be calcuated because of a division by zero error, the data point is shown at the extreme left or extreme right end of the data range. For the subsequent termination graph and most of the ones throughout the section, those data points with a value above 1,000 percent or below -1,000 percent are treated as outliers. Concerning the hypotheses, this standard is also applied to ceiling breaches and for the case of software change orders.

[43] For the population, UCA contracts in the [0–100k] original ceiling category (nearly 2,200 percent) as well as Other IDVs in the largest and smallest contract categories (just under 2,090 and 1,990 percent respectively) are significant but not shown in Figure 1.13-4 for scaling reasons. Subsequent outliers are not reported beyond being noted in the graph, except when they are relevant to the analysis.

Figure 1.13-4 Approximate Average Percentage Rise of Terminations, Fixed-Price vs. Cost-Based



Source: FPDS; CSIS Analysis

Terminations is the dependent variable for which the differences between fixed-price and cost-based contracts are most striking. There is a range of possible contributing factors, from difficulties adapting contracts, to the great risk borne by the vendor, to simply fewer options for softly ending a contract. Regardless, while the fixed-to-cost ratio is smallest among the contracts with ceilings between $10 and $75 million, it is still remarkably high across all original ceiling categories and most control groups.

1.15. Hypothesis 1: Large R&D

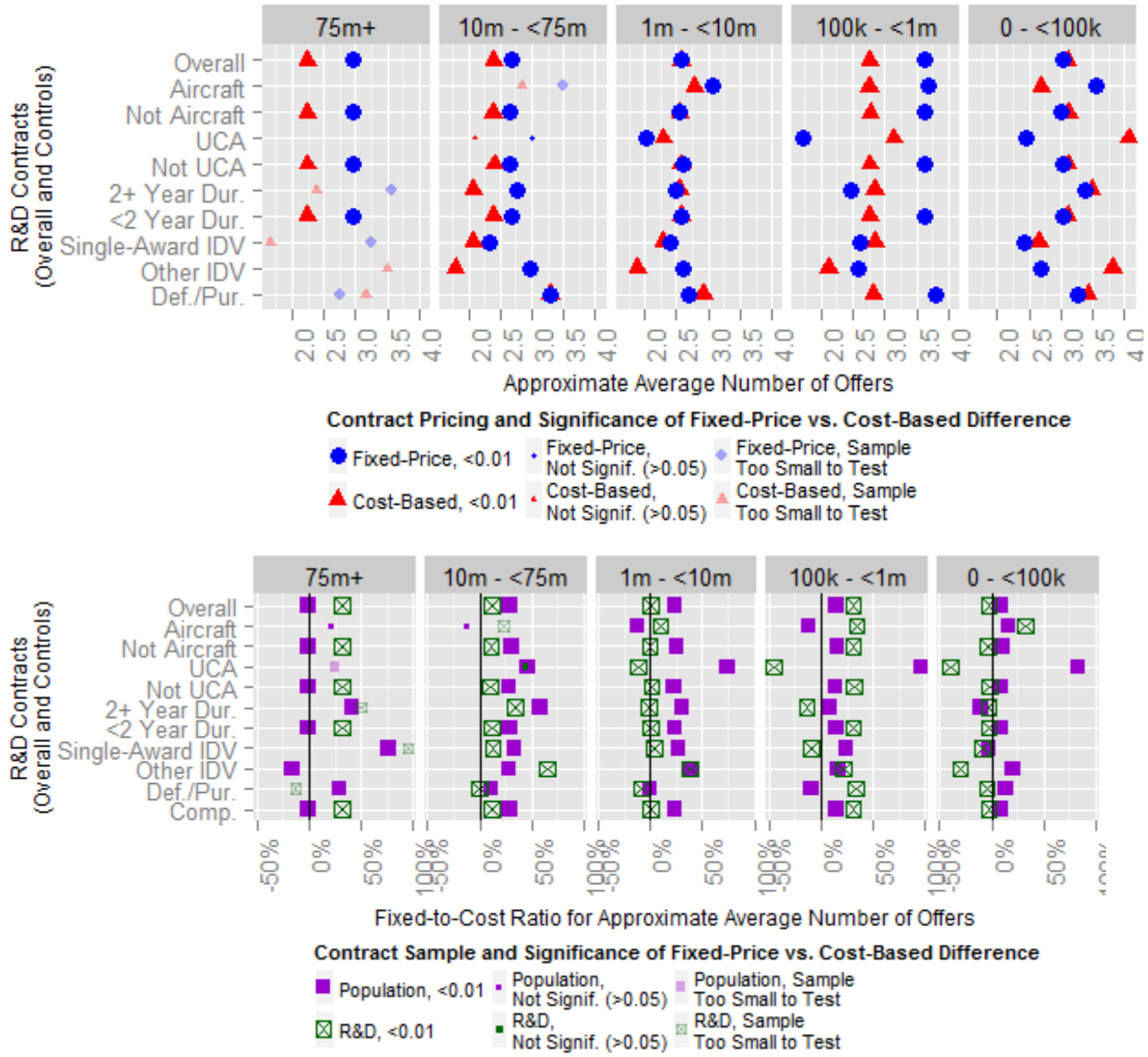
Large R&D contracts that are cost-based perform better than Large R&D contracts that are fixed-price.

The challenges faced by larger fixed-price R&D contracts are not uniform and, contrary to expectations from the hypothesis, challenges do not increase in proportion to original contract ceiling. For projects over $75 million, the chance of contract termination was at least 10 percent for the overall population and for most controls. However, while this aspect conformed to the hypothesis, large fixed-price R&D contracts received more offers and experienced fewer change orders than large cost-based R&D contracts. The fixed-to-cost ratios show that large fixed-price R&D contracts outperformed other large fixed-price contracts by these measures.

The trend in fixed-to-cost ratios is reversed for R&D contracts with ceilings between $1 million and $75 million. The ratios for R&D contracts in that range were worse than the ratios for the general population. These mid-ranged fixed-price contracts received comparatively fewer bids and experienced more and costlier change orders, but they had a lower risk of termination than comparable fixed-price contracts.

The hypothesis is not upheld for the largest category of contracts, where cost-based contracts received comparatively average fewer offers than fixed-price (Figure 1.13-5). The data are more complicated for contracts with original ceilings between $1 million to $75 million contract. For contracts in this range, the fixed-to-cost ratio for R&D contracts is lower, and closer to zero, than the ratio for the overall population. For these R&D contracts, fixed-price still has an edge, but that edge is notably smaller which is consistent with the premise that R&D fixed-price contracts will encounter more problems than typical fixed-price price contracts. Also complicating matters are for UCA contracts with original ceilings below $10 million, cost-based contracts receive comparatively more offers.

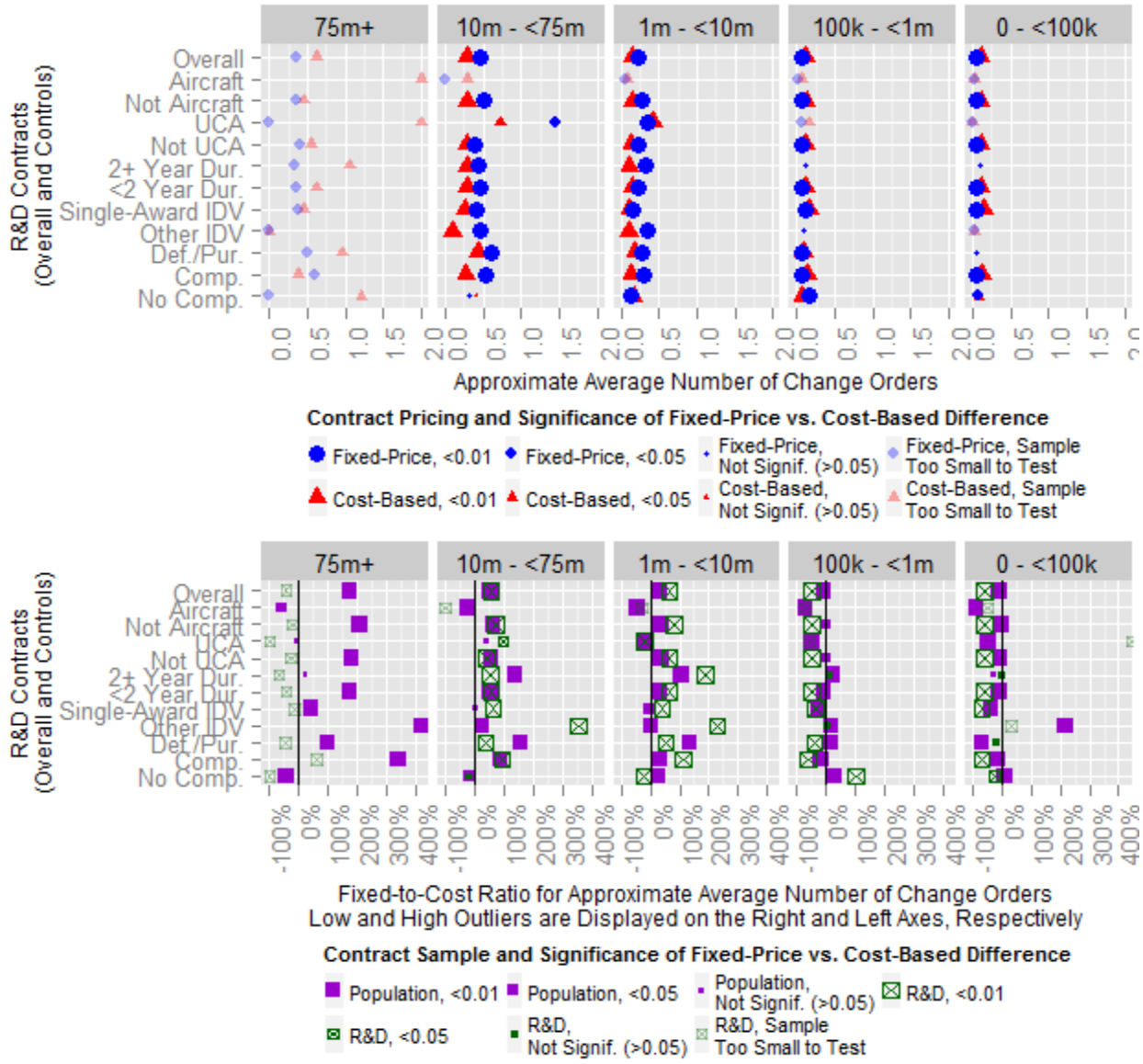
Figure 1.13-5 Approximate Average Number of Offers for R&D Contracts, Fixed-Price vs. Cost-Based Competed Contracts



Source: FPDS; CSIS Analysis

The hypothesis suggests that fixed-price R&D contracts with the highest ceilings would experience higher average numbers of change orders, reflecting more challenges than those faced by cost-based contracts (Figure 1.13-6). When tested, this does not hold for the highest ceiling category, although the results are not significant. However, the next two categories, covering contracts with original ceilings from $1 million to $75 million, do have comparatively more change orders under fixed-price. For R&D contracts with original ceilings between $1 million and $75 million, the fixed-to-cost ratio is higher than for the general population, in keeping with the idea that fixed-price R&D contracts face more problems. The smallest two categories of cost-based contracts experience more change orders than their fixed-price counterparts.

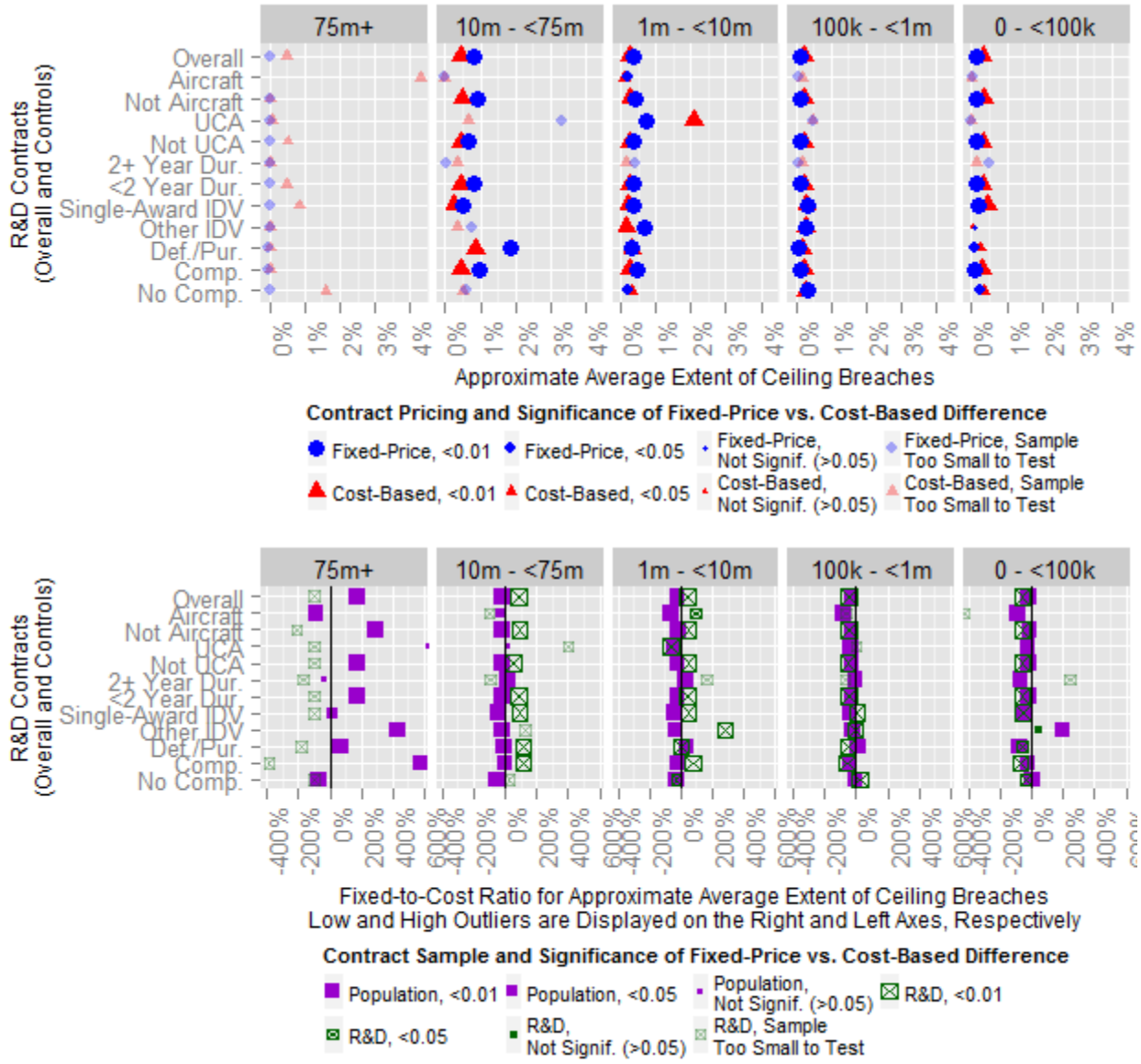
Figure 1.13-6 Approximate Average Number of Change Orders for R&D Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

The hypothesis suggests greater percentage magnitude of ceiling breaches for large fixed-price R&D contracts compared to cost-based R&D contracts of the same size (Figure 1.13-7). As with the previous datasets, this again does not hold true with the largest contracts but does for the next two categories. The results are also more robust than for the average number of change orders, suggesting that changes to R&D fixed-price contracts may be costlier than those to fixed-price contracts in the general population. The results for the smallest two categories reinforce the idea that those R&D contracts with original cost ceilings below $1 million have no worse performance under fixed-price, although as in all cases this could reflect more challenging contracts using this mechanism.

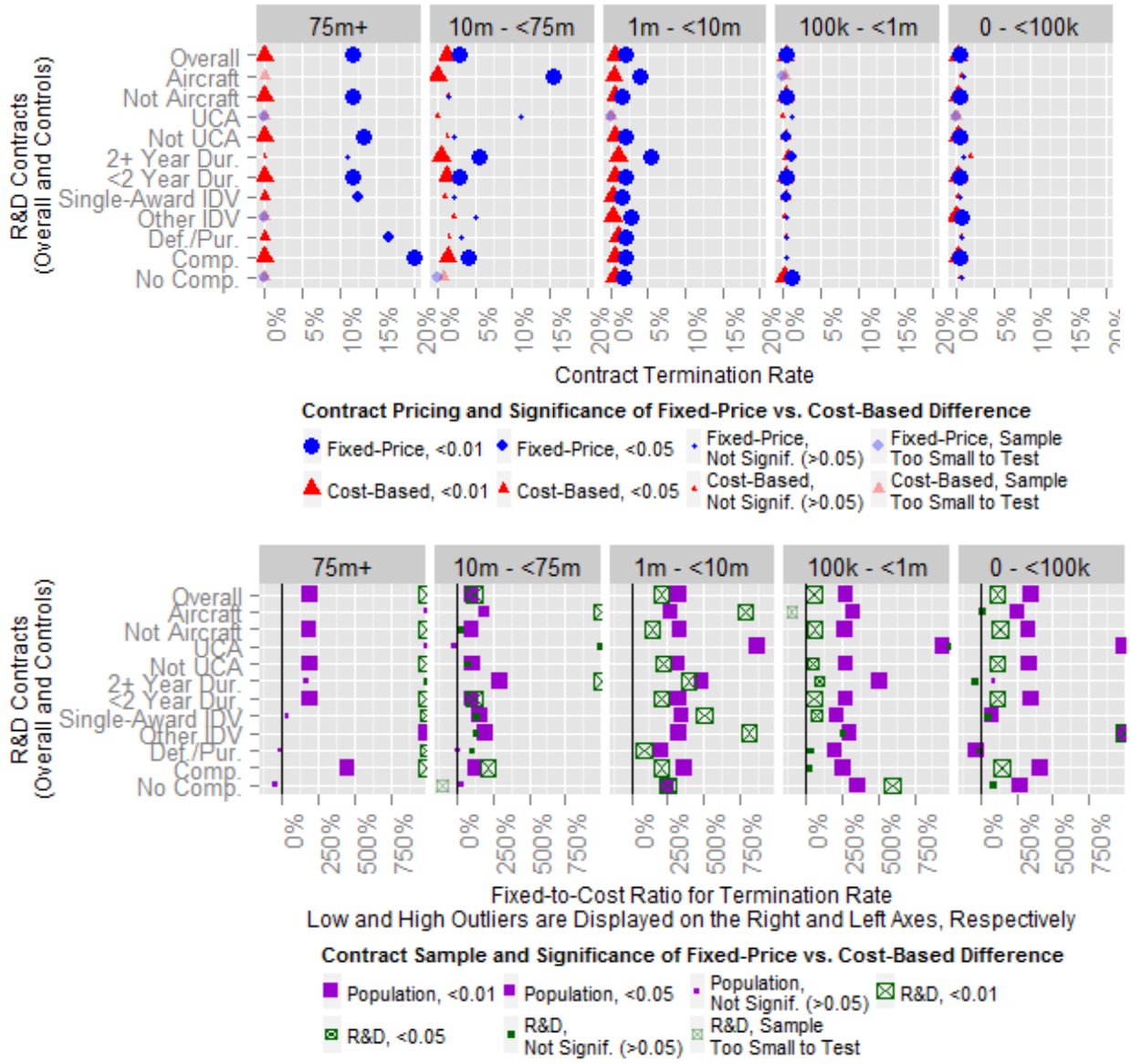
Figure 1.13-7 Approximate Average Extent of Ceiling Breaches for R&D Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

Following trends in the population, all cost categories of fixed-price contracts face greater termination rates (Figure 1.13-8). The hypothesis suggests that large fixed-price R&D contracts will be more likely to be terminated than large cost-based contracts. Upholding the hypothesis, the largest fixed-price contracts regularly had termination rates of over 10 percent, compared to no terminations among the largest cost-based contracts. Particularly worth of note, competed large fixed-price contracts had a one in five chance to be canceled. Aircraft contracts are an exception to this trend, but not one with sufficient sample size to be for the chi-squared test. For the smaller categories of R&D contracts, the difference between the fixed-price and cost-based terminations rates are actually smaller than for the overall population, implying that there is less fluctuation in results from contract choice for smaller R&D contracts.

Figure 1.13-8 Probability of Termination for R&D Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

1.16. Hypothesis 2: Major Defense Acquisition Programs

Major Defense Acquisition Programs (MDAPs) that are cost-based perform better than MDAPs that are fixed-price.

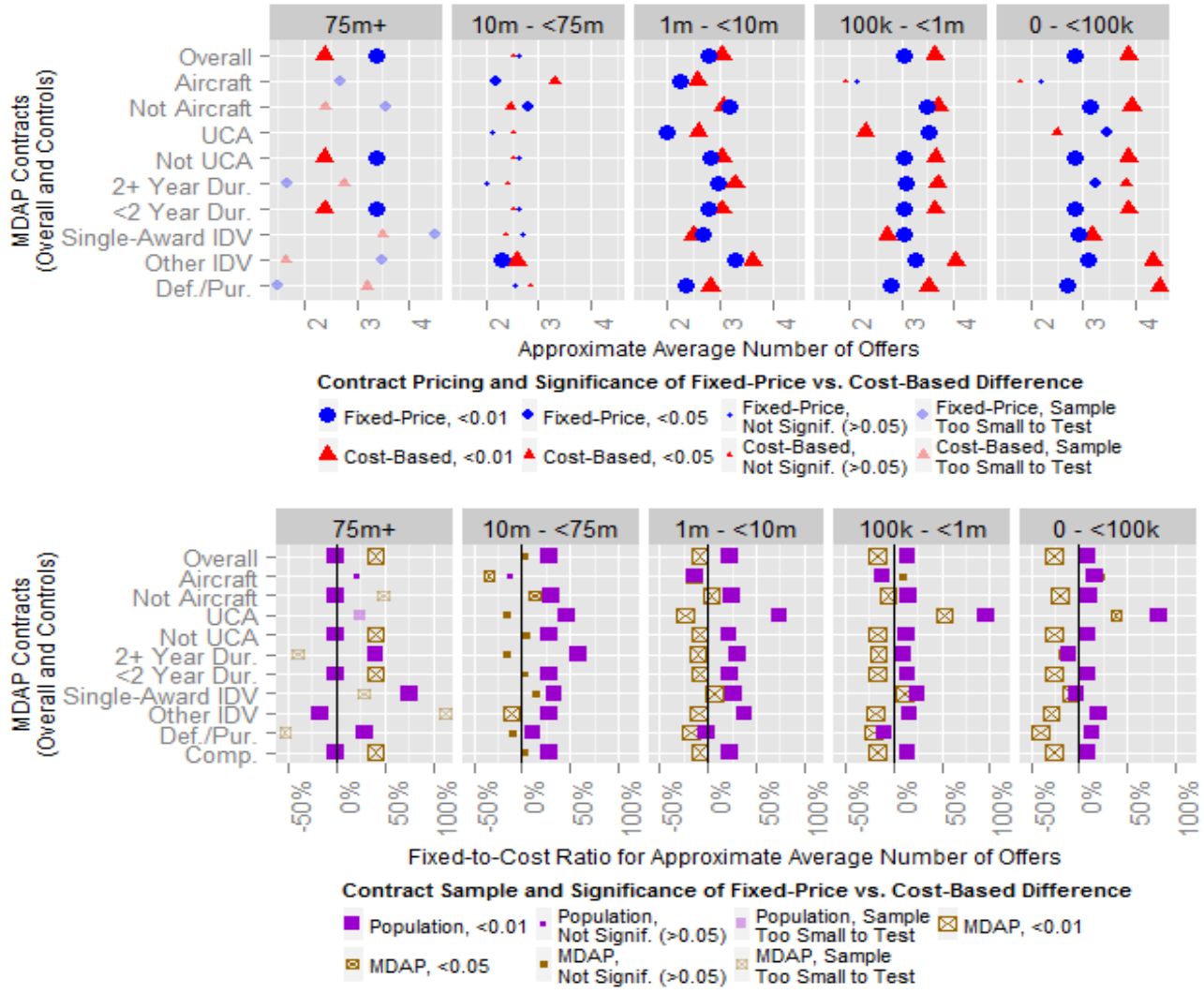
MDAPs were not disproportionately challenging for fixed-price contracts. While fixed-price contracts in this category were still more likely to experience ceiling breaches or termination, they were less likely than contracts in the overall population. The only area in which fixed-price MDAPs consistently underperformed the population was in the number of offers received for contracts with ceilings below $75 million. Competed cost-based MDAP contracts received more offers than those in the general population while the opposite was true for fixed-price contracts. This was not true in absolute terms for R&D contracts. However, the pattern in fixed-to-cost ratios are similar in that R&D contracts with

ceilings between $1 million and $75 million had a lower fixed-to-cost ratio than comparable contracts in the population.

This hypothesis was derived from literature on the challenges of complexity for fixed-price contracts; the study team ultimately decided to use MDAPs as a proxy for complex projects. The lack of support may not directly reflect on that literature but may instead indicate that MDAPs are not an effective proxy for complexity or that these large projects include other hidden variables that are not included within the controls.

For the population in general, all but the largest of fixed-price contracts receive a higher number of expected offers for contracts than do comparatively sized cost-based. This pattern is reversed for MDAPs, where fixed-price contracts receive nearly 50 percent more offers when their original ceilings are $75 million or higher (Figure 1.13-9). For those MDAP contracts with ceilings below $10 million, however, cost-based contracts receive more offers. For all but the largest contracts and a handful of specific controls, fixed-price MDAPs contracts received fewer average offers than cost-based contracts.

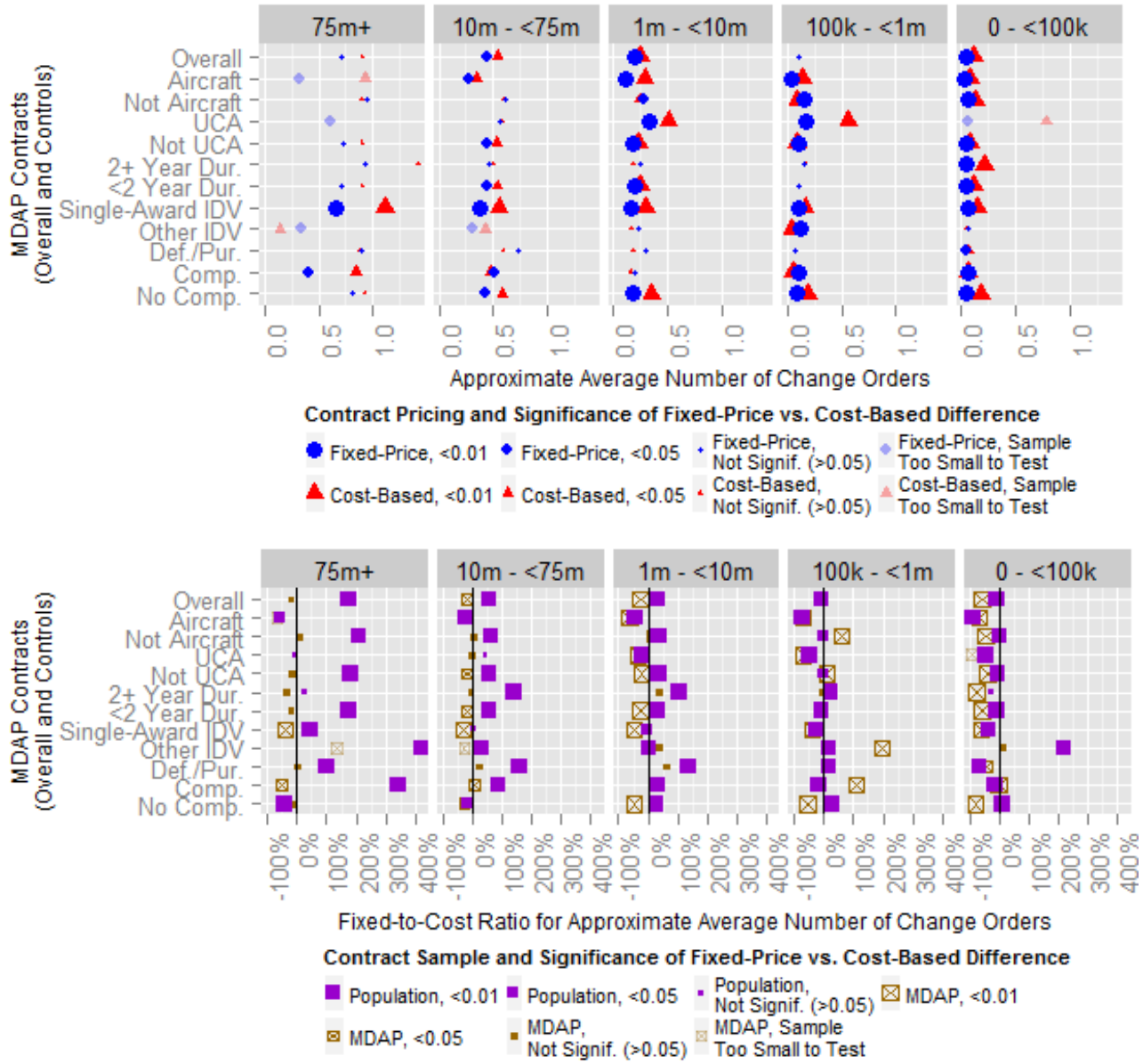
Figure 1.13-9 Approximate Average Number of Offers for MDAP Contracts, Fixed-Price vs. Cost-Based Competed Contracts



Source: FPDS; CSIS Analysis

Data representing the number of change orders for MDAP contracts also contradicted the hypothesis. Overall, the population received more change orders for cost-based contracts than for fixed-price contracts (Figure 1.13-10). For all contracts under $75 million, the number of change orders was comparatively closer between fixed-price and cost-based for the population, making the perceived benefits of fixed-price population as a whole less applicable. As the contracts get smaller, however, fixed-price contracts do continue to receive fewer change orders than cost-based contracts. The percent difference for types of MDAP contracts is not widely differentiated from the population as a whole, aside from in the largest category. Here, the population generally sees more change orders to fixed-price contracts. MDAP data demonstrate the opposite trend, where cost-based contracts receive marginally more change orders than fixed-price contracts.

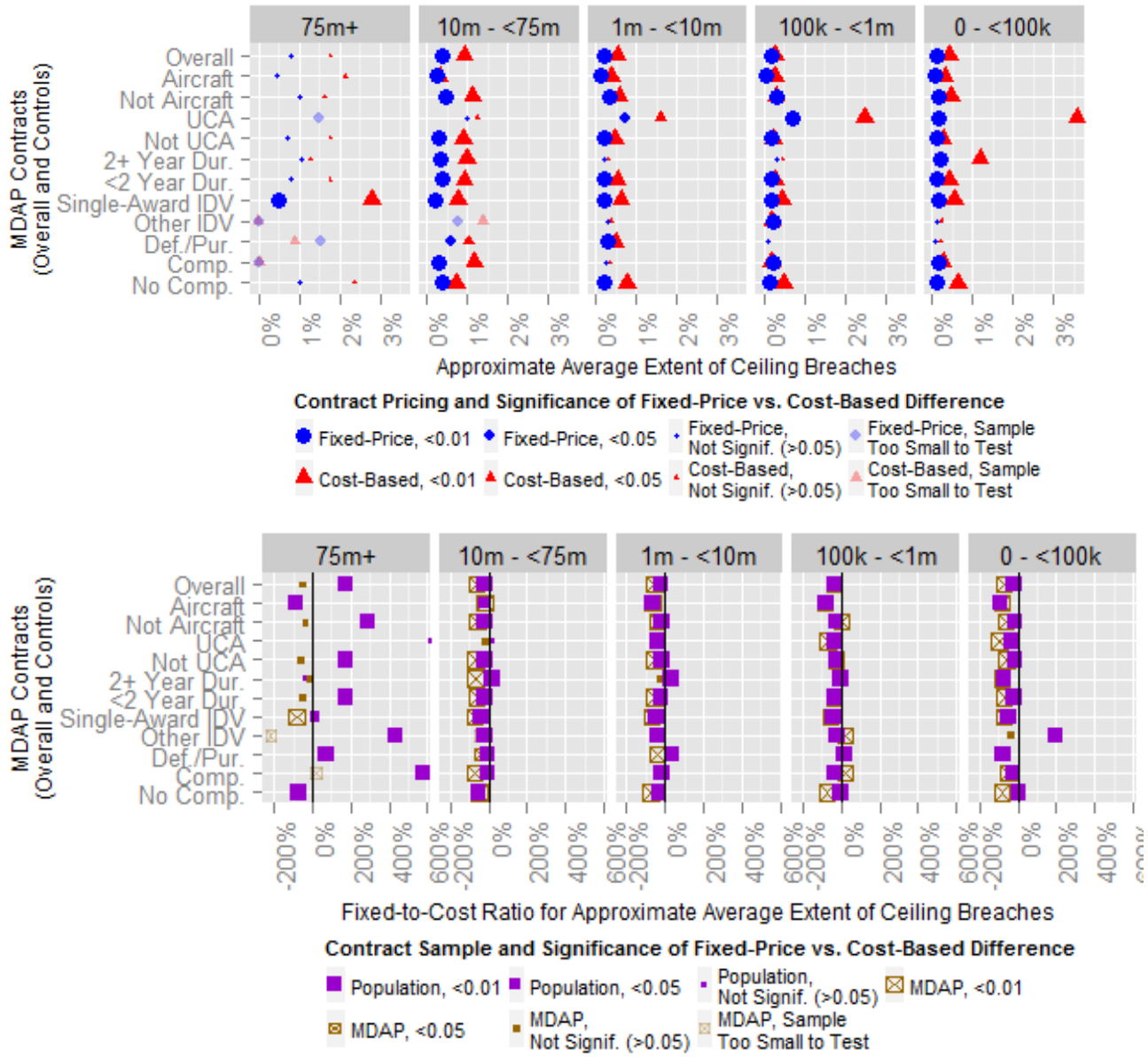
Figure 1.13-10 Approximate Average Number of Change Orders for MDAP Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

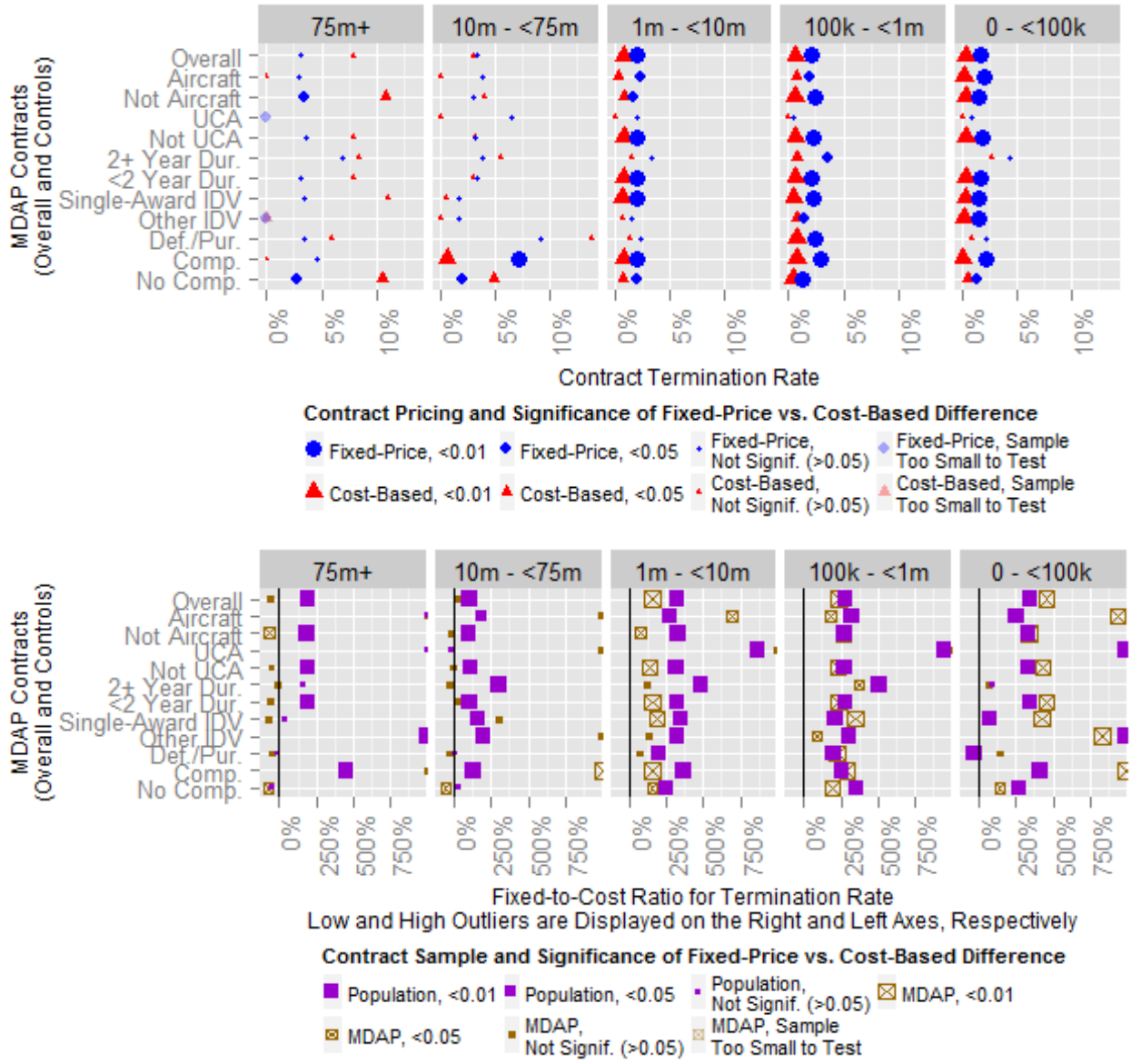
Overall, cost-based contracts saw a larger ceiling breach percentage than did fixed-price contracts, further disproving the hypothesis (Figure 1.13-11). This conclusion represents a similar trend as the overall population. UCA and Single-Award IDV MDAP contracts were specifically notable for their appeal toward fixed-price contracts, which had significantly smaller ceiling breach percentages than cost-based programs. The only category that seems to uphold the hypothesis is the Def./Pur. contracts over $75 million, where cost-based MDAP contracts do receive a smaller percentage of ceiling breaches and thus perform better.

Figure 1.13-11 Approximate Average Extent of Ceiling Breaches for MDAP Contracts, Fixed-Price vs. Cost- Based Contracts



The hypothesis holds that fixed-price contracts will have more problems with complex projects such as MDAPs. Consistent with this hypothesis, fixed-price MDAPs with ceilings lower than $10 million are terminated at higher rates than cost-based MDAP contracts (Figure 1.13-12). In addition, for contracts with the lowest ceilings and several categories of competed and aircraft contracts, MDAP contracts had fixed-to-cost ratios showing a higher marginal risk of termination than in the general population.

Figure 1.13-12 Probability of Termination for MDAP Contracts, Fixed-Price vs. Cost-Based Contracts



However, for overall contracts with original ceilings above $100 thousand, the fixed-to-cost ratios showed a lower marginal risk of termination than in the overall population. While the results were not significant, for the highest ceiling, fixed-price contracts were less likely to be terminated than cost-based contracts. On this basis, the hypothesis is not supported for all but the smallest contracts.

1.17. Hypothesis 3: Long Duration

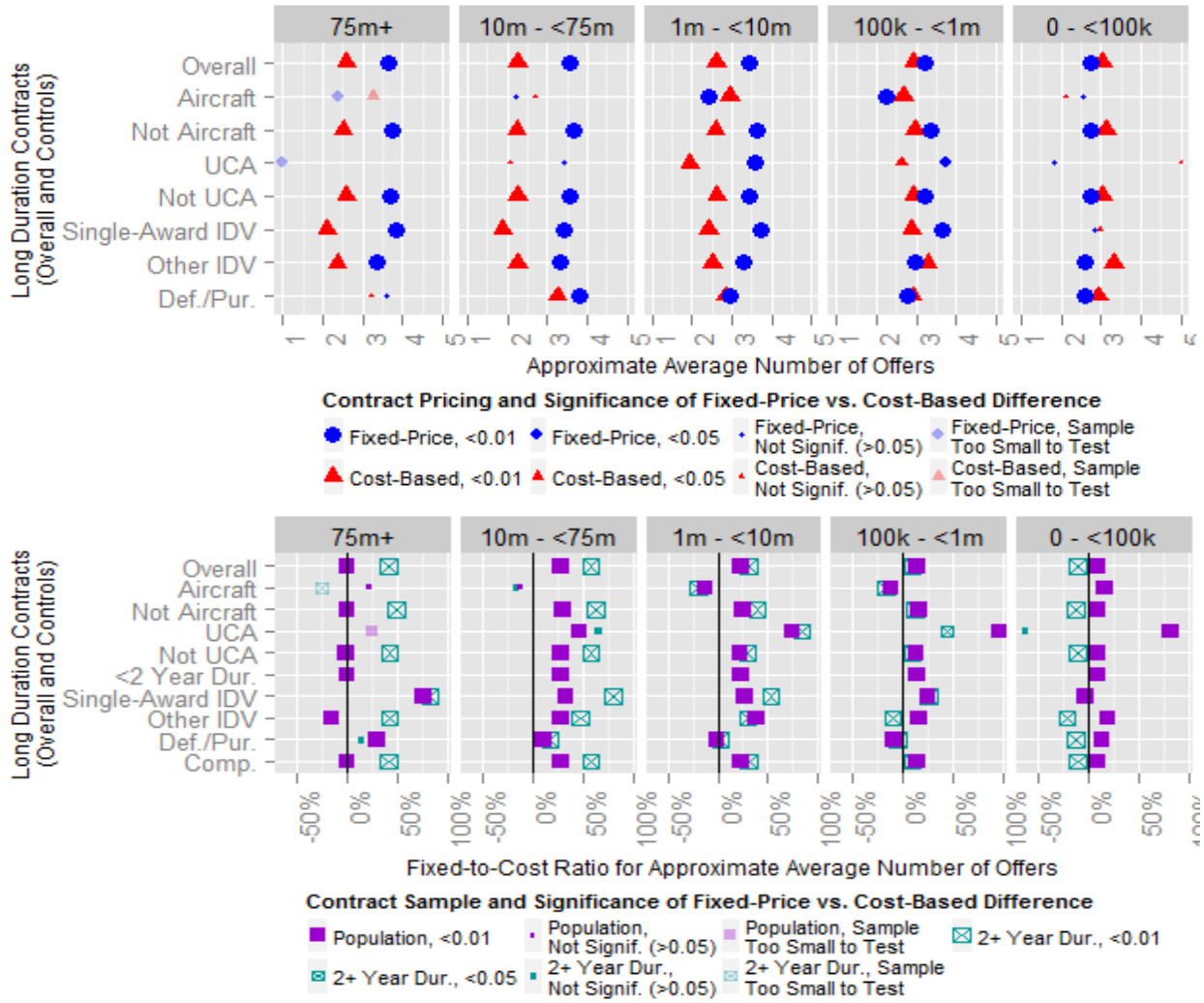
Contracts with a longer duration that are cost-based contracts perform better than longer-duration contracts that are fixed-price.

Longer-duration contracts proved to be the hypothesis most firmly supported by the data. This support was not across the board. As contract ceilings rise, fixed-price contracts with a duration of two or more years receive steadily more offers, on average, than cost-based contracts of similar duration. Nonetheless, for contracts with ceilings between $1 million and $75 million, fixed-price contracts undertook comparatively more change orders, experienced greater growth in contract ceiling, and were

terminated at higher rates. This comparison holds true both between longer-duration cost-based contracts and fixed-price contracts in the overall population. While the interaction of a smaller sample size and limitations of the chi-squared tests prevents drawing any conclusion from the largest category of contracts, the data firmly support the idea that the difficulty of adapting fixed-price contracts becomes a greater liability over time, even if this does not reduce the number of vendors willing to bid on them.

The hypothesis projects that contracts with a longer duration would receive more offers when structured as cost-based contracts than as fixed-price contracts (Figure 1.13-13). This holds true for the smallest category of contracts and for aircraft in all other categories. However, for contracts with original ceilings of $1 million and above, long-duration contracts receive a higher average number of offers as fixed-price than as cost-based. When comparing the fixed-to-cost ratio of long-duration contracts to that of the overall population, a consistent and remarkable trend emerges. For the smallest contracts, the fixed-to-cost ratio is lower than for the population, signifying comparatively fewer offers for fixed-price contracts. However, each step up in size category results in a higher fixed-to-cost ratio. So while the hypothesis holds for the smallest contracts and aircraft, a strong countervailing trend is present for larger contracts.

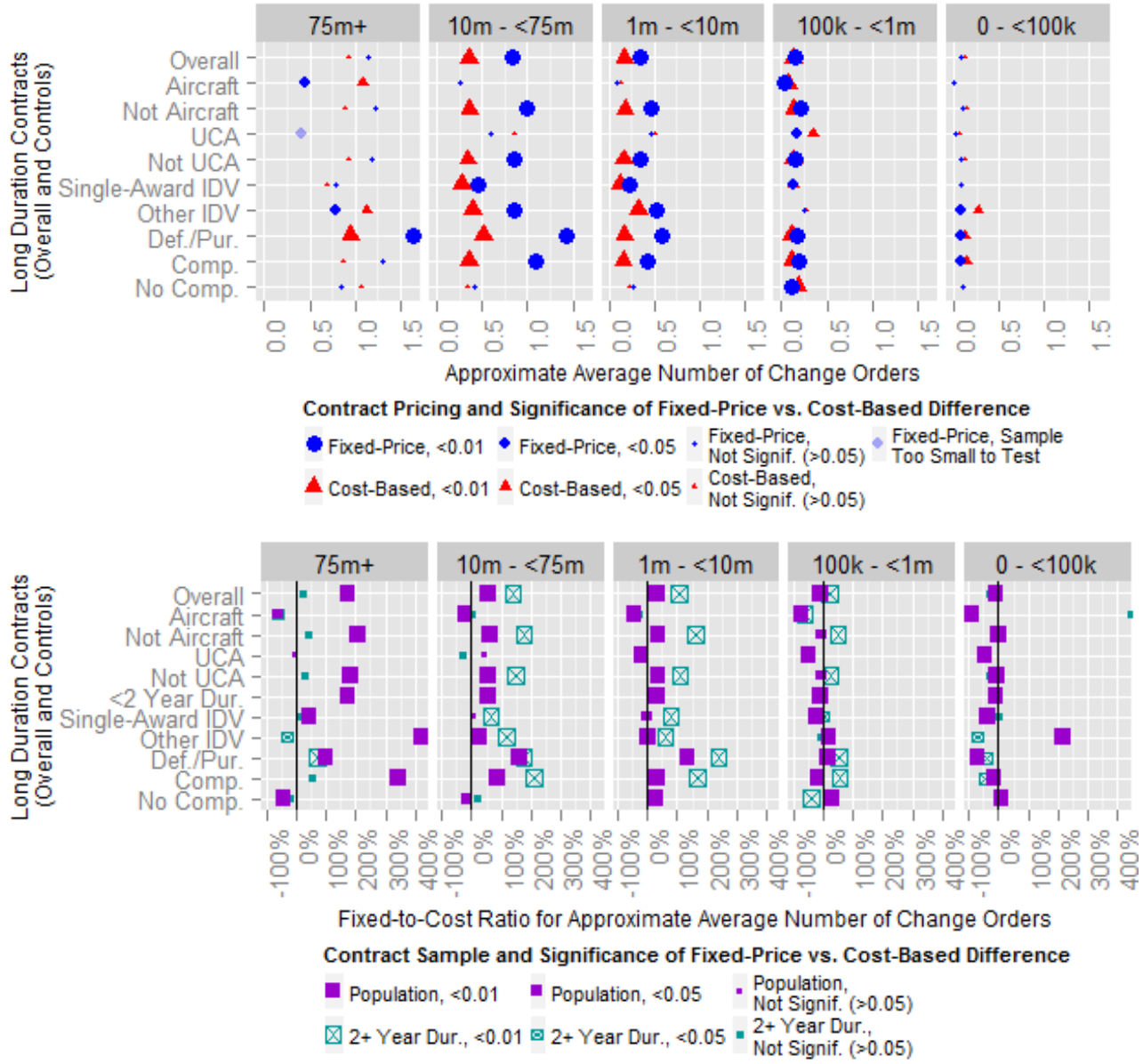
Figure 1.13-13 Approximate Average Number of Offers for Long-Duration Contracts, Fixed-Price vs. Cost-Based Competed Contracts



Source: FPDS; CSIS Analysis

While the overall population experiences more change orders for cost-based contracts than for fixed-price contracts, longer-duration programs show less of this trend than the population as a whole (Figure 1.13-14). For contracts with ceilings higher than $1 million, fixed-price contracts tend to have more change orders than cost-based. There are exceptions, such as Aircraft contracts and Single-Award IDVs, but they are only significant at the 0.05 level. Also contrary to the hypothesis, long-duration contracts with the lowest ceiling category had higher average change-orders for cost-based contracts than for fixed-price. However, those results are largely not significant. For the data that are significant, contracts with original ceilings between $100 thousand and $1 million, the fixed-to-cost ratio shows that long-duration contracts have comparatively more fixed-price change orders than comparable contracts in the overall population. Thus, for the data with the greatest statistical power, the hypothesis is upheld.

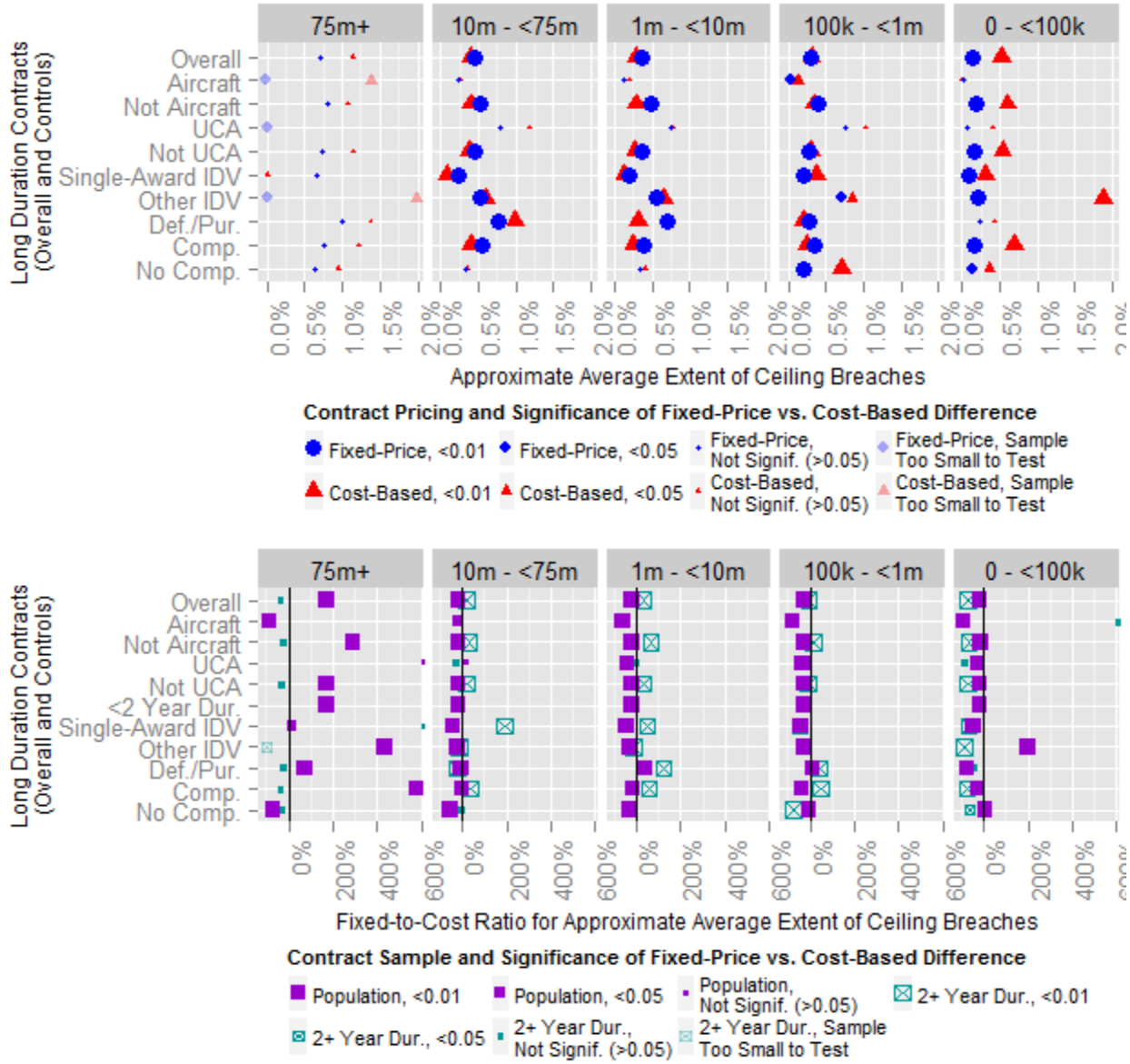
Figure 1.13-14 Approximate Average Number of Change Orders for Long-Duration Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

In absolute terms, fixed-price and cost-based contracts have similar average extent of ceiling breaches for the three middle contract categories (Figure 1.13-15). The highest category is not significant, but the lowest ceiling category runs contrary to this trend and the hypothesis. The support for the hypothesis emerges instead from the fixed-to-cost ratios. While the lowest ceiling category again cuts against the hypothesis, the three middle categories all show that the fix-to-cost ratio is generally higher for the long-duration sample than for the population as a whole. Thus, even if the average extent of ceiling breaches is only slightly higher for long-duration fixed-price contracts, this still shows that fixed-price are at a relative disadvantage versus the overall population.

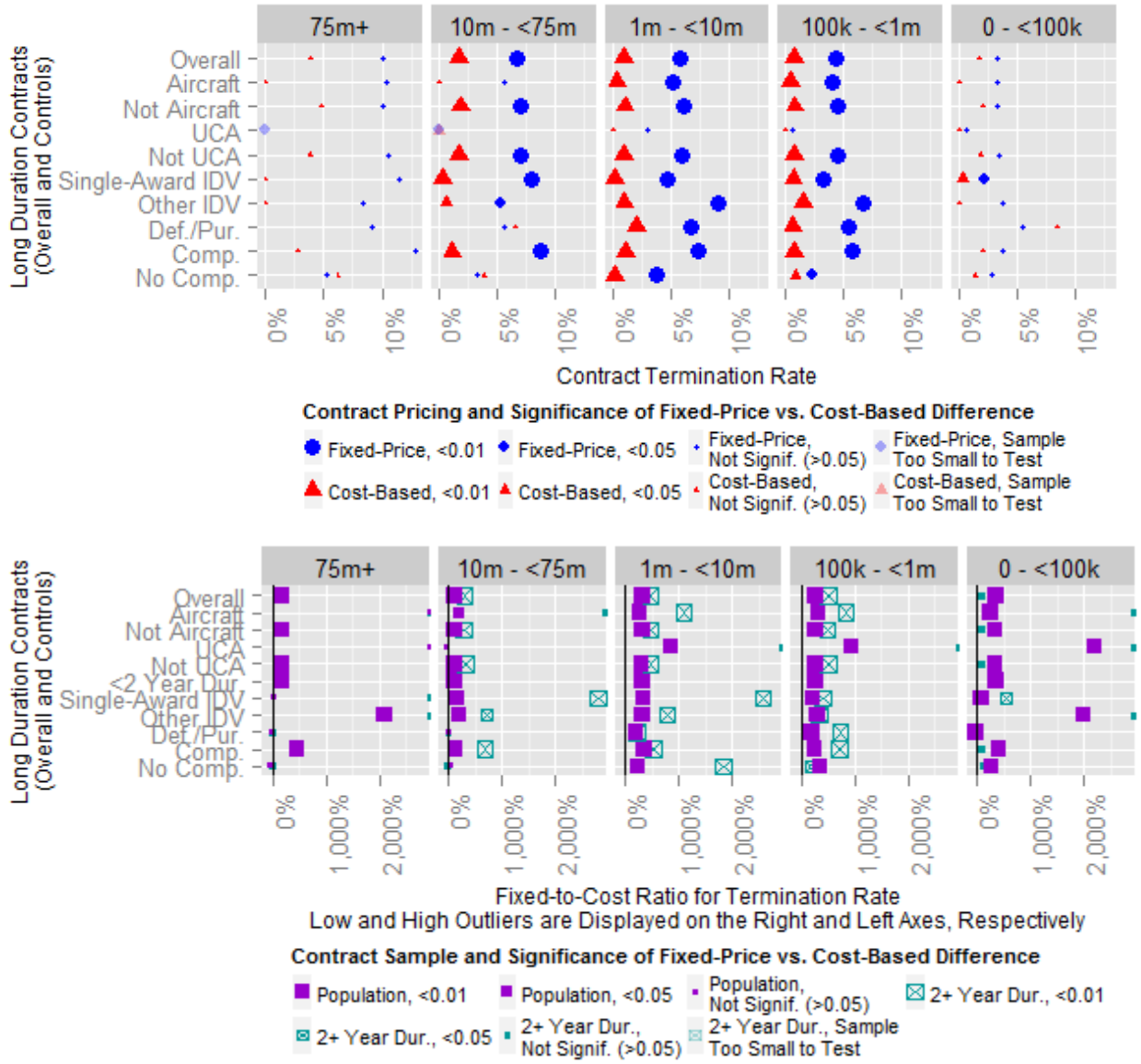
Figure 1.13-15 Approximate Average Extent of Ceiling Breaches for Long-Duration Contracts, Fixed-Price vs. Cost- Based Contracts



Source: FPDS; CSIS Analysis

With a higher probability of termination in fixed-price contracts than in cost-based, large long-duration contracts show the same trend as the population for all controls (Figure 1.13-16). For the three middle categories, the fixed-to-cost ratio for long-duration contracts is in most cases higher than that of the population. For single-award IDVs with ceilings between $1 million and $75 million and contracts with no competition between $1 million and $10 million, this difference is particularly extreme.

Figure 1.13-16 Probability of Termination for Long Duration Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

1.18. Hypothesis 4: Competition

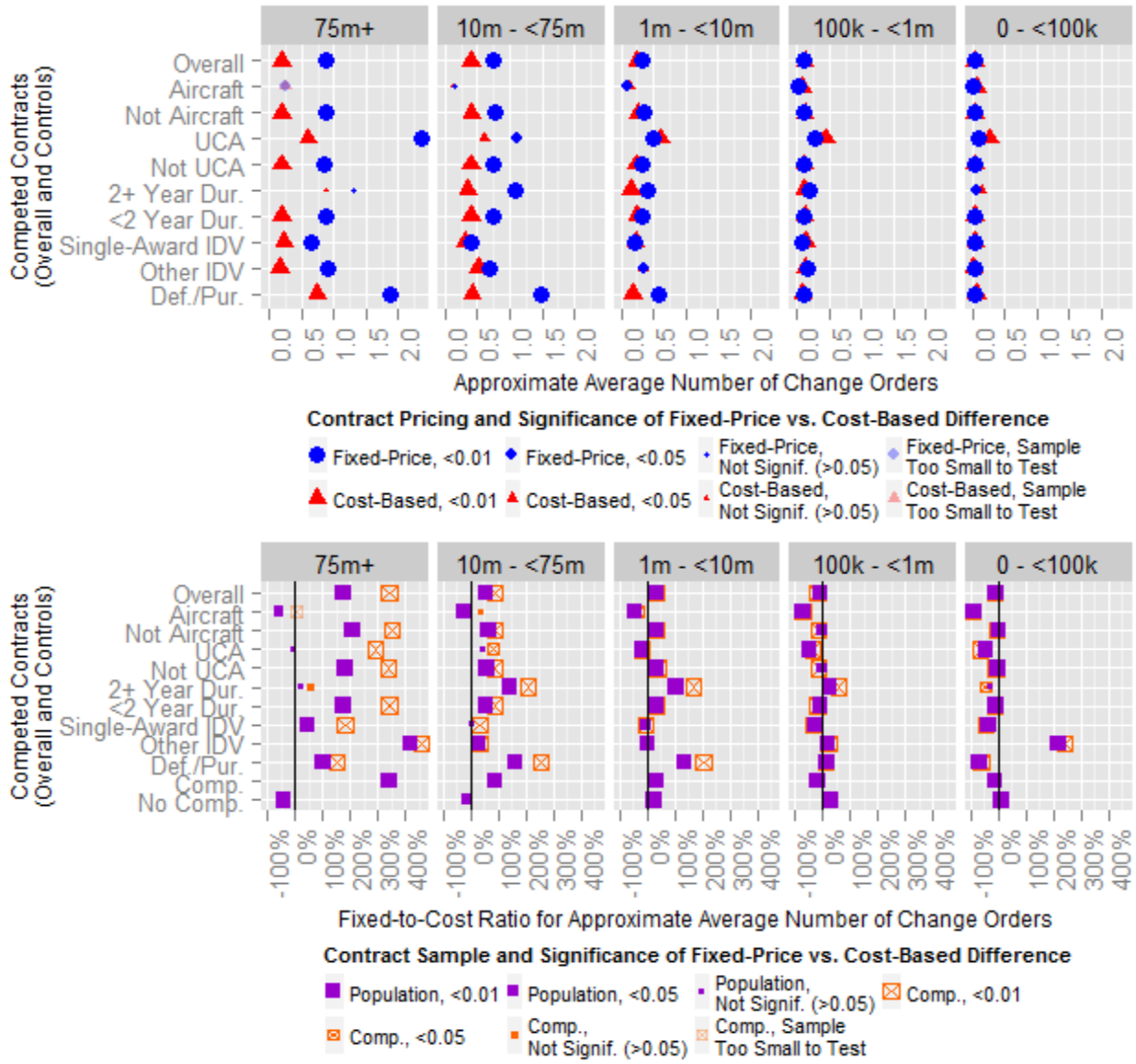
Competed fixed-price contracts will perform better than competed cost-based contracts.

Contrary to the hypothesis, competition does not give a greater boost to fixed-price contracts than it does to cost-based contracts. For contracts with original ceilings above $10 million, fixed-price contracts experience larger ceiling breaches and terminations, with both trends decisively demonstrated in contracts with ceilings above $75 million. In that larger category, change orders, related cost-ceiling increases, and terminations were three to five times more prevalent for fixed-price contracts than for cost-based contracts.

If competed fixed-price contracts were to perform better than competed cost-based contracts, the number of change orders for competed fixed-price contracts would be comparably less than those for cost-based contracts. For smaller competed contracts, we can see this is slightly true only for UCA

contracts; for all other controls, there exists very little difference between the average numbers of change orders (Figure 1.13-17). Above $10 million, fixed-price contracts see a higher percentage of change orders than cost-based contracts, disproving the hypothesis. This trend generally mimics the results of the population in general, though the difference is more dramatic for competed contracts over $75 million.

Figure 1.13-17 Approximate Average Number of Change Orders for Competed Contracts, Fixed-Price vs. Cost-Based Contracts

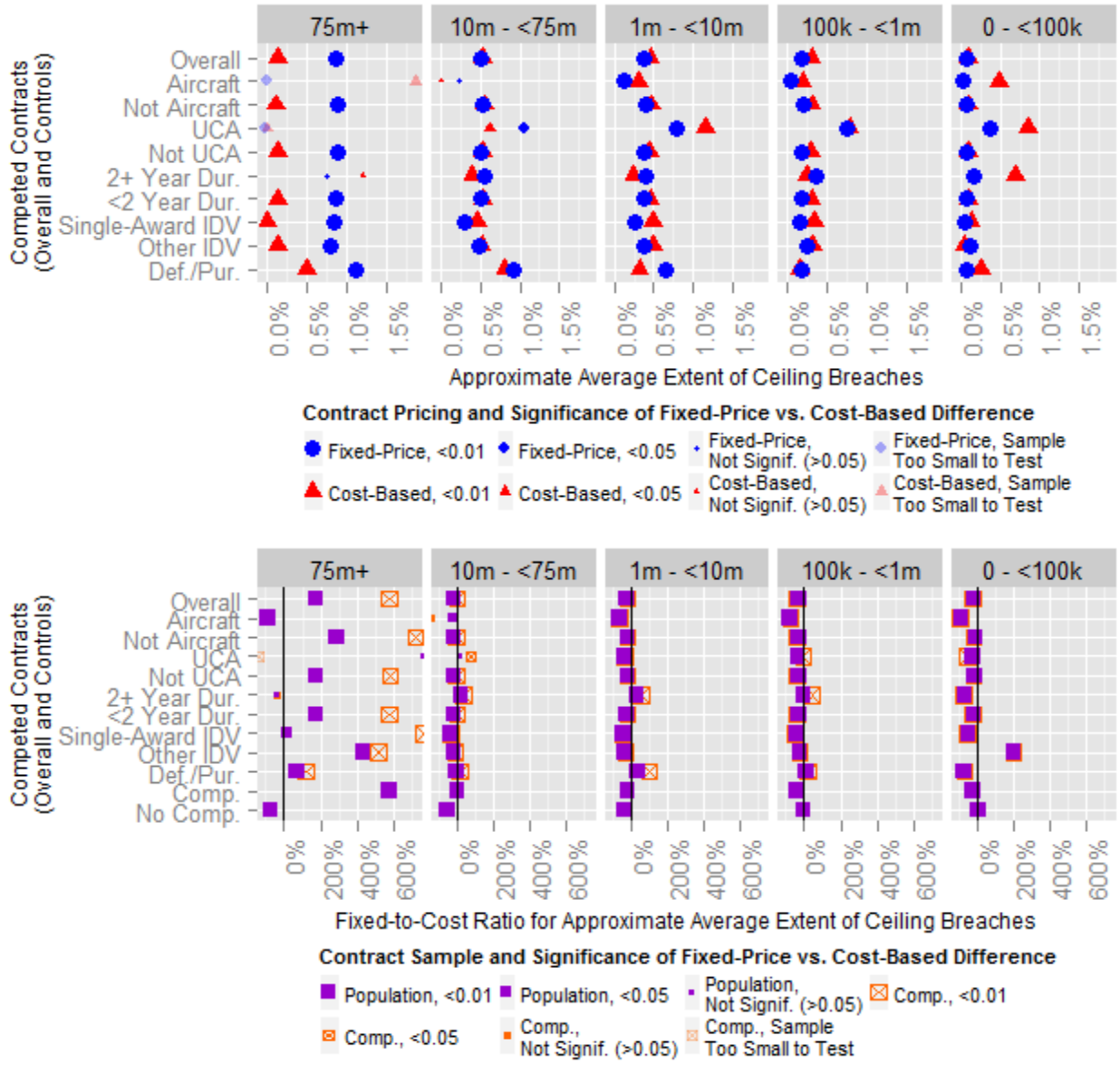


Source: FPDS; CSIS Analysis

Competed contracts have similar patterns to the overall population for smaller contracts but provide a comparative advantage to cost-based contracts as cost ceilings rise (Figure 1.13-18). If it were to support the hypothesis, data would show that competed fixed-price contracts would have lower ceiling breach percentage than do cost-based contracts. This holds true for small contracts, where cost-based contracts show slightly higher ceiling breach percentages across most controls. However, as the lower chart in Figure 1.13-18 shows, for these smaller contracts, the fixed-to-cost ratios for competed

contracts matches the ratio for the overall population of contracts. The trend is therefore not unique to competed contracts.

Figure 1.13-18 Average Extent of Ceiling Breaches for Competed Contracts, Cost-Based vs. Fixed-Price

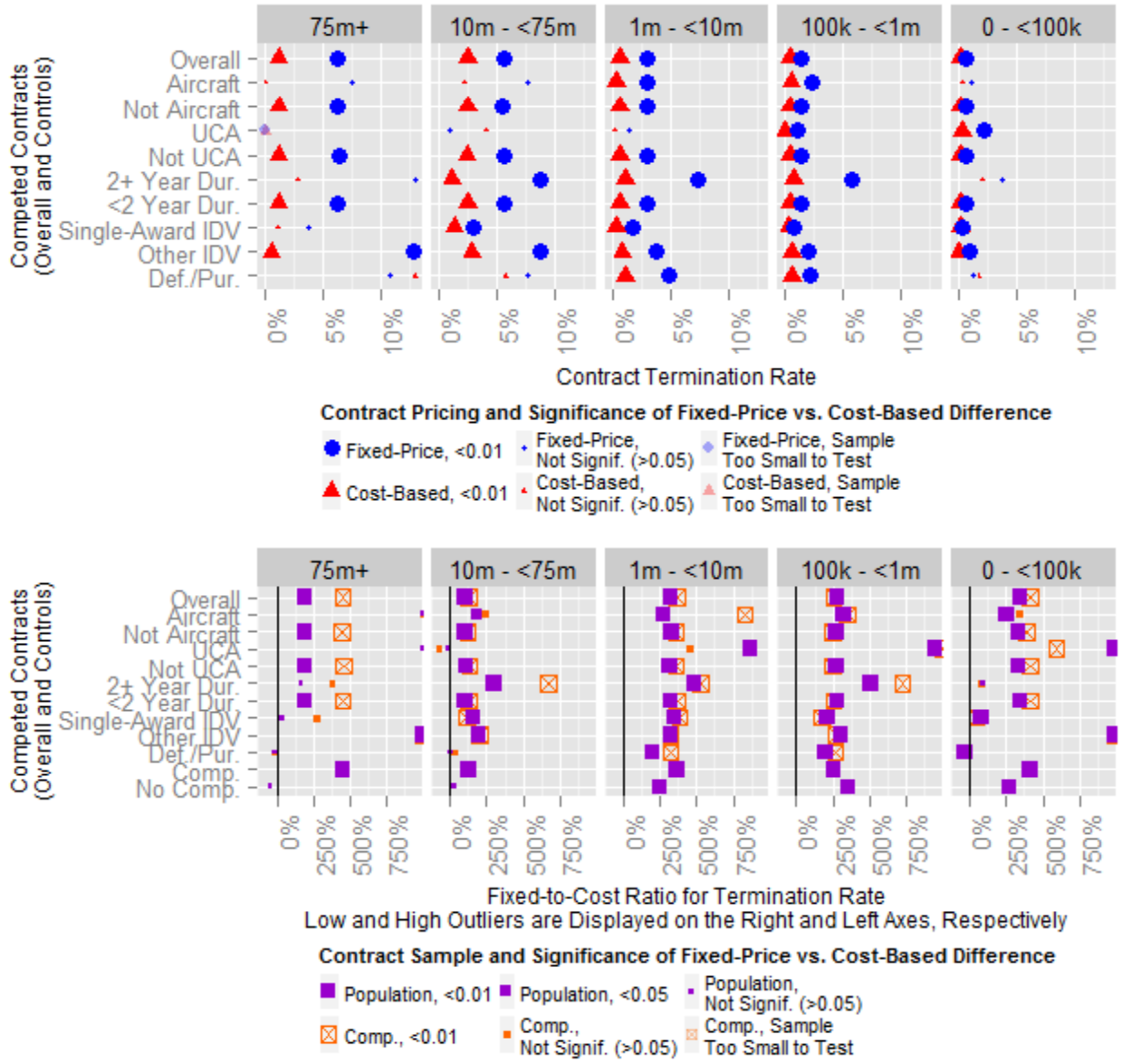


Source: FPDS; CSIS Analysis

Over $1 million, this trend depends on the use of secondary controls and the data are more varied. Larger contracts, specifically those over $75 million, demonstrate a much greater difference between the ceiling breach percentage in fixed-price and cost-based. Fixed-price contracts have a higher ceiling breach percentage than cost-based projects for every control other than UCA, long duration (though data are not as significant), and aircraft. The comparison with aircraft is particularly interesting as it directly opposes the trend in every other category. For large aircraft contracts, fixed-price contracting is therefore much less likely to have high ceiling breaches than cost-based; for most other contracts, however, cost-based contracts are better able to avoid ceiling breaches. The bottom chart shows that competed contracts follow largely the same trend as the population as a whole. Over $75 million, the rate comparison of fixed-price to cost-based ceiling breaches is larger than the population overall.

To align with the hypothesis, the study team expected to see fixed-price competed contracts with a lower percentage of terminations than cost-based competed contracts (Figure 1.13-19). The data demonstrated this to be false for every control with significant data. The difference was smaller for contracts with lower original ceilings and increased with the size of the contract. For contracts over $75 million, the percent of terminated contracts was over 5 percent in every category where the data were very significant, whereas cost-based contracts were terminated only about 1 percent of the comparable cases. This represents a slightly higher rate of fixed-price to cost-based termination than the population overall, particularly for larger contracts. It is important, however, to again note the uneven distribution of fixed-price vs. cost-based contracts in looking at sample size of large contracts.

Figure 1.13-19 Probability of Termination for Competed Contracts, Cost-Based vs. Fixed-Price



Source: FPDS; CSIS Analysis

1.19. Hypothesis 5: Software

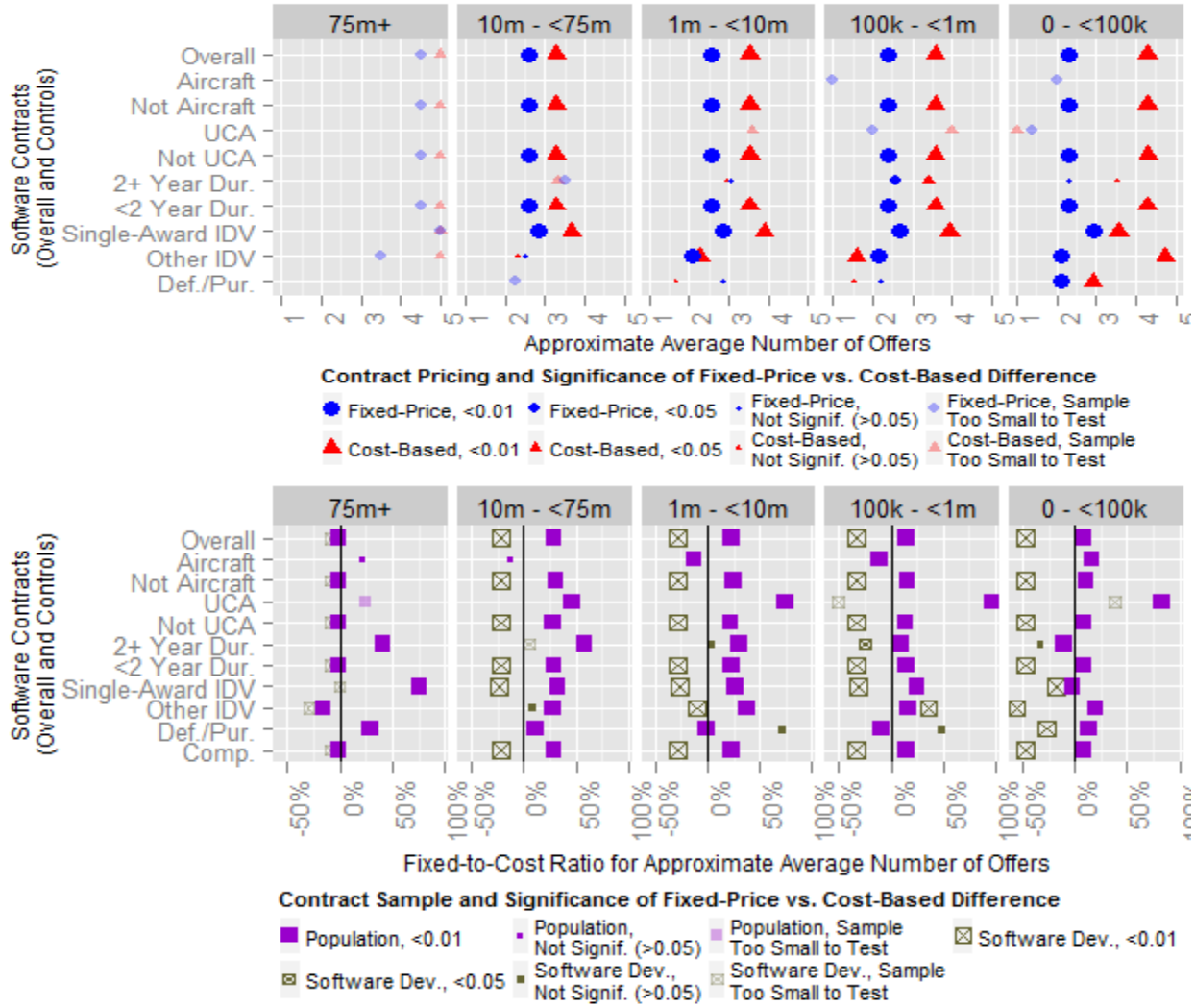
Large software projects that are fixed-price contracts perform better than large software contracts that are cost-based competed contracts.

Large fixed-price contracts with possible software engineering did not prove to be more attractive to vendors. Contrary to the hypothesis, fixed-price software contracts have received fewer offers on average than cost-based contracts and were more likely to be terminated. For change orders the data were in inconsistent and did not reach significance.

The data in

Figure 1.13-20 runs contrary to the hypothesis. If the hypothesis were true, large software contracts that are fixed-price would receive a higher number of offers than cost-based contracts, making them more competitive. However, in almost every size contract category, fixed-price contracts receive fewer offers than comparatively sized cost-based contracts. The significant exception to this is Other IDV contracts with original ceilings between $100,000 and $1 million. The population in general shows a reversal of this trend, where we see a positive percent difference in fixed-price and cost-based number of offers, meaning that fixed-price contracts receive a higher average number of offers in most cases overall. The difference is minimal and not significant for the largest contracts, but still present.

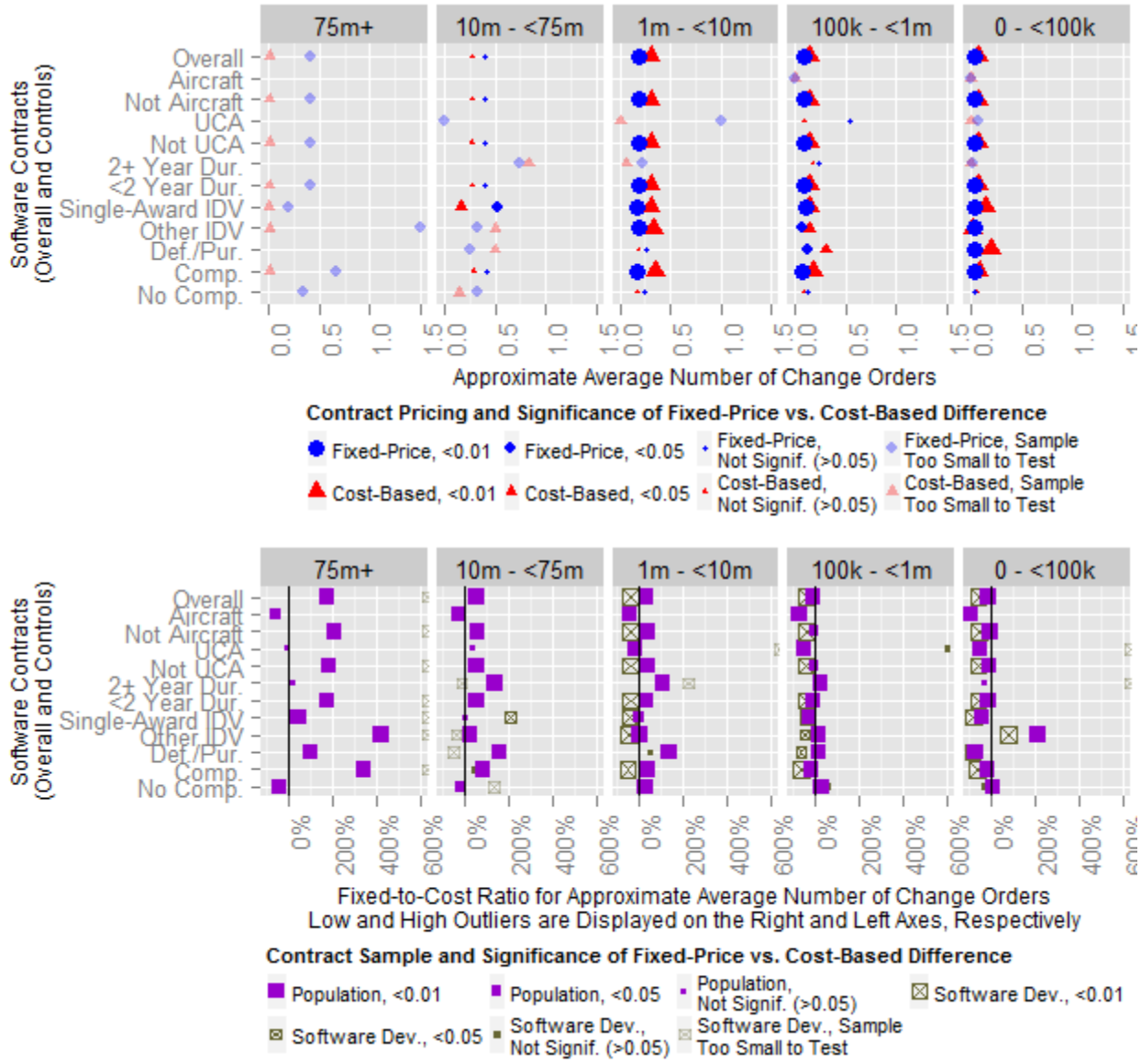
Figure 1.13-20 Approximate Average Number of Offers for Software Contracts, Fixed-Price vs. Cost-Based Competed Contracts



Source: FPDS; CSIS Analysis

The data concerning the average number of change orders provide support for the hypothesis, but only for smaller contracts (Figure 1.13-21). If large software contracts were preforming better under fixed-price contracts than under cost-based contracts, the average number of change orders for fixed-price contracts would be less than the number for cost-based. While this is true for smaller software contracts, this trend does not seem to hold as contracts get larger. As original ceiling size increases, the level of significance decreases and therefore conclusions are less robust. Taking this into account, however, the largest category of cost-based contracts receive close to zero change orders, while the largest fixed-price contracts receive an average of just under half a change order each.

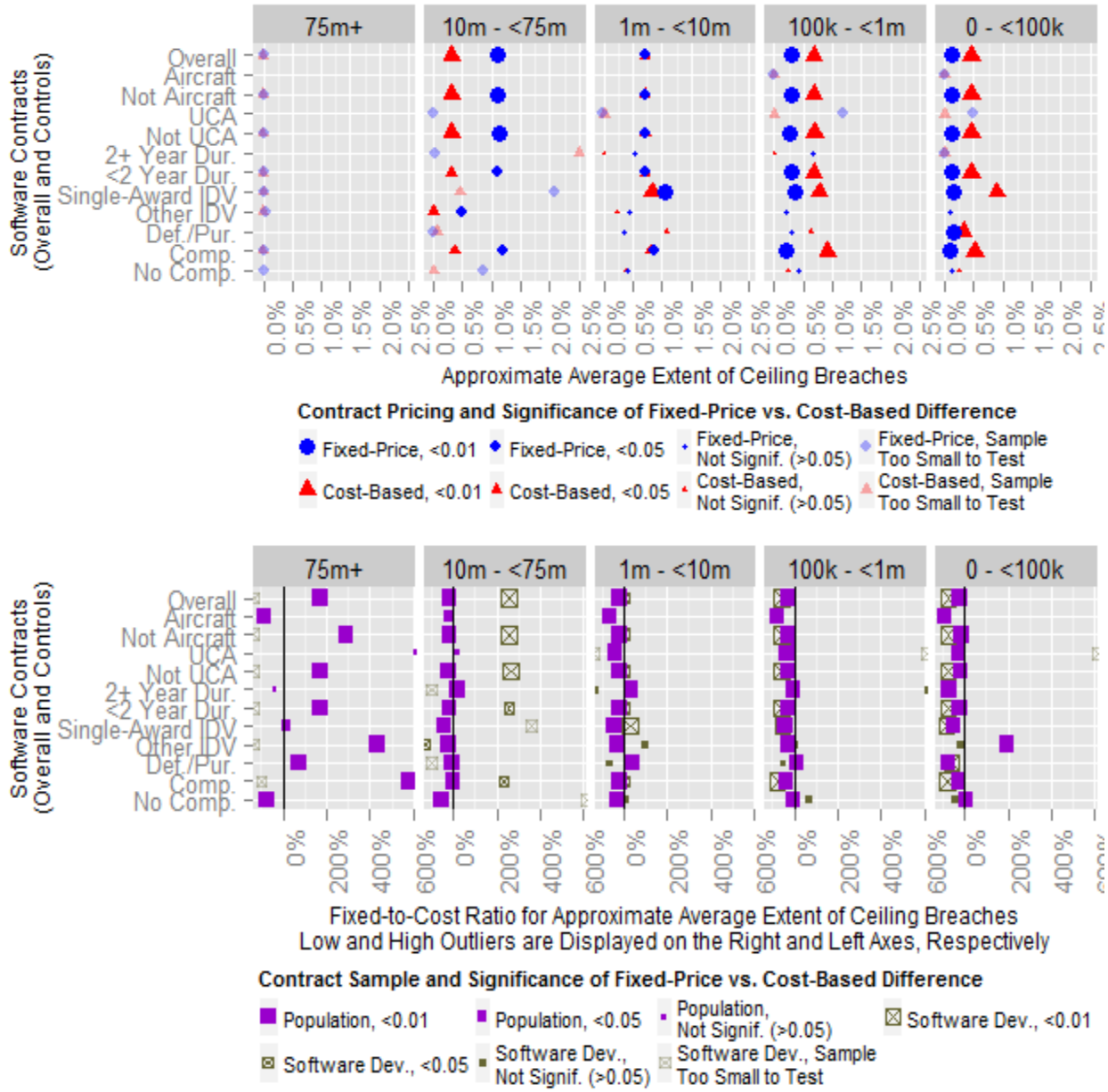
Figure 1.13-21 Approximate Average Number of Change Orders for Software Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

If the hypothesis held in absolute terms, large fixed-price software projects would receive a smaller ceiling breach percentage than would large cost-based software projects (Figure 1.13-22). However, for large contracts there is not a large difference between cost-based and fixed-price contracts in terms of ceiling breaches. For contracts between $10 and $75 million, fixed-price software contracts had slightly higher average ceiling breaches than cost-based, with a small number of not significant exceptions. In contract sizes, this trend largely opposed the overall population trend, where fixed-price had significantly higher ceiling breaches in contracts over $75 million, and where the population saw slightly higher ceiling breaches for cost-based projects in contracts between $10 million and $75 million. Thus, the largest category fixed-price software contracts do appear to perform better than the overall population of large contracts, but the results are not significant.

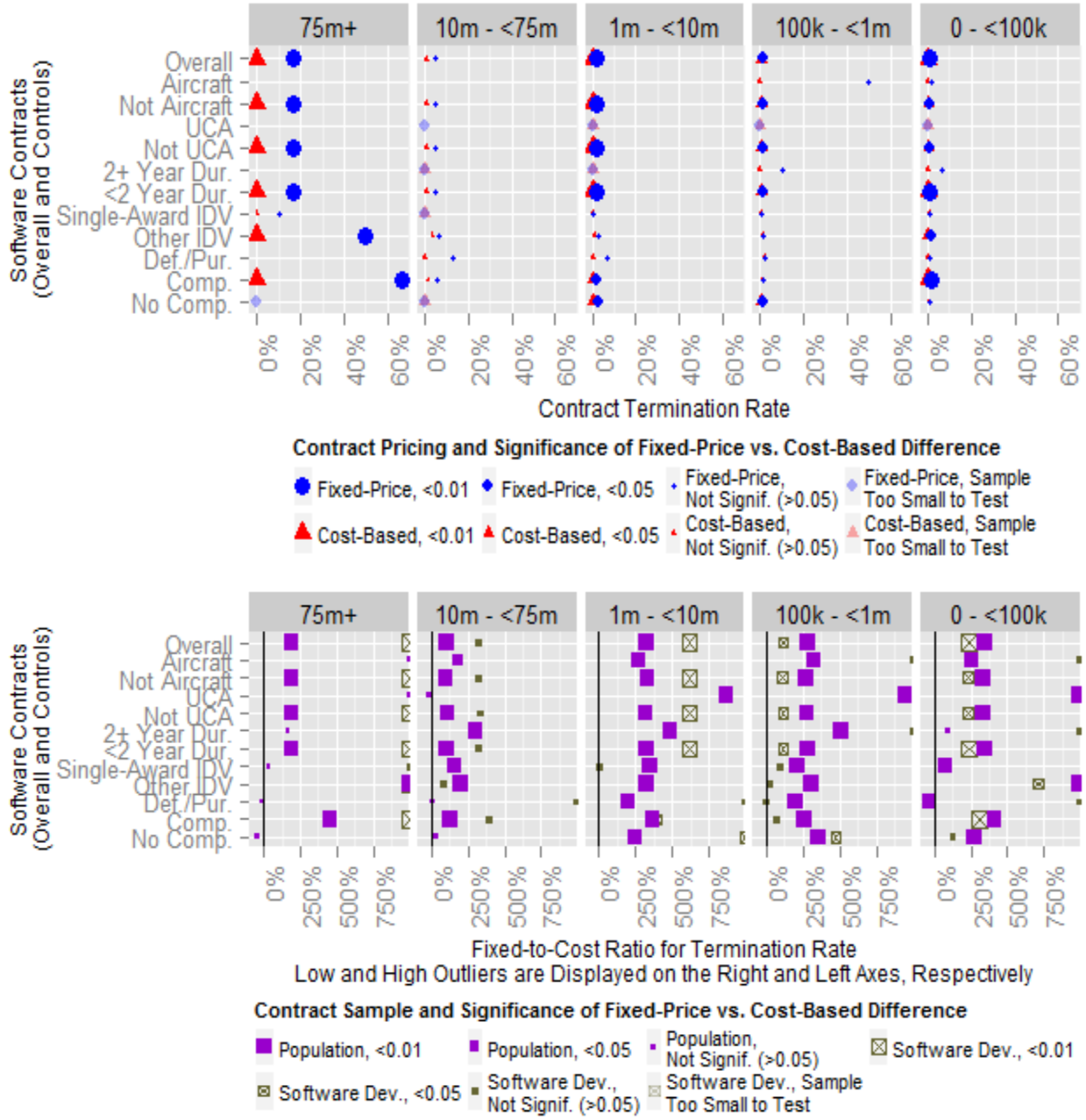
Figure 1.13-22 Approximate Average Extent of Ceiling Breaches for Software Contracts, Fixed-Price vs. Cost- Based Contracts



Source: FPDS; CSIS Analysis

Data for terminated contracts most clearly represent a contradiction to the hypothesis in all but non-competed contract controls (Figure 1.13-23). Since the hypothesis proposed a higher effectiveness of fixed-price contracts for large software contracts, we would expect to see a low rate of termination in this category. However, in contracts over $75 million, almost all terminated contracts were fixed-price and zero percent of terminations came from cost-based contracts. For the largest category of contract size, however, software contracts have a higher rate of fixed-price termination (when compared to cost-based) than the population overall. For software contracts less than 75 million, the data are less significant and show minor difference in cost-based vs. fixed-price.

Figure 1.13-23 Probability of Termination for Software Contracts, Fixed-Price vs. Cost-Based Contracts



Source: FPDS; CSIS Analysis

1.20. Conclusions

The patterns of fixed-price contracting within the FPDS data are striking, vary greatly by size, and do not fully align with past research and conventional wisdom. Discrepancies with past research could, in large part, be attributed to the fact that the choice between fixed-price and cost-based is not randomly assigned but instead reflects the contracting officers' best judgment as to what funding mechanism best suits the work. Because most of the hypotheses being tested by this report are well known, a fixed to-cost ratio near zero may simply mean that contracting officers are already making allowances for the relative strengths and weaknesses of each form of funding. Throughout the discussion below, the original cost ceiling of contracts is a critical factor and is referred to in shorthand as contract size.

Before discussing the specifics of the hypotheses, unexpected trends in the overall population merit attention. Based on fully labeled defense contracts completed between 2007 and 2013, the properties of the population of fixed-price contracts do not consistently match the stylized facts laid out at the start of this report. Fixed-price contracts in all but the highest original ceiling category ($75 million+) receive more offers from vendors than their cost-based counterparts. This shows that contracting officers, on average, are not choosing to use fixed-price contracts mechanisms in situations where vendors would be less willing to make offers.

When considering the population dataset as shown in Figure 1.13-2, fixed-price contracts, as expected, do receive more change orders than cost-based contracts, although this relationship is mediated by contract size and the differences are minimal for smaller contracts (under $1 million). The surprise comes in when looking at the ceiling breaches related to change orders for the total population, shown in Figure 1.13-3. In percentage terms, for all but the largest category of contracts, cost-based contracts have larger ceiling breaches on average. This runs contrary to the idea that the expense of cost-based contracts comes from their higher ceilings while the expense of fixed-price contracts comes from change orders. Thus, this risk of fixed-price contracts appears to be one that contracting officers are already more than compensating for. However, as a result of the methodology for calculating change orders, this finding does not necessarily apply to the extreme cases. In addition, this relationship often does not hold for hypotheses and is often upended for aircraft and non-competed contracts.

It is in partial and complete terminations that fixed-price contracting shows the greatest weakness relative to cost-based contracting. As shown in Figure 1.13-4, across every cost category and for most of the controls, fixed-price contracts have a termination rate that is 100 percent higher than that of cost-based contracts. While terminations are less frequent for contracts with lower ceilings (under $10 million) overall, the fixed-to-cost ratio grows with fixed-price contracts experiencing a termination rate that routinely matches or exceeds a 250 percent increase versus the cost-based rate. The fixed-to-cost ratio for terminations tends to remain high under the hypotheses; however, the dynamics by original ceiling category vary greatly. This differential may be driven in part by differences in closing costs between fixed-price and cost-based contracts, but nonetheless cancelling fixed-price contracts is still a significant burden. The uniformity of these fixed-to-cost ratios indicates that this is an intrinsic risk of fixed-price contracting—one that can only be mitigated, not removed, by wise contracting officers.

In summary, these trends are consistent with a vision of the contracting process that gives both contracting officers and vendors credit for being reasonably savvy about fixed-price contracts at the start of the process. When considering the entire study population of fixed-price contracts with original ceilings below $75 million, vendors have not avoided the risk of termination. However, for those contracts that avoid termination, vendors do appear to be capable of pricing in risk when bidding for fixed-price contracts, resulting in a favorable fixed-to-cost ratio for ceiling breaches. Similarly, fixed-price contracts receive no fewer bids on average than cost-based. This suggests that contracting officers did not push the boundaries of their monopsony power to such an extent that vendors were not willing to

respond to solicitations. However, it should be noted that FPDS does not include data on the number of solicited contracts that were never signed.

Finally, for this sample, the greatest risk of fixed-price contracts is terminations, which present the dual problem of not providing DoD the desired outcome and sometimes threatening the sustainability of the vendor's defense business. That said, interaction between ceiling breaches and terminations also merits greater study in future work. As is shown below, in the summary of hypothesis testing, the fixed-to-cost ratios of terminations and ceiling breaches often went in different directions, perhaps because terminations prevent a significant number of contracts from experiencing greater breaches.

Turning toward the study hypotheses, the results of the testing are also mixed, and in several cases the fixed-price principles being studied appear to resist simplification to easily measurable criteria.

- **Hypothesis 1–Large R&D contracts:** Findings challenged the study team's hypothesis of the comparatively better contract outputs for cost-based large R&D contracts over fixed-price. Large fixed-price R&D contracts with original ceilings of $75 million or more do regularly have a termination rate of 10 percent or more, but the fixed-to-cost ratios measuring the number of offers are higher for R&D contracts than that of the overall population while the fixed-to-cost ratios measuring extent of ceiling breaches are lower. The middle tier of fixed-price contracts, with ceilings between $1 million and $75 million, experienced more change orders and higher related ceiling breaches.
- **Hypothesis 2–MDAPs:** Fixed-price contracts for Major Defense Acquisition Programs largely followed the same trends as overall fixed-price contracts, suggesting that this is not the way to measure complexity's impact on fixed-price performance or that contracting officers already successfully compensate for it. The one exception was that fixed-price MDAP contracts with original ceilings below $75 million received fewer offers than cost-based contracts, contrary to overall population trends.
- **Hypothesis 3–Long Duration:** Contracts that initially allow for a duration of at least two years most consistently behaved as expected, with cost-based contracts performing better than fixed-price. The category did prove challenging in terms of change orders and terminations for fixed-price contracts, and these results faced a substantial limitation in their sample size for large contracts and were routinely too small to judge the significance of the results. However, where significance could be determined, the results were striking. For contracts between $1 million and $75 million, data highly supported the hypothesis by seeing more promising contract outputs in cost-based contracting. On the other hand, larger long-duration, fixed-price contracts continued to receive more offers than cost-based contracts.
  Hypothesis 4–Competition: Overall, competition does not appear to provide any benefits to fixed-price contracts that it does not also provide to cost-based contracts. In some cases, such as terminations, competed fixed-priced contracts actually performed worse than the overall population.
- **Hypothesis 5–Software:** Contrary to the hypothesis, large fixed-price contracts that contained potential software engineering content received fewer offers and were more likely to be terminated than cost-based software contracts. While larger fixed-price software projects did have comparatively minimal ceiling breaches, that variable was not significant.

The results of hypothesis 3 were the most robust and successful at identifying trends that are not consistently ameliorated by contracting officer choices. However, this study raises as many questions as it lends answers, particularly with regard to hypotheses 1 and 2. To aid future researchers in addressing these and other questions, the study team has placed its processing code and dataset online.[44]

[44] See GitHub CSISdefense/Fixed-Price, https://github.com/CSISdefense/Fixed-price.

1.21. About the Project Directors and Authors

Andrew Hunter is director of the Defense-Industrial Initiatives Group and a senior fellow in the International Security Program at CSIS. From 2011 to 2014, he served as a senior executive in the Department of Defense, serving first as chief of staff to undersecretaries of defense (AT&L) Ashton B. Carter and Frank Kendall, before directing the Joint Rapid Acquisition Cell. From 2005 to 2011, Mr. Hunter served as a professional staff member of the House Armed Services Committee. Mr. Hunter holds an M.A. in applied economics from the Johns Hopkins University and a B.A. in social studies from Harvard University.

Gregory Sanders is a fellow with the Defense-Industrial Initiatives Group at CSIS, where he manages a team that analyzes U.S. defense acquisition issues. Utilizing data visualization and other methods, his research focuses on extrapolating trends within government contracting. This requires innovative management of millions of unique data from a variety of databases, most notably the Federal Procurement Database System, and extensive cross-referencing of multiple budget data sources. Mr. Sanders holds an M.A. in international studies from the University of Denver and a B.A. in government and politics, as well as a B.S. in computer science, from the University of Maryland.

Rhys McCormick is a research assistant with the Defense-Industrial Initiatives Group (DIIG) at CSIS. His work focuses on unmanned systems, global defense industrial base issues, and U.S. federal and defense contracting trends. Prior to working at DIIG, he interned at the Abshire-Inamori Leadership Academy at CSIS and the Peacekeeping and Stability Operations Institute at the U.S. Army War College. He holds a B.S. in security and risk analysis from the Pennsylvania State University and is currently pursuing an M.A. in security studies at Georgetown University.

Guy Nzeribe's current work with the Defense-Industrial Initiatives Group focuses on U.S. government contracting. Prior to this position, he had been engaged in industry as an entrepreneur, investment banker, and political analyst. Concurrently, he has carried out numerous consulting engagements both in sole practice and as a member of a practice team, with practice areas including financing structures, international business and trade development, development strategy, technology, knowledge management, and political communications. He earned advanced degrees from both the Universität Wien and Wirtschaftsuniversität in Vienna, Austria. He also holds a post-graduate certificate in project management from Georgetown University.