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Evaluating Consolidation and the Threat of Monopolies within Industrial Sectors

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A Report of the CSIS Defense-Industrial Initiatives Group

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Abstract:

Economics scholars and policy makers have rung alarm bells about the increasing threat of consolidation and concentration within industrial sectors. This paper examines the importance of industrial concentration in two ways: first, a direct relationship between concentration and performance outcomes; and second, an indirect relationship, where concentration influences performance through reduced competition for defense acquisition. The study finds that consolidation correlates with lower rates of termination but has mixed associations with ceiling breaches. Contrary to hypothesis, competition is associated with higher rates of termination and that only single offer competition is associated with lower rates of cost ceiling breaches.

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Executive Summary

In recent years, economists and policymakers have expressed heightened concern over industrial concentration and the potential for monopolies in a number of sectors of the U.S economy, ranging from retail trade and manufacturing to finance and utilities. These concerns extend to the U.S. defense industry, which the nation depends upon to equip its military with a wide array of mission-essential goods and services. Growing concentration may hinder competition, reduce the availability of key supplies and equipment, and diminish vendors' incentives for innovation and performance in government contracts.

To evaluate the urgency of these concerns, this study analyzes the relationship between concentration, competition, and performance outcomes in a large sample of U.S. federal contract transactions executed by the Department of Defense (DOD) between 2007 and 2016. Specifically, the study tests whether and to what extent growing concentration in different industries directly influences contract performance, as well as indirectly influences performance through reducing competition. For analysis purposes, study considers two types of contract performance markers: first, whether a contract breaches its initial cost ceiling, and second, whether it experiences a partial or complete termination. In this way, the study extends upon prior research by considering multiple dimensions of performance. It also contributes to prior research by analyzing the relationships between concentration, competition, and performance outcomes at the level of individual contracts rather than higher levels (e.g., programs) already given significant attention in previous studies.

The study examines consolidation at two levels, 79 broad subsectors and 886 detailed industries. Controlling for a variety of performance-related factors, including contract size, duration, pricing mechanism, purchasing organization, and select industry characteristics, the study finds that consolidation correlates with lower rates of termination but has mixed associations with ceiling breaches. Specifically, subsector concentration is associated with lower rates of ceiling breaches while detailed industry concentration is associated with higher rates of breaches. Contrary to hypothesis,

competition is associated with higher rates of termination and that only single offer competition is associated with lower rates of cost ceiling breaches.

The results on concentration are in accord with the hypothesis that consolidation can result both in improved performance due to economies of scale but also challenges due to reduced contractor incentive to perform lest they be replaced. The association of single-offer competition with fewer ceiling breaches is consistent with competition incentivizing vendors to reduce cost while at the same time motivating some vendors to make aggressive bids that cannot be fulfilled. The decreased likelihood of terminations for competition is contrary to initial expectations but could be explained by vendor lock in which the government may not be as able to replace incumbent vendors due to a lack of alternatives.

These results point to the need for government to carefully monitor costs when doing business with vendors in highly concentrated industries that have fewer competitors and pose a greater risk of vendor lock to incumbents. Furthermore, the government may benefit from understanding the risks of ceiling breaches and terminations for each contracting office and not just industrial sectors, as an unexpected finding was that differences between contracting agencies and office explain much of the variance in outcomes. Understanding the larger commercial market may also be of value, as the availability of such a market is correlated with lower termination rates in concentrated markets. The study also supports the idea that competition is not just a channel for industrial consolidation, but that it can be an independent variable in its own right, for better and worse. Further study of the mechanism of contracting may be rewarding, as the study team had not anticipated the interplay of numbers of offers and contracting outcomes. Finally, the study team hopes the results will be of use to contracting officers and future researchers and will freely share the underlying data and models.

1 Introduction

1.1 Project Motivation—Monopoly, Consolidation, and Implications for Performance

In recent years, economists, policymakers, and other observers have expressed growing concerns over industrial concentration and the threat of monopolies in the U.S. economy.[1] Data on revenue concentration, for example, show that the largest firms in a number of U.S. industries are accruing an increasing percentage of their respective industry's market share. The 50-firm concentration ratio (CR_{50})—which measures the proportion of an industry's revenue accruing to its 50 largest firms—has grown by 10 percent or more over the last 15 years (1997-2012, based on the latest available information) in industries ranging from transportation and warehousing to retail trade to finance and insurance.[2] For example, in the case of finance and insurance, the latest available data (as of 2012) shows the 50 largest firms account for nearly half (48.5 percent) of all revenue in the industry. This figure is even higher elsewhere. In utilities, for instance, the CR_{50} stands at 69.1 percent.[3]

These trends may reflect an actual decline in competition, but it is important to note they could also stem from superior economic performance among firms that may have driven their competitors out of the market. Moreover, production in many industries (like utilities) is subject to at least some degree of economies of scale—where per unit costs fall as production increases, and an industry's total output can be produced more efficiently by fewer, rather than more, firms—making those industries more concentrated to begin with. Finally, while the data reflect what is happening nationally, the actual effects of concentration tend to play out on a lower

[1] For a recent summary and synthesis of current views regarding industrial consolidation, monopoly, and their implications for policy, see Carl Shapiro, "Antitrust in a Time of Populism," forthcoming, *International Journal of Industrial Organization.*

[2] White House Council of Economic Advisors, *Benefits of Competition and Indicators of Market Power* (Washington, DC: White House CEA, 2016), https://obamawhitehouse.archives.gov/sites/default/files/page/files/20160414_cea_competition_issue_brief.pdf

[3] Ibid.

geographical scale (such that the issue is not strictly one of growing concentration nation-wide, but one that affects regional and local markets in particular). Acknowledging these caveats (and their implications for proper public policy response), the increasingly concentrated nature of many industries in the U.S. remains a noteworthy economic development.

Concerns over industrial concentration and potential monopolies also extend to the U.S. defense industry. Maintaining a vibrant, dynamic defense industrial base with vendors that compete vigorously to win contracts and provide the government with products and services is critical to U.S. national security. Indeed, while historically the government has relied on mobilizing a mix of federally-funded arsenals and civilian contractors during wartime to meet its military needs, following WWII, these needs have been met principally by a permanent private defense establishment.

This research project seeks to evaluate the urgency of these concerns by examining the connection between industrial concentration and contract outcomes. It examines the relationship in multiple ways. First, it examines the influence of concentration on the extent of competition. Second, directly, through the influence of concentration in the contract's sector on performance. Third, indirectly, through the effects of competition on contract performance. Finally, both concentration and competition are incorporated into a single model for each performance metric.

As the primary buyer of the defense industry's goods and services, the U.S. government can play a significant role in shaping the industry's size, composition, and economic viability. As a result, the defense industrial organization has evolved (at least in part) in accordance with military spending. Since WWII, the defense budget has cycled between a series of peaks and troughs, generating significant expansions in industrial capacity followed by more modest declines. This pattern resulted in a particularly acute case of capacity overhang following the end of the Cold War, because during the war contractors had invested heavily in plants, equipment, and other assets that were no longer needed following the war's end (and the subsequent drop in defense expenditures). To eliminate inefficiencies

stemming from excess capacity, the Department of Defense (DOD) explicitly encouraged its contractors to merge and offered to share in savings generated from consolidations. Merger activity in the defense industry increased dramatically. Between 1993 and 2000, the number of major prime contractors fell from 50 to six.[4] However, it is still an open question whether and to what extent these mergers actually generated savings—or if the mergers even stemmed as much from the DOD's pro-consolidation policy and post-Cold War budget cuts as they did from economy-wide trends that also drove mergers in non-defense industries.[5]

Defense budgets reversed following 9/11 and grew at rapid double-digit rates for nearly a decade. However, spending reductions mandated by the Budget Control Act (BCA) of 2011 as well as the cuts to Overseas Contingency Operations (OCO) funding around that time—policies collectively referred to as "the drawdown"— have significantly impacted the defense industry. Across individual product and service platforms, a recent analysis showed declines in defense contract obligations from 16 percent for Ships and Submarines to as high as 56 percent for Land Vehicles.[6] Declines in other portfolios varied, according to the analysis, from 19 percent for Aircraft, to 20 percent for Ordinance and Missiles, to 32 percent for Space Systems.[7] Obligations for products, services, and R&D activities not falling under one of these specific platform categories fell by 30 percent, 28 percent, and 19 percent respectively.[8] Within product, service, and R&D categories, the analysis showed that the shares of obligations going to small businesses tended to grow or remain steady, but the share of obligations tended to fall for the Big 5 (Lockheed Martin, Boeing,

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[4] Jacques Gansler, *Democracy's Arsenal: Creating a Twenty-First Century Defense Industry* (Cambridge, MA: MIT Press, 2011).

[5] For a review of competing explanations of post-Cold War U.S. defense industry consolidation, see, e.g., Ryan R. Brady and Victoria A. Greenfield, "Competing Explanations of U.S. Defense Industry Consolidation in the 1990s and Their Policy Implications," *Contemporary Economic Policy* 28, no. 2 (2009).

[6] Rhys McCormack, Andrew P. Hunter, and Greg Sanders, *Measuring the Impact of Sequestration and the Defense Drawdown on the Defense Industrial Base* (Washington, DC: CSIS, 2017). https://csis-prod.s3.amazonaws.com/s3fs-public/publication/180111_McCormick_ImpactOfSequestration_Web.pdf?A10C65W9Qkx07VaJqYcJguCH.7EL3O7W

[7] Ibid.

[8] Ibid.

Raytheon, Northrop Grumman, and General Dynamics) and especially for large and medium size vendors.[9] Across categories and vendor sizes, the analysis found that the number of vendors receiving prime contracts from the Department of Defense dropped in all by 17,000, or nearly 20 percent over the drawdown period.[10]

Whether these vendors fully exited the defense marketplace or remained (e.g., as subcontractors) cannot be definitively established. Nonetheless, existing evidence suggests the U.S. defense industry is in the process of another significant episode of transformation, and officials from both the previous and current administrations have signaled worries over the industry's health and competitiveness. As far back as 2011, Ash Carter, then Under Secretary of Defense for Acquisition, Technology, and Logistics (USD-AT&L, and later Secretary of Defense) stressed the importance of avoiding excessive consolidation among large prime contractors.[11] His successor in the USD-AT&L role, Frank Kendall, took the same view, calling Lockheed Martin's proposed and subsequently executed acquisition of rotary-wing aircraft manufacturer Sikorsky "the most significant change to the defense industry since the general consolidation that followed the Cold War."[12] Kendall warned more generally that continued consolidation, particularly of large prime contractors, could diminish competition, limit the number of suppliers available to the military, erect barriers to entry, and hinder innovation that is key to sustaining U.S. technological superiority.[13] Around the same time, the U.S. Department of Justice (DOJ) and the Federal Trade Commission (FTC) reiterated their commitment to take action against mergers that would dampen innovation and competitive forces and issued a joint statement saying, "many sectors of the defense industry are already highly concentrated [and others] appear to be on a similar trajectory."[14] More

[9] Ibid.
[10] Ibid.
[11] Marcus Weisberger, "Lockheed-Sikorsky Deal Stokes Fears About Industry Consolidation," (Defense One, 2015), http://www.defenseone.com/business/2015/09/sikorsky-lockheed-deal-stokes-fears-about-industry-consolidation/122445/
[12] Ibid.
[13] Ibid.
[14] Department of Justice and Federal Trade Commission, "Joint Statement of the Department of Justice and the Federal Trade Commission on Preserving Competition in the Defense Industry." (Washington, DC: 2016),

recently, under Executive Order 13806, President Trump directed a sweeping review of the industrial base with the aim of determining if its broad composition, capacity, and resiliency can meet a variety of potential supply chain threats.[15] Questions of industrial concentration and monopoly power, as well as their implications for competition and performance, relate importantly to these issues.

https://www.ftc.gov/system/files/documents/public_statements/944493/160412doj-ftc-defense-statement.pdf

[15] Executive Order 13806, "Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States" (Washington, DC: 2017). https://www.whitehouse.gov/presidential-actions/presidential-executive-order-assessing-strengthening-manufacturing-defense-industrial-base-supply-chain-resiliency-united-states/

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2 Literature Review

2.1 Industrial Concentration – Definition and Measurement

Industrial concentration refers to the degree to which a smaller versus a larger number of firms account for production or other measures of market share (e.g., revenue) in some part of the economy.

Taking this idea as a point of departure, a large discourse in the literature has developed around alternative approaches to measuring concentration in practice.[16] One approach is to use concentration ratios, which add shares (whether of production, revenue, or some other activity) of a pre-determined number of firms in a particular market. Commonly used numbers include the top 4, 8, 20, or 50 firms in the market of interest. These ratios are relatively simple to calculate and, compared to other metrics—such as the Herfindahl–Hirschman Index (HHI) —do not impose as large a challenge with data collection, because they do not require data on the shares of every firm in the relevant market place. By contrast, calculating the standard HHI requires data on the shares of every firm in the relevant market place and entails squaring each individual share before adding them (so as to weight the index more strongly toward larger companies). The upsides of this approach include counting shares of every applicable firm and weighting firms with larger shares more heavily in the calculation. Whereas concentration ratios are expressed in percentage terms (with a 100 percent maximum), the HHI varies between a minimum of 0 and a maximum of 10,000 (where one firm accounts for 100 percent of the market and $100^2 = 10{,}000$). For purposes of evaluating mergers and their antitrust implications, the DOJ deems HH indices of 2,500 or higher to be significantly concentrated.[17]

2.2 Causes of Industrial Concentration and Monopolies

Variation in levels of industrial concentration—from very low to monopoly levels where one firm accounts for all of an industry's production, revenue, sales, or

[16] See, e.g., Lachlan B. Curry and K.D. George, "Industrial Concentration: A Survey," *The Journal of Industrial Economics* 31, no. 3 (1983) for commonly-cited review of the literature.
[17] See https://www.justice.gov/atr/herfindahl-hirschman-index

other economic activity— stems from several sources. Differences across industries or within a given industry over time may reflect an underlying decline in competition and attendant increases in market power for leading firms—a common interpretation of recent trends in the U.S.[18]—although one of at least four other forces may also be at play (and, depending on which, may suggest alternative explanations for changes in concentration levels).

First, higher industrial concentration may stem from *economies of scale*, a technological feature of production that leads per unit production costs to fall as output rises. The upshot of this dynamic is that an industry's aggregate output can be most efficiently produced by a smaller, rather than a larger, number of firms.[19] Accordingly, in a case like this, the industry actually operates most efficiently and can charge lower prices for its output with less—as opposed to more—firms in operation. The number of firms may fall due to some firms exiting the marketplace or through mergers and acquisitions. In extreme cases, economies of scale are so high as to make it most efficient for a single firm to produce all of an industry's output, a situation referred to as a *natural monopoly*, which is common among utility companies. Unlike (as discussed below) situations where monopoly power derives from purposefully erected barriers to entry (e.g., government conferring operating privileges exclusively to a single company), natural monopolies arise due to the underlying technology for production of a good or service.[20] Commonly-cited natural monopolies include utilities, where entry of additional firms would entail highly inefficient (and arguably infeasible) recreation of distribution infrastructure like pipes or power lines that one firm has already incurred the costs to build.[21]

Second, and similarly, production may be subject to *learning curves*, where (however high or low scale economies may be) per unit costs fall as firms discover more efficient ways to produce output. According to learning curve theory, through repeated production, firms accumulate knowledge and experience that can be used

[18] See supra note 1.
[19] Dennis W. Carleton and Jeffrey M. Perloff, *Modern Industrial Organization* (Pearson, 2015).
[20] For an early overview of natural monopoly, see Richard A. Posner, "Natural Monopoly and Its Regulation," *Stanford Law Review*, no. 21 (1969),
[21] Rolf W. Kunneke, "Electricity networks: how 'natural' is the monopoly?" *Utilities Policy* 8, (1999).

for purposes of process improvement, efficiency enhancements, and lower per-unit pricing[22] (which may make them more competitive relative to their peers and lead them to capture higher market share). Manufacture of large capital assets like ships, planes, or construction equipment are often suggested to benefit from the learning curve dynamic, because while they may initially entail high costs for design and early unit production, they entail lower costs as production expands.

Third, firms may create barriers to entry or force competitors out through strategic behavior like predatory pricing, hostile takeovers, or alternative forms of vertical acquisition where an incumbent firm acquires lower-level suppliers (thus eliminating potential sources of productive inputs that new entrants need in order to operate). Incumbent firms may act alone to create entry barriers, or they might potentially collude with one another for this purpose. A commonly cited example of collusion to prevent competition involves incumbent firms dividing up customers in lieu of vying with each other to capture as much business as possible. The firms may divide up sales territories, for example, and work together to prevent competitors from entering. Such conduct has been suspected or documented to have happened in industries as diverse as health insurance and chemicals.[23]

Finally, in some instances governments purposefully erect structural barriers to entry that may limit competition that is otherwise likely to arise (e.g., in cases where scale economies do not operate at high levels and concentrate production in a few firms). Governments may create entry barriers through extending protections for intellectual property and innovation (e.g., through patents), through establishing legal and regulatory requirements that must be fulfilled in order to do business in a particular area, or by granting only one or a few firms permission to do a form of business (thereby foreclosing competitors from entering the market). Sufficiently high entry barriers can create monopolies in cases where the underlying technology of production implies strong efficiency gains from having one or only a few producers. Taxis are an often-cited example of a monopoly that city governments

[22] See supra note 5.
[23] For further explanation and specific examples, see <https://www.ftc.gov/tips-advice/competition-guidance/guide-antitrust-laws/dealings-competitors/market-division-or>

have created through regulations such as requiring the purchase of a medallion to drive a cab.

The monosopy nature of the market can also be a barrier. The defense industry sells its products principally to a single buyer: the U.S. government (from which decisions about policy, budgets, and procurement priorities can significantly impact defense industry structure). In addition, concentration in different sectors of the defense industry may stem at least partially from underlying scale economies, learning curve dynamics, and government-imposed regulations, which are often cited as a barrier to further entry by commercial firms. Scale economies and learning curves are fundamental to the production of large, complex assets such as fighter jets and ships, leading to high concentration in these sectors (U.S. aircraft carriers, for example, are built exclusively in one shipyard, operated by Newport News Shipbuilding). And, in both of these sectors (and all others from which government purchases products, services, and R&D support) rules and regulations that firms must adhere to for purposes of bidding on contracts and winning business may constitute a substantial barrier to further competition—particularly for non-traditional firms that could be significant sources of innovation. Experiments with alternative acquisition models and partnerships such as the Defense Innovation Unit – Experimental (DIU_x)—the DoD's Silicon Valley-based unit focused on identifying and acquiring cutting-edge commercial technology solutions for the U.S. military—are ongoing, but large-scale entry of commercial players into the defense marketplace (and attendant growth in competition) remains to be seen.

2.3 Concentration, Competition, and Performance

To the extent it stems from factors such as reductions in competition and barriers to entry (whatever their source), rather than economies of scale, learning effects, or other forces that reflect a firm's active pursuit of ways to enhance efficiency, industrial concentration is concerning because it can reduce economic

welfare and generate market power that firms may use to extract rents in the form of higher prices to consumers.[24]

Empirically, there is a large and now decades-old body of evidence relating increasing concentration to elevated prices and profits for firms.[25] Whether these relationships reflect firms exercising market power to charge excessively high prices and make additional profits is less clear, however. Some research, for example, attributes the observed link between concentration and profits to efficiency gains stemming from learning and harnessing scale economies. These arguments suggest that efficiency-enhancing concentration generates reductions in both prices and costs, but greater reductions in the latter than the former (leading, on average, to higher observed profitability as price-cost differentials grow).[26] This finding is supported by other research demonstrating that, after controlling for firm size, the relationship between concentration and profitability is less strong—suggesting profit growth comes from efficiencies brought about by increasing the scale of production, of which increased concentration is just a byproduct.[27] More recent research comes to the opposite conclusion, finding robust connections between growing concentration, profits from both ongoing business as well as from mergers and acquisitions, and higher stock prices. Rather than reflecting operational efficiency and declining costs, however, this analysis suggests that higher profitability is a function of increased market power.[28]

Compared to research on relationships between concentration, competition, and firm-performance outcomes like profitability, there has been less research conducted on the implications of concentration for other measures of performance. While, as noted, higher profitability from increasing concentration may reflect

[24] See supra note 19.
[25] Literature reviews date back as far as the 1970s, with one review, published in 1974, cataloguing the results of 40 pre-existing studies. See Leonard Weiss, "The Concentration-Profits Relationship and Antitrust," in Goldschmidt et al. (eds.), *Industrial Concentration: The New Learning*, (New York, NY: 1974).
[26] Sam Peltzman, "The Gains and Losses from Industrial Concentration," *Journal of Law and Economics* 20, (1977).
[27] See Yale Brozen, *Concentration, Mergers, and Public Policy,* (New York: Macmillan, 1982).
[28] Gustavo Grullon, Yelena Larkin and Roni Michaely, "Are US Industries Becoming More Concentrated?," Working Paper (2017).

stronger operational efficiency, there are other possible sources that do not imply better performance. As a result, this still leaves open the problem of explicitly examining links between concentration and firm performance along non-financial dimensions.

Moreover, compared to research on the private sector, very little work has been done to examine the implications of industrial concentration for government, specifically in the context of procurement and contracting. Competition is deemed a fundamental source of value in public procurement and is argued to provide higher quality products at lower prices, along with ancillary benefits such as accountability, fraud prevention, and better stewardship of taxpayer resources.[29] In buying simple goods and services, for which many suppliers already exist, the benefits of competition can be powerful. For more complex products—whether inputs into government's provision of public services (e.g., fighter jets for national defense) or public services delivered by non-governmental actors (e.g., social services provided by a nonprofit organization)—markets may be thinner and competition less viable.[30] However, in these cases too, the focus has been on examining the relationships between the quality of products and services on the one hand and competition on the other. Moreover, this work has often been done in the context of one or a few different product types.

Research that independently (or through competition as a mediating channel) explores the link between program level outcomes and concentration, competition, and contractor performance appears to be mostly absent from the existing literature and would add be considerable value. In particular, there's an absence of work that uses large amounts of data to look across numerous product and service categories. There appear to be very few example studies explicitly assessing the link between industrial concentration and performance outcomes in the U.S. defense arena. One example is an analysis finding a positive relationship between concentration and firm

[29] Kate Manuel, *Competition in Federal Contracting: An Overview of the Legal Requirements*. (Washington, DC: Congressional Research Service, 2011).
[30] Donald Kettl, *Sharing Power: Public Governance and Private Markets*. (Washington, DC: The Brookings Institution, 1993).

profitability in the aerospace industry. [31] Another analysis, more closely related to the research presented in this paper, finds evidence that some defense industry mergers generated cost savings in Major Defense Acquisition Programs (MDAPs) but also found that mergers do not categorically generate program-level savings.[32] Unlike the present study, however, this analysis is focused on financial dimensions of performance at the program level. This study extends the literature by looking at both financial and non-financial dimensions of performance and considers outcomes at the contract, rather than the program, level.

[31] Judy B. Davis, *The Impact of the Defense Industry Consolidation on the Aerospace Industry*, (Washington, DC: Industrial College of the Armed Forces, 2006).
[32] Russel V. Hoff, *Analysis of Defense Industry Consolidation Effects on Program Acquisition Costs*, (Monterey, CA: Naval Postgraduate School, 2007).

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3 Conceptual Framework and Hypotheses

This paper posits and tests a conceptual argument linking industrial concentration and contract performance in two ways: first, a direct relationship between concentration and performance outcomes; and second, an indirect relationship, where concentration influences performance through reducing competition for government contract awards and task orders. Specified in this manner, the argument broadens the approach to observing the relationship between concentration and contract performance, accounting for multiple ways that the two variables may be connected.

3.1 Industrial Concentration and Contract Performance – Direct Relationship

The most straightforward way that industrial concentration impacts different markers of contract performance is through a direct relationship between the two variables. That is, changes in the level of industrial concentration are associated with an observable variation in alternative performance benchmarks, including (as considered in this paper) terminations and breaches of cost ceilings.

While arguments about concentration and contract performance may suggest the two are negatively related—with higher concentration leading to poorer performance—these arguments usually imply the presence of a mediating variable. Competition, as discussed in section 3.2, is one such variable. Economies of scale is another, which is often cited when arguing that concentration and performance may instead be positively related. In this case, rather than decreasing competition (and the attendant accumulation of market power a vendor may wield over the government), increasing concentration leads to positive performance, as it reflects efficiency gains from one or more vendors consolidating to operate at a larger scale of production.

Arguments that do not imply or explicitly reference a mediating variable—but instead posit a direct concentration-performance link—are agnostic with respect to whether growing concentration levels foster better or worse performance. Therefore,

for hypothesis testing purposes, the study team does not suggest the direct relationship between concentration and contract performance is positive or negative. Instead, we simply hypothesize that the former may have a direct influence on the latter:

H_1: industrial concentration leads to changes in contract performance

3.2 Industrial Concentration and Contract Performance – Mediating Role of Competition

While concentration and contract performance may be directly related, one common argument is that higher concentration negatively impacts performance by hindering competition that would otherwise act to discipline incumbent vendors. All else equal, greater competition gives the government greater control in their relationship with vendors, providing them with multiple options while forcing vendors to perform well, because they are considered more replaceable.

Through reducing the number of vendors from which government can select for awarding a contract, the argument is that concentration effectively reduces competitive forces. In addition, this would reduce the incumbent vendor's incentive to perform effectively, as the prospect of being replaced is now lower. The incumbent may therefore be less motivated to innovate, control costs, or otherwise ensure its product meets or exceeds the government's requirements. Consequently, the risk of termination or a cost ceiling breach may be elevated.

This line of reasoning points to two hypotheses. First, the logic that industrial concentration's influence on performance through a competition channel implies a relationship between concentration and competition per se. Put simply, as concentration increases, competition decreases. Second, it implies a link between competition and performance outcomes, where reduced competition makes poorer performance more likely. In other words:

H_2: Increasing (decreasing) industrial concentration leads to decreasing (increasing) competition

H_3: Decreasing (increasing) competition makes poor contract performance more (less) likely

4 Data and Methods

4.1 Data Sources and Structure

4.1.1 Data Sources

The study team's primary source of data for this study is the Federal Procurement Data System (FPDS), which tracks all prime federal contract transactions worth $3,500 or more, conducted by most U.S. government department and agencies.[33] CSIS has created its own copy of this database, using data downloaded from USAspending.gov and supplemented at times with the FPDS-NG ad hoc search webtool. The study team supplemented this dataset with economics statistics broken down by NAICS category, as report by the U.S. Census and Bureau of Labor Statistics. During the period of this study, the USA spending website underwent a major update that CSIS is still incorporating into the study team's analysis.

4.1.2 Data Structure

The unit of analysis for the dataset is prime contracts award and task orders. Each contract entry has a unique procurement identifier, and each task order entry has a unique combination of a parent award identifier and procurement identifier. The dataset includes all completed DoD contracts and task orders initiated between fiscal years 2008 and 2016 that were completed by the end fiscal year 2016.[34] For task orders, the dates of inclusion and completion are based on each specific task order, not the date of the larger parent. The data set contains over 11.8 million entries, of which 30.0 percent were removed due to missing data, primarily with reference to undefinitized contract awards. These removed entries accounted for about 18.7 percent of obligations in the original dataset. For computational efficiency

[33] Prominent exceptions include classified contracts, which excludes the entirety of the CIA and some DoD contracts, most prominently in the U.S. Air Force. Other parts of the government are not required to report, such as the Defense Commissary Agency or the U.S. Postal Service. A larger dataset, including 2006 and 2007 values when available, was used to rescale the centered and logged variables.

[34] Completion is measured by having surpassed the current completion date of the contract or task order by at least one year or by contract close out or a partial or complete contract termination.

purposes, the study team has limited the analysis to a random sample of just 250,000 contracts and task orders from the filtered dataset. For simplicity's sake, when this paper refers to contracts it includes both awards and task orders. In those cases where only awards or task orders are being referred to, the more specific term will be used.

The study team has created the contract dataset from FPDS, which expands and updates a dataset used in previous CSIS reports on Fixed-Price[35] and Crisis contracting. [36] To create this dataset, the study team decided how to handle contradictory information within the same field and how to consolidate large numbers of categories in the raw data into more manageable number used in the regression. To mitigate contradictions and to emphasize information available at the time a contract is awarded, as a general principle, the most weight is given to a contract or task orders' initial unmodified transaction. The primary addition to the datasets used in previous reports relates to the North American Industrial Classification System (NAICS). First, the study team calculated the top detailed industry (NAICS 6-digit code) for each contract in the dataset. Second, the study team added a measure for industrial concentration, which was calculated at the NAICS subsector (NAICS 3-digit code) and detailed industry level.[37]

In addition to the contract dataset, the measures of concentration also relied on past and updated work by the study team to consolidate large vendors who may be represented by multiple DUNS numbers (the primary unique identifier for vendors within FPDS). The study team uses an obligation-weighted approach to choose identifiers for manual classification that have received either more than $1 billion in

[35] Andrew Hunter et al., "Avoiding Terminations, Single-Offer Competition, and Costly Changes with Fixed-Price Contracts," *Center for Strategic and International Studies*, 2015, https://csis-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/151216_Sanders_FixedPriceContracts_Web.pdf.
[36] Greg Sanders and Andrew Hunter, "Overseas Contingency Operations Contracts After Iraq: Enabling Financial Management Research and Transparency Through Contract Labeling," *Naval Postgraduate School*, 2017, https://www.researchsymposium.com/conf/app/researchsymposium/unsecured/file/145/SYM-AM-17-051-005_Sanders.pdf.
[37] CSIS has made this dataset publicly available through our github repository (https://github.com/CSISdefense/Vendor/) to other researchers to be used with attribution.

obligations from 2000 to 2017 or $250 million in any year in constant 2017 dollars. Those identifiers which the study team has not manually classified are instead handled via parent codes that are provided by the database. One disadvantage to this approach is that merger and acquisition activity is sometimes backdated to years before the merger occurred. However, the value weighted approach applied by the study team is appropriate for the industrial concentration measures described in the literature review, because the largest firms in a sector are disproportionately important to calculating the HHI.

4.2 Measures of Dependent and Independent Variables

This section introduces the variables used in our regression model. For consistency and ease of data replication, the shortened name of the variable is included in parentheses after the full name. This shorthand name is also used in the definition of the equation and the results.38

4.2.1 Dependent Variables

Rescaled Logged Number of Offers (cl_Offr) is the number of offers each contract received, logged and then rescaled. Sole source awards are treated as receiving a single offer, consistent with how they are classified within FPDS. The study team considered multiple variables to competition: whether or not a contract used competitive procedures, whether or not a contract was competed with multiple offers, and the number of offers received. The study team decided to use number of offers received because it offers the detail of a continuous measure and because it is straightforwardly compatible with regression modeling in a way that binned numbers of offers would not be. The study team took the logarithm of this measure because that transformation puts the same weight on the difference between 1 and 2 offers as the difference between 5 and 10.

[38] Some of the variables were transformed from categorical variables to the mathematical formats used in the dataset, for example Term has a value of “Terminated” or “Not Terminated” while b_Term has a value of 0 or 1. Different prefixes are used depending on data type “b_” refers to binary variables, “n_” refers to numerical variables, “l_” refers to variables that have undergone a logarithmic transformation, and “c_” labels to variables that were rescaled which includes centering (and thus “cl_” is a rescaled logarithmically transformed variable.

The log of the number of offers is rescaled, by subtracting its mean (1.12) and dividing by its standard deviation doubled (2.22). The standard deviation is larger than expected, with a small number of high offer contracts exerting a big effect. Values of -0.5, 0, 0.5 correspond to 1, 3.1, and 9.3, offers respectively. Offers data is missing for less than 2 percent of records.

Partial or Complete Terminations (b_Term) measures whether contracts experience a partial or complete termination, which yields a value of 1, while contracts with no terminations are given the value 0 for this variable. FPDS does not differentiate between complete and partial terminations, so this can include both a cancelled program and a contract that was completed after being initially protested and reassigned. 1.2 percent of contracts have experienced at least one partial or complete termination, and those records account for about 5.6 percent of obligations in the dataset.

Ceiling Breaches (b_CRai) tracks whether the contract had to be changed in a means that risked significant cost increases. To measure this, the study team observed transactions that are contract change orders and considered a ceiling breach to have occurred (assigning a value of 1) if any of these modifications also increased the contract or task order's cost ceiling. Otherwise, the team assigned a value of 0. While only 1.2 percent of contracts have experienced a ceiling breach, the total obligations of those entries account for over 21 percent of obligations in the dataset. In addition, a slim fraction of terminations overlaps with ceiling breaches, despite both accounting for a similar percentage of contracts and task orders.

4.2.2 Study Independent Variables

Study Variables

Competition (CompOffr) is a dummy variable with five values based on whether a contract was competed and, if so, with how many offers received.:

- No Competition includes all sole-source contracts, with single-award vehicles classified based on vehicle level competition and not for the individual task order. This is the baseline variable and does not receive its own dummy.

- 1 offer (nearly 14 percent of contracts and 12 percent of obligations).
- 2 offers (19 percent of contracts and 12 percent of obligations).
- 3-4 offers (21 percent of contracts and 15 percent of obligations).
- 5+ offers (approaching 29 percent of contracts and 25 percent of obligations).

The study team draws on multiple variables in FPDS to make this determination, with some contracts relying on the extent of the competitive field and others relying on the fair opportunity field. The study team used other variations on the measure for competition for earlier versions of this paper, , including the coding competition into three numerical categories for sole source, single offer, and 'effective competition,' i.e. competition with two or more offers, which is used by the DoD when monitoring their own competition rates.[39] However, after the incorporation of the complete multilevel model, this variable proved not to be a significant predictor and the study team increased the granularity to better understand competitive dynamics. Competition is missing from 1.9 percent of contracts and a bit over 1.7 percent of obligated dollars in the dataset.

[39] See for example https://www.acq.osd.mil/dpap/cpic/cp/docs/DoD_FY_2014_Competition_Report.pdf

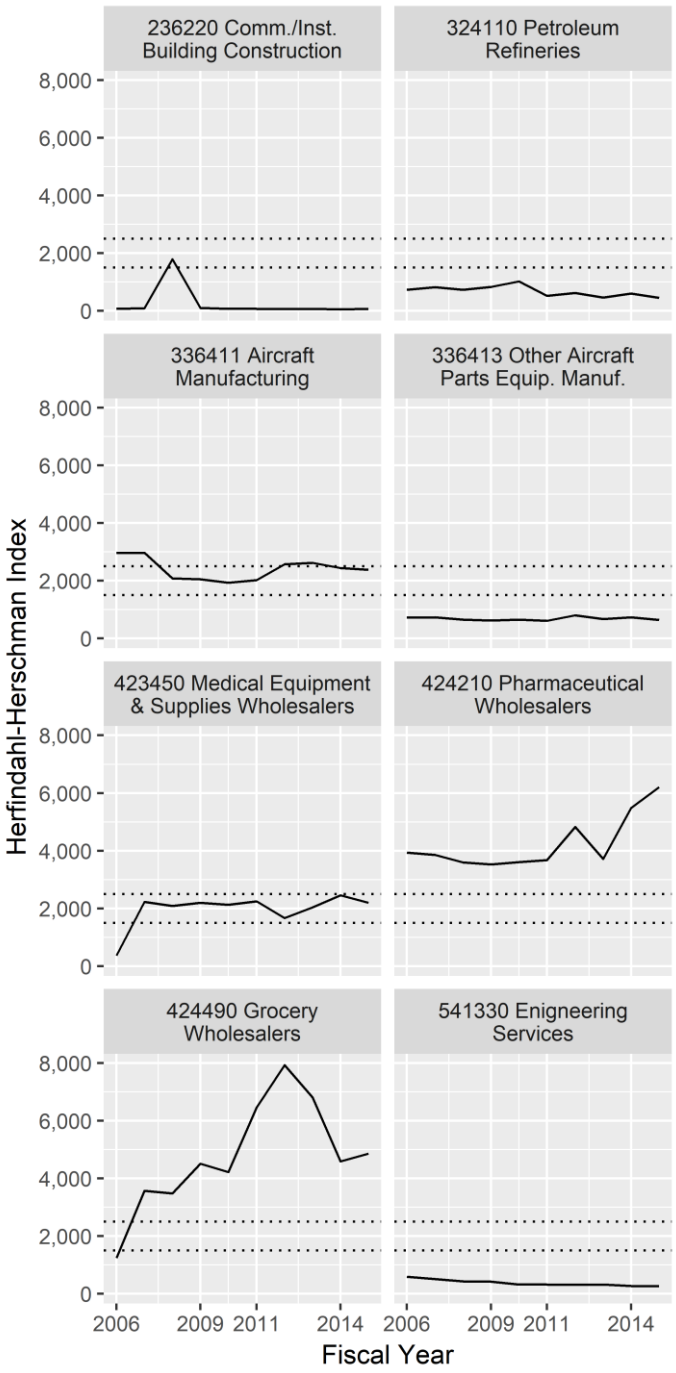

Figure 1. Concentration in Selected Defense-Detailed Industry Categories

Subsector and Detailed Industry Herfindahl-Hirschman Index (**cl_def3_HHI_lag1 and cl_def6_HHI_lag1 respectively**) are a measure of industrial concentration in the defense industrial base. As described in the literature review, the HHI is calculated by squaring the market share of each participant in a

sector. The study team faces two common challenges in creating this variable: identifying and collecting reliable data on market shares and, more fundamentally, defining the scope of the marketplace in which concentration will be analyzed. The study team began with the detailed industry, the six-digit NAICS code and the most detailed level available. After adding economic statistics to the model, the study team decided to include the subsector HHI, the three-digit NAICS code, as well.

Figure 1 shows eight of the top sectors, selected for having either the most contracts or the most obligations over the study period with the HHI shown before logging. The dotted lines are the lower and upper bounds of what the DOJ considers to be a moderately consolidated market. The date range is 2006 to 2015 because subsector and detailed industry HHI are lagged one year. So, for a contract signed in 2009, the concentration measure of industry in 2008 is used.

All else equal, defining a sector more broadly—and thereby including more firms—will tend to reduce concentration levels, whereas a more precise definition will raise them. One downside to this approach is that less-used NAICS codes are reported as highly consolidated because they are used by so few vendors. The advantage of this approach is evaluating the implications of concentration for competition, consumer welfare, and public policy often requires examining trends at a less aggregated level.

For the purposes of this study, market share refers to the percentage of prime obligations within a given fiscal year, which has the notable drawback of not capturing subcontracting activity. In the dataset, this measure is lagged by one year. Both measures are separately logged and rescaled. [40]

- The logged detailed industry HHI is rescaled, by subtracting its mean (7.1 4) and dividing by its standard deviation doubled (1.09). Values of -1, 0, 0. 5, and 1 correspond to 142, 1,266, 3,780, and 11,293 HHI score respectiv ely, with the later value exceeding the upper end of the scale

[40] Centering a variable is a way of making sure the different variables in a regression model are operating on the same scale, which makes it easier to compare coefficients across different variables. Mathematically to center x means c_x = (x –average of x) / (standard deviation of x).

- Logged subsector HHI has a notably lower mean and standard deviation. That variable is using the same formula of subtracting its mean (6.24) and dividing by its standard deviation doubled (0.951). Values of -1, 0, 0.5, and 1 correspond to 76, 512, 1,326, and 3,430 HHI score respectively.

Missing data can be a challenge for both variables for reasoned discussed in section 6.4.5. For the subsector and detailed industry HHI, data is missing for about 0.1 and 2.8 percent of records, respectively, and 0.25 and 3.6 percent of obligated dollars, respectively.

4.2.3 Other Sector-Level Variables

Contract Industrial Sector

NAICS represents the top North American Industrial Classification Code of each contract and is measured by obligated amount. This paper uses a multilevel model that allows for setting a different intercept for detailed each industrial sector, which is discussed in greater detail in the next section (4.3).

As shown in Figure 2, the distribution of DoD contract obligations is focused in a subset of the 24 NAICS 2-digit codes. Manufacturing (31-33) in particular is the top category in dollar and count terms and stands out because that category—like Transportation and Warehousing (48-49) as well as Retail Trade (44-45)—spills over into multiple 2-digit codes. In dollar terms, Professional, Scientific, and Technical Services (54) and Construction (23) are the second and third most prevalent industrial sectors; however, they are less significant in terms of the number of contracts because those sectors have higher value contracts. At the other end of the scale, Wholesale Trade (42) has lower obligations contracts, with less dollars obligated in that sector than either Construction or Professional, Scientific, and Technical Services.

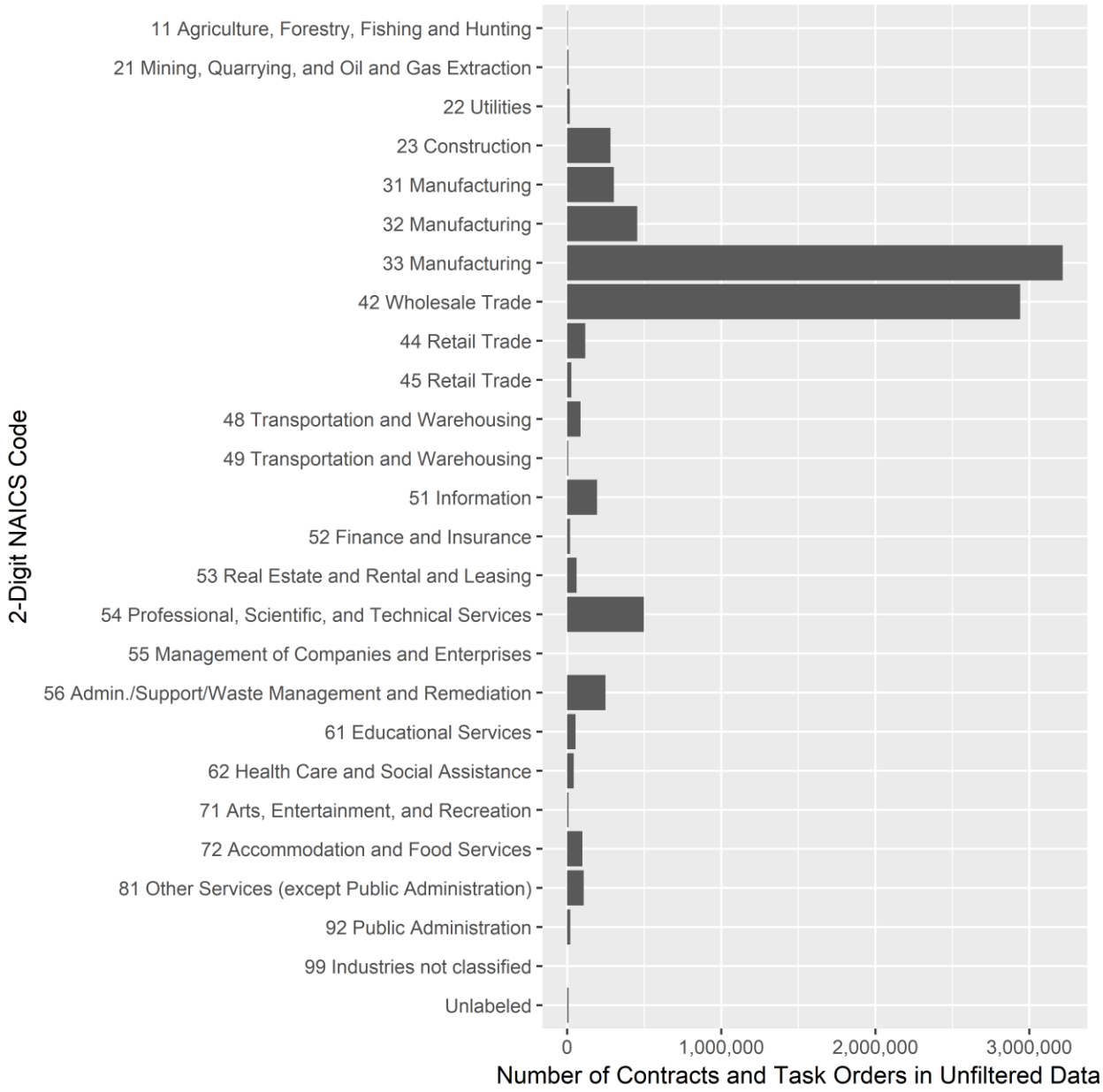

Figure 2. Distribution of Contract Obligations by NAICS 2-Digit Code

Detailed Industry Defense Obligations (cl_def6_obl_lag1)

This variable annually sums total defense obligations by NAICS subsector and detailed industry. It's included in the model with a lag of one year, so the estimator for any contract will be the total obligations in the prior calendar year. It is also calculated at the subsector level, but that variable does not appear directly in

the models but is instead used to help create the subsector ratio. For both variations, when the total is negative or zero, it is treated as a missing value

For the detailed industry values are logged and rescales. This involves subtracting the mean of 20.2 and then dividing by the standard deviation doubled (3.85). Rescaled Values of -1, 0, and 1 correspond to 1.2 million, 58 million, 2.7 billion in current dollar annual obligations. Data is missing for 2.8 percent of records and 3.6 percent of obligations. See section 6.4.5 for a discussion of why the missing data for NAICS categories.

Subsector Ratio and Detailed Industry Ratio (cl_def6_ratio_lag1 and cl_def6_ratio_lag1) compares total defense obligations to revenues in the same NAICS category for the U.S. economy as a whole. The study team learned of this approach and of the necessary sources through the work Nancy Young Moore, Clifford A. Grammich, and Judith D. Mele.[41] The revenue data is only available for 2007 and 2012. Contracts starting in calendar years 2008-2012 use the 2007 value and contracts starting between 2013 and 2015 use the 2012 value. Because obligation and revenue are two different measures, it is possible for the defense obligations to exceed revenue in the U.S. economy as a whole. In that case, the study team capped the variable at 1, which represents complete monosopy by the DoD.

However, for most NAICS categories, defense obligations are only a small proportion of the total economy which can be seen in the logged and rescaled variables.

- The subsector ratio variable is rescaled, by subtracting its mean (-4.99) and dividing by its standard deviation doubled (3.45). Values of -1, 0, and 1 correspond to a defense to civilian ratio of 0.00021, 0.0068, and 0.21 respectively.
- The detailed industry ratios tend to be higher, their subtracted mean is only -4.52 and their doubled standard deviation is larger as well at 69. In the

[41] Nancy Young Moore, Clifford A. Grammich, and Judith D. Mele, "Trends in the DoD Industrial Base," *RAND National Defense Research Institute*, 2016, https://www.researchsymposium.com/conf/app/researchsymposium/unsecured/file/46/Moore_14_SYM-AM-16-117.pdf

resulting rescaled variable, Values of -1, 0, and 1 correspond to defense to civilian ratios of 0.00027, 0.011, and 0.44 respectively."

The subsector and detailed industry ratio are unavailable for about 0.2 and 2.9 percent of records, respectively, and 0.29 and 3.6 percent of obligated dollars, respectively.

Subsector and Detailed Industry U.S. Average Salary (cl_US6_avg_sal_lag1) is a variable calculated by dividing the payroll of the relevant detailed industry by the number of employees. For this dataset it is derived from the economic census, and thus only available in 2007 and 2012 as with the ratio variables. As with the other economic variables it is logged and rescaled. Rescaling subtracts its mean (11) and dividing by its standard deviation doubled (0.798). The resulting variable covers a wide gamut of wages with -1, 0, and 1 corresponding to $26,997, $59,964, and $133,186 dollars respectively. Data is missing for 2.9 percent of contracts and 3.6 percent of obligations.

4.2.4 Other Contract-Level Inputs

Initial Contract Scope

Initial Cost Ceiling (cl_Ceil) is the natural log of the initial contract cost ceiling as reported by the base and all options field, in then-year dollars.[42] The variable is rescaled by subtracting its mean (8.22) and dividing by its standard deviation doubled (5.22). Values of -1, 0, 0.5, and 1 correspond to $20, $3,723, $50,714, and $690,812 respectively. Data is missing for just over 0.04 percent of contracts and transactions, which accounts for just under 0.15 percent of obligated dollars in the dataset.

Initial Duration (cl_Days) is the natural log of the initial maximum duration of the contract in days. The maximum duration is determined by comparing the contract's effective date to the current completion date. The variable is rescaled by

[42] Constant dollars are not to allow for comparability between the contract ceiling and contract's actual expenditures in multiyear contracts. The base and all options ceiling of the contract is in nominal dollars but does not break out the cost ceiling for each individual year of a contract's life. As a result, the ceiling in constant dollars could be approximated, for example by assuming that the ceiling will be split evenly over the life of a contract, but cannot be calculated with any certainty.

subtracting its mean (2.83) and dividing by its standard deviation doubled (3.73). Values of -0.5, 0, 0.5, and 1 correspond to 2.6 days, 17 days, 110 days, and 716 days respectively. Data is missing for under 0.4 percent of contracts and transactions, which represents about 0.57 percent of dataset obligations.

Contract Vehicle

Contracts come in a variety of types, some of which are simple purchase orders, others are complex but single use contract awards, and yet others are task orders that are specific instances of an overarching indirect delivery vehicle. These types are explained below and help define the nature of the contractor/customer relationship.[43] The dataset uses dummy variables for four different types of indirect delivery vehicles:

- **SIDC** is 1 if the vehicle is a single-award indefinite delivery contract and 0 otherwise. These contracts may be initially awarded via competition but afterwards are only used for task orders to a single vendor. They constitute over 64.5 percent of all contracts.
- **MIDC** is 1 if the vehicle is a multiple-award indefinite delivery contract and 0 otherwise. These vehicles have a pool of potential vendors that can receive task orders, and they make up almost 2.7 percent of contracts and task orders.
- **FSSGWAC** is 1 if the vehicle is a Federal Supply Schedule or Government-Wide Acquisition Contract and 0 otherwise. These two consistently multiple-award indirect delivery vehicles constitute 3.8 percent of task orders and contracts.
- **BPABOA** is 1 if the vehicle is a Blank Purchase Agreement or Basic Ordering Agreement and 0 otherwise. These indirect vehicles can be either single-award or multi-award, but taken together they only constitute 1.9 percent of task orders and contracts.

The remaining 27 percent of contracts are contract awards and purchase orders with no parent contract. This is the baseline for the regression model, which is true when all four dummy variables are zero. Vehicle classifications are missing for less than 0.1 percent of contracts and for a similarly small percentage of dataset obligations.

[43] For more detail on contract vehicle types, see the Glossary at USAspending.gov.

Contract Pricing

Fixed-Price (PricingFee) is a categorical variable based on contract pricing and fee structure. The baseline is firm-fixed price contracts, which account for 82 percent of all contracts.

- **Other FP** refers to other fixed-price consists of includes fixe-price redetermination, fixed-price award fee, and fixed-price economic price adjustment and accounts for almost 15 percent of contracts.
- **Incentive** refers to the incentive fee contracts, including fixed-price incentive fee, cost plus incentive fee, and cost sharing. It accounts for only 0.2 percent of contracts.
- **Combination or Other** covers contracts using multiple pricing mechanisms or unusual and unclassified types. It accounts for 0.4 percent of contracts.
- **Other CB** refers to all types of cost-based contracting, excluding incentive fee and accounts for just over 1 percent of contracts.
- **T&M/LH/FPLOE** refers to time and materials, labor hors, and fixed-price level of effort contracts respectively. It accounts for just over 0.8 percent of contracts.

A miniscule percentage of contracts and obligations are unlabeled.

Undefinitized Contract Action (b_UCA) is a binary variable with a value of 1 for contracts that begin as letter contracts or undefinitized contract awards (UCA) and a value of 0 otherwise. They account for a tiny proportion (about than 0.03 percent) of contracts and only 3.7 percent of obligations, but they do significantly correlate with a greater risk of terminations and ceiling breaches. Unfortunately, due to a reporting error in recent years on the now retired version of USAspending.gov, UCA classification is missing for nearly 26 percent of records and over 10 percent of obligations in the dataset. Nonetheless, the predictive power of this variable is sufficient therefore still included in the study.

Contract Location

Any International (b_Intl) is a binary variable with a value of 1 for contracts with any transactions performed internationally and a value of 0 otherwise. 7.6 percent of contracts had an international component as well as nearly 14.5 percent of obligations. Only a miniscule portion of records were unlabeled.

4.3 Empirical Approach

The study team has created one model evaluating the connection between industrial consolidation and competition, four models evaluating all combinations of the study and mediating variables (competition and concentration respectively) with the two contract outcome variables (terminations and ceiling breaches), and finally another two models combining the study and mediating variables for each outcome variable. The initial model allowed the study team to study H_2. The combined model for industrial consolidation and competition were used to evaluate H_1 and H_3 respectively. The middle four model proved less necessary than expected, because neither the coefficients for industrial concentration nor competition notably changes upon the inclusion of the other.

4.3.1 Choice of Econometric Model

For the initial model of industrial consolidation's correlation with competition, the study team used a regression analysis with the outcome variable of the log of number of offers. For this model sole source awards were treaded as having a single offer. The study team used a maximum likelihood logit analysis to analyze both termination and ceiling breaches. Logit is suited to dependent variables which can be true or false, 1 or 0, but not values outside of that range. This approach does not allow for evaluation of the size of a ceiling breach or variations of partial or complete terminations. However, less than 5 percent of contracts or task orders ever experience ceiling breaches or termination, therefore the study team is only focusing on when these events occur and not differences between these cases.

In addition, for each of these models, the study team employs multilevel modeling techniques to capture the differences in expected outcomes between industrial sectors as categorized by NAICS codes and contracting office. Each contract is assigned to a detailed industry NAICS sector based on the NAICS code that received the most overall obligations over the contract's lifespan. Similarly, each contract is assigned a contracting office and agency based on the initial transaction for the contract. Finally, for the initial model of industrial consolidation's correlation

with competition, the initial contract signed date is used to determine the starting calendar year. This results in five groupings:

- Subsector Code with 79 groups within the sample.
- Detailed Industry Code, nested underneath subsector codes with 886 groups within the sample
- Contracting Agency Code with 24 groups within the sample.
- Contracting Office Code, nested underneath the agency codes, with 1,296 groups within the sample.
- Start Calendar Year, with 9 groups from 2008 to 2016.

The equations below use a varying intercept model, which is to say that each of the groupings has a constant term added to the equation based on the termination or ceiling breach rate within that sector. Multilevel modeling techniques are a means to balance between two extremes when considering how to combine data from different groups. The first technique is complete pooling, which means there would be no varying intercept and no differentiation based on a contract's NAICS sector. The second technique is no pooling, which means there is a separate model for each NAICS sector. Multilevel modeling uses "soft constraints," which are covered in more detail in the next section. The study team employed a mix modeling techniques recommended by Andrew Gelman and Jennifer Hill[44] and Nicolas Sommet and Davide Morselli.[45]

4.3.2 Presentation of Estimating Equation

For competition as a mediating variable when estimating the probability of termination, the study team used the following model (subscript i refers to the individual contract or task order, while subscript j refers to the NAICS subsector, subscript k refers to NAICS detailed industry, subscript l refers to contracting

[44] Andrew Gelman and Jennifer Hill, *Data Analysis Using Regression and Multilevel/Hierarchical Models* (New York, NY: Cambridge University Press, 2007). The adoption of these method did not extend to the use of BUGS, an alternative to the LME4 modeler.
[45] Sommet, Nicolas. and Davide Morselli, "Keep Calm and Learn Multilevel Logistic Modeling: A Simplified Three-Step Procedure Using Stata, R, Mplus, and SPSS" *International Review of Social Psychology:* 30(1), (2017), 203-218, DOI: http://doi.org/10.5334/irsp.90

agency, subscript *m* refers to contracting office, and subscript *n* refers to calendar year for those equations that include it):

Equation 1 Industrial Concentration and Competition

$$
\begin{aligned}
&Rescaled\,(Log\,(\,Number\,of\,Offers))_i \\
&= \alpha + \alpha_{j[i]}^{NAICS3} + \alpha_{k[i]}^{NAICS6} + \alpha_{l[i]}^{Agency} + \alpha_m^{Office} + \beta_1 cl\_def3\_HHI\_lag1_i \\
&+ \beta_2 cl\_def6\_HHI\_lag1_i + \beta_3 CompOff1 + \beta_4 CompOff2 + \beta_5 CompOff3\text{-}4_i \\
&+ \beta_6 CompOff5plus_i + \beta_7 cl\_def3\_ratio\_lag1_i + \beta_8 cl\_def6\_obl\_lag1_i \\
&+ \beta_9 cl\_def6\_ratio\_lag1_i + \beta_{10} cl\_US6\_avg\_sal\_lag1_i + \beta_{11} cl\_Ceil_i + \beta_{12} cl\_Days_i + \beta_{13} SIDV_i \\
&+ \beta_{14} MIDV_i + \beta_{15} FSS\text{-}GWAC_i \\
&+ \beta_{16} BPA\text{-}BOA_i + \\
&\beta_{17} Other\_FP_i + \beta_{18} Incentive_i + \beta_{19} Comb\text{-}Other_i + \beta_{20} Other\_CB_i + \beta_{20} TM\text{-}LH\text{-}FPLOE_i + \beta_{20} b\_UCA_i + \beta_{20} b\_In \\
&+ \beta_{21} cl\_def6\_HHI\_lag1_i \cdot b\_UCA_i + \beta_{22} SIDV_i \cdot b\_Intl_i + \beta_{23} MIDV_i \cdot b\_Intl_i + \beta_{24} FSS\text{-}GWAC_i \\
&\cdot b\_Intl_i + \beta_{25} BPA\text{-}BOA_i \cdot b\_Intl_i + \beta_{26} Other\_FP_i \cdot b\_Intl_i + \beta_{27} Incentive_i \\
&\cdot b\_Intl_i + \beta_{28} Comb\text{-}Other_i \cdot b\_Intl_i + \beta_{29} Other\_CB_i \cdot b\_Intl_i + \beta_{30} TM\text{-}LH\text{-}FPLOE_i \cdot b\_Intl_i \\
&+ \epsilon_i, \qquad for\ i = 1\ to\ 249{,}855
\end{aligned}
$$

$$\alpha_j^{NAICS3} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ j = 1\ to\ 79$$

$$\alpha_k^{NAICS6} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ k = 1\ to\ 886$$

$$\alpha_l^{Agency} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ l = 1\ to\ 24$$

$$\alpha_m^{Office} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ m = 1\ to\ 1{,}296$$

$$\alpha_n^{Year} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ n = 1\ to\ 9$$

The second half of the equation merits additional explanation. α_j^{NAICS3} and α_k^{NAICS6} refers to the subsector and detailed industry intercepts, which in this and the subsequent equations will vary for each the 7 3-digit NAICS codes and 866 6-digit NAICS codes. α_l^{Agency}, α_m^{Office} , and α_n^{Year} likewise represent their respective groupings. Andrew Gelman and Jennifer Hill explain the concept in their introductory text book.

> "In the multilevel model, a "soft constraint" is applied to the [α_j^{NAICS3}]'s : they are assigned a probability distribution [see above], with their mean $\mu_{\alpha,}$ and standard deviation σ_a^2 estimated from the data. The distribution has the effect of pulling the estimates of [α_j^{NAICS3}] toward the mean level $\mu_{\alpha,}$ but not all the way…"[46]

[46] Andrew Gelman and Jennifer Hill, 257.

Equation 2 Combined Industrial Concentration and Competition and Ceiling Breaches

To avoid repetition, only the final combined equations for ceiling breach and termination are displayed here. The exclusively concentration and competition models follow the same pattern, but omit the other study variable(s) and relevant interactions.

$$
\begin{aligned}
&Probability\ of\ Ceiling\ Breach\ (y_i = 1\ ) \\
&= Logit^{-1}\Big(\alpha + \alpha_{j[i]}^{NAICS3} + \alpha_{k[i]}^{NAICS6} + \alpha_{l[i]}^{Agency} + \alpha_{m}^{Office} + \beta_1 cl\_def3\_HHI\_lag1_i \\
&+ \beta_2 cl\_def6\_HHI\_lag1_i + \beta_3 CompOff1 + \beta_4 CompOff2 + \beta_5 CompOff3\text{-}4_i \\
&+ \beta_6 CompOff5plus_i + \beta_7 cl\_def3\_ratio\_lag1_i + \beta_8 cl\_def6\_obl\_lag1_i \\
&+ \beta_9 cl\_def6\_ratio\_lag1_i + \beta_{10} cl\_US6\_avg\_sal\_lag1_i + \beta_{11} cl\_Ceil_i + \beta_{12} cl\_Days_i + \beta_{13} SIDV_i \\
&+ \beta_{14} MIDV_i + \beta_{15} FSS\text{-}GWAC_i \\
&+ \beta_{16} BPA\text{-}BOA_i + \\
&\beta_{17} Other\_FP_i + \beta_{18} Incentive_i + \beta_{19} Comb\text{-}Other_i + \beta_{20} Other\_CB_i + \beta_{20} TM\text{-}LH\text{-}FPLOE_i + \beta_{20} b\_UCA_i + \beta_{20} b\_I \\
&+ \beta_{21} CompOff1 \cdot b\_UCA_i + \beta_{22} CompOff2 \cdot b\_UCA_i + \beta_{23} CompOff3\text{-}4_i \cdot b\_UCA_i \\
&+ \beta_{24} CompOff5plus_i \cdot b\_UCA_i + \beta_{25} cl\_def6\_HHI\_lag1_i \cdot b\_UCA_i + \beta_{26} cl\_Ceil_i \cdot b\_UCA_i \\
&+ \beta_{27}\ \text{cl}\_def6\_HHI\_lag1_i \cdot cl\_def6\_obl\_lag1_i + \epsilon_i\Big), \qquad for\ i = 1\ to\ 249{,}855 \\
&\alpha_j^{NAICS3} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ j = 1\ to\ 79 \\
&\alpha_k^{NAICS6} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ k = 1\ to\ 886 \\
&\alpha_l^{Agency} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ l = 1\ to\ 24 \\
&\alpha_m^{Office} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ m = 1\ to\ 1{,}296
\end{aligned}
$$

Equation 3 Combined Industrial Concentration and Competition and Terminations

$$
\begin{aligned}
&Probability\ of\ Termination\ (y_i = 1\ ) \\
&= Logit^{-1}\Big(\alpha + \alpha_{j[i]}^{NAICS3} + \alpha_{k[i]}^{NAICS6} + \alpha_{l[i]}^{Agency} + \alpha_{m}^{Office} + \beta_1 cl\_def3\_HHI\_lag1_i \\
&+ \beta_2 cl\_def6\_HHI\_lag1_i + \beta_3 CompOff1 + \beta_4 CompOff2 + \beta_5 CompOff3\text{-}4_i \\
&+ \beta_6 CompOff5plus_i + \beta_7 cl\_def3\_ratio\_lag1_i + \beta_8 cl\_def6\_obl\_lag1_i \\
&+ \beta_9 cl\_def6\_ratio\_lag1_i + \beta_{10} cl\_US6\_avg\_sal\_lag1_i + \beta_{11} cl\_Ceil_i + \beta_{12} cl\_Days_i + \beta_{13} SIDV_i \\
&+ \beta_{14} MIDV_i + \beta_{15} FSS\text{-}GWAC_i \\
&+ \beta_{16} BPA\text{-}BOA_i + \\
&\beta_{17} Other\_FP_i + \beta_{18} Incentive_i + \beta_{19} Comb\text{-}Other_i + \beta_{20} Other\_CB_i + \beta_{21} TM\text{-}LH\text{-}FPLOE_i + \beta_{22} b\_UCA_i + \beta_{23} b\_I \\
&+ \beta_{24} cl\_def6\_HHI\_lag1_i \cdot b\_cl\_Days_i + \beta_{25} cl\_def6\_HHI\_lag1l_i \cdot cl\_def6\_obl\_lag1_i \\
&+ \beta_{26}\ \text{cl}\_def3\_HHI\_lag1_i \cdot cl\_def3\_ratio\_lag1_i + \epsilon_i\Big), \qquad for\ i = 1\ to\ 249{,}855 \\
&\alpha_j^{NAICS3} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ j = 1\ to\ 79 \\
&\alpha_k^{NAICS6} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ k = 1\ to\ 886 \\
&\alpha_l^{Agency} \sim N(\mu_{\alpha,}, \sigma_a^2), \qquad for\ l = 1\ to\ 24
\end{aligned}
$$

$$\alpha_m^{Office} \sim N(\mu_{\alpha,}, \sigma_a^2),\ for\ m = 1\ to\ 1{,}296$$

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5 Results

This section groups the models not by hypothesis but by outcome variable: number of offers, ceiling breaches, and terminations. This approach was chosen because models with the same outcome, such as ceiling breaches, are more similar than those with the same study variable, such as competition. The next section, 6 Discussion, collects and analyzes these results across different outputs. When interpreting coefficients, section 4.2 is an important reference as all of the continuous variables in these models have been logged, centered around the logged mean, and rescaled such that a one unit change in the variable corresponds to a two standard deviation change in the log of the original input. This approach is used so that the magnitude of the coefficients of variables with different base scales can be more easily cross compared. Gelman and Hill specifically recommend dividing by twice the standard deviation so that the continuous variables may also be more easily compared with dummy variables that have not been recentered. [47]

5.1 Industrial Concentration's Correlation with Competition

This model examines the relationship between the number of offers a contract receives and two study input variables: the subsector industrial concentration and the detailed industry industrial concentration. The model, shown in Table 1, finds a significant negative relationship between concentration and competition but with a surprising low magnitude. In keeping with H_2, sectors that are less concentrated are associated with more offers. The study finds a 1 unit increase in the subsector HHI is associated with a 5 percent of a unit increase in the number of offers received. For the detailed industry, the result is not significant and, contrary to H_2, goes in the opposite direction and has only a fifth of the magnitude.

This multilevel model includes varying intercepts that are not shown in the table: the who, what, and when of each contract and task order. The intraclass correlation coefficient calculates the influence of each grouping. The who intercepts

[47] Andrew Gelman and Jennifer Hill, 55-57.

explain 25.7 percent of the model variance and is tracked by the contracting office (16.4 percent) and agency within the DoD (9.4 percent). The what intercepts explain another 11.3 percent of the variance between the subsector (1.9 percent) and NAICS detailed industry (9.4 percent). The when intercepts, which are only included in this model due to its minimal influence on performance measures, refers to the start year of the contract or task order and explains only 0.7 percent of the variance. The greater explanatory power of agency and office variables suggests that varying competitive approaches and vendors relationship with contracting offices may affect bidding behavior more than vendor industrial focus.

From the economic sector variables, the most noteworthy estimator is the amount of defense obligations for the detailed industry, with a 1 unit increase in obligations within that detailed industry estimating an 8 percent of a unit increase in the rescaled number of offers. Contract vehicle has a minimal influence on number of offers (with the exception of BPA/BOAs, which correlate with 6 percent fewer offers than FFP). The initial scope of the contract is not a significant estimator.

Contracts which incorporate some form of cost-based agreement correlate with 2 to 9 percent fewer offers than FFP. In the other direction, fixed- price contracts that are neither incentive nor firm-fixed-price estimate 21 percent more offers. The study team looked at the interaction of the average salary in a detailed industry and pricing mechanism, thinking that higher salaries might be associated with higher complexities and thus greater risk for FFP. However, the interaction with salary only magnified the above trends. The results for UCAs are more in line with expectation, as they estimate 9 percent fewer offers, and this phenomenon is slightly, but not significantly, amplified in detailed industries that are more concentrated.

Table 1. Regression Model of Log (Number of Offers)

	Concentration
(Intercept)	**-0.11** (0.04)**
Study Variables	
Log(Subsector HHI)	**-0.05** (0.00)***
Log(Det. Ind. HHI)	0.01 (0.00)·
NAICS Characteristics	
Log(Subsector Ratio)	-0.00 (0.01)
Log(Det. Ind. Def. Obl.)	**0.08** (0.01)***
Log(Det. Ind. Ratio)	**-0.01** (0.00)***
Log(Det. Ind. U.S. Avg. Salary)	**-0.02** (0.01)***
Contract Characteristics	
Log(Init. Ceiling)	0.00 (0.00)
Log(Init. Days)	**0.01** (0.00)***
Vehicle=S-IDC	**-0.01** (0.00)***
Vehicle=M-IDC	-0.00 (0.01)
Vehicle=FSS/GWAC	0.00 (0.00)
Vehicle=BPA/BOA	**-0.06** (0.01)***
Pricing=Other FP	**0.21** (0.00)***
Pricing=Incentive Fee	-0.02 (0.01)
Pricing=Combination or Other	**-0.03** (0.01)*
Pricing=Other CB	**-0.05** (0.01)***
Pricing=T&M/LH/FP:LoE	**-0.07** (0.01)***
UCA	**-0.09** (0.01)***
Performed Abroad	**-0.13** (0.01)***
Interactions	
Log(Det. Ind. HHI):UCA	-0.05 (0.02)·
Vehicle=S-IDC:Performed Abroad	**0.12** (0.01)***
Vehicle=M-IDC:Performed Abroad	**0.06** (0.02)***
Vehicle=FSS/GWAC:Performed Abroad	**0.07** (0.02)***
Vehicle=BPA/BOA:Performed Abroad	**0.07** (0.02)***
Pricing=Other FP:Log(Det. Ind. U.S. Avg. Salary)	**0.51** (0.01)***
Pricing=Incentive Fee:Log(Det. Ind. U.S. Avg. Salary)	-0.07 (0.08)
Pricing=Comb./or Other:Log(Det. Ind. U.S. Avg. Salary)	**-0.10** (0.03)**
Pricing=Other CB:Log(Det. Ind. U.S. Avg. Salary)	**-0.26** (0.03)***
Pricing=T&M/LH/FP:LoE:Log(Det. Ind. U.S. Avg. Salary)	**-0.36** (0.03)***
AIC	131551.64
BIC	131927.07
Log Likelihood	-65739.82
Num. obs.	249855
Var: Office:Agency (Intercept)	0.03
Var: NAICS:NAICS3 (Intercept)	0.01
Var: NAICS3 (Intercept)	0.00
Var: Agency (Intercept)	0.01
Var: StartCY (Intercept)	0.00
Var: Residual	0.10

***p < 0.001, **p < 0.01, *p < 0.05, ·p < 0.1. Logged inputs are rescaled. For this model, sole source contracts are treated as having 1 offer.

Also in line with expectations, contracts performed internationally are associated with a 13 percent of a unit reduction in offers. The model also bears out the idea that indefinite delivery vehicles are used to mitigate this trend, as single-award IDCs almost entirely counter this penalty, and other vehicles cut it roughly in half, but all forms of indefinite delivery vehicles mitigate this trend

5.2 Ceiling Breaches' Correlation with Industrial Concentration and Competition

Table 2 shows the models for ceiling breaches first using industrial concentration and competition as separate inputs, and then including them both in the same model. This approach was chosen because if competition was primarily a channel for industrial concentration, then we would expect the coefficients for the study variables to change markedly based on the inclusion of the other. This proved not to be the case, so for simplicity's sake, the analysis will focus on the model that included both variables.

The models show that, in keeping with H_1, concentration significantly correlated with ceiling breaches at both the subsector and detailed industry level. Surprisingly, the directions of the estimated coefficients of these variables oppose one another. While interpreting the sign of the relationship is straightforward, interpreting the coefficient requires an addition step because the models for ceiling breach and terminations use logit models, which are well suited to the binary output measures chosen by the study team. To meaningfully interpret the results, it is necessary to transform them with an inverse logit function to provide an odds ratio. These results can be seen in Table 3 below. In interpreting these ratios, a value of 1 would mean no relationship between the variable and ceiling breaches. The value of 0.69 for log(Subsector HHI) indicates that one unit increase in the HHI would be associated with a 41 percent reduction in ceiling breaches. The value of 1.22 for log(Det. Ind HHI) would estimate a 21 percent increase in the prevalence of ceiling breaches. The 2.50% and 97.50% give the 95 percent confidence interval for the odds ratio. If the 95 percent confidence interval does not overlap with the 1, then the odds ratio is significant at the 0.05 level. These values were slightly different for the

model that included both competition and concentration, but retained approximate direction, magnitude, and significance.

The subsector coefficient has a greater strength, but the interactions show that the detailed industry HHI might have more influence under the right circumstances. Namely, for detailed industries with more defense obligations, the interaction with the HHI is associated with a higher risk of ceiling breaches (odds ratio 1.30). This interaction was tested because one property of the HHI is that it tends to be higher for smaller sectors. This follows naturally from the means by which it is calculated.

Table 2. Ceiling Breach Odds Ratios

Ceiling Breach Odds Ratios			95 Percent Conf. Interval	
Model	Variable	Odds Ratio	Lower Bound	Upper Bound
Concentration	Log(Subsector HHI)	0.68	0.56	0.83
Concentration	Log(Det. Ind. HHI)	1.21	1.03	1.42
Competition	Comp=1 offer	0.76	0.66	0.89
Competition	Comp=2 offers	0.98	0.84	1.13
Competition	Comp=3-4 offers	0.92	0.8	1.05
Competition	Comp=5+ offers	0.99	0.87	1.13
Both	Log(Subsector HHI)	0.69	0.57	0.83
Both	Log(Det. Ind. HHI)	1.22	1.04	1.44
Both	Comp=1 offer	0.76	0.66	0.89
Both	Comp=2 offers	0.98	0.84	1.13
Both	Comp=3-4 offers	0.92	0.8	1.04
Both	Comp=5+ offers	0.99	0.87	1.13

Table 3. Logit Models of Ceiling Breaches

	Concentration	Competition	Both
(Intercept)	**-5.33** (0.27)***	**-5.24** (0.27)***	**-5.26** (0.27)***
Study Variables			
Log(Subsector HHI)	**-0.38** (0.10)***		**-0.38** (0.10)***
Log(Det. Ind. HHI)	**0.19** (0.08)*		**0.20** (0.08)*
Comp=1 offer		**-0.27** (0.08)***	**-0.27** (0.08)***
Comp=2 offers		-0.02 (0.08)	-0.02 (0.08)
Comp=3-4 offers		-0.09 (0.07)	-0.09 (0.07)
Comp=5+ offers		-0.01 (0.07)	-0.01 (0.07)
NAICS Characteristics			
Log(Subsector Ratio)	**-0.50** (0.20)*	**-0.49** (0.20)*	**-0.51** (0.20)*
Log(Det. Ind. Def. Obl.)	**0.19** (0.09)*	**0.20** (0.09)*	**0.18** (0.09)*
Log(Det. Ind. Ratio)	-0.02 (0.04)	-0.02 (0.04)	-0.02 (0.04)
Log(Det. Ind. U.S. Avg. Salary)	**-0.15** (0.07)*	**-0.16** (0.07)*	**-0.15** (0.07)*
Contract Characteristics			
Log(Init. Ceiling)	**1.45** (0.07)***	**1.44** (0.07)***	**1.44** (0.07)***
Log(Init. Days)	**0.49** (0.07)***	**0.49** (0.07)***	**0.48** (0.07)***
Vehicle=S-IDC	**-0.30** (0.06)***	**-0.30** (0.06)***	**-0.30** (0.06)***
Vehicle=M-IDC	0.05 (0.08)	0.08 (0.08)	0.08 (0.08)
Vehicle=FSS/GWAC	-0.17 (0.10)·	-0.15 (0.10)	-0.14 (0.10)
Vehicle=BPA/BOA	**-0.40** (0.14)**	**-0.42** (0.14)**	**-0.39** (0.14)**
Pricing=Other FP	-0.15 (0.27)	-0.17 (0.27)	-0.15 (0.27)
Pricing=Incentive Fee	**2.28** (0.30)***	**2.27** (0.30)***	**2.27** (0.30)***
Pricing=Combination or Other	**0.60** (0.21)**	**0.60** (0.21)**	**0.59** (0.21)**
Pricing=Other CB	-0.10 (0.15)	-0.09 (0.15)	-0.09 (0.15)
Pricing=T&M/LH/FP:LoE	-0.07 (0.23)	-0.08 (0.23)	-0.08 (0.23)
UCA	**2.25** (0.20)***	**2.47** (0.22)***	**2.58** (0.23)***
Performed Abroad	-0.22 (0.12)·	-0.18 (0.12)	-0.19 (0.12)·
Interactions			
Log(Det. Ind. HHI):Log(Det. Ind. Def. Obl.)	**0.25** (0.11)*		**0.26** (0.11)*
Log(Det. Ind. HHI):UCA	**0.79** (0.29)**		**0.65** (0.31)*
Log(Init. Ceiling):UCA	**-2.12** (0.32)***	**-1.87** (0.32)***	**-1.95** (0.32)***
Comp=1 offer:UCA		-0.58 (0.43)	-0.64 (0.43)
Comp=2 offers:UCA		**-2.28** (1.00)*	**-2.11** (0.99)*
Comp=3-4 offers:UCA		**-0.99** (0.46)*	**-0.91** (0.46)*
Comp=5+ offers:UCA		**-2.08** (0.74)**	**-1.96** (0.74)**
AIC	18128.02	18121.48	18110.13
BIC	18409.59	18444.77	18475.13
Log Likelihood	-9037.01	-9029.74	-9020.06
Num. obs.	249855	249855	249855
Var: Office:Agency (Intercept)	1.09	1.08	1.08
Var: NAICS:NAICS3 (Intercept)	0.28	0.30	0.28
Var: NAICS3 (Intercept)	0.24	0.25	0.25
Var: Agency (Intercept)	0.65	0.65	0.65

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

For example, one would expect Raytheon to have a substantial share of the guided missile detailed industry, but when zooming out to the transportation manufacture subsector, it is only one of the big 5 defense contractors. Thus, the detailed industry HHI matters more in the detailed industries where the DoD buys a lot, like the aforementioned guided missiles, rather than those where it buys a little, such as any of the agriculture or mining sectors. This relationship is only significant at a p-value of 0.10, but the magnitude is sufficient to make it of interest.

While H_1 is upheld for ceiling breaches, albeit in both directions, the results are weaker for competition. H_3 predicts that competition will be associated with better performance, and, indeed, the odds ratios for competition are below 1.0 regardless of the number of offers. However, this finding is only significant for competition with a single offer (odds ratio 0.76), and even were it significant for greater numbers of offers, the magnitude of the reduction would still be quite small. This is a surprising result because competition with only a single offer is typically not considered to be effective competition. One explanation might be that more offers increase the chance that one of the vendors is making a high-risk aggressive bid. Another possible explanation is that this metric only captures whether breaches occur, and not whether any money was saved by competition. Both of these concepts are explored in more detail in the Discussion section.

This multilevel model includes varying intercepts for the who and what of the contract but not the start year. The intraclass correlation coefficient again shows that the organization doing the buying explains the most variance (31.1 percent) divided between agency (11.7 percent) and contracting office (19.5 percent). The NAICS category is less important than for estimating the number of offers, explaining only 9.5 percent of variance. The division is fairly even between the subsector (4.4 percent) and detailed industry (5.0 percent). The preponderance of influence suggests the unobserved contracting policy and instrument variation between different military departments, agencies, and offices lead to significant variation in how change orders are used and contract ceilings are set.

The economic variables were contrary to expectation in two cases. First, at the subsector level, those subsectors where DoD obligations had a higher ratio to overall U.S. revenue estimated less frequent ceiling breaches (odds ratio 0.69). This suggests that the DoD may not be achieving the potential risk reduction benefits of contracting in sectors where there is a larger commercial market available. Also surprising is that the higher U.S. average salaries in the detailed industry estimated a lower risk of ceiling breach (ratio 0.86). The study team uses that variable as a proxy for the unobserved skill requirements in that part of the economy, which in turn is a proxy for complexity. This suggests the limitations of average wage as a proxy. Since each detailed industry has its own intercept, the model may already be capturing unobserved complexity more effectively than the study team's choice of variable. More in line with expectations is that detailed industries with more defense obligations run a greater risk of ceiling breaches (odds ratio 1.20).

When examining contract characteristics, both higher logged initial contract ceilings and longer logged initial durations estimate higher risks of ceiling breaches (odds 4.21 and 1.62, respectively). This is in line with expectation, as larger scoped contracts are typically more complex and harder to predict, although the importance of ceiling over duration is noteworthy. In terms of contract vehicles, both single-award IDCs and BPA/BOAs estimated lower risks of ceiling breaches, which may reflect an institutionalized partnership between government and industry. On the other hand, this includes both of the vehicles with single-award variants, and in this case, a contracting officer may find it easier to start a new task order than to issue a change order.

The results on pricing mechanism included some results that were in line with expectation, but one troubling surprise. The result that ran directly contrary to expectations was that incentive fee contracts, which includes both fixed-price incentive fee and cost-plus incentive fee, estimated eightfold increase in risk of ceiling breaches (odds ratio of 9.64). This result is discussed in greater detail in section 6.3.

The other pricing results are in keeping with expectations. Combination and other contracts use unusual or mixed pricing approaches, which suggests complexity and may explain why they estimate a greater chance of ceiling breaches (1.81 odds ratio). Meanwhile, UCAs are associated with an order of magnitude increase in the rate of ceiling breaches (13.26 odds ratio). Interactions also estimate that multi-offer competition and less concentrated sectors both are associated with a lower risk of ceiling breach. Finally, and less intuitively, a larger ceiling size is associated with a lower risk of ceiling breach.

5.3 Termination's Correlation with Industrial Concentration and Competition

The termination models lend weaker support for H_1's prediction that industrial concentration significantly correlates with contract performance. As with ceiling breaches, the three models (just concentration, just competition, and both) have roughly similar coefficient. So, for simplicity sake, the study team focused on the model incorporating both study variables. As shown in Table 4, a greater subsector HHI is associated with an increased risk of termination (odds ratio 1.28) which notably is the opposite direction as the relationship between subsector HHI and ceiling breaching. Also reversed is the coefficient for Det. Ind. HHI, but the relationship is not significant. Turning to interaction, as shown in Table 5, the subsector HHI's estimation of increased risk of termination is further increased when the Subsector Ratio is high, which is to sway in those subsectors where the DoD obligations account for a significant portion of total U.S. revenues, although this interaction was only significant at the 0.10 p-value level.

Table 4. Terminations Odds Ratio

Terminations Odds Ratio			95 Percent Conf. Interval	
95 Model	Variable	Odds Ratio	Lower Bound	Upper Bound
Concentration	Log(Subsector HHI)	1.29	1.08	1.54
Concentration	Log(Det. Ind. HHI)	0.86	0.7	1.04
Competition	Comp=1 offer	1.21	1.05	1.41
Competition	Comp=2 offers	1.37	1.17	1.6
Competition	Comp=3-4 offers	1.48	1.28	1.72
Competition	Comp=5+ offers	2.24	1.95	2.57
Both	Log(Subsector HHI)	1.28	1.08	1.53
Both	Log(Det. Ind. HHI)	0.86	0.71	1.05
Both	Comp=1 offer	1.21	1.05	1.41
Both	Comp=2 offers	1.36	1.16	1.6
Both	Comp=3-4 offers	1.48	1.28	1.71
Both	Comp=5+ offers	2.23	1.94	2.56

Table 5. Logit Model Results for Terminations

	Concentration	**Competition**	**Both**
(Intercept)	**-5.17** (0.15)***	**-5.51** (0.13)***	**-5.47** (0.13)***
Study Variables			
Log(Subsector HHI)	**0.25** (0.09)**		**0.25** (0.09)**
Log(Det. Ind. HHI)	-0.15 (0.10)		-0.15 (0.10)
Comp=1 offer		**0.19** (0.08)*	**0.19** (0.08)*
Comp=2 offers		**0.31** (0.08)***	**0.31** (0.08)***
Comp=3-4 offers		**0.40** (0.08)***	**0.39** (0.08)***
Comp=5+ offers		**0.80** (0.07)***	**0.80** (0.07)***
NAICS Characteristics			
Log(Subsector Ratio)	0.07 (0.12)	0.07 (0.12)	0.07 (0.12)
Log(Det. Ind. DoD Obl.)	-0.03 (0.07)	-0.07 (0.07)	-0.03 (0.07)
Log(Det. Ind. Ratio)	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)
Log(Det. Ind. U.S. Avg. Salary)	-0.04 (0.05)	-0.03 (0.06)	-0.02 (0.05)
Contract Characteristics			
Log(Init. Ceiling)	**0.43** (0.06)***	**0.41** (0.06)***	**0.42** (0.06)***
Log(Init. Days)	**1.21** (0.08)***	**1.18** (0.07)***	**1.22** (0.08)***
Vehicle=S-IDC	**-0.54** (0.06)***	**-0.58** (0.06)***	**-0.57** (0.06)***
Vehicle=M-IDC	**-0.57** (0.12)***	**-0.62** (0.12)***	**-0.61** (0.12)***
Vehicle=FSS/GWAC	**-0.28** (0.10)**	**-0.32** (0.10)**	**-0.31** (0.10)**
Vehicle=BPA/BOA	**-0.72** (0.15)***	**-0.67** (0.15)***	**-0.71** (0.15)***
Pricing=Other FP	**-0.84** (0.15)***	**-0.81** (0.15)***	**-0.82** (0.15)***
Pricing=Incentive Fee	-0.01 (0.43)	0.10 (0.43)	0.09 (0.43)
Pricing=Combination or Other	-0.87 (0.48).	-0.84 (0.48).	-0.84 (0.48).
Pricing=Other CB	-0.47 (0.28).	-0.44 (0.28)	-0.44 (0.28)
Pricing=T&M/LH/FP:LoE	-0.15 (0.31)	-0.11 (0.32)	-0.11 (0.32)
UCA	**0.63** (0.15)***	**0.77** (0.15)***	**0.78** (0.15)***
Performed Abroad	**0.39** (0.10)***	**0.42** (0.10)***	**0.43** (0.10)***
Interactions			
Log(Det. Ind. HHI):Log(Init. Days)	0.13 (0.14)		0.14 (0.14)
Log(Det. Ind. HHI):Log(Det. Ind. DoD Obl.)	0.18 (0.11)		0.17 (0.11)
Log(Subsector HHI):Log(Subsector Ratio)	0.46 (0.24).		0.42 (0.24).
AIC	24037.30	23898.05	23891.98
BIC	24318.87	24169.20	24215.27
Log Likelihood	-11991.65	-11923.03	-11914.99
Num. obs.	249855	249855	249855
Var: Office:Agency (Intercept)	0.72	0.75	0.73
Var: NAICS:NAICS3 (Intercept)	0.10	0.11	0.10
Var: NAICS3 (Intercept)	0.07	0.07	0.07
Var: Agency (Intercept)	0.04	0.02	0.02

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

While the termination model lends mixed support for H_1, it directly contracts H_3's prediction that competition will be correlated with better performance. Instead, no matter the number of offers, competitive procedures estimated a higher risk of termination. Moreover, those categories with more offers had a greater risk, escalating from competition with a single offer (1.21 odds ratio), to competition with two offers (1.36 odds ratio), to competition with 3-4 offers (1.48 odds ratio), to the peak at competition with five or more offers (2.23 odds ratio). The study team believes that multiple distinct explanations may play a role in this phenomenon. First, as with ceiling breaches, competitions where there are likely to be multiple bidders may encourage bid-to-win strategies that sometimes prove to entail too much risk and may also, at times, indicate a failure to limit the field to qualified vendors. On the other hand, the government may be loath to resort to termination when there is no alternative vendor available. This explanation does little to explain the dramatic difference between competition with two offers and with five or more (odds ratios of 1.36 and 2.24 respectively) but may help explain the difference between contracts that used competitive procedures and those that did not. Finally, bid-protests are one source of partial or complete terminations that are launched by losing vendors and thus are focused on competed contracts.

For terminations, the multi-level portions of the model were still important but less important than they were for number of offers and ceiling breaches. The organization doing the contracting accounted for 17.8 percent of the model variance, according to the intraclass correlation coefficient, with only a small portion (0.5 percent) captured at the agency level and the rest (17.3 percent) observed at the contracting office level. Similarly, the NAICS category was less influential and accounted for 4.0 percent of variance overall, with the subsector level (1.5 percent) being less influential than the detailed industry level (2.4 percent). The economic sector variables reached even 0.10 significance only in interaction with the study variables, as was mentioned above regarding the interaction of subsector ratio and subsector HHI.

In contrast to the economic sector variables, contract scope is a powerful estimator of terminations. Reversing the observation for ceiling breaches, the log of

the initial duration is most strongly associated with a greater risk of termination (3.36 odds ratio). That said, the log of initial contract ceiling still remains significant and is associated with a jump in terminations by more than a half in for every significant digit increase in ceiling size (odds ratio 1.52). Contract vehicle is also uniformly significant, with all indefinite vehicles predicting lower likelihood of termination. This is strongest for BPA/BOAs, multiple award IDCs, and single-award IDCs, with odds ratios of 0.49, 0.54, 0.57 respectively. Contributing factors to the correlation may be that experienced vendors, with a stronger relationship with the government, are more likely to use these vehicles. In addition, in some cases, contracting officers may be sufficient to address a problem by issuing no more task orders rather than needing to pursue outright terminations. The final vehicle category, FSS/GWACs, have a wider but prequalified vendor pool and still have a 0.74 odds ratio.

Contract pricing has less estimating power, although “other fixed price,” a category made up of fixed price redetermination, fixed price award fee, and fixed price economic price adjustment, is associated with a greater than 50 percent reduction in the risk of termination (odds ratio 0.44). While the direction of this coefficient is not surprising, its magnitude is. In an interesting contrast to the ceiling breach results, combination and other pricing contracts estimate a lower rate of termination (odds ratio 0.43) despite being more likely to experience ceiling breaches, though only with at a p-value less than 0.10 level. The same is true for ceiling breaches, but only for the concentration model (it is not significant in the competition or both models). In keeping with ceiling breaches, UCAs estimate a significantly increased rate of termination (odds ratio 2.18), although the interactions with UCA did not prove significant and were left out of this model for reasons of parsimony.

Finally, complicating the expectations that contracts with nowhere else to turn may be harder to terminate, those with an international place of performance are notably more likely to be terminated (odds ratio 1.53). This result would be consistent with the idea that these contracts are often in more challenging settings, particularly for the DoD, and at times may involve dealing with a less familiar industrial base.

6 Discussion

6.1 Industrial Concentration

While the strength of the correlation varies between metrics, this paper found firm support for the first hypothesis:

- H_1: industrial concentration leads to changes in contract performance

The theoretical literature indicated that the effect on performance could go in both directions. Consolidated vendors may be better able to deliver economies of scale, efficiently integrate a range of different products and services, and make investments. On the other hand, greater concentration shifts the balance of power in the direction of the vendor and can ultimately risk putting the government in a monopoly situation where the government has fewer alternatives or is vendor locked with incumbents who lack the incentive to control costs. The models' estimates were consistent with both of these possibilities, depending on the NAICS level under consideration and the output metric, as shown in Table 6.

Table 6. Concentration Summary Table

Concentration Summary Table		Odds Ratio	95th Percent Confidence Interval		Significant Interactions
Output	Variable		Lower Bound	Upper Bound	
Ceiling Breaches	Log(Subsector HHI)	0.69	0.57	0.83	--
Ceiling Breaches	Log(Det. Ind. HHI)	1.22	1.04	1.44	Positive with Log(Det. Ind. Def. Obl.) and UCA.
Terminations	Log(Subsector HHI)	1.28	1.08	1.53	Weak positive (p-value <0.1) with Log(Subsector Ratio)
Terminations	Log(Det. Ind. HHI)	0.86	0.71	1.05	--

6.1.1 Subsector Industrial Concentration (NAICS 3-digit code)

An increase in subsector HHI significantly correlates with less competition, with a lower rate of ceiling breach, and with a higher rate of termination. This incongruous combination might reflect that there are real economies of scale to be had in many subsectors of defense acquisition, but also that those sectors that are

more naturally monopolistic may face higher risk. Subsectors where the DoD is the largest buyer face an even greater risk of terminations. That said, the DoD's interaction with subsector ratio has a high magnitude but is only significant at the p-value<0.1 level. Thus, in broad terms, those subsectors that are highly concentrated and more defense-unique do face a greater risk of terminations, but not one that can be traced to challenges of executing within projected costs.

One factor to keep in mind is that subsectors are notably larger and less concentrated than detailed industries. The logarithmic mean of HHI is below 500. A 0.5 unit increase still leaves this metric below 1500 and thus in low concentration territory. This reflects the fact that only a small percentage of contractors fall in highly consolidated subsectors.

6.1.2 Detailed Industry Industrial Concentration (NAICS 6-digit code)

Detailed industry concentration is significantly associated with a higher risk of ceiling breaches, but a lower risk of terminations. However, in the latter case, the result is only significant with a p-value of 0.1. This combined result may still be consistent with a high detailed industry HHI both correlating with worse performance and also leaving the government vendor locked due to the absence of viable competitors. The risk of vendor lock is more plausible with detailed industry concentration, as the mean HHI value is over a thousand, and a change of one unit increases that value to over three thousand, well into the territory of a highly concentrated sector according to the DoJ standards.

On the other hand, the contrast between subsector concentration and detailed industrial concentration as well as between different metrics at the same level might indicate the importance of choice of which level(s) of NAICS categories to include. In addition, the direction of this relationship should be read remembering that the model includes both subsector HHI and detailed industry HHI. The study team also experimented with a model that included only the detailed industry level, which had less explanatory value but was nonetheless significant. This robustness testing found that when only one HHI value was included, the results were closer to the subsector results than the detailed sector. This concern is mitigated by the

interaction between detailed industry defense obligations and industrial concentration.

Taken together, the risk of ceiling breaches is estimated to be highest for contracts in NAICS category where the subsector HHI is low but the detailed industry has considerable defense obligations and a high HHI. This combination may may indicate that detailed industry consolidation has occurred despite the absence of a natural monopoly. The estimated risk of termination is highest for NAICS categories with above average subsector consolidation, a comparatively small commercial sector is, and a detailed industry where concentration is below average. The difference between the average value of the subsector HHI and the detailed industry HHI means that this could easily be true in those cases where there are few detailed industries to be found under a given subsector. The risk for both metrics is magnified when UCAs are present, but that issue is discussed in section 6.3.

6.2 Competition

The second and third hypotheses have a stricter requirement of support, as in each case they indicate the direction of the relationship:

H_2: Increasing (decreasing) industrial concentration leads to decreasing (increasing) competition

H_3: Decreasing (increasing) competition makes poor contract performance more (less) likely

The regression model estimating the number of offers, found support for H_2, although the magnitude of the relationship was less than the study team expected. H_3 found mixed support at best: only competition with a single offer significant estimated fewer ceiling breaches. In addition, all categories of competition are associated with a greater risk of terminations. Furthermore, those categories of competition with more offers, in ascending order, faced greater risk of terminations.

6.2.1 Relationship between Industrial Concentration and Competition

As was covered in results section 5.1, greater subsector industrial concentration does decrease the number of offers received, but the coefficient is

only -0.05, meaning a one unit change in subsector HHI only leads to a 5 percent decrease in number offers. Furthermore, the detailed industry HHI did not have a significant relationship to the number of offers received. This comparatively low magnitude suggests that a variety of factors (not included in the model) better explain much of the variance in number of offers.

The first possible explanation is barriers to entry. This can be conceived as an outer wall, the challenges for commercial vendors seeking to enter the federal market, as well as an inner wall, the difficulty in establishing a relationship with any given agency or contracting office. The outer wall is by no means absolute. In those cases where there is less of a commercial sector available there also tend to be fewer offers, as measured by the detailed industry ratio of defense obligations to total U.S. revenue estimates. However, the magnitude of that coefficient is quite low, with the total size of the defense sector for that detailed industry being a more important estimator. The height of the inner wall is indicated by the high intercorrelated coefficients for the contracting agency and office. Even after accounting for a range of NAICS sector characteristics, agency and office account for over a quarter of the variation in the model (9.4 percent for agency and 16.4 percent for office). This suggests that the market is often segmented by purchasers and not just by economic categories of vendors which suggests that government-imposed barriers to entry may be as significant as economically structural dynamics.

However, barriers to entry may not tell the whole story. More offers can be a means to an end but may be sacrificed to achieve other ends. Even in a detailed industry with many potential vendors, contracting officers may choose to prioritize speed or other goals rather than running up the score after they have achieved multiple offers. In fact, due to small business promotion efforts, contracting officers may limit competition to only small businesses if there are at least two viable contenders. On the other hand, agencies and contracting offices are evaluated based on the proportion of obligations awarded using competitive procedures, and percentage of competed obligations awarded after receiving multiple offers. Thus, even in concentrated detailed industries, contracting officers may choose to compete contracts and actively solicit vendor participation (even in consolidated sectors and

even if it takes more work to find competitors). Taken together, the model and this analysis suggest that industrial concentration is only one of many factors that influences the extent of competition.

6.2.2 More offers May Not Be Better

The findings in Table 7 do show that competition is associated with a lower chance of ceiling breaches, but that this is only significant for single offer competition (odds ratio 0.76). For terminations, the significant findings for all considered categories reject the hypothesis as formulated. The ceiling breach results do have limits to their robustness. Earlier versions of the models coded competition numerically with no competition coded as 0, single offer competition as 0.5, and multi-offer competition as 1. Under that definition, the ceiling breach model did not prove significant once the full suite of multilevel groupings was included.

Table 7. Competition Summary Table

Competition Summary Table			Odds Ratio	95th Percent Confidence Interval		Significant Interactions
Output	Model	Variable		Lower Bound	Upper Bound	
Ceiling Breaches	Both	Comp=1 offer	0.76	0.66	0.89	--
Ceiling Breaches	Both	Comp=2 offers	0.98	0.84	1.13	Positive with UCA.
Ceiling Breaches	Both	Comp=3-4 offers	0.92	0.8	1.04	
Ceiling Breaches	Both	Comp=5+ offers	0.99	0.87	1.13	
Terminations	Both	Comp=1 offer	1.21	1.05	1.41	--
Terminations	Both	Comp=2 offers	1.36	1.16	1.6	--
Terminations	Both	Comp=3-4 offers	1.48	1.28	1.71	--
Terminations	Both	Comp=5+ offers	2.23	1.94	2.56	--

As was raised in the results section, a straightforward interpretation of these results is that multi-offer competition may introduce mounting pressure for bids that will win the competition, even if they are not necessarily profitable for the vendor or may involve other risks. The more than doubling of risks for competition with 5+ also may suggest that outright unqualified bidders, who would need more than a change order to turn around their contract, may be more likely to win when there are many offers in play.

Another explanation that may explain why competition is associated across the board with a higher rate of terminations is that competition does presume that the government has another offer available. If they have no viable alternatives to turn to, the government may prefer means of sanction short of outright termination despite always having the option to terminate the contract of an underperforming vendor for convenience. This question may be better addressed by a research design that incorporates deobligations or other sanctions.[48] If this explanation is correct, challenges would be more likely to lead to termination for competed contracts and those in less consolidated markets.

In addition, the flip side of this bid-to-win explanation is that the government may still be receiving an important benefit from competition, just not one captured in the output variables used. Namely, if potential vendors bid more aggressively for multi-offer competition, then competed contracts should generally be less expensive than their sole source alternatives. Both ceiling breaches and terminations remain quite rare in the total universe of DoD contracts and task orders. As a result, if competition results in aggressive bids and lower prices, the DoD may still come out ahead from an expected value perspective. The ceiling breach and failure rate may be higher, but saving money on all contracts might be worth more than doubling a low baseline termination rate. Likewise, the possibility of another vendor stepping in does mitigate the downside of non-mission critical terminations. However, this calculation will vary from contracting office to contracting office and detailed industry to detailed industry. Aggressive bidding may be more damaging when the baseline risk of underperformance is higher.

Altogether, these findings contradict the simple story that all good things, competitive procedures, more offers, and contract outcomes naturally go together. This does not mean that benefits cannot be seen. Single offer competition does correlate with a lower rate of ceiling breaches. This suggests that competitive

[48] See for instance the doctoral dissertation Brunjes, B. (2016). "Designing for Success: Managerial Influence on Federal Contractor Performance." PhD Dissertation, University of Georgia.

procedures may deliver some benefits even when only one vendor answers the solicitation. In addition, judging by the metrics in this study, there appears to be more risk as the number of offers increases. This also suggests that the DoD may be wise in being classifying anything with two or more offers as effective competition and giving even higher grades to competitions that exceed that standard. Contracting officers may already be acting on this insight, which may help explain why we do not see more offers in sectors with low consolidation as is discussed in section 6.2.1.

6.3 Other Noteworthy Results

UCAs have significant negative correlations with both terminations and ceiling breaches, justifying their classification as a high-risk contract type. Competition and detailed industry consolidation can both mitigate this association, although the relevant interactions were not significant in the termination model and thus were left out. The change order based metric used by this report may be especially sensitive to UCAs because any UCA that increases its cost ceiling when definitized will automatically be classified as having experienced a ceiling breach. Furthermore, cautious contracting officers may choose a deliberately low not to exceed value for UCAs until the details have been nailed down. Likewise, contracting officers may be more confident in setting a ceiling after reviewing proposals from multiple vendors.

Contrary to expectations, incentive fee contracts were also found to be associated with much higher rates of ceiling breaches. This runs directly opposite the findings of the Performance of the Defense Acquisition System report, which employs financial reporting data that can directly observe overruns but are not available to the general public.[49] This discrepancy may be partially explained by the differences between the overall contract dataset used by this study and the MDAP dataset used by that report, but the difference underlines the importance of the caveats discussed in Section 6.4.3.

[49] Kendall, Frank, *Performance of the Defense Acquisition System, 2014* (Washington, DC: U.S. Department of Defense, June 13, 2014), https://dod.defense.gov/Portals/1/Documents/pubs/Performance-of-Defense-Acquisition-System-2014.pdf

6.4 Robustness and Limitations of the Research

The study team has chosen to use reproducible methods to ease replication and also allow other researchers to build on our data in their own directions. The study team would also like to highlight those areas where research team decisions, and computational challenges, may have the greatest influence on the robustness of the results.

6.4.1 The Multilevel Models Experienced Failure to Converge Warnings

The study team has encountered persistent challenges with this warning, particularly when including detailed industry and contracting office groupings within the model. The creators of the regression and maximum likelihood tools that are used in this analysis have identified a likely culprit for this problem:

> "Exploratory analyses suggest that (1) the naive estimation of the Hessian may fail for large data sets (number of observations greater than approximately 1e5); (2) the magnitude of the scaled gradient increases with sample size, so that warnings will occur even for apparently well-behaved fits with large data sets."[50]

The study team was able to perform many of the recommended tests, and the resultant models matched the results of the models included in this paper. However, the study team was not able to complete tests on all seven models using the full range of available optimizers and encountered eigen value errors with some optimizers.

6.4.2 Limitations of Performance Metrics

Both ceiling breaches and terminations only look at specific aspects of contract and task order performance. The ceiling breach measure in particular does not test how the original or final cost ceiling compares to any should cost price, only whether the ceiling changed from the original. The source of the dataset, FPDS, does not include quantity information as a standalone field, and even if it were

[50] "convergence: Assessing Convergence for Fitted Models" *lme4: Linear Mixed-Effects Models using 'Eigen' and S4*. (R Package Documentation: 8/17/2018), https://rdrr.io/cran/lme4/man/convergence.html

available, the product or service code and NAICS categories combined are probably not specific enough to make apples-to-apples price comparisons. Likewise, the study team chose to use a binary measure of ceiling breach, which does not differentiate between large and small increases. As was aforementioned, the study team was driven by the rarity of ceiling breaches to make this choice. The logit model prioritizing understanding when ceiling breaches occur rather than estimating their magnitude.

The termination measure is more robust, though it does include multiple forms of termination, both for convenience and default. In addition, partial and complete terminations are grouped within the FPDS data. As is noted earlier in the discussion section, the study may not capture badly performing contracts when the government does not have an alternative vendor available.

6.4.3 Defining Sectors

The direction of study variables does change depending on what NAICS levels are included in the multilevel model and which consolidation measures are used. The inputs ultimately included, subsector HHI and detailed industry HHI, do have a 0.57 correlation with each other but do not register as a problem when judging by the variance inflation factor. In robustness tests, the study team found that if only the detailed industry is included and the subsector HHI is more significant, then the direction of the detailed industry coefficient changes to match the removed subsector coefficient.

Conceptually, sector definition is also a challenging issue as typically the more fine grained the sector definitions, the greater the consolidation. The study team has attempted to address this concern by including a range of economic sector metrics and also setting separate intercepts at both the subsector and detailed industry level. However, choosing the levels to include is a judgment call, and the team has tried to make the implication of our choices as clear as possible.

6.4.4 MDAPs and Incentive Fees

Major Defense Acquisition Programs are the basis of much of the research on defense contracting. That data is subject to its own challenges and peculiarities, but, generally speaking, offers a bigger picture and higher fidelity view than the contract-level perspective. That said, while MDAPs account for the largest defense projects, much of defense acquisition is not for development or is for smaller projects. The study team was not able to include a MDAP multilevel grouping in the dataset due to data quality challenges. This may strain the independence of observations assumptions that underlies statistical tests used in this paper because if one contract for a MDAP experiences challenges, delays may cascade to other contracts that are dependent upon it. Happily, the problem of interrelated contracts is mitigated by the inclusion of contracting offices, which capture some of the organization lines of responsibility.

Relatedly, one of the largest anomalies found by the study was that incentive fee contracts estimated and extremely high risk of ceiling breaches. The termination models found no significant results for incentive fees, which suggests that this may be a peculiarity in the ceiling breach metric or a challenge encountered when incentive fee contracts are used outside the MDAP context where their benefits are better established.

6.4.5 Missing data and Limitations of the Economic Census

Thirty percent of contracts had to be excluded due to missing data, though this only excludes 18.7 percent of obligations. Some of these problems can be traced to FPDS reporting and also the recent switchover to a new USASpending.gov reporting system and some degradation in reporting in the final years of the old system. This was a particularly pertinent problem for undefinitized contract actions, which fell between the cracks when the column was renamed from letter contracts.

On the economic statistics side, the biggest limitation is that many of the statistics used in this study, such as revenue, are only reported every five years. This means that the ratio variable used in this study has a lag of between 1 and 6 years, depending on how far the contract start year is form 2007 and 2012. In

addition, the economic census does not include the NAICS public administration sector as well as an esoteric mix of non-government organization categories. Contracts in these categories have been excluded from the contract data calculations as well, including the calculation of subsector defense obligations.

Finally, the definition of some NAICS categories shifted between 2007 and 2012. Those subsectors and detailed industries whose codes were changed were treated as having missing data, with the one exception of code: 541710 Research and Development in the Physical, Engineering, and Life Sciences. That code had split into two, 541711 and 541712, which gave greater detail on biotechnology. There are tens of billions of dollars in these sectors, and to avoid losing them, the study team manually combined these codes, thus treating NAICS industry 54171 as if it were a detailed industry.

6.4.6 Residuals for High Fitted Values

The study team plotted binned residuals for the logit models to examine the discrepancy between estimated values and actual outcome. This approach sorts all of the data based on the fitted value, and then groups the data into some number of bins—50 for the purposes of this example. Each bin then calculates the average fitted value as well as the average outcome variable. Because the outcome variables for the logit models are binaries, their average value is equivalent to the percent of data in that bin for which the outcome, a ceiling breach or termination, occurs. These bins were then graphed using a scatter plot with the fitted average values on the x-axis and the actual average on the y-axis. Across multiple models, there tended to be a single bin with the highest fitted values, typically in the 0.1 to 0.2 range. In the final model, this bin also reliably has a large negative residual, which is to say that the estimated value does identify some of the highest risk contracts, but even so, underestimates their risk. This suggests that there is some important input, perhaps MDAP membership, that this model is missing.

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7 Conclusions

Across the world, managing consolidation in the defense sector is a substantial challenge for both economic and industrial policy. Countries with comparatively smaller or less developed industrial bases often seek to promote consolidation, hoping national champion firms will gain the economics of scale to compete internationally. Even the United States, the global leader in defense spending, whose primary market is its own military, encouraged consolidation during the post-Cold War drawdown in the 1990s, a policy that was shared with the defense industry at what is evocatively referred to as ”The Last Supper.”

Conversely, in the United States, Congress and the Executive branch, in statue, regulation, and policy, have put substantial emphasis on the importance of competition. Likewise, scrutiny is applied to mergers and acquisitions in the defense sector, and small business promotion policies seek to avoid excessive reliance on a small number of large companies.

- **Concentration Matters but the Effects Depend on How You Define Sectors**

The study’s results reflect the contradictions surrounding consolidations. Industrial concentration matters, is associated with a higher rate of termination at the subsector level, and, depending on the circumstance, is significantly associated with changes in the rate of ceiling breaches in both directions. This complexity also shows the wisdom in approaches like the sector-by-sector tier-by-tier review under DoD’s Better Buying Power Initiative and the current Administration’s industrial base review, which attempt to go deep in understanding the challenges of each sector rather than only looking to top-level aggregate scores.

- **Competition Strategies Should Account for Aggressive Bidding**
- **Single Offer Competition May Still Deliver Value**

The strong association between contracts that received more offers and a higher estimated rate of termination suggests that while having more competing vendors may bring lower base prices, it may also correlate with a greater risk of

failure. Likewise, single-offer competition is associated with a lower rate of ceiling breaches than sole source awards, but multioffer competition does not significantly correlate with a lower rate. This does not mean that competition does not save money overall. This study does not have the metrics to examine whether competed contracts cost less than their sole-source alternative. However, when devising competition strategies, DoD should consider variation in risk tolerance and inherent risk from office to office and sector to sector. Further study is also warranted as to how approaches to competition and set asides can mitigate or aggravate these risks.

- **Vendor Bases Appear to be Strongly Segmented Down to the Contracting Office Level**
- **Industrial Concentration and the Size of the Commercial Market Significantly but Weakly Predict the Number of Offers**
- **Larger Commercial Markets Do Not Correlate With Lower Rates of Ceiling Breaches, but are Associated with Lower Termination Rate in Concentrated Markets**

While this study was not primarily focused on the challenges and benefits of commercial acquisition for the DoD, a variety of findings from the model have implications for those studying these issues. First, the study allowed for each detailed industry and contracting office to have its own intercept, and this revealed that for estimating purposes, who is doing the buying trumps the structure of the industry of the product or service being acquired. No small part of this is likely attributable to unobserved differences in contracting approaches and mission, but nonetheless, this finding suggests that market segmentation and barriers to entry are not just a matter of commercial suppliers versus defense suppliers, but also can draw dividing lines between contracting offices.

On that same note, the significant explanatory power of contract vehicles (and their varying situational relevance) suggests that the choice of vehicles should perhaps be given additional attention as a factor that influences contract outcomes. As ever, these findings reinforce the judgment and human capital needed for successful acquisition policy and the absence of one-size fits all solutions—even for foundational strategies such as competition.

- **Contracting Officer Judgment Matters and Could be Supplemented by Better Awareness of How Their Area of Responsible Compares to Other Parts of the DoD**

As the discussion and conclusion of this paper indicate, that even for competition, a touchstone and watchword of federal acquisition practice, context and tradeoffs matter. This study's dataset reflects the best judgment choices of contracting officers, rather than random application of contract and competition strategies, and does not offer easy defense-wide answers. However, contracting officers could benefit from knowing what the estimated ceiling breach and termination rates are for their organization and relevant market segment. In low-risk and risk-tolerant sectors, pursuing competition more aggressively may bring savings with a manageable downside. In higher risk sectors, better estimating and investigating of vendor qualification may reduce the chances of later terminations.

- **Current Understanding of Competition in Defense Acquisition, and More Generally Under Monosopy, is Undertheorized and We Offer Our Contract and Task Order Dataset and Economic Sector Datasets to those Seeking Both Broad Overviews and Deep Dives**

Many of the issues of concern to defense acquisition officials are also on the minds of many of those studying the economy writ large, with its superstar firms that are sizeable enough to develop their own industrial bases.[51] In particular, this study would be well complemented by deep dives into individual sectors that do not face some of the same limitations of DoD-wide research.[52]

[51] Neil Irwin, "The Upshot: Are Superstar Firms and Amazon Effects Reshaping the Economy?" New York Times (New York, August 25, 2018), https://www.nytimes.com/2018/08/25/upshot/big-corporations-influence-economy-central-bank.html

[52] We encourage any researchers and officials interested in the underlying data to reach out to Gregory Sanders at GSanders@csis.org or to access our repository directly at https://github.com/CSISdefense/Vendor

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Appendix: Model Diagnostics

Figure 3. Fitted and Residual Plots for Ceiling Breaches

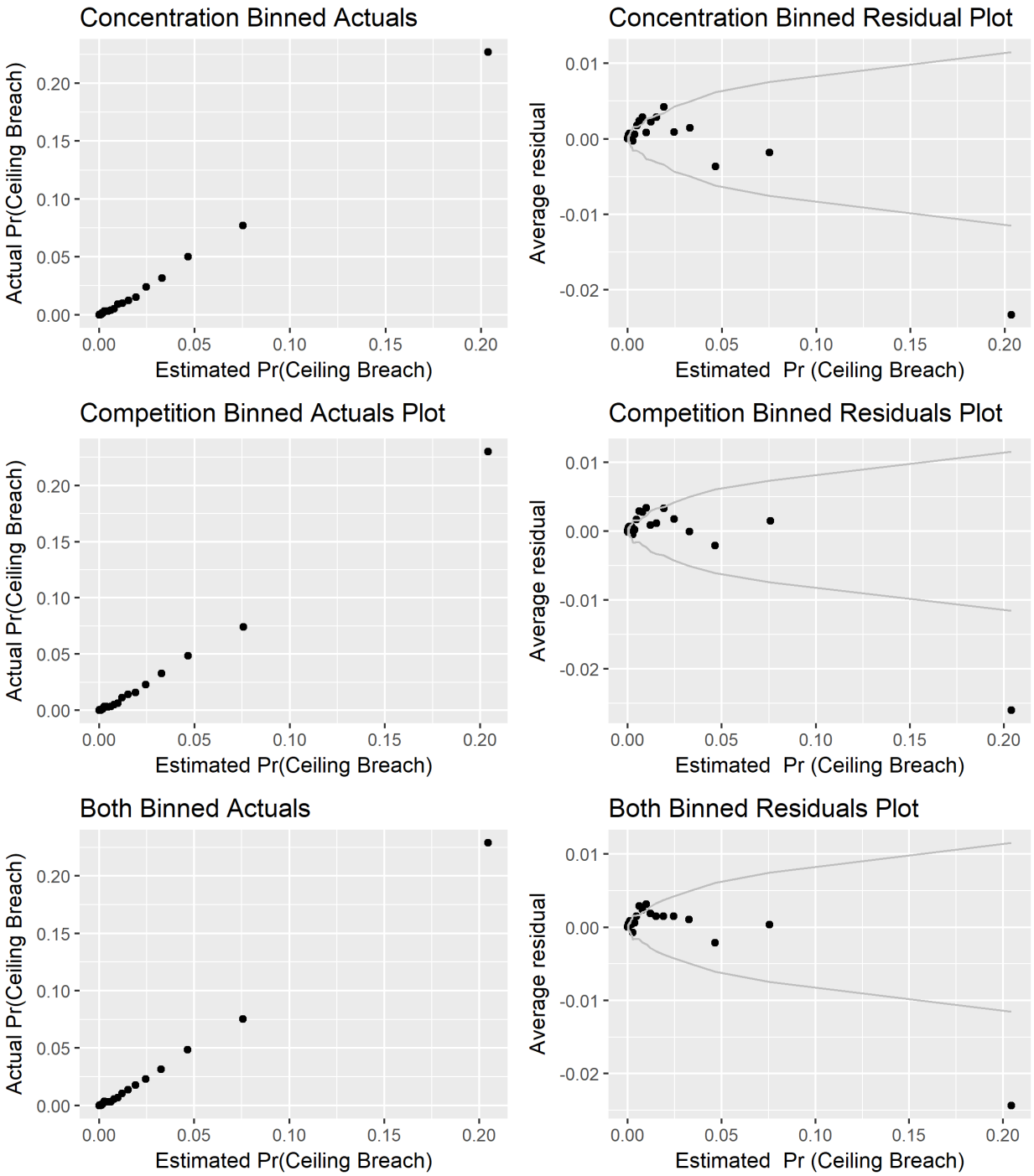
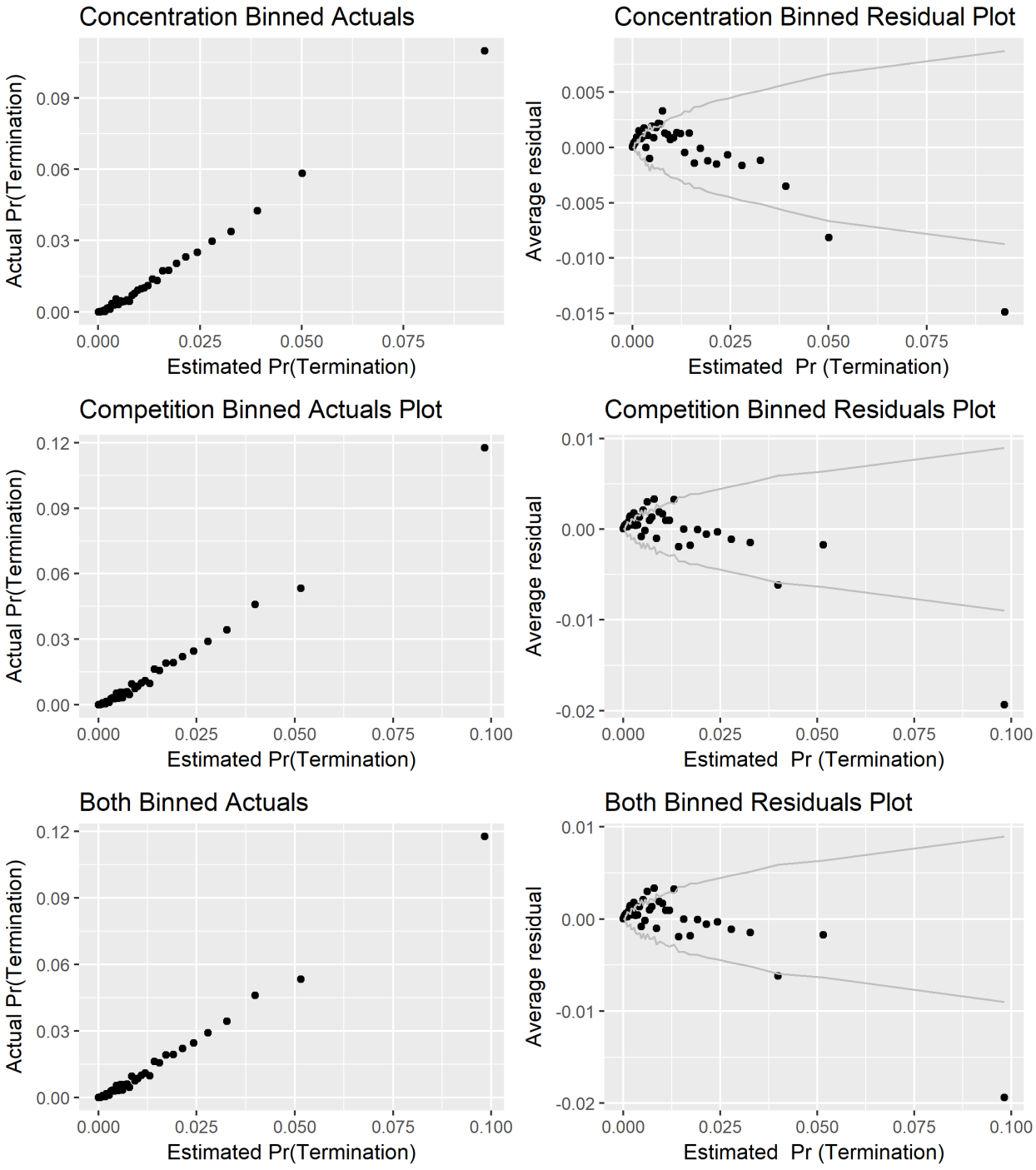


Figure 4. Fitted and Residual Plots for Terminations



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