September 2020

Measuring Service Contract Performance

Preliminary Findings on Effects of Service Complexity, Managerial Capacity, and Paired History

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A Report of the CSIS DEFENSE-INDUSTRIAL INITIATIVES GROUP

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Abstract

Contracts pertaining to services face challenges relating to defining tasks and measuring performance. The literature identifies three overarching characteristics of interest: service complexity, contract-management capacity, and paired history. This report takes a large dataset approach, primarily employing information in the publicly available Federal Procurement Data System. Multiple performance measures were examined: whether some options were exercised, and if so whether all options were exercised; did a ceiling breach occur, and if so, how large; and did a termination occur. The study found that a greater number of years of past office and vendor partnership estimated better outcomes in all models except ceiling breach size. The study also found that the invoice rate appears to act as an effective proxy for complexity, significantly estimating a lower chance of all options being exercised and of more likely and larger ceiling breaches.

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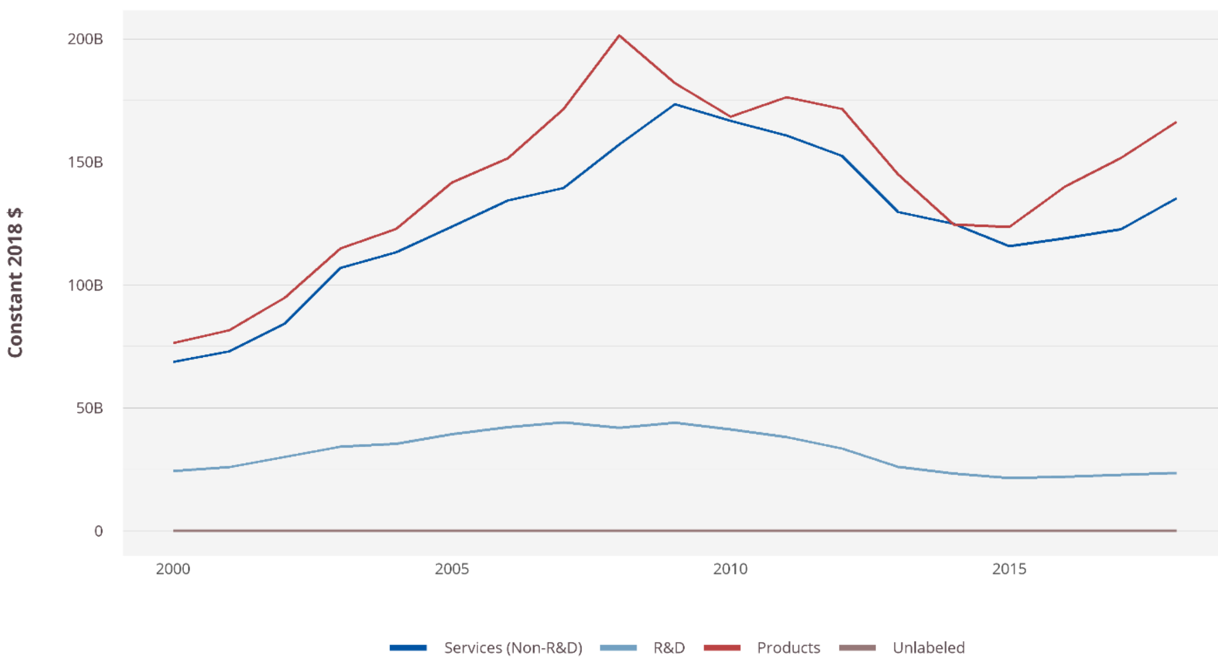
CHAPTER 1

Introduction

Service contracts have long been understood to be distinct from product contracts in key ways, with added ambiguity and their own sets of challenges. Products are countable or otherwise objectively measurable, and while testing to see whether they meet requirements can prove complicated and controversial, there is at least a common item being argued over and measured. Service contracts, on the other hand, inherently put more attention on the qualitative aspects of labor. Even if simple service contracts—like those for transportation or custodial services—have straightforward results to evaluate, they can nonetheless introduce a host of concerns, for example, when taking place in contingency environments such as Afghanistan. Even familiar services such as construction must often be evaluated in part on the quality of the process and not just the outcome, as waiting to observe the quality of the final building means that problems (e.g., low-quality concrete leading to cracks) would be much more expensive to resolve. The services which are the most challenging to evaluate are those that do something new or ill-defined, where trying to put all the details in the contract from the outset can not only be an exercise in futility but be actively counterproductive. In such situations, the buyer and contractor have to solve problems together that were not fully anticipated when the contract was initiated.

Figure 1: Defense Contract Obligations by Area



Source: FPDS; CSIS analysis

This report addresses three broad categories of characteristics that are especially important for services contracting: service complexity, contract-management capacity, and paired history. These characteristics are highly relevant to government contracting, but they are also key concerns in the private sector. Figure 1 shows the extent of U.S. Department of Defense (DoD) spending for services, adjusted for inflation and compared to products and R&D between fiscal year (FY) 2000 and FY 2018. Services and Product contract obligations, and to a lesser extent R&D obligations, rise and fall along with larger military spending trends. Each category increased after the 9/11 attacks and subsequent wars in Iraq and Afghanistan, declined after the 2007 to 2011 withdrawal from Iraq and 2011 Budget Control Act, and began to turn around with the 2014 start of the campaign to defeat ISIS, with further growth accompanying the 2017 National Security Strategy, which emphasized great power competition. In FY 2018, service obligations rose to nearly $135 billion, the seventh-highest annual total over the 19 years of the period and nearly twice the obligations in FY 2000. For context, total DoD outlays in FY 2018 were nearly $601 billion, thus, while not an apples to apples comparison, it is safe to say that roughly one in every five dollars of DoD outlays is going to service contracts.

For DoD, services constitute a significant portion of contract spending, which is also true of the U.S. federal government in general. As Figure 1 shows, DoD services by themselves are consistently second only to product acquisition spending, with obligations on the same order of magnitude. Across the entire FY 2000-FY 2018 period, service contracts constitute between 39 and 46 percent of total DoD contract spending. Despite this, from a regulatory or policy perspective, they are often relegated to a lower priority than contracting for products or R&D. This has been observed not only by critics in Congress (who have a range of concerns about services contracts) but also from the DoD itself, where improving services acquisition tradecraft was a prominent part of the Better Buying Power initiatives (some of the history of these acquisition reform efforts can be seen in Rhys McCormick's "Measuring the Outcomes of Acquisition Reform by Major DoD Components").[1] Suffice it to say, the problems of services contracting have long been a known issue.

While prioritizing major defense acquisition programs over services acquisition is specific to the DoD, the challenges of contracting for services are universally acknowledged: in the private sector, in sectors and levels of government, and in nonprofit organizations. Trends in the wider economy also suggest that services may be further growing in importance, as software as a service and space launch services compete with acquisition approaches that would treat rockets or software packages as products. This study takes a new quantitative look at service contract performance by employing the Federal Procurement Data System (FPDS), an open-source transaction database with records of over a million service contracts from the past decade. This large dataset approach builds on past research on the public and private sector, which typically has relied on surveys with smaller samples or on case studies.

Scope

The research project seeks to answer the following questions:

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[1] Rhys McCormick et al., *Measuring the Outcomes of Acquisition Reform by Major DoD Components* (Washington, DC: CSIS, 2015), https://www.csis.org/analysis/measuring-outcomes-acquisition-reform-major-dod-components.

- Under which circumstances are service contracts likely to encounter challenges (as measured by terminations and cost ceiling breaches) or to prosper (as measured by the exercising of options)?
- Which policy choices regarding services contracting influence these outcomes, for better or worse?

This iteration of the study focuses specifically on DoD contracts within the 2008 to 2015 study period. Past CSIS work with the contract dataset has covered contracts for both products and services, but to better focus on the challenges of service contracting, this effort focuses on three especially relevant aspects of the topic:

First, *service complexity*, as discussed above, can indicate how difficult it will be to specify or monitor the performance of a service. A more complex service may require technical expertise to create contracts or evaluate outcomes; furthermore, it may require a collaborative partnership between the government and the contractor in order to have a chance at success.

Second, *contract-management capacity* seeks to capture the capabilities and approaches of the contracting organization that correlate with better performance of service contracts. Related to this topic is also the issue of overcoming the principal-agent problem—the sometimes-divergent interests of government and contractor—by means of contract formation, monitoring, and enforcement where necessary, but also through approaches that encourage cooperative problem solving.

Third, *paired history* is the buildup to the present relationship between the government and the contractor, which is central to service contract success, as touched on in the prior two categories. With complex service contracts, fully specifying what is necessary and then enforcing contract terms is not enough, and excessive reliance on contracting provisions can be counterproductive. However, while cooperation in the contracting relationship is important, a larger environment of competition is key to ensuring proper vendor incentives.

To measure contracting outcomes, this study builds on an approach developed in past CSIS studies which have looked at contract terminations and cost-ceiling breaches. This contract-centric approach is expanded in the present paper in two ways. First, the look at ceiling breaches now considers not only whether they occur but also their magnitude if they do. Second, this paper adds a measure for positive performance by looking at exercised options. Options are portions of a contract that are specified but not awarded when the contract starts, leaving the government the choice of whether to invoke them during the tenure of the contract.

Although they are sometimes invoked in lower performance situations as well, options can be a good indicator of positive performance, since a contract with more options invoked is generally one where the customer desires more from the contractor and the contractor is happier to have the additional revenue—or at least to not require the transaction costs of winning a new contract or task order.

CHAPTER 2

Literature Review

This literature review will clearly delineate the different aspects of service contract management into three parts. The first is service characteristics, which discusses aspects of the service itself, with emphasis on service complexity. The second section focuses on the customer for the service and their contract-management capacity. The third section analyzes the relationship between the customer and the vendor, with special attention to their paired history.

Service Characteristics

The relative complexity of a given contract is a determinant of the level of cost (in labor, funds, or both) required by the government to effectively manage it. In this vein, the literature delineates between low-, mid-, and high-complexity contracts. Joaquin and Greitens helpfully summarize the literature on these categories: for low-complexity contracts, "many of the expectations can be stated in the request for proposals to minimize the demands on the contract manager's knowledge and responsibilities," while "[u]nder mid-complexity scenarios, requests for proposals are more detailed and specific, and managers need to possess more technical expertise."[2] For highly complex services, or when the means of delivery for the service are not clearly understood, the agency and the contractor should enter into a true public-private partnership and recognize that the service to be provided will evolve in a dynamic manner, according to the framework proposed by Lawther.[3]

High-complexity services and a lack of advanced knowledge are associated with tasks where the customer requires a service or capability that is definitively new; from a defense perspective, this could be new software architecture or the maintenance of advanced and recently developed equipment as well as the related domain of research and development. Fernandez finds, as expected, that task uncertainty is a significant factor in diminishing contract performance and that this result is robust across three different modeling approaches.[4]

In addition to the uncertainty, measurement difficulty, and transaction costs associated with complex services, the literature also identified asset specificity as an important

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[2] M. Ernita Joaquin and Thomas J. Greitens, "Contract Management Capacity Breakdown? An Analysis of U.S. Local Governments," *Public Administration Review* 72, no. 6 (August 2012): 809, doi:10.1111/j.1540-6210.2012.02587.x.
[3] Wendell C. Lawther, *Contracting for the 21st Century: A Partnership Model* (Arlington, VA: PricewaterhouseCoopers Endowment for the Business of Government, 2002), 33, http://www.businessofgovernment.org/sites/default/files/LawtherReport.pdf.
[4] Sergio Fernandez, "What Works Best When Contracting for Services? An Analysis of Contracting Performance at the Local Level," *Public Administration* 85, no. 4 (October 2007): 1133, doi:10.1111/j.1467-9299.2007.00688.x.

dimension for contracting in general. Williamson defines asset specificity as "the degree to which durable, transaction-specific investments are required to realize least cost supply . . . The issue is less whether there are large fixed investments, though this is important, than whether such investments are specialized to a particular transaction."[5] Services with this trait would be at greater risk of vendor-lock, because those firms that have made the particular investments would have a strong advantage over the larger pool of potential competitors that had not specialized in that particular service. Brown and Potoski find a relationship between asset specificity and frequency of field observation and that the extent of asset specificity influences government ability to contract for a service, especially management services.[6] On the other hand, Fernandez determines that asset specificity, when operating on its own, is unrelated to service contracting success.[7]

Contract-Management Capacity

While there are various definitions of contract-management capacity in the literature, many of them do not create a complete picture of the actual scope of managing contracts. A helpful all-encompassing definition is provided by Brown and Potoski:

> Contracting is not a one-size-fits-all proposition. The success or failure of any alternative service-delivery arrangement likely depends on how well governments can manage the entire contract process, from assessing the feasibility of contracting through implementation to monitoring and evaluation-activities that require strong government contracting capacity. Governments investing in contract-management capacity may be better positioned to harness the promise of effective contracting while avoiding its pitfalls.[8]

The prior section discussed some of the circumstances that influence the choice to produce a service in house or to turn to contracting as well as the choice of which contracting mechanisms may be appropriate. However, while this difficulty may be external in origin, governments are not without agency. Brown and Potoski conclude that "governments can respond to poor conditions by investing in the managerial capacity to identify suitable situations for contracting, negotiate strong contracts, and monitor vendor performance."[9]

Brown and Potoski determine three subfields of contract-management capacity that align with phases of contracting: feasibility assessment, implementation, and evaluation capacities, and note "[a]ll three capacities are needed for effective contracting."[10] Yang, Hsieh, and Li build on this model by renaming Brown and Potoski's "implementation

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[5] Oliver E Williamson, "The Economics of Organization: The Transaction Cost Approach," *American Journal of Sociology* 87, no. 3 (November 1981): 555, https://www.jstor.org/stable/2778934.

[6] Trevor L. Brown and Matthew Potoski, "Managing Contract Performance: A Transaction Costs Approach," *Journal of Policy Analysis and Management* 22, no. 2 (March 2003), doi:10.1002/pam.10117; and Trevor L. Brown and Matthew Potoski, "Contracting for Management: Assessing Management Capacity Under Alternative Service Delivery Arrangement," *Journal of Policy Analysis and Management* 25, no. 2 (March 2006), doi:10.1002/pam.20175.

[7] Sergio Fernandez, "Understanding Contracting Performance: An Empirical Analysis," *Administration and Society* 41, no. 1 (2009): 87-88, doi:10.1177/0095399708330257; and Fernandez, "What Works Best When Contracting for Services?," 1135. The latter report did find a significant interaction between asset specificity and trust, discussed later in this review.

[8] Trevor L. Brown and Matthew Potoski, "Contract-Management Capacity in Municipal and County Governments," *Public Administration Review* 63, no. 2 (March 2003): 153, https://www.jstor.org/stable/977587.

[9] Ibid., 162.

[10] Brown and Potoski, "Managing Contract Performance," 155.

capacity" to "formulation," which emphasizes that the first measures—assessment of whether contracting is the proper approach and in creating and finding a vendor for the contract—both take place before a contract is signed. Yang, Hsieh, and Li add an additional measure which they call "implementation," taking it to mean the government's ability to enable contractor success during the execution of the contract.[11] The evaluation stage takes place last, once there is performance to measure, although for many contracts, evaluation occurs during and not just after the contract is in place. This observation echoes discussion in the prior section on the importance of government being able to effectively manage public-private relationships, identifying it as a component of contract-management capacity. We adopt the Yang, Hsieh, and Li approach below to organization findings from the literature on contract management capacity. Not all measures neatly fit into this phased approach. For example, Romzek and Johnston identify two dimensions that correlate with better performance that are relevant across multiple phases: "resource adequacy" and "intensive training for state contract management staff."[12]

First, feasibility assessment capacity (called agenda setting by Yang, Hsieh, and Li) is defined by Brown and Potoski as "the capacity to determine whether to make or buy the good or service (examples include hiring staff trained in market analysis or legislative study groups to assess whether a service or function is appropriate for contracting) process during which the values and preferences of stakeholders are manifested and compromised."[13] Yang, Hsieh, and Li found a nuanced relationship between their agenda setting capability and performance. Their examination of selected public administrator self-reported data determines that increased assessment capacity is positively associated with cost reduction but not with efficiency increase or quality improvement. Moreover, Yang, Hsieh, and Li find that there is a time component to management capacity, in that the cost-reduction impact of agenda setting decreases with time.[14]

The next category, formulation capacities, includes a wide variety of ex ante steps well summarized by Yang, Hsieh, and Li: "setting a fair bidding process, identifying the best-fit contractor, and reaching an excellent contract."[15] They find that formulation capacity does have a significant relationship with cost savings and quality in particular but that across all three performance metrics the relationship is "curviolinear" or "n-shaped." They find that "the results are consistent with our argument that information searching, contract negotiation, and contract writing entail transaction cost that may offset their potential benefits, and that overuse of contracts may hamper the development of trust and collaboration."[16] Fernandez summarizes the relational contracting literature as warning that contract-writing capacity can be misapplied as "even moderate levels of complexity and uncertainty increase the likelihood that some of the contract requirements will be erroneous."[17] By this logic, developing contract specification capacity could be a distraction

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[11] Kaifeng Yang, Jun Yi Hsieh, and Tzung Shiun Li, "Contracting Capacity and Perceived Contracting Performance: Nonlinear Effects and the Role of Time," *Public Administration Review* 69, no. 4 (July/August 2009): 684, doi:10.1111/j.1540-6210.2009.02017.x.

[12] Barbara S. Romzek and Jocelyn M. Johnston, "Effective Contract Implementation and Management: A Preliminary Model," *Journal of Public Administration Research and Theory* 12, no. 3 (July 2002): 434, 437-438, doi:10.1093/oxfordjournals.jpart.a003541.

[13] Brown and Potoski, "Contract-Management Capacity," 155.

[14] Yang, Hsieh, and Li, "Contracting Capacity and Perceived Contracting Performance," 690.

[15] LiIbid., 683.

[16] Ibid., 690.

[17] Fernandez, "What Works Best When Contracting for Services?," 1127.

from making a cultural shift away from strictly measurable design specifications into a greater emphasis on relationship and communication.

However, another form of formulation capacity, the ability to evaluate potential vendors, has shown more promising results. Fernandez, statistically identifying and analyzing top performers, finds that ex ante evaluation of vendors does not influence the success of average contracts but is a significant determinant of the most successful contracts.[18] Romzek and Johnston do not directly study the capability to evaluate vendors, but the evaluations of vendor staffing and financials constitute two of the seven characteristics they identify as improving contract performance.[19]

The role of competition is subject to more controversy. Brown and Potoski note that "[f]or some time, it has been clear that favorable external conditions, such as community support for contracting and competition among potential vendors, can improve the likelihood of successful contracting."[20] In their study of social services, Romzek and Johnston include the "level of competition among providers" among their factors for successful contracting but also note that on the other hand noted that stability may have been an important omitted variable. This results in some tension with competition as "[t]heoretically, contract managers would be confronted by a far less complicated management task in a highly competitive environment. In reality, contract management requires some minimal level of stability to allow networks of contractors and government managers to cushion the unforeseen impacts that inevitably occur in the delivery of complex social services."[21] Fernandez finds less support for competition, with higher numbers of bidders associated with worse results. Performance may depend on the acquisition approach more than the formation capacity as "ongoing competition between contractors during the implementation phase, rather than ex ante competition during the bidding phase, appears to be the form of competition that improves overall contracting performance."[22] This finding aligns with Sanders and Huitink's analysis of competition for product and service contracting, which found that while competitive procedures were associated with a greater risk of terminations, less concentrated industries, which would facilitate the availability of competition in implementation, had lower rates of termination.[23]

The next stage, process implementation, includes public–private governance capacity and focuses on management after the contract is signed. The literature supports the importance of government and the private sector working together during the contracting period to increase the quality of the service. Yang, Hsieh, and Li provide substantial evidence for this, highlighting the value of "government agencies' active, ongoing involvement in or support for the contractor's operation."[24] Put another way, the key implementation question for the government is "how can we help the contractor succeed?"[25] Yang, Hsieh, and Li found that "implementation capacity has a curvilinear relationship with cost saving," with moderate

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[18] Ibid., 1135-1136. However, this finding was not replicated in Fernandez, "Understanding Contracting Performance," 92.
[19] Romzek and Johnston, "Effective Contract Implementation and Management," 438-441.
[20] Brown and Potoski, "Contract-Management Capacity," 162.
[21] Romzek and Johnston, "Effective Contract Implementation and Management," 443, 447.
[22] Fernandez, "Understanding Contracting Performance," 86.
[23] Gregory Sanders and Zach Huitink, *Evaluating Consolidation and the Threat of Monopolies within Industrial Sectors* (Washington, DC: CSIS, 2019), 56, https://www.csis.org/analysis/evaluating-consolidation-and-threat-monopolies-within-industrial-sectors.
[24] Yang, Hsieh, and Li, "Contracting Capacity and Perceived Contracting Performance," 684.
[25] Ibid., 684.

levels having the most benefits.[26] They further find that the passage of time increases the importance of implementation capacity: "However, the function also shows that time moderates the relationship in that the benefits of implementation activities are multiplied or strengthened as time passes, indicating that efforts to develop collaboration and mutual support will have long-term advantages."[27]

Their results support the relational governance school of thought and that performance may be improved through "mechanisms such as mutual dependence, trust, parallel expectations, and joint action holds great promise to improve contracting performance."[28] Fernandez found that joint problem solving has a significant and robust positive relationship with contract performance and that this relationship is even stronger among the most successful contract relationships. Moreover, Fernandez finds that "[s]ince public managers work more closely with the contractor's staff to solve performance issues that arise during the life of the contract, the level of contracting performance tends to increase, as experts on relational contracting have predicted."[29] Fernandez replicated these results in a later study that found that even with new methods, joint problem solving remains positively correlated with a range of contracting performance measures.[30]

The last category is evaluation or monitoring capacity, which is the ability of the government to monitor a contractor's performance and to enforce the contract. "[In-depth planning for contractor performance measurement" is one of Romzek and Johnston's factors for successful contract performance.[31] Yang, Hsieh, and Li suggest that a "strong evaluation capacity may promote cost reduction and efficiency increases but may not help improve quality."[32] However, they also find that a weaker system had no benefit and that for efficiency increases the value of evaluation activities decreases over time. This suggests that a contract needs more evaluation in the beginning; once expectations are clearly established, execution runs much more smoothly. On the other hand, Fernandez does not show any robust significant impact of either the scope or intensity of monitoring activities; there are mixed results depending on the enforcement mechanism employed.[33] Fernandez's findings indicate that legalistic means are more effective than alternative dispute resolution:

> In fact, among the high performing cases, tactics such as imposing financial penalties and threatening to terminate the contract seem to enhance contracting performance more than alternative means for resolving disputes, such as negotiation and mediation, since the coefficient for reliance on alternative means for resolving disputes is not statistically significant.[34]

It is worth remarking that, two years later, Fernandez finds the complete opposite for services for a study employing a similar International City/County Management Association

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[26] Ibid., 691.
[27] Ibid., 691.
[28] Ibid., 691.
[29] Fernandez, "What Works Best When Contracting for Services?," 1132.
[30] Fernandez, "Understanding Contracting Performance," 91.
[31] Romzek and Johnston, "Effective Contract Implementation and Management," 443, 447.
[32] Yang, Hsieh, and Li, "Contracting Capacity and Perceived Contracting Performance," 691.
[33] Fernandez, "What Works Best When Contracting for Services?," 1136; and Fernandez, "Understanding Contracting Performance," 92-93.
[34] Fernandez, "What Works Best When Contracting for Services?," 1135.

dataset but employing new methods that no longer weight high performers.[35] For this overall sample, Fernandez's measure for negotiation, arbitration, and mediation is correlated with better results, and employment of legal enforcement mechanisms is not significant.[36] In addition to discussing how contract-management capacity influences service contract performance, the literature also considers whether service contracts can be used to augment in-house contract-management capacity. This could involve using the same contractor for service production and monitoring or separating the responsibilities. Brown and Potoski report that "at the national level, many federal agencies now employ third-party evaluators to assess the quality of production activities for which they have contracted (e.g., information technology), a practice often referred to as 'independent verification and validation.'"[37] For example, service contracts can be used to delegate management responsibilities (for instance, monitoring outcomes) to vendors: "All service delivery management need not occur within government, though effective contracting clearly requires that governments maintain some contract-management capacity. For example, even though governments can transfer some monitoring responsibilities to vendors, they likely still need to monitor their vendors' performance to some degree."[38] While governments rely on contracting out to perform less direct monitoring, Brown and Potoski find "that governments more than make up for this management deficit by contracting with vendors to perform management service."[39] In the case of easy-to-measure services, contract managers can focus more on outcome monitoring and less on the actual production of the service. In such cases, external monitoring becomes an attractive option, and contract managers need still remain involved in evaluation but can quickly check the vendors' intensive reports against their own outcome observations.

However, Brown and Potoski caution that their sample focused on refuse collection—the results may not extend to harder to measure services—and present a framework for when contracting out is appropriate based on service production and service management transaction cost. Delegating complex monitoring to the vendor is obviously susceptible to the agent opportunism problem.[40] Furthermore, one additional consideration is that contracting for management tasks can carry a large amount of risk, specifically that "the government will enter into a monopoly relationship with the vendor for both service production and management."[41] This could come about if the government no longer retained sufficient management technical capacity to make key decisions without its contracting partner.

Customer-Vendor Relationship

As mentioned in the contract-management capacity section above, especially for complex services contracts, a capable customer and contractor may both be necessary, but without trust, the relationship may not be unable to survive the unexpected. The process implementation contract-management capabilities to align incentives in a public-private

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[35] Pertinent methods are discussed in Fernandez, "What Works Best When Contracting for Services?," 1130-1131; and Fernandez, "Understanding Contracting Performance," 76.
[36] Fernandez, "Understanding Contracting Performance," 91.
[37] Brown and Potoski, "Contracting for Management," 338.
[38] Ibid., 324, 338.
[39] Ibid., *340*.
[40] Ibid., 328.
[41] Ibid., 327.

partnership or to engage in joint problem solving may both facilitate the building of trust. Looking at the specific case of defense Performance-Based Logistics arrangements, Sanders and Ellman found through interviews that contract length and mechanisms that allow extensions for good behavior were both helpful for this instance of public-private partnership. In addition, in keeping with other literature, properly aligning incentives through metrics and feedback from stakeholders (e.g., weapon system operators) was necessary but not necessarily sufficient to build a good relationship.[42] Fernandez ably summarizes literature on trust before laying out the expected relationship:

> Interorganizational trust should have independent positive effects on contracting outcomes, including greater efficiency, higher quality of service, and more resilient contractual relationships with fewer disruptions . . . the influence of trust on performance would be greater in mature contractual relationships, where the agent has had sufficient time to gain the principal's confidence, than in nascent ones.[43]

This was borne out in his modeling where trust has a positive independent effect on overall contracting performance; in fact, it has the "highest standardized coefficient" in Fernandez's ordinary least squared models, which suggests a strong relationship between factor and outcome.[44] However, the expected interactions between trust and contract duration did not prove significant nor did the model show that trust could substitute for monitoring or vice versa. The only significant interaction that was that trust matters more when asset specificity is high than when it is low. This can be attributed to the way that having to make domain specific investments raises the importance of the relationship between vendor and customer, because it makes finding new partners more costly.[45]

As in other aspects of life, trust involves risks. The principal-agent problem, a theoretical concept in contracting that explores the sometimes conflicting interests of customers and vendors, is at the core of a rich vein of literature that sometimes raises concerns that can be in tension with some of those emphasizing the concept of relational contracting. Smith and Smythe raise concerns that "[w]hile trust is invaluable in reducing transaction costs and promoting organizational stability," it can make it difficult to react to changing circumstances and needs and "mask the underinvestment of government in adequate monitoring capabilities."[46] Brown and Potoski provide some evidence that longer-term contracts "may also begin to mirror monopoly relationships, exposing governments to the risk that vendors will shirk their responsibilities."[47] When comparing short-term to long-

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[42] Gregory Sanders and Jesse Ellman, Use of Incentives in Performance-Based Logistic Contracting (Washington, DC: CSIS, 2018), 54-56, https://www.csis.org/analysis/use-incentives-performance-based-logistics-contracting#:~:text=Performance-Based%20Logistic%20(PBL),the%20customer%20and%20the%20vendor. Strictly speaking, performance-based logistics contracts are often categorized as product contracts, in keeping with the emphasis on having the system in question available for use rather than reimburse based on services performed. That said, while many existing examples would be excluded from the dataset used in this project, they share many traits in common with high-complexity service contracts.
[43] Fernandez, "Understanding Contracting Performance," 73.
[44] Ibid., 86.
[45] Ibid., 87. On that same page, Fernandez notes that some of the literature on trust suggests the possibility of an "endogenous or simultaneous relationship between trust and performance." This observation encompasses the challenge that the casual relationship between trust and performance can easily flow in either or both directions. Therefore one of the models in his paper employs a two-stage least squares regression to account for endogeneity.
[46] Steven Rathgeb Smith and Judith Smyth, "Contracting for Services in a Decentralized System," Journal of Public Administration Research and Theory 6, no. 2 (April 1996), 295, doi:10.1093/oxfordjournals.jpart.a024311.
[47] Brown and Potoski, "Contracting for Management," 336.

term contracts, the short-term contracts had notably more spot checks (95 versus 68, annually), although long-term contracts were more likely to engage in citizen surveys.[48]

These different schools of thought interact with and reply to one another and, as in the aforementioned case of Fernandez's findings on the use of legalistic enforcement mechanisms, sometimes have diverging results in different works from the same scholar.[49] Johnston and Romzek also emphasize that it is not safe to assume that either a legalistic or a relationship-base accountability mechanism will necessarily be available[50]:

> Privatization and contracting are popular initiatives these days, but they are often undertaken without consideration for contract-management complications, accountability implications, or the presence of market features necessary to enhance efficiency. . . . Unless government administrators recognize the accountability dynamics underlying contracting, they may find the contract results very different from those anticipated by the state officials who made the decision to contract out in the first place.[51]

Yang, Hsieh, and Li review many scholars on each side of this question and in reporting their results emphasize the role of time, with upfront government capacities mattering the most at the start, and perhaps laying the groundwork for partnership, but the capacity to build collaboration mattering most over time.[52] Yang, Hsieh, and Li go so far as to suggest that "Developing an authentic collaborative relationship with the contractor is the best way to achieve long-term performance benefits."[53] Yang, Hsieh, and Li offer a possible synthesis of this conclusion and concerns about privatization by raising "a fundamental, value-laden question: If the government can develop superior cap CHAPTER 2

acities necessary for contracting out, then why cannot it develop capacities necessary for internal delivery?" This circles back to the first phase of feasibility assessment and underlines the importance of understanding how both relationships and institutional capacities are grown.

Finally, one wrinkle in customer-prime contractor relationships is that, especially in high-complexity contracts, much of the work may be done by subcontractors. Mentioning sub-relationships, Fernandez examined the use of subcontractors because "arrangements involving multiple subcontractors imposes additional burdens on the prime contractor, including higher coordination costs, the likelihood of delays, and sometimes even conflict over the choice of goals and means, all of which ultimately weaken performance."[54] The use of multiple subcontractors had a significant negative relationship with performance in the overall OLS sample but was not significant in the case of high performers.[55]

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[48] Ibid., 336.

[49] Legalistic approaches were found to correlate with better performance in Fernandez, "What Works Best When Contracting for Services?," 1135. However, subsequent research found that negotiation, arbitration, and mediation had a significant relationship with performance in Fernandez, "Understanding Contracting Performance," 91. In both cases, the other means was not significant.

[50] Fernandez, "What Works Best When Contracting for Services?," 1135.

[51] Jocelyn Johnston and Barbara Romzek, "Contracting and Accountability in State Medicaid Reform: Rhetoric, Theories, and Reality," Public Administration Review 59, no. 5 (September/October 1999): 394, doi:10.2307/977422.

[52] Yang, Hsieh, and Li, "Contracting Capacity and Perceived Contracting Performance," 692.

[53] Ibid., 693.

[54] Fernandez, "What Works Best When Contracting for Services?," 1129.

[55] Ibid., 1134.

CHAPTER 3

Conceptual Framework and Hypothesis

This paper posits and tests a conceptual argument linking three categories of characteristics with services contract performance: (1) the complexity of the service being contracted; (2) contract-management capacity on the part of the buyer; and (3) the extent of the relationship history between the buyer and the contractor. By explicitly discussing all three characteristics, the argument captures the inherent challenges of services contracting—both those pertaining to the buyer and those applicable to individual vendors. Since the Federal Procurement Data System (FPDS) does not contain direct measures of these variables, the paper will introduce proxies for each under the relevant hypotheses.

SERVICE COMPLEXITY

There are three broad ways in which the concepts related to the inherent complexity of the underlying service, and its related transaction costs, can introduce challenges to contract performance. First, it may raise the technical expertise required from acquisition officials. A simple service, such as lawn mowing, can be easily specified and overseen, while a more complicated service, such as aircraft maintenance, requires a higher level of understanding and assurance, as important problems might not be immediately visible. Second, service complexity increases the challenge of specifying the service in clear and comprehensive terms. When acquiring new services (or ones that otherwise involve significant uncertainty), acquisition officials and contractors cannot simply rely on the initial performance work statement to deliver a successful outcome. Rather, they must be able to flexibly incorporate changing conditions or new information. This greater requirement for partnership asks more of both buyer and vendor and leaves significant room for disagreement and conflicting interests. Third, the service may involve investments that do not easily translate into other work, which can make both the customer and the contractor more dependent on one another. In both cases, this complexity makes the work more demanding and, all else being equal, therefore raises the risk of negative contracting outcomes.

> H_1: As service complexity increases (decreases), the likelihood of cost ceiling breaches and terminations increases (decreases) and the likelihood of exercised options decreases (increases).

The paper employs two labor-based measures to attempt to capture service complexity. Service contracting inherently emphasizes labor and measures of pay, and the number of employees is a metric that can be relevant across disparate forms of services contracting.

The first measure is the average salary for the North American Industrial Classification System (NAICS) detailed industry that the contract is classified under. There can be different reasons for higher salaries, but one of them is the difficulty of the work and the experience and education required.

H_{1A}: As average *detailed industry salary* increases (decreases), the likelihood of cost ceiling breaches and terminations increases (decreases) and the likelihood of exercised options decreases (increases).

The second measure is more specific to service contracting: average cost per employee. The average cost is calculated based on averages for the given product or service code, although the study team hopes to incorporate direct contract-level measures where available in future iterations. It employs an existing government metric, the invoice rate, that approximates how much the government is charged annually for each comparable full-time employee supporting a service contract. A service contract with a large number of lower-paid staff would have a lower invoice rate, for instance, than one that employed a small number of experts or that had extensive capital costs. Similarly, a service contract that provides contracting personnel only, for work in government facilities and using government equipment, would have a lower invoice rate than a comparable contract that also promises a full package of services and charges overhead for the infrastructure in place to help deliver them. In the latter case, these non-personnel expenses may indicate a service with greater asset specificity. As with average salary, this hypothesis assumes that scarcer labor or labor acquired at a greater premium, all else being equal, indicates a more complex service.

H_{1B}: As the service code invoice rate increases (decreases), the likelihood of cost ceiling breaches and terminations increases (decreases) and the likelihood of exercised options decreases (increases).

CONTRACT-MANAGEMENT CAPACITY

Contract-management capacity can manifest in a variety of forms, including assessment, contract-formulation capacity, evaluation, and ability to sustain a public-private partnership. The literature already demonstrates the importance of this capacity, in particular for the more complex services discussed for H_1.

H_2: As a contracting office's contract-management capacity increases (decreases), the likelihood of cost ceiling breaches and terminations decreases (increases) and the likelihood of exercised options increases (decreases).

The first measure of contract-management capacity considered here aligns with process implementation capacity and is the only one that the FPDS reports on directly: performance-based services acquisition (PBSA). Defined in 48 Code of Federal Regulations §37.601 (2019), PBSA tracks multiple measures relevant to public-private partnership governance, including the foundation of how the contract is defined. Performance-based services acquisition "[d]escribes the requirements in terms of results required rather than the methods of performance of the work."[56] Other characteristics included measurable performance standards, plans for monitoring, and the potential for monetary adjustments depending on the quality of the output.

H_{2A}: As the contract office proportion of performance-based services acquisition increases (decreases), the likelihood of cost ceiling breaches and terminations decreases (increases) and the likelihood of exercised options increases (decreases).

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[56] General Services Administration (GSA), GSA Federal Procurement Data System-Next Generation (FPDS-NG) Data Element Dictionary (Washington, DC: 2020), 55, https://www.fpds.gov/downloads/Version_1.5_specs/FPDSNG_DataDictionary_V1.5.pdf.

For the other assessments of contract-management capacity, specific measures employed by prior surveys and case studies are not available within the FPDS, and headcount data for contracting officers is not publicly available at the contracting office level. To capture this important but elusive variable, this paper therefore employs a measure that scales based on the contracting office's history. This approach assumes that the throughput with a given type of product or service code correlates with the development of technical expertise. As covered in the prior section, complexity and expertise requirements can vary greatly from one category to another, and a contracting office may have high capacity in one area that would not translate to a new area.

> H_{2B}: As the contract office service code experience increases (decreases), the likelihood of cost ceiling breaches and terminations decreases (increases) and the exercised options increase (decrease) for that service.

PAIRED HISTORY

The last characteristic discussed follows naturally from observing the importance of partnership, trust, and the ability to handle difficult problems and uncertainty together: the relationship between the contractor and buyer. The literature suggests that a perfectly written contract is no guarantee of, nor substitute for, effective collaboration. In the absence of data directly pertaining to trust, this hypothesis focuses on the history of interaction that provides the opportunity to build a deeper relationship.

> H_3: As the extent of the history between the contracting office and vendor increases (decreases), the likelihood of cost ceiling breaches and terminations for that partnership decreases (increases) and the likelihood of exercised options increases (decreases).

The first measure is the number of past years of the relationship between the contracting office and the contractors, with a single transaction between the two in a given fiscal year enough to qualify that year as part of a continuing relationship. The second measure is the number of actions on the vendor's contracts with that office. Contract action counts vary wildly from contract to contract, but even if the obligated amount per action is small, they still represent more opportunities for interaction for the office and contractor and thus may serve as a proxy for communication.

> H_{3A}: As the number of paired years a vendor has contracted with an office increases (decreases), the likelihood of cost ceiling breaches and terminations for that partnership decreases (increases) and the likelihood of exercised options increases (decreases).

> H_{3B}: As the number of paired actions a vendor has performed for an office increases (decreases), the likelihood of cost ceiling breaches and terminations for that partnership decreases (increases) and the likelihood of exercised options increases (decreases).

CHAPTER 4

Data and Methods

Data Sources and Structure

The primary source of this paper is the Federal Procurement Data System, which is the transaction database for U.S. government contracts, military as well as civilian, for both products and services. With some exclusions—such as classified contracts, the U.S. postal service, and the Defense Commissary Agency—all U.S. federal government contracts above a $3,500 threshold are reported into FPDS. Services contracts are delineated using FPDS-specific product or service codes; we are excluding R&D contracting for the purposes of this report. The study team maintains their own copy of the FPDS, which has been supplemented by the ad hoc search tool and information from various data dictionaries. This and past contract datasets are freely available for download for other researchers.

FPDS data has been supplemented using the Services Contract Inventory, which was mandated by the *2010 Consolidated Appropriations Act*.[57] The study team continues working on importing and matching contracts from both the civilian agency data held by the General Service Administration (GSA) and the separate DoD dataset. The analysis relies not on the contract inventory itself, which is only available for larger contracts in the first place, but on the invoice rates derived for product and service codes through the work of the U.S. Army. Those invoice rates are used on an annual basis to estimate the number of comparative full-time employees for contracts in the inventory that lack more detailed data. Data for rates applicable to Overseas Contingency Operations are broken out for analysis from those for all other defense contracts, since they are of special interest because they imply coverage of contractors supporting military operations overseas, including those directly present in Iraq and Afghanistan.

This report uses individual service contracts or task orders as the unit of analysis.[58] These are identified in FPDS through the unique combination of a procurement identifier and, for task orders, a parent procurement identifier. The dataset is made up of completed contracts and task orders for services contracts for the DoD with their entire lifespan between FY 2008 and FY 2015.[59] Many of the variables in the dataset have been developed and fine-tuned over three CSIS reports on fixed-price contracts, industrial consolidation and

[57] GSA, Service Contract Inventory (Washington, DC: 2019).
[58] The overarching contracts for indefinite delivery vehicles are also reported in FPDS, but they are not included in the dataset because the study team instead chose task orders as the unit of analysis.
[59] Completion is measured by having no modifications involving new obligations or any form of increased ceilings since the end of calendar year 2016, not counting terminations and closeouts. In addition, to be counted as completed, contracts that were not terminated or closed out must have a current completion date before the start of calendar year 2017.

competition, and crisis-funded contracts.[60] Service contracts are less numerically prevalent than their products counterparts but still constitute 1.26 million contracts and task orders during the study period. Additionally, 7.0 percent by count and 6.7 percent by value obligated are eliminated from the sample because of missing data.

The exercised options outcome variable focuses on a narrower subset of contracts and task orders, namely those with unexercised options as of their initial transaction. This reduces the count tenfold: only 94,000 contracts and task orders qualify. It is nonetheless important to exclude unqualifying contracts from the options exercised sample: the choice of whether or not to include options in a contract is a contract formulation decision, not a direct reflection of performance on a given contract. The importance of contracts and task orders with options is affirmed by their value, and they account for 29.6 percent of the total services dataset. Their missing data rate is similar to the overall dataset (if with an expanded gap between count and value): data is missing for 11.8 percent of contracts and task orders by count and 5.1 percent by value. Henceforth in this study, for simplicity, both contract awards and task orders will be referred to simply as contracts, except in those cases where the distinction matters.

INVENTORY OF CONTRACTED SERVICES

The Inventory of Contracted Services (ICS) is mandated across the federal government, and it has an obvious value to this project above and beyond the inclusion of the invoice rate variable. The inventory combines data not available elsewhere with contract data from the Federal Procurement Data System (FPDS) and the System for Award Management (SAM). By statute, the DoD inventory process is separate from the standard GSA process used for civilian agency reporting. The study team analyzed ICS data from both the DoD and GSA to better understand service contract complexity and found that each source has its own set of challenges. Starting in FY 2012, DoD ICS data generally includes comparable contractor full-time equivalents (CFTE) counts as well as related information and clear ICS guidance. By comparison, although ICS data sourced from the GSA is easier to import—not being spread across as many sometimes inconsistent Excel tabs as the DoD data—the GSA relies on supplemental documents to explain its ICS, documents that have not been published for some years, which poses difficulties in cross-checking and reference.

The main challenge in importing the data was the inconsistent format in which the data was reported and published. This complicated the consolidation process before import to the CSIS database system, especially for tasks such as validating data type and generating unique identifiers. Together with widespread underreporting, especially in later years, utilizing contract-level reporting proved impractical. Nonetheless, the study team was successful in importing and using key DoD guidance documents to extract annual service code-level invoice rates.

[60] Andrew Philip Hunter, Gregory Sanders, and Rhys McCormick, Avoiding Terminations, Single-Offer Competition, and Costly Changes with Fixed-Price Contracts (Washington, DC: CSIS, 2015), https://www.csis.org/analysis/avoiding-terminations-single-offer-competition-and-costly-changes-fixed-price-contracts; Sanders and Huitink, Evaluating Consolidation and the Threat of Monopolies within Industrial Sectors; Gregory Sanders and Andrew Hunter, Overseas Contingency Operations Contracts After Iraq: Enabling Financial Management Research and Transparency Through Contract Labeling (Washington, DC: CSIS, 2017), https://defense360.csis.org/oco-contracts-after-iraq/.

Measures of Dependent and Independent Variables

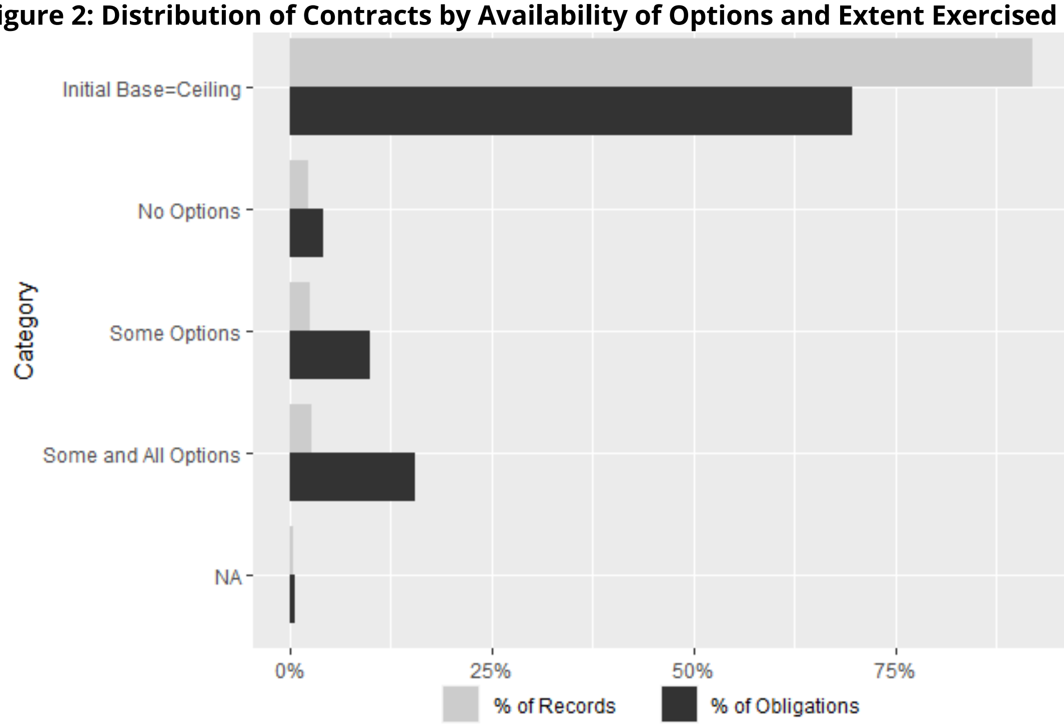
DEPENDENT VARIABLES

This paper includes three performance outcomes measured across five dependent variables: (1) the likelihood that some options will be exercised and, in that case, that all options will be exercised; (2) the likelihood that a ceiling breach will occur and, if a breach does occur, what the breach size will be; and (3) the likelihood of terminations. Each of the dependent variables are explained below.

Exercised Options

A contract's exercised options are tracked by a pair of metrics: whether *some options* are exercised and whether *all options* are exercised. In contrast to terminations and ceiling breaches, this is a positive measure of contract performance, reflecting that the buyer has chosen to acquire additional services within the scope of the original contract and is willing to pay a higher price as a result. One common source of options is multiple-year contracts where the original "base" contract only covers the first year. Both government and contractor may assume that this extension will take place with a high degree of confidence, but in strictly legalistic terms, the buyer is under no obligation to continue and may unilaterally allow the contract to end without the liability that may be incurred in a termination. The vast majority of contracts do not have options available to exercise at contract start. However, the minority of contracts with options available account for a sizable portion of spending, as is shown in Figure 2 below. In keeping with the premise that exercised options signify a greater desire by the government to employ the vehicle as well as more revenue for the contractor, note that contracts in the "Some Options" and the "Some and All Options" rows show substantially more spending than those contracts with available options that were left unexercised.

Figure 2: Distribution of Contracts by Availability of Options and Extent Exercised



The first metric is whether *some options* were exercised. This metric is a binary variable that is true if the contract has passed one of two tests. The test is whether it has at least one transaction that meets all three of the following criteria:

1) The transaction's reason for modification is an exercised option, a supplemental agreement for work within scope, or a funding-only action (collectively known as "steady scope" modifications).
2) The base and exercised options value of the contract increases as part of the transaction.
3) The base and all options value of the contract does not increase as part of the transaction.

The study team used this conservative definition in order to ensure that exercised options were clearly differentiated from cost overruns. As a secondary threshold, contracts with exercised options growth that exceeded the total ceiling growth, after setting aside close-out and termination transactions, were also counted as exercising some options. Thus by these two tests, a contract could qualify if it had an exercised option with an appropriate reason for modification not accompanied by ceiling growth or if its exercised option growth was clearly greater than its ceiling growth.

The second metric is a binary variable that tracks whether *all options* were exercised. A contract can qualify by meeting either of two tests: (1) if the base value of the contract plus exercised options meeting the three prong criteria described above exceeds the initial contract ceiling, after accounting for administrative reductions and (2) if the base and all exercised options value exceeds both the initial contract ceiling and the cumulative contract ceiling, after setting aside transactions for terminations and closeouts.[61] This metric rounds up in order to allow for some imprecision in the raw data, and thus any contract that reaches 95 percent of the gap between the initial base and the relevant ceilings also is treated as having exercised all options. As can be seen in
Table ***1***, two-thirds of contracts with available options exercise some options, and half of contracts exercising some options go on to exercise all options.

[61] Specifically, if the sum of modifications for administrative and steady-scope base and exercised options is less than zero, then the exercised options measure is reduced by that amount.

Table 1: Frequency of Some Options, All Options, Ceiling Breach Likelihood, and Terminations

Variable	Comparison Group	Value	% of records	% of $s
Some Options	Contracts with Available Options	0 (No Qualifying Exercised Options)	30.46%	13.99%
		1 (Some Options)	68.79%	85.71%
		Not Available	0.75%	0.31%
All Options	Contracts Exercising Some Options	0 (Only Some Options)	48.62%	39.04%
		1 (All Exercised Options)	51.33%	60.95%
		Not Available	0.06%	0.01%
Ceiling Breach Likelihood	Full Data Set	0 (None)	93.83%	74.52%
		1 (Ceiling Breach)	6.17%	25.48%
Terminations	Full Data Set	0 (Unterminated)	98.14%	97.57%
		1 (Partial or Complete Termination)	1.86%	2.43%

Note: Not Available data includes contracts for which exercised option or ceiling values could not be effectively calculated, for example, those where steady-scope and administrative reductions exceeded increases.

Table 2: Ceiling Breach Size for Breached Contracts

Variable Name	Min	Max	Median	Geometric Mean	% of records NA	% of Obligation to NA records
Ceiling Breach Size	0	$10.8 Billion	$ 11,276	$10,436	3.71%	4.67%

Note: NA refers to not available data, for example, because negative steady-scope or administrative adjustments exceeded the initial increase in ceiling size.

Ceiling Breaches

Ceiling breaches, or cost increases past an established threshold, are tracked by a pair of measures. *Breach likelihood* is a binary variable that is true if a contract's cost ceiling has increased as part of a conventional change order or a change order that definitizes the contract (collectively "change orders"). Each transaction in the database tracks the change in obligated amount, contract ceiling, and base and exercised options, as well as the reason for that change. As shown in Table *1*, over 6 percent of services contracts experience a ceiling breach, a notably higher rate than the "1.04 percent" for the full DoD contracts dataset.[62]

Breach size is a continuous variable tracking the cost ceiling increase, measured in 2018 constant dollars based on the contract's starting fiscal year. For the *breach size* measure, the sample is limited only to those contracts that have experienced a breach, so the model does not report how likely the breach would be to occur in the first place. Thus it would be possible for a contract characteristic to have a negative correlation with the likelihood of ceiling breaches but a positive correlation with breach size, which would mean that it was associated with rarer but greater magnitude breaches. While this is a smaller sample, over a fifth of all obligations in the dataset went to contracts experiencing breaches. As shown in Table 2, both the average and median breach size were around $10,000, but the upper bound of ceiling increases for DoD services in the period was in excess of $10 billion. That high figure does show a weakness of metric, and while the study team has taken steps to increase the reliability of these figures, contract ceilings are not given the same level of scrutiny as contract obligations.

Both measures focus on change orders rather than modifications requesting additional work because the combination of a change order and an increase in ceiling suggests an unanticipated development that will cost the acquirer more money. Furthermore, the variables intentionally measure ceiling change, not obligations, because ceiling changes typically do record the reason for the change but many obligations are funding-only actions that do not differentiate between whether the spending supports a prior change order, an exercised option, or other forms of new work. In those cases where there appears to have

[62] Sanders and Huitink, Evaluating Consolidation and the Threat of Monopolies within Industrial Sectors, 19.

been a correction made via administrative or steady-scope ceiling modifications, the ceiling breach size measure is reduced accordingly.[63]

Terminations

Terminations are measured using a binary variable that is set to true if a contract has experienced a partial or complete termination at any point in its lifespan. This includes terminations for default and convenience (partial or complete), as well as terminations for cause and legal contract cancellations.[64] Perhaps unintuitively, this can include both a traditional cancellation of a major weapon system and the cancellation and reassignment of a contract due to a bid protest. The overwhelming majority of terminated contracts have no obligations after their final termination date. However, among contracts with higher ceilings, substantial spending after termination is common and in line with Federal Acquisition Regulations Part 49, which allows for settlement spending; this may explain most of the post-termination spending in the data. The study team found no clear dividing line between partial and complete terminations and therefore chose to include all instances of terminations, whether they occurred at the start or end of a contract.

As shown in
Table ***1***, terminations are rare, although roughly twice as common as in the overall DoD dataset, where "0.91 percent of contracts experienced at least one partial or complete termination."[65] Perhaps surprisingly, overlap between terminations and ceiling breaches is small.

STUDY INDEPENDENT VARIABLES

Service Complexity

Detailed industry salary: Each contract in the FPDS is labeled by its NAICS detailed industry category, the most granular level available in NAICS codes. The U.S. Economic Census provides enough data to calculate average wage, although it is only available every five years and thus has a variable lag of one to five years based on the time since the last census.

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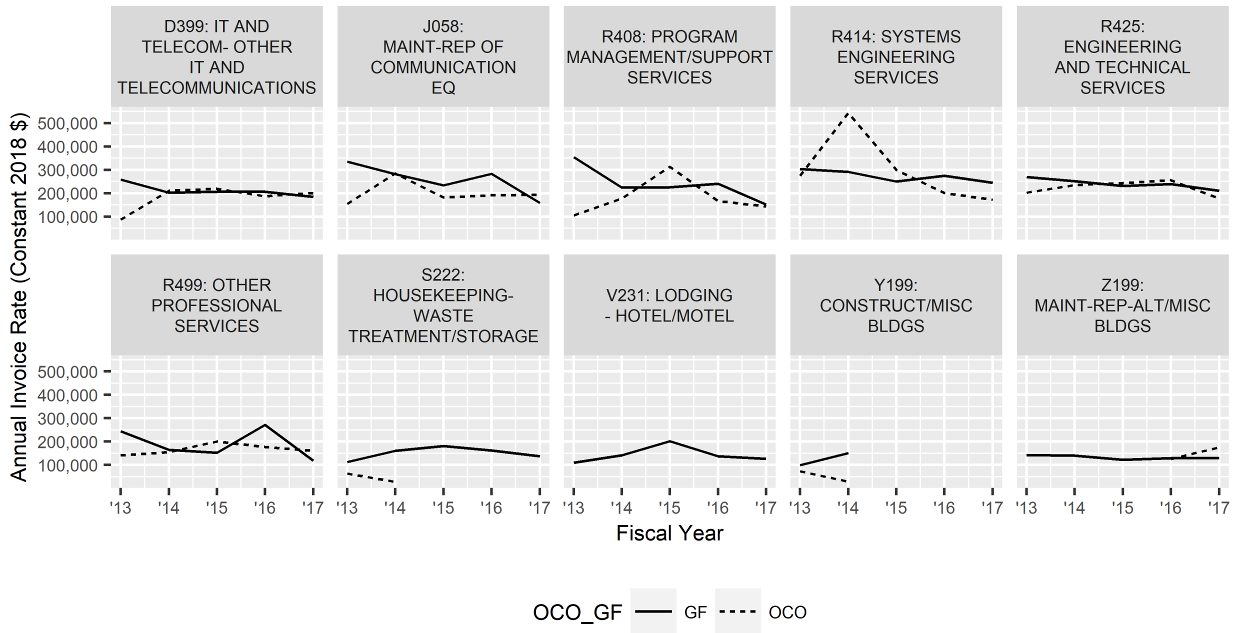
[63] The specific process largely aligns with the one used for exercised options. If the sum of administrative modifications and steady-scope modifications is less than zero, then the ceiling breach measure is reduced by that amount. However, if the reduction is made due to a change order, as part of a closeout or termination or for other reasons, the ceiling breach amount is not adjusted. The study team reviewed transaction records and contract totals and believes that administrative and steady-scope net reductions are most likely to capture corrections or updates. This metric intentionally does reduce the size of the ceiling breach in response to descoping change orders or due to descoping or ceiling reductions as part a termination or closeout.

[64] The source for termination labels does differentiate between different types of terminations, but it groups partial and complete terminations together within those categories. Due to the rarity of the more severe forms of termination—that is, terminations for default or cause—the study team did not differentiate between different degrees of terminations.

[65] Sanders and Huitink, Evaluating Consolidation and the Threat of Monopolies within Industrial Sectors, 19.

Figure 3: Comparable Full-time Employee Invoice Rate of the Top 10 Service Codes



Service code invoice rate: The average annual charge rate for comparable full-time employees within the service code in question. The invoice rate is available through the Service Contract Inventory and is dependent on U.S. Army calculations at the individual product or service code level or for the broad service category.[66] The rates are broken out between the rates for Overseas Contingency Operations and General Funds, and this study used prior work on identifying crisis contracts to match contracts appropriately. The most used service codes, in both quantity and obligation terms, are shown in **Figure 3** and show broad patterns in line with expectations: "Lodging – Hotel/Motel" and "Maintenance-Repair-Alternative/Miscellaneous Buildings" have the lowest invoice rates, while more complex services, such as "Maintenance-Repair of Communications Equipment" and "Systems Engineering Services," are high.

When the invoice rate for a specific product or service code is available for the prior fiscal year, that factor is used. When the invoice rate is available for a code but not for the prior year, for example, "Construction/Miscellaneous Buildings" in **Figure 3**, the average across all years is imputed. This approach is used for all contracts that started prior to 2014. For those codes with no reported invoice rates, the broad service code is used instead—for that year if available, and from an average of the invoice rate for all available years otherwise. This investigation did reveal oddities in the later years, with multiple categories suddenly declining in 2016 and some categories' rates collapsing in 2017. Sometimes the end of a single contract can do a great deal to explain fluctuations, as the study team found for "Waste Treatment & Storage Facilities," but this was not the case consistently. Table 3

[66] Product or service codes have four characters. Services codes start with a letter and product codes start with a number. The broad services category (e.g., the letter Y for construction or the letter D for automated data processing) refers to the first letter of the services code. To learn more about these codes, see GSA, Product and Service Code Manual (Washington, DC: June 2019), https://www.acquisition.gov/psc-manual.

shows the descriptive statistics for these variables, which are logged and rescaled in the model.

Table 3: Detailed Industry Salary and Service Code Invoice Rate Descriptive Statistics

Variable Name	Min	Max	Median	Geometric Mean	1 unit below	1 unit above	% of records NA	% of Obligation to NA records
Detailed Industry Salary	9,996	278,829	62,596	58,069	26,170	128,850	2.91%	1.01%
Service Code Invoice Rate	7,370	1,908,520	167,631	163,065	59,833	444,403	0.10%	0.04 %

Contract-Management Capacity

Office PBSA proportion: What share of office obligations for a given office were for performance-based services acquisition in the prior year.

Office service code experience: For any given contract, what proportion of obligations for the office went to contracts with the same product or service code over the past seven years. Table 4 shows the descriptive statistics for these variables, which are rescaled in the model.

Table 4: Office PBSA Proportion, Service Code Experience, and Paired Years Descriptive Statistics

Variable Name	Min	Max	Median	Arithmetic Mean	1 unit below	1 unit above	% of records NA	% of Obligation to NA records
Off. PBSA prop.	0%	100%	28.5%	34.4%	-25.8%*	94.7%	0.03%	0.00%
Off Serv. Code Exp.	0%	100%	1.3%	12.6%	-37.4%*	62.6%	0.03%	0.00%
Paired Years	0	7	4	3.53	-1.31*	8.38*	0.18%	0.52%

* 1 unit below/above values are less than minimum/maximum value for variable.

Paired History

Paired years: For any given contract's vendor and office pairing, how many of the past seven years involved interaction between the vendor and the office. For a new relationship, this value would be zero. Table 4 shows the descriptive statics for this variable, which is rescaled in the model.

Paired actions: For any given contract's vendor and office pairing, how many contracting actions did the vendor perform for that office across all contracts in the prior year. Table 5 shows the descriptive statistics for this variable, which is incremented by 1 to make zeros eligible for logarithmic transformation and is then logged and rescaled.

Table 5: Paired Actions Descriptive Statistics

Variable Name	Min	Max	Median	Geometric Mean	1 unit below	1 unit above	% of records NA	% of Obligation to NA records
Paired Actions	1**	7,806,579	27	35	0.5*	2,673	0.18%	0.52%

* 1 unit below/above values are less than minimum/maximum value for variable.
** True minimum value is 0.

Empirical Approach

The study team has created five statistical models, one per dependent variable metric. The binary outcome metric, used in the *Some Options, All Options, Breach Likelihood*, and *Terminations* models, uses a maximum likelihood logit multilevel model. In the case of the only continuous metric, *Breach Size*, an ordinary least squares multilevel regression is used. The samples vary between models based on relevance: the *Some Options* model is limited to defense service contracts with initial options to exercise; the *All Options* model's sample is limited to those contracts that exercise some options; *Terminations* and *Breach Likelihood* use the entire 1 million record defense services sample; and finally the *Breach Size* model is limited to a sample of those contracts that experienced a ceiling breach. The varying models are used to allow the *All Options* model to build off the *Some Options* results and the *Breach Size* model to build off the *Breach Likelihood* results. The estimating equations for each of these five statistical models are presented in Annex B.

In creating these models, all of the continuous variables are rescaled by subtracting the mean and then dividing by twice the standard deviation. The base values for the study variables are summarized above in the prior section. For the summary of the continuous variables, see Annex A.

SUMMARY OF INCLUDED CONTROL VARIABLES

The term "multilevel" refers to a modeling approach that captures differences between both individual contracts and larger groupings. This approach adopts techniques employed by Andrew Gelman and Jennifer Hill (2017) and Nicolas Sommet and Davide Morselli (2017) that allow for a different intercept for each of the sectors, acquirers, places of performance, and start fiscal years of each contract. "Acquirers" refers to the hierarchical description of each customer: the individual of contracting office (level 2) and the agency they report to (level 3). "Sectors" refers to the hierarchical description of the type of service: from top to bottom, the service area (level 2), the NAICS detailed industry (level 3), and the NAICS subsector (level 4).[67] Place of performance and start fiscal year are both captured by level 2 variables without further hierarchy. The multilevel groupings employed in this model and their respective counts are shown at the end of the each estimating equation in Annex B.

The more traditional level 1 inputs, in addition to the study variables discussed in the prior section, include three categories of inputs as controls.

Subsector-level and Detailed Industry Variables

The first category of variables draws on defense and overall U.S. economy NAICS economic sector data. NAICS codes are hierarchal: detailed industries have six-digit codes and the first three digits of that code refer to the parent subsector.

Subsector/detailed industry Herfindahl-Hirschman Index (HHI): Measures the level of consolidation within a given subsector or detailed industry (separate variables). This is calculated by squaring the percentage share of obligations going to each contractor and summing them up. The result is then logged and rescaled. This approach gives the greatest weight to the shares of the most prominent vendors, and a higher value represents greater consolidation.

Subsector/detailed industry DoD:U.S.: As the name suggests, this pair of variables indicates a ratio of the size of the DoD sector, measured in obligations, versus the comparable U.S. sector, measured in dollars of revenue. A larger ratio indicates a more defense-oriented sector and a smaller ratio indicates that the commercial, non-government, and civil sectors are proportionately larger. The ratio is capped at one, logged and rescaled.

Office and Vendor-Office Pair Variables

This focus on the contracting office as well as the pairing of the contract's vendor and office are the first categories that are new to this paper.

Office obligations: How much the office spent, in logged constant 2018 obligations, over the prior seven fiscal years. One dollar is added to this total to allow offices with no spending history to be logged.

Office focus: How concentrated the office's contract counts are in a small number of detailed industries. It uses the HHI transformation but tracks the number of contracts in each detailed industry rather than the dollars to each vendor. This value is then logged and rescaled, with a high value representing most contracts coming from a small number of codes. For an office with no history, the average value is imputed.

Paired share: What portion of the contracting spending of the office this vendor has won. It is calculated as the proportion of office obligations over the prior seven years that went to the vendor in question, rescaled. A high value in this variable may reflect vendor lock.

Contract-level Variables

There are three continuous scope variables that measure different aspects of the scale of the contract.

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[67] The service areas were originally developed for CSIS services reports (Berteau et al., 2013), although in those reports the categories of "facility-based" and "construction" were combined.

Initial base: The initial base of the contract converted into 2018 dollars based on contract start year, logged and rescaled.

Initial ceiling:base: The ratio of the initial ceiling to the *initial base*, the difference between the two being the sum of options that could be exercised.

Planned duration: The number of days between the signed date and the anticipated completion date based on the options exercised as reported at contract start, logged and rescaled.

Competition: Whether a contract was competed for, and if so, how many offers were received. There is a baseline of *no competition* and three alternatives further subdividing this variable: available for competition but receiving only *1 offer*, competed for and receiving *2–4 offers*, and competed for and receiving *5+ offers*.

Vehicle: The mechanism by which the service contract was awarded. There is a baseline of definitive contracts and purchase orders but also four types of indefinite delivery vehicles on which lines this variable is further subdivided: Single-Award IDCs (*S-IDC*), Multi-Award IDCs (*M-IDC*), Federal Supply Schedule or Government-Wide Acquisition Contracts (*FSS-GWAC*), and Blank Purchase Agreement or Basic Ordering Agreements (*BPA-BOA*).

Pricing: The method of payment for the vendor. A firm fixed-price method is used as a baseline, with six alternatives handled by dummy variables: (1) *incentive fee* contracts (whether fixed-price or cost-based and also including cost sharing contracts); (2) contracts made up of a combination of pricing methods or that are otherwise atypical, coded as *combination/other* contracts; (3) contracts where the form of reimbursement is driven by explicitly set rates (time and materials, labor hours, or fixed-price: level of effort, coded as *T&M/LH/FP:LoE*); (4) *other fixed-price*, including all types of fixed-price not covered by earlier categories; (5) whether the contract began as an undefinitized contract award (*UCA*); and (6) *other cost-based*, covering all types of cost-based contracts not covered by earlier categories.

Crisis funding: Whether the funding for a service was drawn from an emergency account. The baseline is drawing from non-emergency accounts, with three alternatives subdividing the variable into Overseas Contingency Operations (OCO), disaster response, and the American Recovery and Reinvestment Act (ARRA, coded as *recovery act* in the analysis).

Results

Options

Table 6 shows the results of the logit models for whether *Some Options* are exercised in a given contract and for whether *All Options* are exercised in a given contract. In Table 6 and subsequent model tables, the sign of the coefficient estimates whether the variable has a positive or negative association with the outcome measure. Likewise, because the variables are rescaled, their relative influence can be judged by comparing the absolute value of different coefficients, with larger values estimating a stronger relationship. However, the study team encourages the reader to interpret effect magnitude for a given variable by looking at the logit coefficients after they are transformed into odds-ratio form, as is done for all study variables in Table 7. An odds ratio of one indicates there is no relationship between a given variable and the outcome in question, while a ratio of greater than one suggests a positive relationship and a ratio of less than one suggests a negative relationship.

Service Complexity

Only one of the *service complexity* variables was statistically significant in either model. More specifically, *detailed industry salary* had no statistically significant effect in the models on the probability of options being exercised, while *office service code invoice rate* did have a statistically significant (at the 5 percent level) effect in the *All Options* model—where an increase in the invoice rate estimated a lower likelihood of all options being exercised. It should be noted, however, that when invoice rate was interacted with the pricing options variable, three of the cost-based pricing option schemes (*other cost-based*, *UCA*, and *combination/other*) estimated significant positive association with the likelihood of all options being exercised (significant at the 1 percent, 0.1 percent, and 5 percent levels, respectively).

Contract-Management Capacity

In *office PBSA proportion* did not have an independent statistically significant influence in either the *Some Options* model or the *All Options* model, and thus failed to support hypothesis $H_{2A.}$

That said, in the *Some Options* model, the interaction term between *paired actions* and *office PBSA proportion* estimated a statistically significant positive relationship between office use of performance-based contracting and the probability that some options are exercised, for a given level of *paired actions* (significant at the 0.1 percent level).

Table 6: Some Options and All Options

	Some Options Model	All Options Model
(Intercept)	**0.61** (0.19)**	**1.27** (0.13)***
Study Variables		
Log(Det. Ind. Salary)	0.03 (0.06)	0.06 (0.05)
Log(Serv. Code Invoice Rate)	**-0.07** (0.03)*	-0.05 (0.03)
Office PBSA Prop.	-0.02 (0.04)	0.04 (0.04)
Office Serv. Code Exp. %	0.00 (0.05)	**0.17** (0.05)***
Paired Years	**0.32** (0.02)***	**0.13** (0.02)***
Log(Paired Actions+1)	-0.01 (0.04)	**-0.13** (0.04)**
Contract Characteristics		
Log(Init. Base)	0.02 (0.03)	**-0.19** (0.03)***
Log(Init. Ceiling:Base)	**0.25** (0.01)***	**-0.79** (0.02)***
Log(Planned Dur.)	**0.42** (0.03)***	**-0.38** (0.04)***
Comp=1 offer	**0.07** (0.03)*	-0.00 (0.03)
Comp=2-4 offers	**0.11** (0.03)***	-0.02 (0.03)
Comp=5+ offers	**-0.17** (0.03)***	**-0.09** (0.03)**
Vehicle=S-IDC	**-0.70** (0.04)***	**-0.17** (0.04)***
Vehicle=M-IDC	**-0.30** (0.04)***	**-0.15** (0.04)***
Vehicle=FSS/GWAC	**-0.18** (0.04)***	-0.07 (0.04)$^{\cdot}$
Vehicle=BPA/BOA	**-0.52** (0.07)***	**0.27** (0.08)**
Pricing=Other Fixed-Price	**-0.56** (0.15)***	**-0.57** (0.20)**
Pricing=Incentive Fee	-0.33 (0.27)	0.32 (0.25)
Pricing=Comb./Other	**0.32** (0.08)***	-0.10 (0.07)
Pricing=Other Cost-Based	**0.14** (0.06)*	**0.17** (0.06)**
Pricing=T&M/LH/FP:LoE	0.00 (0.06)	-0.04 (0.06)
Pricing=UCA	-0.07 (0.11)	-0.11 (0.14)
Crisis=Recovery Act	**-0.36** (0.16)*	-0.24 (0.21)
Crisis=Disaster	-0.32 (0.30)	**-1.58** (0.43)***
Crisis=OCO	**-0.99** (0.10)***	**-0.43** (0.11)***
NAICS/Office Characteristics		
Log(Subsector HHI)	**-0.15** (0.06)**	0.02 (0.05)
Log(Subsector DoD:U.S.)	-0.04 (0.07)	0.05 (0.06)
Log(Det. Ind. HHI)	**-0.19** (0.04)***	**-0.10** (0.04)*
Det. Ind. DoD:U.S.	-0.06 (0.06)	**0.17** (0.06)**
Log(Office Obl.+1)	**0.14** (0.05)**	**-0.11** (0.03)***
Log(Office Focus)	**-0.48** (0.05)***	-0.08 (0.05)
Paired Share %	**-0.12** (0.05)*	-0.09 (0.05)
Interactions		
Log(Serv. Code Invoice Rate):Pricing=Other Fixed-Price		-0.10 (0.55)

Table 6: Some Options and All Options

	Some Options Model	All Options Model
Log(Serv. Code Invoice Rate):Pricing=Incentive Fee		-0.27 (0.54)
Log(Serv. Code Invoice Rate):Pricing=Other Cost-Based		0.29 (0.18)
Log(Serv. Code Invoice Rate):Pricing=Comb./Other		**0.40** (0.13)**
Log(Serv. Code Invoice Rate):Pricing=T&M/LH/FP:LoE		0.07 (0.18)
Log(Serv. Code Invoice Rate):Pricing=UCA		**0.89** (0.33)**
Office PBSA Prop.:Paired Share %	**0.29** (0.07)***	0.12 (0.08)
Office Serv. Code Exp. %:Log(Office Obl.+1)	**1.08** (0.14)***	
Office Serv. Code Exp. %:Log(Office Focus)		**0.24** (0.10)*
Paired Years:Pricing=Other Fixed-Price	0.01 (0.34)	
Paired Years:Pricing=Incentive Fee	**1.12** (0.47)*	
Paired Years:Pricing=Comb./Other	**-0.57** (0.17)***	
Paired Years:Pricing=Other Cost-Based	0.11 (0.08)	
Paired Years:Pricing=T&M/LH/FP:LoE	-0.07 (0.11)	
Paired Years:Pricing=UCA	-0.05 (0.22)	
Log(Init. Base):Log(Init. Ceiling:Base)	**0.50** (0.02)***	
AIC	88,975.17	73,416.80
BIC	89,434.70	73,850.61
Log Likelihood	-44,438.59	-36,660.40
Num. obs.	87,387	62,180
Var: ServArea:(NAICS6:NAICS3) (Intercept)	0.12	0.06
Var: Office:Agency (Intercept)	0.55	0.22
Var: NAICS6:NAICS3 (Intercept)	0.04	0.12
Var: Place (Intercept)	0.14	0.06
Var: NAICS3 (Intercept)	0.05	0.00
Var: Agency (Intercept)	0.06	0.07
Var: StartFY (Intercept)	0.05	0.02

***p < 0.001, **p < 0.01, *p < 0.05, ·p < 0.1. Numerical inputs are rescaled.

In the *Some Options* model, *office service code experience* proportion when considered by itself did not have a statistically significant relationship with the probability that some options are exercised, failing to support H_{2B}. However, the interaction term between *office obligations* and *office service code experience* estimated a highly significant, large-magnitude positive relationship between the level of *office service code experience* and the probability that some options are exercised, at a given level of *office obligations*. For most contracting offices with greater than average obligations, the interaction effect will outweigh the effect of *office* *service code experience* on its own, and thus *i* had a positive relationship with the probability that some options are exercised. For reference, the median value of the logged, standardized, and rescaled measure of *office obligations* was 0.128, which resulted in a net regression coefficient of 0.08 for *office service code experience*, a net positive relationship with the probability that some options are exercised.

For the *All Options* model, the results were more supportive for H_{2B}. The measure of *office service code experience* (as a percentage) had a statistically significant effect: a higher level of *office service code experience* estimated a greater probability that *all options* in a given contract are exercised. For every one-unit increase in the standardized measure of *office service code experience*, the odds that all options are exercised in a contract rose by a factor of 1.19, as can be seen in the odds ratio listed for this variable in Table 7. This relationship was reinforced by the interaction between *office service code experience* and *office focus*, which indicates that for offices that primarily worked with a smaller number of service codes, the relationship between service code experience and all options being exercised is stronger.

Paired History

For both *Some Options* and *All Options*, *paired years* demonstrated a positive relationship with the probability that some options are exercised, when considered on its own (significant at the 0.1 percent level in both cases). For a one-unit increase in the standardized measure of *paired years*, the odds that some options will be exercised rose by a factor of 1.38; the odds that all options will be exercised rose by a factor of 1.13.

Table 7: Options Study Variable Odds Ratios

	Variable	Odds Ratio	95% Confidence Interval	
			Lower Bound	Upper Bound
Some Options Model	Log(Det. Ind. Salary)	1.03	0.92	1.14
	Log(Serv. Code Invoice Rate)	0.93	0.89	0.99
	Office PBSA Prop.	0.98	0.9	1.07
	Office Serv. Code Exp. %	1	0.9	1.11
	Paired Years	1.38	1.32	1.44
	Log(Paired Actions+1)	0.99	0.92	1.08
All Options Model	Log(Det. Ind. Salary)	1.06	0.95	1.17
	Log(Serv. Code Invoice Rate)	0.95	0.9	1.01
	Office PBSA Prop.	1.05	0.96	1.14
	Office Serv. Code Exp. %	1.19	1.07	1.32
	Paired Years	1.13	1.09	1.19
	Log(Paired Actions+1)	0.88	0.81	0.95

As shown in Table 6 above, *paired years* also showed statistically significant interaction with several categories of contract pricing systems. When contract pricing is incentive-based, *paired years* had a very high-magnitude significant positive relationship with *some options* probability (significant at the 5 percent level). When pricing falls into the *combined/other* category, the relationship between *paired years* and *some options* flipped to negative but remained statistically significant at the 5 percent level. Thus, H_{3A} is entirely supported in the *All Options* model and largely substantiated in the *Some Options* model, unless contract pricing falls into the *combined/other* category.

The *paired actions* had no statistically significant relationship with the probability of *some options* when considered on its own. Moreover, the *paired actions* variable estimated a negative relationship with the probability that all options are exercised (significant at the 0.1 level). H_{3B} is therefore not supported for *Some Options* or *All Options*.

Further Discussion

While the reader will be left to pick through the control variables largely on their own, the contract scope variables are worth commenting on briefly. In the *Some Options* model, the *initial ceiling:base* ratio and the *planned duration* of the contract all had positive highly significant relationships with the probability that some options will be exercised. The *All Options* model showed the opposite relationship, where *initial ceiling:base* and *planned duration* were correlated with a lower probability that all options will be exercised. In the *All Options* model, *initial base* was also significant with a negative coefficient, but in some options model it was not.

The two above multilevel models include varying intercepts for the government contracting office or agency, the service area, the NAICS detailed industry and subsector, the place of performance, and the contract start fiscal year. The variances are listed at the bottom of Table 6, where a greater value indicates greater variation in the intercepts for different categories within the variable—in other words, some levels have higher magnitude positive intercepts and some have lower negative intercepts. In both of these models, but particularly in the *Some Options* model, there was a large degree of variance between government purchasing entities, implying that a sizeable portion of the overall variance, especially in the *Some Options* model, is driven by differences between contracting offices or agencies. This suggests that while the results hold, much of the variation in whether some or all options of a contract are exercised depends on factors specific to the contracting office or agency. In the *Some Options* model, service area and place of performance also accounted for a fairly large portion of the variance, but they had a much smaller presence in the *All Options* model.

Ceiling Breaches

Table 8 shows the results for the logit model of ceiling breach likelihood in the left column and the ordinary least squares regression model for ceiling breach size among contracts experiencing a breach in the right column. While the *Breach Size* regression coefficients can be interpreted as direct estimates of the influence of variables on contract size, the *Breach Likelihood* logit coefficients are more straightforward to understand after being transformed into odds ratios, as is done for the study variables in Table 9 below.

Service Complexity

For service complexity, only the *service code invoice rate* was significant (0.1 percent level for both the *Breach Likelihood* and *Breach Size* models). A one-unit increase in the rescaled *service invoice rate estimated* was associated with a 1.05 odds ratio for *ceiling breach likelihood* and an 8 percent increase in *breach size* when a breach has occurred (significant at the 0.1 percent level in both cases), in line with the predictions of H_{1B}.

Contract-management Capacity

For office contract-management capacity, the results were more complicated and offered little support for H_2. *Office PBSA proportion* estimated a greater likelihood of ceiling breaches (significant at the 1 percent level), contrary to expectations, but had no significant effect on breach size. That said, for the *Breach Likelihood* model, the interaction of *office PBSA proportion* and the *planned duration* estimated a lower *breach likelihood* and, when a breach has occurred, a smaller *breach size* (significant at the 0.1 percent level in both cases). The interaction of an *office PBSA proportion* and another study variable, the *paired actions*, had complicated results, which are covered in the next subsection.

For *office service code experience*, neither model supported the hypotheses as the sign of each coefficient was positive, showing increased risks which is contrary to expectations (significant at the 1 percent level).

Paired History

The paired year variables relevant to H_{3A} was significant but only for *Breach Likelihood* and not *Breach Size*. A one-unit increase in rescaled *paired years* estimated a 0.91 times lower likelihood of ceiling breaches (significant at the 0.1 percent level). Contrary to expectation, a one-unit shift in rescaled *paired actions* estimated a 1.56 times greater likelihood of ceiling breaches (significant at the 0.1 percent level). However, given that a breach occurred, *paired actions* correlated with smaller *breach sizes*, with a one-unit shift in the rescaled paired action methods being associated with 7 percent reduction. The interaction between *paired actions* and *office PBSA proportion* was significant for both models, but with opposite signs. The interaction between *paired years* and *office PBSA proportion* estimated a higher likelihood of breaches, but the *Breach Size* model found that a one-unit increase of these two rescaled variables together estimated an 18 percent decrease in *breach size* (significance of 0.1 percent in both cases).

Table 8: Ceiling Breaches

	Likelihood (Logit)	Size Given Breach (Regression)
(Intercept)	**-4.32** (0.18)***	**8.80** (0.12)***
Study Variables		
Log(Det. Ind. Salary)	-0.07 (0.06)	-0.05 (0.06)
Log(Serv. Code Invoice Rate)	**0.05** (0.01)***	**0.08** (0.02)***
Office PBSA Prop.	**0.12** (0.03)***	-0.03 (0.03)
Office Serv. Code Exp. %	**0.17** (0.02)***	**0.12** (0.03)***
Paired Years	**-0.09** (0.01)***	0.03 (0.02)
Log(Paired Actions+1)	**0.45** (0.02)***	**-0.07** (0.03)*
Contract Characteristics		
Log(Init. Base)	**1.37** (0.01)***	**2.66** (0.02)***
Log(Init. Ceiling:Base)	**0.30** (0.01)***	**0.29** (0.02)***
Log(Planned Dur.)	**0.30** (0.01)***	**0.06** (0.02)**
Comp=1 offer	0.00 (0.02)	-0.01 (0.03)
Comp=2-4 offers	**0.13** (0.01)***	**-0.09** (0.02)***
Comp=5+ offers	**0.19** (0.01)***	**-0.05** (0.02)*
Vehicle=S-IDC	**-0.48** (0.02)***	0.03 (0.02)
Vehicle=M-IDC	**-0.14** (0.02)***	-0.00 (0.03)
Vehicle=FSS/GWAC	-0.00 (0.03)	**0.11** (0.05)*
Vehicle=BPA/BOA	**-0.39** (0.03)***	**-0.15** (0.05)**
Pricing=Other Fixed-Price	**-0.59** (0.06)***	**-1.02** (0.10)***
Pricing=Incentive Fee	**2.37** (0.07)***	**0.79** (0.11)***
Pricing=Comb./Other	**0.29** (0.05)***	**0.47** (0.07)***
Pricing=Other Cost-Based	-0.05 (0.03)	**0.88** (0.05)***

Table 8: Ceiling Breaches

	Likelihood (Logit)	Size Given Breach (Regression)
Pricing=T&M/LH/FP:LoE	**0.13** (0.04)**	**0.65** (0.07)***
Pricing=UCA	0.04 (0.04)	**0.33** (0.06)***
Crisis=Recovery Act	0.08 (0.04)·	-0.06 (0.06)
Crisis=Disaster	0.07 (0.09)	**0.40** (0.13)**
Crisis=OCO	-0.07 (0.05)	0.07 (0.07)
NAICS/Office Characteristics		
Log(Subsector DoD:U.S.)	-0.04 (0.03)	**0.14** (0.05)**
Log(Det. Ind. HHI)	0.03 (0.07)	0.11 (0.08)
Det. Ind. DoD:U.S.	**-0.11** (0.03)***	0.01 (0.04)
Log(Office Obl.+1)	0.05 (0.05)	**0.15** (0.06)**
Log(Office Obl.)	0.00 (0.02)	0.02 (0.02)
Log(Office Focus)	**-0.34** (0.04)***	0.01 (0.05)
Paired Share %	**-0.22** (0.02)***	**0.08** (0.03)*
Interactions		
Office PBSA Prop.:Log(Paired Actions+1)	**0.46** (0.02)***	**-0.18** (0.04)***
Office PBSA Prop.:Log(Planned Dur.)	**-0.10** (0.02)***	**-0.17** (0.03)***
AIC	362,045.48	277,317.31
BIC	362,541.73	277,710.89
Log Likelihood	-180,980.74	-138,615.66
Num. obs.	1,000,000	69,776
Var: ServArea:(NAICS6:NAICS3) (Intercept)	0.25	0.13
Var: Office:Agency (Intercept)	1.47	0.15
Var: NAICS6:NAICS3 (Intercept)	0.12	0.05
Var: Place (Intercept)	0.27	0.10
Var: NAICS3 (Intercept)	0.16	0.07
Var: Agency (Intercept)	0.17	0.06
Var: StartFY (Intercept)	0.02	0.00
Var: Residual		3.04

***p < 0.001, **p < 0.01, *p < 0.05, ·p < 0.1. Numerical inputs are rescaled.

Further Discussion

Moving to the contract-level control variables, the results relating to competition showed a noteworthy contrast between the two models: for multi-offer competition, the relationship for *breach likelihood* and *breach size* was estimated in opposite directions. For *breach likelihood*, competition with 2 to 4 offers and with 5 or more offers both estimated a respective greater likelihood of ceiling breaches (a ratio of 1.14 and 1.21 at the 5 percent and 0.1 percent significance levels, respectively). For *breach size when a breach occurred*, the results were the opposite: competition with 2 to 4 offers estimated 9 percent smaller breaches, and competition with 5 or more offers estimated 5 percent smaller breaches (significant at the 0.1 and 5 percent levels, respectively).

The results were more consistent for the scope variables *initial base*, *initial ceiling:base*, and *planned duration*. The base size of the contract was a powerful predictor of *breach likelihood*, and a one-unit increase in rescaled base size estimated a 3.94 times increase in *breach likelihood* and a 266 percent increase in *breach size*, given the occurrence of a breach (significance at the 0.1 percent level in both cases).

The *vehicle* variable proved to be influential in estimating *breach likelihood*, with single-award IDCs, multiple award IDCs, and BPA/BOA all estimating a lower chance of a breach occurring (each significant at the 0.1 percent level). For *breach size*, BPA/BOAs estimated smaller breaches, while FSS/GWAC vehicles estimated larger breaches, though in both cases this effect was only significant at the 5 percent level. *Pricing* went the other way, being a weaker estimator for *breach likelihood* than for *breach size,* with incentive fee contracts standing out as associated with a higher *breach likelihood* and greater *breach size* when a breach occurs. For the controls based on NAICS sector statistics, the results for the *Breach Likelihood* model and the *Breach Size* model did not align with different variables proving significant between the different models. The *subsector/detailed industry DoD:U.S.*, having a proportionally larger defense sector, estimated a lower likelihood of breaches for *detailed industry DoD:U.S.,* but for the *subsector DoD:U.S.* those breaches that did occur were estimated to be larger (significance levels of 0.1 percent and 1 percent, respectively). Unlike the other models, *subsector HHI* was not included in this model because variance inflation factor checks indicated that the inclusion of this variable raised risks of multicollinearity unless one of the NAICS measures was removed.

The last category of level 1 control variables is the office characteristics. In the *Breach Likelihood* model, a one-unit increase in the rescaled measure of the percent of an office's market held by a single vendor—the *paired share* variable—was associated with a 0.89 times lower chance of a ceiling breaching occurring but also with 8 percent larger *breach size* when one occurred (significant at 0.1 and 5 percent levels, respectively). For both the *Breach Likelihood* and *Breach Size* models, a larger office volume of obligations—the *office obligations* metric—estimated greater risks. The *office focus* estimated that more focused offices were less likely to experience a breach (significant at the 0.1 percent level).

Table 9: Ceiling Breach Study Variables Odds Ratio

		95 % Conf. Interval	
Variable	Odds Ratio	Lower Bound	Upper Bound
Log(Det. Ind. Salary)	0.93	0.83	1.04
Log(Serv. Code Invoice Rate)	1.05	1.02	1.08
Office PBSA Prop.	1.12	1.07	1.18
Office Service Exp. %	1.18	1.13	1.24
Paired Years	0.91	0.89	0.93
Log(Paired Actions+1)	1.56	1.5	1.62

Turning to multilevel variables, recall that there are different intercepts for *office* and agency (levels 2 and 3): service area, NAICS detailed industry, and *NAICS* subsector (levels 2 through 4); place of performance (level 2) and start fiscal year (level 2). Among these, contracting offices (level 2) and their parent agencies (level 3) explained a fair amount of the observed variance. Contracting offices in particular explained the most variance in each model; moreover, in the *Breach Likelihood* model, they explained more variance than the rest of the level 2–4 variables put together.

Terminations

Table 10 shows the multilevel model for contract terminations and the corresponding estimates for regression coefficients. As described in the prior section, this is a logit model, so for the convenience of the reader in interpreting effect magnitudes, the odds ratios for study variables are listed in Table 11.

Service Complexity

No service contract complexity variable was statistically significant on its own. The interaction between *detailed industry salary* and the *pricing* categorical variable was significant for several pricing systems. For the *other-fixed price* and time *and materials/labor hours/fixed price:level of effort* categories of pricing, the model estimated a negative relationship between average salary and the probability of the contract being terminated (significant at the 0.1 percent level). However, when contract pricing falls into the *other cost-based* category (which encompasses almost all cost-plus contracts), there was a positive relationship estimated between *detailed industry salary* and the probability of termination occurring, though this effect was only statistically significant at the 1 percent level.

Table 10: Terminations Model

	Termination
(Intercept)	**-4.56** (0.15)***
Study Variables	
Log(Det. Ind. Salary)	-0.03 (0.06)
Log(Serv. Code Invoice Rate)	-0.01 (0.02)
Office PBSA Prop.	**0.09** (0.04)*
Office Serv. Code Exp. %	**0.41** (0.04)***
Paired Years	**-0.26** (0.02)***
Log(Paired Actions+1)	**-0.07** (0.03)*
Contract Characteristics	
Log(Init. Base)	**0.27** (0.02)***
Log(Init. Ceiling:Base)	**0.49** (0.01)***
Log(Planned Dur.)	**0.87** (0.03)***
Comp=1 offer	**0.36** (0.03)***
Comp=2-4 offers	**0.35** (0.03)***
Comp=5+ offers	**0.72** (0.03)***
Vehicle=S-IDC	**-0.66** (0.03)***
Vehicle=M-IDC	**-0.39** (0.03)***
Vehicle=FSS/GWAC	**-0.17** (0.05)***
Vehicle=BPA/BOA	**-0.92** (0.06)***
Pricing=Other Fixed-Price	**-1.52** (0.09)***
Pricing=Incentive Fee	**-1.25** (0.45)**
Pricing=Comb./Other	-0.11 (0.11)
Pricing=Other Cost-Based	**-0.42** (0.08)***
Pricing=T&M/LH/FP:LoE	**-0.44** (0.09)***
Pricing=UCA	**-0.80** (0.15)***

Table 10: Terminations Model

	Termination
Crisis=Recovery Act	-0.21 (0.13)
Crisis=Disaster	**0.49** (0.20)*
Crisis=OCO	0.02 (0.07)
NAICS Characteristics	
Log(Subsector HHI)	-0.01 (0.05)
Log(Subsector DoD:U.S.)	-0.01 (0.07)
Log(Det. Ind. HHI)	0.00 (0.04)
Det. Ind. DoD:U.S.	0.11 (0.06)$^{\cdot}$
Office Characteristics	
Log(Office Obl.+1)	0.01 (0.03)
Log(Office Focus)	**-0.31** (0.05)***
Paired Share %	**-0.13** (0.04)***
Interactions	
Paired Years:Pricing=Other Fixed-Price	**-1.42** (0.15)***
Paired Years:Pricing=Incentive Fee	0.30 (0.94)
Paired Years:Pricing=Comb./Other	0.24 (0.23)
Paired Years:Pricing=Other Cost-Based	**0.41** (0.14)**
Paired Years:Pricing=T&M/LH/FP:LoE	**-0.62** (0.18)***
Paired Years:Pricing=UCA	-0.53 (0.28)$^{\cdot}$
AIC	137657.97
BIC	138201.49
Log Likelihood	-68782.99
Num. obs.	1000000
Var: CrisisProductOrServiceArea:(NAICS:NAICS3) (Intercept)	0.19
Var: Office:Agency (Intercept)	0.74
Var: NAICS:NAICS3 (Intercept)	0.13
Var: PlaceCountryISO3 (Intercept)	0.38
Var: NAICS3 (Intercept)	0.04
Var: Agency (Intercept)	0.07
Var: StartFY (Intercept)	0.00

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$. Numerical inputs are rescaled.

Contract-Management Capacity

A higher level of office *service code experience or office PBSA proportion* was associated with a higher probability of contract termination, exactly the opposite of what was expected in H_2 (significant at the 0.1 and 5 percent levels, respectively).

Paired History

The *paired years* variable demonstrated a negative relationship with the probability of termination—specifically, a one-unit increase in the standardized measure of *paired years* led to a 33 percent fall in the odds of termination, which provides evidence in favor of H_{3A} (significant at 0.1 percent level). For *paired actions* the results were also significant though of lower magnitude, with a one-unit increase in the scaled variable associated with a 7 percent lower *termination likelihood,* supporting for H_{3B}.

Further Discussion

There are several interesting relationships exhibited among the control variables that are worth commenting on. First, *competition*, across the board, was associated with a higher risk of termination (significant at the 0.1 percent level). The magnitude of the relationship was greatest for competition with 5 or more offers, which had an odds ratio of 2.05 times greater likelihood of termination versus contracts that were not competitively awarded.

The contract-scope controls *initial base*, *initial ceiling:base*, and *planned duration* all estimated positive relationships with the probability of contract termination—that is, contracts with larger initial purchases, longer planned time periods, or elevated amounts of options relative to their base size were all more likely to be terminated (significant at the 0.1 percent level).

Table 11: Termination Study Variables Odds Ratio

		95 % Conf. Interval	
Variable	Odds Ratio	Lower Bound	Upper Bound
Log(Det. Ind. Salary)	0.97	0.86	1.09
Log(Serv. Code Invoice Rate)	0.99	0.94	1.03
Office PBSA Prop.	1.09	1.01	1.18
Office Service Exp. %	1.5	1.38	1.63
Paired Years	0.77	0.74	0.81
Log(Paired Actions+1)	0.93	0.88	0.99

Turning to office characteristics, *office focus* was associated with a lower rate of termination, with a one-unit increase in the scaled variable tied to a 26 percent reduction in termination likelihood (significant at the 0.1 level). A smaller reduction in termination risk was also found for *paired share*. A one-unit increase in the rescaled proportion of office obligations going to the vendor in question was associated with a 12 percent reduction in risk of termination likelihood (significant at the 0.1 level).

The variance for each multilevel category is included at the bottom of Table 10. A larger variance corresponds with a greater range in intercepts for that multilevel variable, which is to say that the differences between categories within the variable can matter more. The variance for acquirer (office and agency) is quite elevated, suggesting a large portion of the variety in termination outcomes comes from variation between offices. While not as high, the cumulative variance for sector-based variables is also elevated, as is the variance for place of performance, again implying that a substantial portion of overall variation in the data is driven by differences between categories rather than within them.

Discussion

This section presents cross-cutting tables that include all the relevant models as well as the study variables and related interactions for each hypothesis. The hypothesized relationship is noted for each model, and significant results that support the hypothesis are highlighted in grey.

Service Complexity

For the *Some Options, Breach Likelihood*, and *Breach Size* models, there is support for H_{1B}'s argument, showing that *service code invoice rate* might be a proxy for service contract complexity. This finding, summarized in Table 12, was significant at the 0.1 percent level for ceiling breach likelihood and the average size of the resulting breaches, and it was significant at the 5 percent level for the likelihood of exercising *some options*. However, no such support was found for H_{1A}, which examined the average U.S. salary paid in the detailed industry in question.[68]

[68] At the 0.10 significance level, the service code invoice rate does predict a lower likelihood of any options being exercised, but this result does not meet the significance standard of this report.

Table 12: Service Complexity Results across Models

	Options Exercised		Ceiling Breach		Termination
	P(Some) (Logit)	P(All| Some) (Logit)	P(Breach) (Logit)	Breach Size | Breach (OLS)	P(Term.) (Logit)
Hypothesized Relationship	**Negative**		**Positive**		**Positive**
Log(Det. Ind. Salary)	0.03 (0.06)	0.06 (0.05)	-0.07 (0.06)	-0.05 (0.06)	-0.03 (0.06)
Log(Serv. Code Invoice Rate)	**-0.07*** (0.03)	-0.05 (0.03)	**0.05***** (0.01)	**0.08***** (0.02)	-0.01 (0.02)
Log(Serv. Code Invoice Rate): Pricing=Other Fixed-Price		-0.10 (0.55)			
Log(Serv. Code Invoice Rate): Pricing=Incentive Fee		-0.27 (0.54)			
Log(Serv. Code Invoice Rate): Pricing=Comb./Other		0.29 (0.18)			
Log(Serv. Code Invoice Rate): Pricing=Other Cost-Based		**0.40**** (0.13)			
Log(Serv. Code Invoice Rate): Pricing=T&M/LH/FP:LoE		0.07 (0.18)			
Log(Serv. Code Invoice Rate): Pricing=UCA		**0.89**** (0.33)			

Some possible explanations for *service code invoice rate* consistently outperforming the *detailed industry salary* are less theoretically interesting; for example, service codes, as a measure specific to government contracting, may have smaller bands of service contract complexity than detailed industry. Another complicating factor is that detailed industries in many cases include provision of not just services but also of products or R&D. That said, the study team examined the possibility of greater reliance on service codes over NAICS codes, but they did not find that service codes performed better on their own.

That said, when considering this difference, it is helpful to review the underlying characteristics that service complexity is intended to measure: knowledge requirements, uncertainty and difficulty in measurement, and asset specificity. While both metrics have relevance in each area, invoice rate may do a better job of capturing the range of concepts covered by service complexity. When a contract touches on the dimensions of asset specificity laid out by Williamson—setting up facilities at a particular site, investing in special purpose assets, or staff that have learned or will learn by doing—all of these factors would likely increase invoice rates but, aside from the human asset measures, may not be captured in salaries.[69] Meanwhile a high wage contract may be a form of labor substitution, provisioning a highly experienced or educated worker who nonetheless works under the direct supervision of the government customer. The government may simply be getting

[69] Williamson, The Economics of Organization, 555.

what it pays for in terms of salary and not be taking on higher risk, despite bringing on contractors from an expensive detailed industry.

This kind of relationship does not exist, however, with *Terminations* or in the *Some Options* model. For terminations, this could also reflect *service code invoice costs* capturing asset specificity. As Brown and Potowski note, "specialized investments raise entry barriers in subsequent rounds of contracting, creating monopolistic conditions in which a vendor can opportunistically exploit the contracting organization by raising prices or reducing service quality with little risk of penalty."[70] That said, the controls that more directly measured monopoly risks—the HHI indices, the paired share of obligations, and the presence of competition—often estimated a lower likelihood of ceiling breaches, even if they also at times significantly estimated that these breaches would be higher and that the likelihood of terminations would be lower.

An alternative explanation ties the difficulty of measuring complex service contracts. Lawther argues "[t]he greater the complexity/uncertainty, however, the less probable valid measures can be obtained."[71] Thus measurement may be easier in lower-cost categories such as "Operation/Dining Facilities" and "Custodial – Janitorial Services." By comparison, medium- and higher-complexity categories can be technically demanding to monitor, such as "Architecture-Engineering Services," or may represent a greater extent of partnership, such as interaction-intensive administrative and managerial support services captured in "Other Professional Services." Measurement challenges might make it harder to determine whether an option should be exercised or whether a termination was appropriate, but even in those cases the government can track changes to cost ceilings. On the other hand, all options are less likely to be exercised when invoice rates are high, which does indicate some judgment on performance. That said, the decision to not exercise all options may be an easier one than the choice to not exercise some, let alone to terminate a contract.

The interaction between all options and pricing also found that when invoice rates were high, all options were more likely to be exercised for certain contract pricing mechanisms: combination/other contracts, all of the cost-based contract variables with the exception of incentive fee contracts, and UCAs. This phenomenon is consistent with a use of these contracting mechanisms to reduce uncertainty observed by Sanders and Ellman: "determining price at the start of a project can be a high-risk endeavor, and the government may prefer a cost-based contract as a means of avoiding a higher risk premium."[72] That said, contrary to expectations, no such relationship was found in the interaction with *service code invoice rate* and *incentive fee contracts.*

The *service code* invoice findings suggest that deeper study on the small subset of contracts included within the services contract inventory may be worthwhile. *Service code invoice rate* can differentiate between higher-charging and lower-charging service categories but not between comparatively expensive and low-cost vendors within the same category. That analysis would face data quality challenges. Unfortunately, this report's investigation did reveal oddities in the later years, with multiple categories suddenly declining in 2016 and with some categories collapsing their rate in 2017. Sometimes the end of a single large

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[70] Trevor L. Brown and Matthew Potoski, "Transaction Costs and Contracting: The Practitioner Perspective," Public Performance & Management Review 28, no. 3 (March 2005), 329, https://www.jstor.org/stable/3381157.
[71] Lawther, "Contracting for the 21st Century, 7.
[72] Sanders and Ellman, Use of Incentives in Performance-Based Logistic Contracting, 30.

contract can do a great deal to explain fluctuations, as the study team found with Waste Treatment & Storage Facilities, but that explanation did not hold in other cases. Because this variable is defined to refer back to service code characters in the year prior to contract start, the 2016 and 2017 invoice rates are not included in any of the statistics; that said, these challenges could be an obstacle to future research. In addition, any contract-level examination of rate does run the risk of a reverse causation challenge, as a contract that is performing poorly may have fluctuations in staffing levels as a result of problems and not only as a source of them. Furthermore, future researchers may benefit from examining whether product or service codes, such as managerial contracts, can do a better job than NAICS detailed industries in identifying potential risk categories.

Finally, one of the contract-level controls included in the study may also act as a proxy for service contract complexity. Specifically, the ratio of initial contract ceiling to base significantly estimates changes in performance measures for all the dependent variables. As was discussed in Chapter 4Chapter 0, the majority of contracts have no options to exercise, but those with options represent a disproportionate share of obligations. This measure may relate to service contract complexity: unexercised options give the contacting office greater flexibility but may also reflect greater uncertainty about how the contract will be executed. A greater *initial ceiling:base* ratio, that is to say a contract with more room to expand, did positively estimate a greater likelihood of ceiling breaches and breach sizes, although base size was the more influential factor. For the *Some Options* and *All Options* models, in line with expectations, a greater ratio estimated a higher chance that some options would be executed but a lower chance that all would be. However, the most intriguing result was that despite the flexibility offered by a large ratio, the *termination likelihood* went up substantially; in fact, the influence of the *initial ceiling:base* ratio on termination risk was estimated to have a higher magnitude than the influence of the *initial base* itself, although a lower one than the contract's *planned duration*.

While factors other than service contract complexity do drive up the ratio—limitations on multiyear funding for Operations and Maintenance contracts, for example—practitioners and future researchers should nonetheless consider whether mechanisms found to mitigate the risks of complex services, for example, a closer partnership, may be more important in situations where there is a large proportion of options to be exercised. On the other hand, it may also be worth examining whether more options might increase the complexity of some contracts that might otherwise be simpler rather than providing flexibility to aid in managing the service's inherent complexity.

Contract-Management Capacity

The results largely did not support—and were often significantly contrary to—the expectations of H_2. As shown in Table 13, the sole finding that directly supports the hypothesis is that for contracts with some options exercised, a greater degree of office service code experience estimated a higher likelihood that all options would be exercised (significant at the 0.1 percent level). However, for all other dependent variables, higher *office service code experience* significantly estimated worse performance (i.e. lower likelihood of some options exercised, more likely and larger ceiling breaches, and more likely terminations).

Turning to interactions, the interaction between *office obligations* and *office service code proportion* positively estimated a greater likelihood that some options would be exercised (significant at the 0.1 percent level). The magnitude of this relationship is higher than any other in the contract-management capacity category and suggests that the volume of experience with a service that an office has may matter more than its proportion. However, for All Options, it is instead customers with a greater *office focus* that have a stronger positive relationship between *service code proportion* and the possibility that all options will be exercised, given some exercised options.

Table 13: Contract-Management Capacity Results Across Models

	Options Exercised		**Ceiling Breach**		**Termination**
	P(Some) (Logit)	**P(All| Some)** (Logit)	**P(Breach)** (Logit)	**Breach Size | Breach** (OLS)	**P(Term.)** (Logit)
Hypothesized Relationship	**Positive**		**Negative**		**Negative**
Office PBSA Prop.	-0.02 (0.04)	0.04 (0.04)	**0.12** (0.03)***	-0.03 (0.03)	**0.09** (0.04)*
Office Serv. Code Exp. %	0.00 (0.05)	**0.17** (0.05)***	**0.17** (0.02)***	**0.12** (0.03)***	**0.41** (0.04)***
Office PBSA Prop.: Log(Paired Actions+1)			**0.46** (0.02)***	**-0.18** (0.04)***	
Office PBSA Prop.: Log(Planned Dur.)			**-0.10** (0.02)***	**-0.17** (0.03)***	
Office PBSA Prop.: Paired Share %	**0.29** (0.07)***	0.12 (0.08)			
Office Serv. Code Exp. %: Log(Office Obl.+1)	**1.08** (0.14)***				
Office Serv. Code Exp. %: Log(Office Focus)		**0.24** (0.10)*			

In the case of *office PBSA proportion*, there were no significant results for two of the dependent variables. For *some options*, *breach likelihood* metrics, and terminations, the results were significant and opposed to the hypothesis: a greater proportion of office performance-based contracting estimated a lower likelihood that some options would be exercised and a higher likelihood of ceiling breaches and terminations. However, the interactions do show mixed results that support some of the findings.

The interactions explored all focused on the proportion of office performance-based contracting, and thus they overlap with the literature on relational contracting as well as the relationship history results discussed in the next section. Yang, Hsieh, and Li center their definition of implementation capacity around the customer's ability to create public-private partnerships.[73] Performance-based services contracting is one means of facilitating such partnerships, and thus the interactions tested were combinations under which partnerships may prove more likely to be successful. For the two models dealing with

73 Yang, Hsieh, and Li, "Contracting Capacity and Perceived Contracting Performance," 692.

options, the interaction between *office PBSA proportion* and the *paired share* of office obligations sought to examine whether performance-based approaches may mitigate the potential risks of reliance on a particular vendor. The interaction did estimate a higher likelihood that some options would be exercised (significant at the 0.1 percent level). Another tested interaction for the *Breach Likelihood* model was the relationship between *office PBSA proportion* and the *planned duration* of the contract. The result adds support to Yang, Hsieh, and Li's finding that the performance influence of process implementation capacity increased over time; indeed, the interaction did estimate a lower *breach likelihood* and smaller *breach size* (both significant at the 0.1 percent level).[74] The remaining interactions with the number of paired contract actions (the *paired actions* study variable) had a significant positive or negative influence on performance, depending on the model, and are discussed in the next section.

While the service-code and performance-based contracting interaction terms have some results in line with theory, overall it does not appear that the two proxy variables used in H_2 were successful in capturing the larger phenomenon of office capacity. For *office PBSA proportion*, the problem may be that the reputation of performance-based contracting is so strong that offices that only weakly adhere to its tenets may overclaim their involvement in it. For the related field of performance-based logistics, past CSIS work has found that the definitions used can vary widely and often can be overly expansive. The interactions do suggest that this field does add some value, but it may be better employed in future research efforts on a contract-by-contract basis rather than to study office-level trends.

The explanation may simply be that even a rough proxy for office capacity may require personnel or at least office-specific budget information that is not available through FPDS or other open-source reporting. The models do indicate that there are office characteristics not captured in the level 1 controls: in each of the five models, the varying intercepts for each contracting office explain more variance than the remainder of the higher-level terms included in the model.

For the *Terminations* and *Breach Likelihood* models, *office focus* proved more promising than either of the two office capacity study variables. This measure of the distribution of contract counts between different NAICS sectors found that an office more focused on a small number of sectors estimated a lower risk of breaches or termination (both significant at 0.1 percent level). However, for the two models dealing with options, a focused office was less likely to exercise some options and less likely to go on to exercise all options once some options had been exercised (significant at the 0.1 and 5 percent level, respectively).

For future researchers, the best case would be greater access to statistics on contracting offices. Absent that, possible areas of interest may be to focus specifically on contracts for managerial capacity, which Brown and Potoski discussed both as a way to increase office capacity and as being a risk area for monopoly in certain circumstances.[75] Another approach would build on the fact that many offices rely on a small number of indefinite delivery contracts and examining the relationship of offices to vehicles, as well as considering the inclusion of specific contract vehicles as a level of analysis, which may capture some of the unexplained office variance in the model. Finally, this dataset may be usefully combined with more survey-based approaches that focus on federal contracting, such as those

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74 Ibid., 691.
[75] Brown and Potoski, "Contracting for Management," 333-336.

performed by Apte and Rendon, to calibrate whether this dataset can replicate the importance of office capacity in those cases where more detailed survey measures are available.[76]

Paired History

The history between a vendor and contracting office, as shown in Table 14, proved the most reliable estimator of the study variables, supporting H_{3A}. *Paired history*, the count of years out of the past seven that the buyer had the vendor under contract, estimated a greater likelihood of some and all options being exercised, a lower likelihood of ceiling breach, and a lower likelihood of termination (significant at the 0.1 percent level in all cases). For average contract breach size, no significant relationship was found. *Paired history* does not directly measure trust, though it should make ex ante evaluation easier because the office would have more information on hand regarding vendor past performance.[77] Yang, Hsieh, and Li found significant differences in which contract management capacities matter over time, and while they were focused on the duration of an individual contract, rather than the larger government-vendor relationship, the same dynamics may apply.[78] In the best case, this sustained partnership may be an opportunity to develop trust and, as Fernandez covers, to build a relationship that engages in joint problem solving.[79] The study team looked at interactions between *paired history* and *pricing mechanism* in two of the models, but the results were sufficiently inconsistent within and between models as to resist straightforward analysis.

The study team had limited the number of years considered for both practical and theoretical reasons. The practical reason is that FPDS data is most readily available starting in FY 2000; additionally, limiting this and other longer-term variables to seven years allows for an equivalent observation period, regardless of contract start year. The theoretical justification for this decision draws from the finding by Fernandez that the influence of trust does not increase over longer relationships, with reference to longer duration contracts.[80] Seven years, particularly given that the rotation of contracting office personnel typically happens on a faster cycle, gives enough time for a trusting relationship to be established.

However, the frequency of buyer-vendor interactions, as measured by the logged number of contract actions between the buyer and vendor, was largely ineffective at estimating positive performance. For the *Breach Size* and *Terminations* models, *paired actions* correlated with smaller *breach size* when a breach occurred and fewer terminations, both significant at the 5 percent level. However, for the remaining models there was no relationship or worse a significant relationship with worse performance outcomes, as was the case for *the All Options and Breach Likelihood* models. The simplest explanation for this may be that the frequency of contract actions may tell us more about the structure of a contract, for example, whether equipment is separately rented each time it is used or whether it is made consistently

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[76] Uday Apte and Rene Rendon, Services Supply Chain in the Department of Defense: Defining and Measuring Success of Services Contracts in the U.S. Navy (Monterey, CA: Naval Postgraduate School, 2013), https://calhoun.nps.edu/handle/10945/45029.
[77] Fernandez, "Understanding Contracting Performance," 70.
[78] Yang, Hsieh, and Li, "Contracting Capacity and Perceived Contracting Performance," 692/
[79] Fernandez, "Understanding Contracting Performance," 91.
[80] Ibid., 87.

available over the period of a year and only leads to a contract action when it is maintained by the vendor. While contract actions are opportunities for monitoring or working more closely, a greater number of contract actions may indicate such greater contract specificity or a relationship that is more literally transactional. Yang, Hsieh, and Li warn that "[p]articularly, in situations that are characterized by wicked problems and uncertainty, a fully specified contract, regard less of its costs, may not be a good mechanism to ensure cooperation and performance."[81]

For the two models dealing with ceiling breaches, the *office PBSA proportion* was interacted with the *paired actions*. This combination was meant to test whether offices oriented toward performance-based contracting would be more likely to experience a behavior Fernandez notes, that "[t]rust between public organizations and private contractors can develop over time, however, through repeated interaction and as the contractor demonstrates goodwill and its ability to perform."[82] Under this theory, the frequency of connections between the two partners would thus reinforce the quality of the relationship. Contrary to expectation, the results for *Breach Likelihood* indicated lower estimated performance, with the interaction term estimating a lower likelihood that some options would be exercised and a higher likelihood of ceiling breaches (significant at the 0.1 percent level). However, the results for *Breach Size*, given the occurrence of a breach, were in line with expectations and estimated smaller breaches (significant at the 1 percent level).

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[81] Yang, Hsieh, and Li, "Contracting Capacity and Perceived Contracting Performance," 691.
[82] Fernandez. "Understanding Contracting Performance," 70.

Table 14: Paired History Results Across Models

	Options Exercised		Ceiling Breach		Termination
	P(Some) (Logit)	**P(All| Some) (Logit)**	**P(Breach) (Logit)**	**Breach Size | Breach (OLS)**	**P(Term.) (Logit)**
Hypothesized Relationship	**Positive**		**Negative**		**Negative**
Paired Years	**0.32** (0.02)***	**0.13** (0.02)***	**-0.09** (0.01)***	0.03 (0.02)	**-0.26** (0.02)***
Log(Paired Actions+1)	-0.01 (0.04)	**-0.13** (0.04)**	**0.45** (0.02)***	**-0.07** (0.03)*	**-0.07** (0.03)*
Office PBSA Prop.: Log(Paired Actions+1)			**0.46** (0.02)***	**-0.18** (0.04)***	
Paired Years:Pricing=Other Fixed-Price	0.01 (0.34)				**-1.42** (0.15)***
Paired Years:Pricing=Incentive Fee	**1.12** (0.47)*				0.30 (0.94)
Paired Years:Pricing=Comb./Other	**-0.57** (0.17)***				0.24 (0.23)
Paired Years:Pricing=Other Cost-Based	0.11 (0.08)				**0.41** (0.14)**
Paired Years:Pricing=T&M/LH/FP:LoE	-0.07 (0.11)				**-0.62** (0.18)***
Paired Years:Pricing=UCA	-0.05 (0.22)				-0.53 (0.28)·

The contrast between *paired actions* and *paired history* suggests that sometimes it is the existence and duration of a relationship, not its frequency, that may be the more important estimator of the potential for trust. That said, the finding raises the question of what role past obligations play and asks whether vendor lock might explain the government's eagerness to exercise some or all options as well as its hesitation to terminate contracts.

Conclusions

Between service complexity, contract-management capacity, and paired history, this report found the most straightforward relationship between the paired history and contract performance. The relationship between the pair estimated better performance across both of the study team's established contract performance measures (*Breach Likelihood* and *Terminations*) and also across two-thirds of the new measures (*Some Options* and *All Options*, but not *Breach Size*). This is consistent with a common observation in the literature that trust takes time to develop, although Joaquin and Greitens raised a relevant concern: that "settling" on favorite vendors could lead to declines in competition, and reward monopolistic tendencies, advantaging larger contractors.[83]

The consistency of paired history has important implications beyond the metrics contained in this report. As past CSIS work by Cohen has found, the number of new entrants into DoD contracts has been declining, which echoes a larger national trend of decline in new business starts.[84] The DoD seeks a competitive marketplace in which new and non-traditional entrants can bring ideas from the larger commercial and research spheres to support the department's mission. However, as Rozmek and Johnston note, contracting officers may also be motivated in seeking the stability of a known partner.[85] The same dynamics may contribute to a less welcoming environment for start-ups in an increasingly services-oriented national economy.

The literature's complementary emphasis on the importance of cooperative partnership and the benefit of competition suggest that while recruiting first-time vendors is a worthy objective, practitioners and researchers should also pay attention to developing means to build trust and cooperative problem-solving relationships with new vendors and in taking advantage of the strengths while minimizing the risks of longstanding relationships. Overcoming these challenges may require additional government contract-management capacity. Possible avenues for future research and effort include vendor mentorship programs, programs that work with non-traditional vendors even after they have won their first contract (such as Small Business Innovative Research).

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[83] Joaquin and Greitens, Contract Management Capacity Breakdown?, 713.
[84] Samantha Cohen, New Entrants and Small Business Graduation in the Market for Federal Contracts (Washington, DC: CSIS, 2018), https://www.csis.org/analysis/new-entrants-and-small-business-graduation-market-federal-contracts; Ben Casselman, "A Start-Up Slump Is a Drag on the Economy. Big Business May Be to Blame," New York Times, September 20, 2017, https://www.nytimes.com/2017/09/20/business/economy/startup-business.html#:~:text=the%20main%20story-,A%20Start-Up%20Slump%20Is%20a%20Drag%20on%20the%20Economy,Business%20May%20Be%20to%20Blame.&text=Unemployment%20has%20fallen%2C%20and%20the%20stock%20market%20has%20soared.&text=Economists%20say%20the%20answer%2C%20to,understanding%20of%20what%27s%20behind%20it..
[85] Rozmek and Johnston, Effective Contract Implementation and Management, 449.

Secondarily, service complexity, as measured by *service code invoice rate*, estimated a lower chance that all options would be exercised and a greater likelihood and size of ceiling breaches. The robustness of these results supports that there is value in exploring whether invoice rate could tell us more about whether a given service requires contract-specific investment. This outcome also suggests that despite its flaws, the services contract census has value as an oversight tool and may be worth reinvigorating. Nonetheless, the fact that this relationship was not found for *Some Options* and *Terminations* does reveal limits to this approach. Other variables, such as the ratio of initial cost ceiling to base, may help fill this void, but some relatively easily collected forms of reporting, such as including simple specificity measures such as length of contract, can give a clearer picture of the service-contracting challenge the federal government is taking on.[86]

Finally, the complex findings on office capacity are also an indicator of a bigger-picture data gap. Information on civilian and military acquisition personnel is collected but not available to open-source researchers and in many cases, is closely held even for those within the government. This data gap makes it harder to provide evidence of where investing in the workforce has paid off, limiting the ability to respond to persistent calls from Congress for headquarters reductions, which may lead to suboptimal management of the contracting workforce. Perhaps widespread reporting on training, average tenure, and budgets could respect the practical considerations of contracting offices in protecting their data while still allowing large dataset analysis. All of these would, of course, still be proxies, best able to capture whether an office is under-resourced or under-trained rather than whether it was deploying its resources well. However, the ability to do such an analysis would be a definite step forward. The models showed that even after the inclusion of a range of contract and contracting office variables, there was a great deal of variance in the estimated effect each office had relating to contracting performance. This data gap ties into a larger challenge identified by Loren Schulman, who notes that "to understaff and undermanage civilian counterparts does our uniformed force an enormous disservice. We measure what we value, we manage what we measure. Why, then, are there no national security civilian readiness metrics?"[87] Schulman's point has a broad scope, but the literature combined with the unexplained variance suggests that identifying quality office capacity measures would be a place to start for better employment of civilian workforce metrics. In the absence of new data, those doing the hard work of examining contracting office staffing and sharing such information with other practitioners through venues such as the Acquisition Research Symposium, are to be commended for addressing a clear need.

Where office capacity data does exist, such as the performance-based services contracting measures, it may be undermined by the temptation to broadly define what qualifies as a contracting technique (e.g. performance-based contracting, using the existing literature and formal policy). The stronger results in interactions suggest that relying on multiple pieces of evidence to confirm performance-based approaches may be wise when seeking to measure the extent of implementation and whether these approaches are working.

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[86] Subsequent to the completion of this report, contract solicitation was added to data reported by USAspending.gov. Examining the gap between solicitation date and signed date can be an asset for future researchers, although the value will depend on the reliability of the reporting.

[87] Loren DeJonge Schulman, "National Security is Made of People," Defense One, November 7, 2019, https://cdn.defenseone.com/b/defenseone/interstitial.html?v=9.22.4&rf=https%3A%2F%2Fwww.defenseone.com%2Fideas%2F2019%2F11%2Fnational-security-made-people%2F161132%2F.

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Annex A Rescaled Control Summary

Table 15: Logged Control Variable Descriptive Statistics

Variable Name	Min	Max	Median	Geo-metric Mean	1 unit below	1 unit above	% of records NA	% of Obl. to NA records
Contract Characteristics								
Log(Init. Base)	0.01	27.8 Bil	30,395	34,728	465	2.5 Mil	0.47%	0.61%
Log(Initial Ceiling: Base)	1	29.0 Mil	1	1.099	0.5*	2.643	0.47%	0.62%
Log(Planned Duration)	1	33,049	120	82	3	2,359	2.25%	1.76%
NAICS/Office Characteristics								
Log(Subsector HHI)	28	10,000	228	222	29	1,676	0.64%	0.54%
Log(Subsector DoD:U.S.)	<0.01	0.16	0.03	0.02	<0.01	0.34*	1.16%	0.71%
Log(Detailed Ind. HHI)	22	10,000	583	599	56	6,415	2.42%	0.85%
Log(Detailed Ind. DoD:U.S.)	<0.01	1	0.03	0.02	<0.01	2.13*	3.06%	1.08%
Log(Office Focus)	94	10,000	706	812	80*	8,285	0.10%	0.09%

* *1 unit below/above values are less than minimal value for variable.*

Table 16: Incremented and then Logged Control Variable Descriptive Statistics

Variable Name	Min	Max	Median	Geometric Mean	1 unit below	1 unit above	% of records NA	% of Obl. to NA records
NAICS/Office Characteristics								
Log(Office Obligations+1)	1**	182.3 Bil	1.6 Bil	1.1 Bil	2.1 Mil	534 Tril*	0.03%	0%

* 1 unit below/above values are less than minimal value for variable. ** True minimum value is 0.

Table 17: Unlogged Continuous Control Variable Descriptive Statistics

Variable Name	Min	Max	Median	Geometric Mean	1 unit below	1 unit above	% of records NA	% of Obl. to NA records
NAICS/Office Characteristics								
Paired Share	0.000	1.000	0.002	0.049	-0.261*	0.358	0.19%	0.52%

* 1 unit below/above values are less than minimal value for variable.

Annex B Presentation of Estimating Equation

As described in Chapter 4, this paper includes five different equations: likelihood some options are exercised; likelihood all options are exercised; likelihood of a ceiling breach; size of ceiling breach given a breach occurring; and likelihood of termination. The variable indicators used in the equations are listed in Annex A. Each predictor in the equations has a subscript *i*, which refers to the individual contract or task order. The level 2, 3, and 4 variables are listed at the start of each equation with an α coefficient that has a different intercept for each value of with the underlying variable (that is, subscripts *j*, *k*, *l*, *m*, *n*, *o*, and *p)* and whose calculation is described in the corresponding formula at the end of equation. Subscript *j* refers to the NAICS subsector, subscript *k* refers to the NAICS detailed industry, subscript *l* refers to the service area, subscript *m* refers to the contracting agency, subscript *n* refers to the contracting office, subscript *o* refers to the place of performance, and subscript *p* refers to the calendar year (for those equations that include it). The remaining variables have β coefficients, with each non-base level of the categorical variables receiving a separate coefficient.

Equation 1: Some Options Exercised Likelihood

$$
\begin{aligned}
&Estimated\ Probability(y_i = 1) \ = \ Logit^{-1}(\alpha \ + \ \alpha_{j[i]}^{NAICS3} \ + \ \alpha_{k[i]}^{NAICS6:NAICS3} \ + \alpha_{l[i]}^{NAICS6:NAICS3:ServArea} \ + \\
&\alpha_{m[i]}^{Agency} \ + \ \alpha_{n[i]}^{Office:Agency} \ + \alpha_{o[i]}^{Place} \ + \ \alpha_{p[i]}^{StartFY} \ + \beta_1 Intercept \ + \ \beta_2 Log(Det.\ Ind.\ Salary)_i \ + \\
&\beta_3 Log(Serv.\ Code\ Invoice\ Rate)_i \ + \ \beta_4 Office\ PBSA\ Prop.\ \beta_5 Office\ Serv.\ Code\ Exp.\ \%_i \ + \\
&\beta_6 Paired\ Years_i \ + \ \beta_7 Log(Paired\ Actions + 1)_i \ + \ \beta_8 Log(Init.\ Base)_i \ + \beta_9 Log(Init.\ Ceiling{:}\ Base)_i \ + \\
&\beta_{10} Log(Planned\ Dur.)_i \ + \ (\ \beta_{11} 1\ Offer_i \ + \ \beta_{12} 1\ Offer_i + \ \beta_{13} 5plus\ Offers_i\ ) \ + \ (\ \beta_{14} Single\text{-}Award_i \ + \\
&\beta_{15} Multi\text{-}Award_i + \ \beta_{16} FSS\text{-}GWAC_i + \ \beta_{17} BPA\text{-}BOA_i\ ) \ + \ (\ \beta_{18} Other\ Fixed\text{-}Price_i \ + \\
&\beta_{19} Incentive\ Fee_i \ + \ \beta_{20} Comb\text{-}Other_i \ + \ \beta_{21} Other\ Cost\text{-}Based_i \ + \ \beta_{22} Time\ \&\ Materials_i \ + \\
&\beta_{23} UCA_i\ ) \ + \ (\ \beta_{24} ARRA_i \ + \ \beta_{25} Disaster_i \ + \ \beta_{26} OCO_i\ ) \ + \ \beta_{27} Log(Subsector\ HHI)_i \ + \\
&\beta_{28} Log(Subsector\ DoD{:}\ U.S.)_i \ + \ \beta_{29} Log(Det.\ Ind.\ HHI)_i \ + \ \beta_{30} Log(Det.\ Ind.\ DoD{:}\ U.S.)_i \ + \\
&\beta_{31} Log(Office\ Obl. {+}1)_i \ + \beta_{32} Log(Office\ Focus)_i \ + \ \beta_{33} Paired\ Share_i \ + \\
&\beta_{34} Office\ PBSA\ Prop._i \cdot Paired\ Share_i \ + \ \ (\ \beta_{35} Office\ PBSA\ Prop_i \cdot Other\ Fixed\text{-}Price_i \ + \\
&\beta_{36} Office\ PBSA\ Prop_i \cdot Incentive\ Fee_i \ + \ \beta_{37} Office\ PBSA\ Prop_i \cdot Comb\text{-}Other_i \ + \\
&\beta_{38} Office\ PBSA\ Prop_i \cdot Other\ Cost\text{-}Based_i \ + \ \beta_{39} Office\ PBSA\ Prop_i \cdot Time\ \&\ Materials_i \ + \\
&\beta_{40} Office\ PBSA\ Prop_i \cdot UCA_i\ ) \ \beta_{41} Office\ Serv.\ Code\ Exp.\ \%_i \cdot Log(Office\ Focus)_i + \\
&\beta_{42} Log(Init.\ Base)_i \cdot Log(Init.\ Ceiling{:}\ Base)_i \ + \ \ \epsilon_i,\ for\ i = 1\ to\ 87{,}387
\end{aligned}
$$

$$
\begin{gathered}
a_j^{NAICS3} \sim \ N(\mu_\alpha, \sigma_\alpha^2),\ for\ j = 1\ to\ 78; \\
a_k^{NAICS3:NAICS6} \sim \ N(\mu_\alpha, \sigma_\alpha^2),\ for\ k = 1\ to\ 635; \\
a_l^{NAICS3:NAICS6:ServArea} \sim \ N(\mu_\alpha, \sigma_\alpha^2),\ for\ l = 1\ to\ 1{,}577; \\
a_m^{Agency} \sim \ N(\mu_\alpha, \sigma_\alpha^2),\ for\ m = 1\ to\ 24 \\
a_n^{Agency:Office} \sim \ N(\mu_\alpha, \sigma_\alpha^2),\ for\ n = 1\ to\ 773 \\
a_o^{Place} \sim \ N(\mu_\alpha, \sigma_\alpha^2), \quad for\ n = 1\ to\ 124 \\
a_p^{StartFY} \sim \ N(\mu_\alpha, \sigma_\alpha^2),\ for\ o = 1\ to\ 9
\end{gathered}
$$

Equation 2: All Options Exercised Likelihood

$$Estimated\ Probability(y_i = 1)\ =\ Logit^{-1}(\alpha\ +\ \alpha_{j[i]}^{NAICS3}\ +\ \alpha_{k[i]}^{NAICS6:NAICS3}\ +\alpha_{l[i]}^{NAICS6:NAICS3:ServArea}\ +\ \alpha_{m[i]}^{Agency}\ +\ \alpha_{n[i]}^{Office:Agency}\ +\alpha_{o[i]}^{Place}\ +\ \alpha_{p[i]}^{StartFY}\ +\beta_1 Intercept\ +\ \beta_2 Log(Det.\ Ind.\ Salary)_i\ +\ \beta_3 Log(Serv.\ Code\ Invoice\ Rate)_i\ +\ \beta_4 Office\ PBSA\ Prop.\ \beta_5 Office\ Serv.\ Code\ Exp.\ \%_i\ +\ \beta_6 Paired\ Years_i\ +\ \beta_7 Log(Paired\ Actions+1)_i\ +\ \beta_8 Log(Init.\ Base)_i\ +\beta_9 Log(Init.\ Ceiling{:}\ Base)_i\ +\ \beta_{10} Log(Planned\ Dur.)_i\ +\ (\ \beta_{11} 1\ Offer_i\ +\ \beta_{12} 2\text{–}4 Offers_i +\ \beta_{13} 5plus\ Offers_i\ )\ +\ (\ \beta_{14} Single\text{–}Award_i\ +\ \beta_{15} Multi\text{–}Award_i +\ \beta_{16} FSS\text{–}GWAC_i +\ \beta_{17} BPA\text{–}BOA_i\ )\ +\ (\ \beta_{18} Other\ Fixed\text{–}Price_i\ +\beta_{19} Incentive\ Fee_i\ +\beta_{20} Comb\text{–}Other_i\ +\ \beta_{21} Other\ Cost\text{–}Based_i\ +\ \beta_{22} Time\ \&\ Materials_i\ +\beta_{23} UCA_i\ )\ +\ (\ \beta_{24} ARRA_i\ +\ \beta_{25} Disaster_i\ +\ \beta_{26} OCO_i\ )\ +\ \beta_{27} Log(Subsector\ HHI)_i\ +\beta_{28} Log(Subsector\ DoD{:}\ U.S.)_i\ +\ \beta_{29} Log(Det.\ Ind.\ HHI)_i\ +\ \beta_{30} Log(Det.\ Ind.\ DoD{:}\ U.S.)_i\ +\ \beta_{31} Log(Office\ Obl.+1)_i\ +\beta_{32} Log(Office\ Focus)_i\ +\ \beta_{33} Paired\ Share_i\ +\ (\ \beta_{34} Log(Serv.\ Code\ Invoice\ Rate)_i \cdot Other\ Fixed\text{–}Price_i\ +\ \beta_{35} Log(Serv.\ Code\ Invoice\ Rate)_i \cdot Incentive\ Fee_i\ +\ \beta_{36} Log(Serv.\ Code\ Invoice\ Rate)_i \cdot Comb\text{–}Other_i\ +\ \beta_{37} Log(Serv.\ Code\ Invoice\ Rate)_i \cdot Other\ Cost\text{–}Based_i\ +\ \beta_{38} Log(Serv.\ Code\ Invoice\ Rate)_i \cdot Time\ \&\ Materials_i\ +\beta_{39} Log(Serv.\ Code\ Invoice\ Rate)_i \cdot UCA_i\ )\ +\ \beta_{40} Office\ Serv.\ Code\ Exp.\ \%_i \cdot Log(Office\ Focus)_i\ +$$

$$\epsilon_i,\ for\ i = 1\ to\ 62{,}180$$
$$a_j^{NAICS3} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ j = 1\ to\ 74;$$
$$a_k^{NAICS3:NAICS6} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ k = 1\ to\ 589;$$
$$a_l^{NAICS3:NAICS6:ServArea} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ l = 1\ to\ 1{,}406;$$
$$a_m^{Agency} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ m = 1\ to\ 24$$
$$a_n^{Agency:Office} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ n = 1\ to\ 694$$
$$a_o^{Place} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\quad for\ n = 1\ to\ 109$$
$$a_p^{StartFY} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ o = 1\ to\ 9$$

Equation 3: Ceiling Breaches Likelihood

$$Estimated\ Probability(y_i = 1)\ =\ Logit^{-1}(\alpha\ +\ \alpha_{j[i]}^{NAICS3}\ +\ \alpha_{k[i]}^{NAICS6:NAICS3}\ +\alpha_{l[i]}^{NAICS6:NAICS3:ServArea}\ +\ \alpha_{m[i]}^{Agency}\ +\ \alpha_{n[i]}^{Office:Agency}\ +\alpha_{o[i]}^{Place}\ +\ \alpha_{p[i]}^{StartFY}\ +\beta_1 Intercept\ +\ \beta_2 Log(Det.\ Ind.\ Salary)_i\ +\ \beta_3 Log(Serv.\ Code\ Invoice\ Rate)_i\ +\ \beta_4 Office\ PBSA\ Prop.\ \beta_5 Office\ Serv.\ Code\ Exp.\ \%_i\ +\ \beta_6 Paired\ Years_i\ +\ \beta_7 Log(Paired\ Actions+1)_i\ +\ \beta_8 Log(Init.\ Base)_i\ +\beta_9 Log(Init.\ Ceiling{:}\ Base)_i\ +\ \beta_{10} Log(Planned\ Dur.)_i\ +\ (\ \beta_{11} 1\ Offer_i\ +\ \beta_{12} 2\text{–}4 Offers_i +\ \beta_{13} 5plus\ Offers_i\ )\ +\ (\ \beta_{14} Single\text{–}Award_i\ +\ \beta_{15} Multi\text{–}Award_i +\ \beta_{16} FSS\text{–}GWAC_i +\ \beta_{17} BPA\text{–}BOA_i\ )\ +\ (\ \beta_{18} Other\ Fixed\text{–}Price_i\ +\beta_{19} Incentive\ Fee_i\ +\ \beta_{20} Comb\text{–}Other_i\ +\ \beta_{21} Other\ Cost\text{–}Based_i\ +\ \beta_{22} Time\ \&\ Materials_i\ +\beta_{23} UCA_i\ )\ +\ (\ \beta_{24} ARRA_i\ +\ \beta_{25} Disaster_i\ +\ \beta_{26} OCO_i\ )\ +\ \beta_{27} Log(Subsector\ HHI)_i\ +\beta_{28} Log(Subsector\ DoD{:}\ U.S.)_i\ +\beta_{29} Log(Det.\ Ind.\ HHI)_i\ +\ \beta_{30} Log(Det.\ Ind.\ DoD{:}\ U.S.)_i\ +\ \beta_3 Log(Office\ Obl.+1)_i\ +\ \beta_{32} Log(Office\ Focus)_i\ +\ \beta_{33} Paired\ Share_i\ +\ \beta_{34} Office\ PBSA\ Prop._i \cdot Log(Paired\ Actions+1)_i\ +\ \beta_{35} Office\ PBSA\ Prop._i \cdot Log(Planned\ Dur.)_i\ +\ \epsilon_i,\ for\ i = 1\ to\ 1{,}000{,}000$$

$$a_j^{NAICS3} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ j = 1\ to\ 82;$$
$$a_k^{NAICS3:NAICS6} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ k = 1\ to\ 879;$$
$$a_l^{NAICS3:NAICS6:ServArea} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ l = 1\ to\ 3{,}217;$$
$$a_m^{Agency} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ m = 1\ to\ 24$$
$$a_n^{Agency:Office} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ n = 1\ to\ 1{,}092$$
$$a_o^{Place} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\quad for\ n = 1\ to\ 191$$
$$a_p^{StartFY} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ o = 1\ to\ 9$$

Equation 4: Ceiling Breach Size Given Breach Occurrence

$$Estimated\ Log(y_i)\ =\ \alpha\ +\ \alpha_{j[i]}^{NAICS3}\ +\ \alpha_{k[i]}^{NAICS6:NAICS3}\ +\ \alpha_{l[i]}^{NAICS6:NAICS3:ServArea}\ +\alpha_{m[i]}^{Agency}\ +\ \alpha_{n[i]}^{Office:Agency}\ +\ \alpha_{o[i]}^{Place}\ +\ \alpha_{p[i]}^{StartFY}\ +\ \beta_1 Intercept\ +\beta_2 Log(Det.\ Ind.\ Salary)_i\ +$$

$$\beta_3 Log(Serv.\ Code\ Invoice\ Rate)_i\ +\ \beta_4 Offic\ PBSA\ Prop.\ \beta_5 Office\ Serv.\ Code\ Exp.\ \%_i\ + \beta_6 Paired\ Years_i\ +\ \beta_7 Log(Paired\ Actions+1)_i\ +\ \beta_8 Log(Init.\ Base)_i\ +\ \beta_9 Log(Init.\ Ceiling: Base)_i\ + \beta_{10} Log(Planned\ Dur.)_i\ +\ (\ \beta_{11} 1\ Offer_i\ +\ \beta_{12} 2\text{–}4 Offers_i + \ \beta_{13} 5plus\ Offers_i\ )\ + (\ \beta_{14} Single\text{–}\ Award_i\ + \beta_{15} Multi\text{–}\ Award_i\ +\ \beta_{16} FSS\text{–}\ GWAC_i + \ \beta_{17} BPA\text{–}\ BOA_i\ )\ + (\ \beta_{18} Other\ Fixed\text{–}Price_i\ +\ \beta_{19} Incentive\ Fee_i\ + \beta_{20} Comb\text{–}\ Other_i\ +\ \beta_{21} Other\ Cost\text{–}\ Based_i\ + \beta_{22} Time\ \&\ Materials_i\ +\ \beta_{23} UCA_i\ )\ +\ (\ \beta_{24} ARRA_i\ +\ \beta_{25} Disaster_i\ +\ \beta_{26} OCO_i\ )\ + \beta_{27} Log(Subsector\ HHI)_i\ + \beta_{28} Log(Subsector\ DoD: U.S.)_i\ +\ \beta_{29} Log(Det.\ Ind.\ HHI)_i\ + \beta_{30} Log(Det.\ Ind.\ DoD: U.S.)_i\ +\ \beta_{31} Log(Office\ Obl.+1)_i\ +\ \beta_{32} Log(Office\ Focus)_i\ + \beta_{33} Paired\ Share_i\ + \beta_{34} Office\ PBSA\ Prop._i \cdot Log(Paired\ Actions+1)_i\ + \beta_{35} Office\ PBSA\ Prop._i \cdot Log(Planned\ Dur.)_i$$

$$\epsilon_i,\ for\ i = 1\ to\ 69{,}776$$

$$a_j^{NAICS3} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ j = 1\ to\ 76;$$
$$a_k^{NAICS3:NAICS6} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ k = 1\ to\ 568;$$
$$a_l^{NAICS3:NAICS6:ServArea} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ l = 1\ to\ 1{,}326;$$
$$a_m^{Agency} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ m = 1\ to\ 23$$
$$a_n^{Agency:Office} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ n = 1\ to\ 670$$
$$a_o^{Place} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\quad for\ n = 1\ to\ 132$$
$$a_p^{StartFY} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ o = 1\ to\ 9$$

Equation 5: Terminations

$$Estimated\ Probability(y_i = 1)\ =\ Logit^{-1}(\alpha\ +\ \alpha_{j[i]}^{NAICS3}\ +\ \alpha_{k[i]}^{NAICS6:NAICS3}\ + \alpha_{l[i]}^{NAICS6:NAICS3:ServArea}\ + \alpha_{m[i]}^{Agency}\ +\ \alpha_{n[i]}^{Office:Agency}\ + \alpha_{o[i]}^{Place}\ +\ \alpha_{p[i]}^{StartFY}\ + \beta_1 Intercept_i\ +\ \beta_2 Log(Det.\ Ind.\ Salary)_i\ + \beta_3 Log(Serv.\ Code\ Invoice\ Rate)_i\ +\ \beta_4 Office\ PBSA\ Prop.\ \beta_5 Office\ Serv.\ Code\ Exp.\ \%_i\ + \beta_6 Paired\ Years_i\ +\ \beta_7 Log(Paired\ Actions+1)_i\ +\ \beta_8 Log(Init.\ Base)_i\ + \beta_9 Log(Init.\ Ceiling: Base)_i\ + \beta_{10} Log(Planned\ Dur.)_i\ +\ (\ \beta_{11} 1\ Offer_i\ +\ \beta_{12} 2\text{–}4 Offers_i + \ \beta_{13} 5plus\ Offers_i\ )\ + (\ \beta_{14} Single\text{–}\ Award_i\ +\ \beta_{15} Multi\text{–}Award_i + \ \beta_{16} FSS\text{–}\ GWAC_i + \ \beta_{17} BPA\text{–}\ BOA_i\ )\ + (\ \beta_{18} Other\ Fixed\text{–}Price_i\ + \beta_{19} Incentive\ Fee_i\ +\ \beta_{20} Comb\text{–}\ Other_i\ +\ \beta_{21} Other\ Cost\text{–}\ Based_i\ + \beta_{22} Time\ \&\ Materials_i\ + \beta_{23} UCA_i\ )\ +\ (\ \beta_{24} ARRA_i\ +\ \beta_{25} Disaster_i\ +\ \beta_{26} OCO_i\ )\ + \beta_{27} Log(Subsector\ HHI)_i\ + \beta_{28} Log(Subsector\ DoD: U.S.)_i\ +\ \beta_{29} Log(Det.\ Ind.\ HHI)_i\ + \beta_{30} Log(Det.\ Ind.\ DoD: U.S.)_i\ +\ \beta_{31} Log(Office\ Obl.+1)_i\ + \beta_{32} Log(Office\ Focus)_i\ + \beta_{33} Paired\ Share_i\ +\ (\ \beta_{34} Paired\ Years_i \cdot Other\ Fixed\text{–}\ Price_i\ + \beta_{35} Paired\ Years_i \cdot Incentive\ Fee_i\ + \beta_{36} Paired\ Years_i \cdot Comb\text{–}\ Other_i\ + \beta_{37} Paired\ Years_i \cdot Other\ Cost\text{–}\ Based_i\ +\ \beta_{38} Paired\ Years_i \cdot Time\ \&\ Materials_i\ + \beta_{39} Paired\ Years_i \cdot UCA_i\ )\ +\ \epsilon_i\ +\ \epsilon_i,\quad for\ i = 1\ to\ 1{,}000{,}000$$

$$a_j^{NAICS3} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ j = 1\ to\ 82;$$
$$a_k^{NAICS3:NAICS6} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ k = 1\ to\ 879;$$
$$a_l^{NAICS3:NAICS6:ServArea} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ l = 1\ to\ 3{,}217;$$
$$a_m^{Agency} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ m = 1\ to\ 24$$
$$a_n^{Agency:Office} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ n = 1\ to\ 1{,}092$$
$$a_o^{Place} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\quad for\ n = 1\ to\ 191$$
$$a_p^{StartFY} \sim\ N(\mu_\alpha, \sigma_\alpha^2),\ for\ o = 1\ to\ 9$$

Annex C Model Diagnostics

Figure 4: Fitted and Residual Plots for Exercised Options

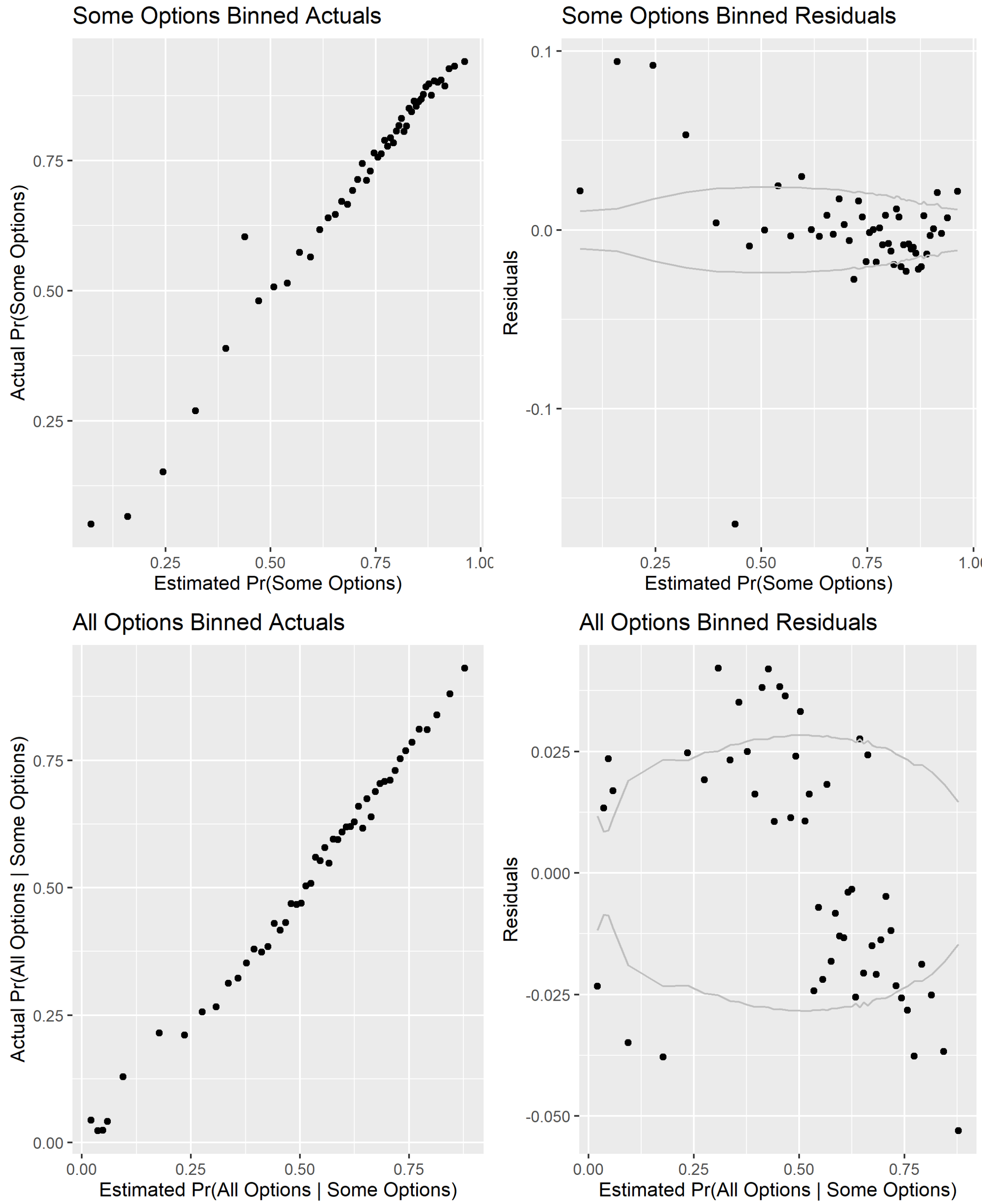

Figure 5: Fitted and Residual Plots for Ceiling Breaches

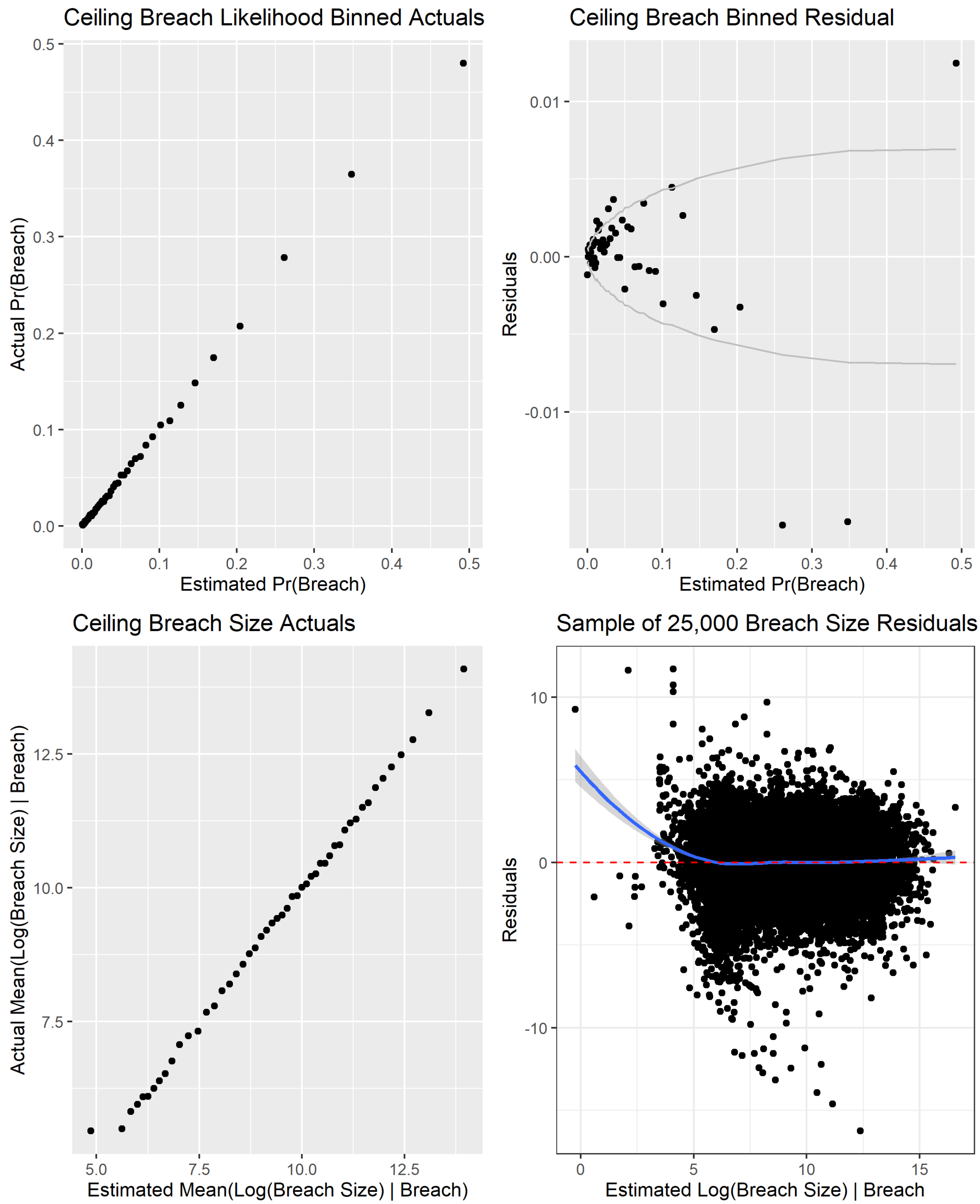

Figure 6: Fitted and Residual Plots for Terminations

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