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Rodrigo Carril
Mark Duggan

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The Impact of Industry Consolidation on Government Procurement: Evidence from Department of Defense Contracting

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ABSTRACT

We study the relationship between market structure and public procurement outcomes. In particular, we ask whether and to what extent consolidation-driven increases in industry concentration affect the way in which the government procures its goods and services. We focus on the defense industry, by far the largest contributor to federal procurement spending in the U.S. This industry experienced a sharp increase in the level of concentration during the 1990s, driven by a series of large mergers between defense contractors. Using detailed microdata on Department of Defense (DoD) contract awards, we estimate the causal effect of industry concentration on a series of procurement outcomes, leveraging the differential impact of these mergers across product markets. We find that market concentration caused the procurement process to become less competitive, with an increase in the share of spending awarded without competition, or via single-bid solicitations. Increased concentration also induced a shift from the use of fixed-price contracts towards cost-plus contracts. However, we find no evidence that consolidation led to a significant increase in acquisition costs of large weapon systems, nor to increased spending at the product market level. We infer that the government's buyer power, especially relevant in this context given the government is often the only purchaser, constrained firms from exercising any additional market power gained by consolidation.

Rodrigo Carril
Stanford University
Department of Economics
579 Serra Mall
Stanford, CA 94305-6072
rcarril@stanford.edu

Mark Duggan
Stanford University
Department of Economics
579 Serra Mall
Stanford, CA 94305-6072
and NBER
mgduggan@stanford.edu

I. INTRODUCTION

National defense spending in the US accounts for more than 15 percent of the federal government's budget. Yet despite its large size, this area of government activity has received very limited attention in empirical economics research. An important feature of defense spending in the US is that it is to a significant extent "contracted out": procurement contract obligations between the Department of Defense (DoD) and the private sector represent roughly half of the national defense budget.[1] At the same time, almost two-thirds of all contract spending by the federal government is awarded by the DoD. This implies that US military needs generate more than a $300 billion market every year, which to date remains relatively unexplored.[2]

In this paper we aim to begin filling this gap in the literature by exploring how the market structure of the private industries that serve the government affects the procurement process. In particular, we ask whether and to what extent market-level concentration affects the way in which the DoD awards contracts and the ultimate effect on the cost of the procured goods and services. On the one hand, less concentrated markets will typically have more competitors, which may serve to increase efficiency and reduce markups. On the other hand, there may be significant economies of scale such that a smaller number of large-sized competitors can deliver superior quality at a low price.

To investigate this question, we exploit sharp increases in market concentration occurring in the mid-1990s, when major defense contractors engaged in a wave of consolidation. Between 1990 and 2000, the share of federal defense contract spending awarded to the five largest private firms rose from 21.7% to 31.3%, driven by a series of several large mergers among defense contractors. The most significant of these mergers occurred during a period of less than five years.

We conduct two complementary analyses. First, we leverage micro-level data from DoD contracts and exploit the heterogeneous impact that these mergers had on different product markets from which the federal government purchases goods and services. The key idea behind our identification strategy is that initial market shares of merging firms varied widely across product markets, which implies that a given merger will have differential expected impacts on concentration across these markets. Combining this variation with the differential timing of each particular merger,

[1] Most of the remaining spending is accounted for by personnel costs including for those serving in the Army, Navy, Air Force, Marines, and Coast Guard.
[2] Table A1 presents budgetary and contract spending data for major agencies of the US federal government.

we identify the causal effect of increased concentration on a series of procurement outcomes, such as the level of competition, the choice of contractual form, and product level spending.

In our second analysis, we focus exclusively on major defense acquisition programs. These consist of high-profile multi-year contracts, typically for the development and acquisition of large weapon systems. The advantage of focusing on this narrower set of contracts is that, because of the magnitude of the public funds involved, they are subject to detailed periodic reporting requirements on acquisition costs and other more detailed performance measures. We use these acquisition programs to study the ultimate impact of industry consolidation on procurement costs. Our identification strategy consists of comparing programs run by contractors that did and did not participate in one of the large mergers that took place over our sample period. Under a parallel trends assumption, we can estimate the causal impact of a contractor's merger on the cost of procuring from them after the merger has gone into effect.

Our results suggest that the increased concentration driven by these mergers significantly decreased the level of competition in the award of procurement contracts. We also find that more concentration caused a shift from the use of fixed-price contracts towards a higher reliance on cost-plus contracts. To get a sense of the magnitudes of our estimates, consider the increase in concentration that a particular market would experience, had there been a hypothetical merger between two competitors with initial market shares of 10% each. Our estimates suggest that such an event would have increased the share of dollars awarded noncompetitively or via single-bid contracts by 18%. It would have also increased the share of dollars in cost-plus contracts by 36%. Robustness checks to our preferred specifications as well as placebo tests using a failed (announced but ultimately blocked by federal regulators) merger provide further evidence in support of our findings.

We think that these results are of interest since the determinants of procurement terms (i.e. the choice of awarding mechanism and of contract type) for other areas of government activity and in the private sector have been subject to significant interest in the economics literature, which we reference below. But they are also important because of what they could imply for the efficiency in the use of government's funds. Authorities have made explicit efforts to limit the use of noncompetitive and cost-plus contracts, since they are associated with the risk of wasteful spending.[3]

Despite this concern, we do not find that consolidation led to changes in procurement costs. First, contract spending did not change differentially in product markets that experienced higher

[3] See, for example, President Barack Obama's "Memorandum on Government Contracting," from March 4, 2009. Available online by Gerhard Peters and John T. Woolley, The American Presidency Project. http://www.presidency.ucsb.edu/ws/?pid=85815. We return to the guidelines established by this Memorandum below.

concentration due to the cited mergers. Second, major acquisition programs that contracted with consolidating firms did not experience a divergent trend in acquisition costs, relative to programs with non-merging contractors. We estimate a very small, positive, but statistically insignificant effect on acquisition cost *levels*. Across a range of specifications, we also estimate a very small effect (this time, negative and insignificant) in the *growth rate* of acquisition costs. At the 95 percent level, we can reject that the merger of a prime contractor led to an increase in the growth rate of acquisition costs of more than 2.5 percentage points. All of our point estimates for impacts on acquisition costs are statistically indistinguishable from 0.

It has long been recognized that, *ex ante*, the effects of horizontal mergers are ambiguous because of a fundamental trade-off between a reduction in competition and potential productivity gains (Williamson 1968; see also Whinston 2007). While those elements are also present here, we think that this setting is special because of the added presence of the federal government's monopsonistic power. Buyer power is likely to be of particular relevance in our context, due to a combination of two factors: (i) the government is the main (in some cases, only) customer in many of these markets, and (ii) the dynamic and repeated nature of the procurement process generates incentives not to excessively exploit short-term profit opportunities by raising markups. This is particularly true for the acquisition of large weapon programs, where we obtain our null result on acquisition costs. We argue that this buying power plays a key role in preventing firms for exercising the potential market power obtained from consolidation.

We build on a large empirical literature that studies the relationship between market structure and market outcomes. Seminal contributions include Borenstein's (1989) study of route concentration and prices in the airline industry, and Bresnahan and Reiss' (1991) pioneer analysis of the effects of entry in concentrated markets. We see our paper as contributing to two branches of this literature. The first one has focused on studying the effects (typically, price-effects) of consummated horizontal mergers.[4] The second one consists of a series of recent papers that document a generalized increase in market concentration over the last decades, arguing that it has contributed to slower wage and output growth.[5] We add to this literature by focusing on an industry – defense– that has not previously received much attention in the literature, and that is special in that the government is not only a

[4] These studies have retrospectively analyzed mergers occurring in a wide range of industries, including airlines (Borenstein 1990), banking (Focarelli and Panetta 2003), consumer products like cereal and liquor (Ashenfelter and Hosken 2010), petroleum refinery (Hosken, Silvia and Taylor 2011), health insurance (Dafny, Duggan and Ramanarayanan 2012), mortgages (Allen, Clark, and Houde 2014), and breweries (Ashenfelter, Hosken, and Weinberg 2015).

[5] See, for example, De Loecker and Eeckhout (2017), Autor et al. (2017), Azar et al. (2017).

concerned party as a regulator, but also as the main buyer. In other words, the consequences of consolidation in this case can impact aggregate efficiency, but also the government's budget directly.

We also contribute to the literature on the determinants of procurement contract terms. Building on Goldberg (1977), Bajari and Tadelis (2001) propose a theory of procurement contracts that emphasizes the choice of contract terms as a means for influencing the *ex post* performance of the underlying project. The implications of this framework have subsequently been explored empirically.[6] While most empirical applications have focused on the private sector, Warren (2014) studies the determinants of procurement terms in the context of the US federal procurement system. He argues that increases in contracting officers' levels of workload lead to a higher use of noncompetitive and cost-plus contracts. Like Warren (2014), we contribute to this literature by focusing on public procurement, and add to the set of existing results by studying market structure as a determinant of award mechanisms and contractual form.

This paper is also generally related to a growing literature that studies the determinants of efficiency in public procurement.[7] More specifically, it contributes to a small literature studying the economic aspects of defense procurement in the United States. Rogerson (1994) provides a summary of early studies of the economic incentives that characterize the defense procurement process. Similarly, Lichtenberg (1995) surveys work on the economics of defense R&D. In line with this earlier work, Draca (2012) argues that defense procurement increases the innovation output of private contractors. Another recent example consists on Bhattacharya (2018), who studies the economics of R&D contests, focusing on the case of the DoD's Small Business Innovation Program.

But the most related study to our own is that of Hensel (2010). Motivated by our same question, the author uses data from major acquisition programs and runs time series regressions to test for structural breaks in acquisition costs following a merger of a program's contractor. She then computes the share of the programs that exhibit a statistically significant change in their per-unit costs. Since a relative majority of the programs show a decrease in per-unit costs, the author interprets this as evidence that the mergers generated efficiency gains. We improve on this analysis in three ways. First, we leverage micro-data from the near universe of contracts between the DoD and private contractors, and use a research design to address the endogeneity in the occurrence and timing of the mergers.

[6] Bajari, McMillan, and Tadelis (2008) show that more complex projects tend to be awarded less competitively. Kalnins and Meyer (2004) find that cost-plus contracts tend to be preferred when quality is harder to observe, and when costs are difficult to estimate ex ante. Corts and Singh (2004) argue that cost-plus contracts are more prevalent as buyers and sellers have longer and more frequent interactions.

[7] See, for example, Bandiera et al. (2009), Lewis-Faupel et al. (2016), Coviello and Gagliarducci (2017), Best et al. (2017), Coviello et al. (2018).

Second, this richer data allows us to explore the effect of consolidation on other outcomes such as the use of competition and the choice of contractual form. Third, while we use the same data as Hensel (2010) in the second part of our analysis, we strengthen the empirical methodology by pooling together all acquisition programs –both affected and unaffected– in order to use the latter as a counterfactual for the former in a difference-in-differences framework.

In the next section, we present some institutional detail and other background information that is relevant to our study. Section III describes both of the data sets that we utilize while Section IV describes our empirical methodology. In Section V we present our main empirical results, which we discuss and interpret in Section VI. Section VII concludes.

II. BACKGROUND

DoD procurement: regulation and procurement terms

More so than all other agencies of the federal government, the Department of Defense (DoD) spends a significant share of its budget in procurement contracts, with contract spending accounting for more than half of the DoD budget in recent years.[8] The DoD purchases everything from military aircraft to office supplies, and contracts for services ranging from IT support to janitorial.

Most of the contracting activity is conducted at a highly decentralized level. For example, in the Defense Contract Action Data System dataset that we describe below, we observe more than 3,000 distinct contracting offices awarding funds over our sample period. The scope of action for these contracting offices is defined and limited by the Federal Acquisition Regulation (FAR), and its supplement for the DoD (DFARS).

One of the key responsibilities of contracting officers is to define the procurement terms. In particular, a key decision is whether to award a contract competitively or to seek direct negotiation with one or more pre-selected sources. The FAR mandates that contracting officers shall *"promote full and open competition in the acquisition process"* (FAR 6.000) but gives the officer some discretion to award without competition under some special circumstances, including the existence of a unique responsible source, urgency, national security, and public interest (FAR 6.302).

Contracting officers must also decide the terms of the contract pricing. Perhaps the most important dimension of this is whether to compensate the awardee on a fixed-price or on a cost-plus

[8] See Table A1.

basis. Again, the FAR and DFARS establish guidelines for the most appropriate pricing terms for each acquisition type, typically favoring the use of fixed-price contracts.

While studying the determinants of contractual form in procurement is important in and of itself, procurement terms are also relevant because, according to the authority, these are systematically correlated with the risk of overspending. In fact, federal authorities have explicitly deemed noncompetitive and cost-plus contracts as undesirable, and have set targets for each agency to reduce their reliance on these types of contracts.[9]

In our empirical analysis below, we will explicitly study whether and to what extent these procurement terms (whether to award competitively and the choice between fixed-price and cost-plus contracts) are significantly affected by consolidation-led changes in market concentration.

Major Defense Acquisition Programs

The DoD conducts special procedures for acquisitions that are expected to exceed certain expenditure levels. These programs are called Major Defense Acquisition Programs (MDAP) and are subjected to special acquisition rules and to an additional level of scrutiny. An MDAP is a program for which it is estimated that total expenditure for research, development, and test and evaluation (RDT&E) will exceed $480 million or that procurement expenditures will exceed $2.79 billion.[10] Examples of these programs include the F-22 fighter aircraft, the Blackhawk helicopters, and the Tomahawk missiles.

Given the substantial size of these acquisition programs, the DoD is required by law to submit to Congress detailed periodic reports with the evolution of their costs, schedule, and performance. These are known as Selected Acquisition Reports (SAR). The standard requirement is to submit a new SAR for each program annually. However, if a particular program experiences a per-unit cost increase of more than 15% or a schedule delay of more than 6 months, an additional SAR has to be submitted at the end of the next quarter. We use the information contained in these reports to track the evolution of acquisition costs for these especially large contracts and to test whether they are impacted following industry consolidation.

[9] On March 2009, President Obama sent a memorandum to the heads of executive departments and agencies, mandating them to find ways to decrease their use of noncompetitive and cost-plus contracts, which were qualified as "high-risk". This resulted in agencies establishing specific targets on the share of dollars obligated through these type of contracts.
[10] Figures in FY 2014 constant dollars.

Period of study: budgets and industry concentration

Our period of analysis will be the seventeen-year period from 1985 through and including 2001. We focus on this period since it was during the 1990s that there was a significant increase in concentration in the defense industry. At the same time, it was a period during which there were no abrupt changes in defense spending trends.

Following a massive buildup over the first few years of the Reagan administration, DoD budgets started declining during the second half of the 1980s and continued shrinking smoothly until the late 1990s. After a few years of moderate increases, a rapid buildup began, driven partially by the response to the September 2001 terrorist attacks. Therefore, by focusing on the fiscal years from 1985 through 2001, we take advantage of the fact that the sharp increase in concentration occurs without any stark change in overall DoD spending trends, which could be problematic for separately identifying the effects of concentration. Figure 1 shows how aggregate contract spending and concentration evolved over our sample period, confirming the described patterns. While total contract obligations followed a smooth declining trend, the share of contract obligations awarded to the largest five contractors rose steadily.

This substantial increase in concentration was largely driven by a series of mergers between defense contractors. In fact, the DoD itself was reported to have encouraged consolidation between contractors in the early 1990s, as a response to recent and expected future budget cuts following the end of the Cold War.[11] Among the many M&A operations, four stand out as the largest ones: Northrop's purchase of Grumman Corporation (1994), the merger between Lockheed Corporation and Martin Marietta (1995), the merger between McDonnell Douglas and Boeing (1997), and the acquisitions of Hughes Aircraft and Texas Instruments by Raytheon (1997).

Table 1A and Table 1B list the top 20 defense contractors in FY1990 and FY2000. As the tables shows, most of the contractors involved in these landmark transactions were already among the largest contractors in FY1990. Over the next decade, the share of contract dollars going to the top 5 contractors increased by roughly 50%, with four out of those five contractors being the result of the previously mentioned mergers. Interestingly, in 1998, an additional mega-deal between Lockheed Martin and Northrop Grumman was proposed, but this time blocked by the Department of Justice with

[11] According to the Washington Post, July 4, 1997, *"The frenzy of defense industry mergers can be traced to 1993, when then-Deputy Defense Secretary William Perry invited executives to dinner. At an event now referred to as "the last supper," Perry urged them to combine into a few, larger companies because Pentagon budget cuts would endanger at least half the combat jet firms, missile makers, satellite builders and other contractors represented at the dinner that night."*

support from DoD. We use all of the approved mergers as a source of variation in industry concentration and the rejected merger for a set of placebo tests. Table 2 summarizes these four mergers along with the one rejected merger.

III. DATA

We use two main sources of data. The first one is the Defense Contract Action Data System (DCADS), which consists of detailed administrative records of all non-classified contracts awarded by the DoD, valued at or above $25,000. The second one comes from the Selected Acquisition Reports (SAR) that the DoD is required to submit periodically to Congress and which contains detailed information on acquisition costs of large programs (typically weapon systems).

The main advantage of the DCADS is its comprehensiveness, allowing us to study virtually all contract spending by the DoD during our period of analysis. One important disadvantage, however, is that while we observe information related to the competitive procedures and procurement terms, we are not able to observe the evolution of acquisition costs or other measures of performance. This is why we complement the analysis from the DCADS using the SARs, where we sacrifice completeness by focusing on a smaller number of large acquisition programs. This latter data set allows us to observe detailed information on unit costs and program schedule for the same project over time. Analyses using these two complementary data sets will therefore allow us to obtain a more complete picture of the effects of consolidation on government procurement outcomes. We now describe each of these two data sources in more detail.

Defense Contract Action Data System (DCADS)

Dataset description

The DCADS contains records of all prime contracts of at least $25,000 awarded by all Military Services and Agencies between FY1976 and FY2006. The data is maintained by the U.S. National Archives and Records Administration and is publicly available. Despite the detailed information about a large segment of federal spending, only a handful of previous papers in economics have taken advantage of these comprehensive data.[12]

[12] Examples include Lichtenberg (1988), Guthrie and Hines (2011), Draca (2012), and Nakamura and Steinsson (2014).

An observation in this dataset is a *contract action*, which includes any step taken that results in either the formation or modification of a contract. This means that for a single contract we may see multiple observations or contract actions (e.g. the initial award plus follow-up modifications for additional services). For each observation, we observe the exact date of transaction, the funds obligated by the contract action, the identities of both the awardee and the specific contracting office, a code that specifies the good or service being transacted, and a set of variables describing the solicitation and award process. For our main period of analysis (FY1985-FY2001), we observe approximately 250 thousand contract actions per fiscal year, for a total of 4.3 million observations.

The identity of the awardee is revealed by their Dun & Bradstreet DUNS code, a unique nine-digit identifier for businesses. We use the DUNS code of the parent company of the contract awardee as reported in our data. However, there are frequently multiple DUNS codes that refer to the same firm. To address this issue, we manually consolidate DUNS codes for more than 150 of the largest private contractors.

The description of the type of product being transacted is given by the Federal Supply Classification code. This system classifies every contract action with one of more than 5,000 codes. These very detailed codes can be aggregated up to 101 different categories, 77 of them corresponding to goods and 24 of them to services. As we will note below, these categories will constitute the basis for our definition of product markets.

The data also contain important characteristics about the contract terms and about the solicitation procedures that led to the award, characteristics that the authority considers are correlated with the risk of overspending. In particular, we observe whether or not a contract was awarded using competitive procedures, whether a solicitation received a single offer or multiple bids, and whether the contract pricing remunerates the awardee on a fixed-price or a cost-plus basis. We will use these variables to evaluate whether and to what extent consolidation systematically affected the use of high-risk (noncompetitive, single-bid and cost-plus) contracts.

Summary statistics

In the background section we described Table 1A and Table 1B, which show the largest defense contractors at two points in time, FY1990 and FY2000, with the goal of documenting the consolidation-driven increase in concentration over the 1990s. These tables are obtained from the DCADS by aggregating contract actions at the firm by fiscal year level.

Similarly, in Table 3 we aggregate contract actions at the product category level, and show the largest ones in terms of spending. Among the goods, the largest categories are aircraft, communications, and guided missiles. The largest service categories are research and development (R&D), professional support, and maintenance/repair of equipment.

Finally, in Table 4 Panel A we present summary statistics of the disaggregated microdata, using the full 4.3 million observations during our study period. The average contract action obligates $830K (in 2016 dollars). Regarding contract terms, 71% of the contract actions correspond to competitively awarded contracts,[13] 34% to single-offer contracts, and 78% to fixed-price contracts. When we weight actions by their dollar amount, we observe that 54% of the dollars are awarded via competitive contracts, 36% through contracts with a single bid, and 68% in fixed-price contracts. The difference between the weighted and unweighted percentages implies that larger contracts are less likely to be competitively awarded and are less likely to have fixed price contracts.

Limitations

The DCADS is a comprehensive dataset that allows to observe virtually all defense contract spending during our sample period with a significant level of granularity. However, an important weakness of these data is that we cannot observe quantities purchased in each contract, and therefore cannot infer the unit cost of purchasing a given product. Similarly, no performance or quality measures are reported for the contracts. This means that the analysis based on the DCADS will mainly allow us to make statements about how market structure affects procurement terms, in particular the level of competition and the type of pricing incentives that the contracts provide. While important, this analysis is incomplete, since we also want to assess how concentration ultimately affects acquisition costs. This is why we complement the analysis with a second data source that is narrower in its coverage but is significantly more detailed in terms of unit costs and other procurement outcomes.

Selected acquisition reports (SARs) summary tables

Dataset description

[13] An additional 3% correspond to follow-on to competed actions.

We constructed our second dataset by compiling information from the Selected Acquisition Reports (SARs) that the DoD is required to periodically submit to Congress. Each report summarizes the cost, schedule, and performance status of Major Defense Acquisition Programs (MDAPs). Each report is a lengthy and detailed document, but the DoD publishes summary tables that compile the key variables for all active MDAPs, most importantly unit acquisition costs.

We use the data included in these summary tables from 1985 through 2001 to build this dataset. The tables list each active acquisition program by name, the military branch in charge of it, the year in which the program started (referred to as the base year), current estimates of total acquisition costs and quantities, and the cost and quantity estimates that were available in the base year. With these pieces of information, the DoD computes an estimate of the *change* in total acquisition costs in the current year with respect to the baseline estimates. Importantly, this cost growth estimate adjusts for changes in quantities purchased, which occur frequently.[14]

By combining the information in all of these annual tables, we can construct a panel dataset in which we follow acquisition programs over the years that they remain active. We restrict attention to the 190 programs that we observe for at least three years during our study period. Panel B of Table 4 presents summary statistics of this dataset. The average program in our sample is active for 6.3 years during our study period, which gives us 1,192 program-year observations. The average program was estimated to have a total cost of $10.8B (in FY2016 dollars) at baseline. On average, total acquisition costs grow by 2.8% annually (adjusting for changes in quantity purchased).

IV. EMPIRICAL FRAMEWORK

We study the impact of industry consolidation on public procurement using two complementary identification strategies. Both approaches leverage the sharp increase in market concentration generated by the four mergers among top DoD contractors listed in Table 2. The first analysis exploits the heterogeneous impact of these mergers across product markets. The second

[14] As an example, consider a program that is expected to last 3 years, and suppose that there are no inflation or quantity changes. At baseline (year 1), this program is expected to have a *total cost* of $10B over its lifetime. In year 2, suppose the *total cost* is now estimated to be $11B, either because of higher realized costs or because of increased expected costs. In year 3, the program ends and suppose the estimate of *total cost* is now fully realized and equals $11B, just like in the previous year. The *cost growth* estimate (difference between current year and baseline) would be 10% for year 2, and also 10% for year 3. We define the *annual cost growth* as the first difference of this variable, to measure year-to-year changes in cost estimates. In this case, *annual cost growth* would have been equal to 10% and 0% in years 2 and 3 respectively. In practice, when translating the *total cost* estimates into *cost growth* estimates, the DoD adjusts the magnitudes to account for the effects of inflation and quantity changes.

analysis is based on variation across large acquisition programs, only some of which were directly affected by these mergers. We now describe these two strategies in detail.

Market-level analysis

Market definition and sample construction

Our first analysis takes advantage of the differential impact that consolidation had across the different product markets within which the DoD purchases goods and services. If two firms operate in multiple markets, then depending on their initial market shares, a merger between them will have very different effects on the level of market concentration. This empirical strategy was previously used by Dafny, Duggan and Ramanarayanan (2012) (henceforth, DDR), who study the merger between two large health insurers in the US, both of which had varying market shares across geographic markets.

We adapt DDR's approach to our setting making three key modifications. First, instead of geographic markets, we focus on variation across product markets. Second, we extend the framework to allow for multiple mergers occurring at different moments over time. Third, we use a merger that was rejected by federal regulators as a placebo test to test whether our estimates are capturing a causal effect or instead some unobserved factor that is correlated with proposed mergers.

Geographic markets make little sense in the context of DoD procurement. Procurement contracts are hardly a homogeneous good (see Table 3), so that firms that sell in the same geographic area may not be relevant competitors. A more natural approach is to think of all geographic areas as one integrated market, but to distinguish across the different good and service categories that the DoD contracts for. Conceptually, we think of a contract as reflecting an exogenously determined need for a particular product. Depending on what that specific product is, there is a set of potential suppliers that can offer it, and therefore that are competitors in that product market.

We use the goods and services categories in the DCADS data to define our product markets. Recall that each individual action has a code that classifies the contract into one of 101 good or service categories. We aggregate the DCADS micro data to create our analysis sample, in which an observation is a product category (henceforth, market) i in fiscal year t. We use the 97 markets for which positive spending was observed in each year during our entire 17-year study period (FY1985-FY2001), which gives us a balanced panel of 1,649 observations.

For each market-year, we compute the level of concentration, as measured by the Herfindahl-Hirschman index (HHI).[15] This will be our key explanatory variable, and equals the sum of squared market shares within the product category.[16] We multiply this by 10,000 so that a product market in which one firm has a monopoly would have a value of 10,000. Alternatively, if there are N firms and each has an equal 1/N market share, then the value of the HHI would be 10,000 / N.

We construct dependent variables related to the level of competition and contractual form: the share of contract dollars in the product category that were awarded noncompetitively, the share of contracts dollars where only one offer was received, and the share of dollars in fixed-price (rather than cost-plus) contracts. Additionally, we compute total contract spending (dollars obligated) at the market-year level. Since there is wide variation in market sizes, in our baseline specification we will weight different markets based on the number of contracts observed in a pre-sample period (FY1980-FY1984). Table 5 Panel A presents summary statistics on our market-level analysis sample.

While Figure 1 documented the rise in concentration at the aggregate level, we can now do the same using our market-level data. Figure 2 shows the distribution of changes in HHI at the market level between FY1984 and FY1992, and compares it to the distribution of changes between FY1992 and FY2000. As the figure demonstrates, most product markets had only a small change in their concentration levels between FY1984 and FY1992. However, many product markets experienced substantial HHI increases between FY1992 and FY2000. The rise in concentration is even more visible when we weight markets by size, suggesting that larger markets were the ones that experienced the largest increases in concentration.

Econometric specification and identification

Our main empirical specification is of the form:

$$Y_{it} = \alpha + \lambda_i + \rho_t + \beta \cdot HHI_{it} + \varepsilon_{it} \quad (1)$$

where Y_{it} is an outcome variable and HHI_{it} is the Herfindahl-Hirschman index of market i in fiscal year t. This specification also includes market fixed effects to account for baseline differences across product categories in the share awarded competitively and in the other outcome variables of interest.

[15] This corresponds to the sum of the squares of all contractor's market shares.

[16] A firm's market share is defined as its revenues in the product category divided by total revenues in the product category.

We also include year fixed effects to account for common changes at the national level such as in contracting procedures by the government. Our main coefficient of interest is β, which if properly estimated captures the effect of market concentration (as measured by the HHI) on the procurement outcome of interest.

Of course, changes in concentration over time may be driven by many factors that could also influence procurement outcomes. For example, one company may discover a new method of production that makes it much more efficient than its competitors. This may cause the government to award more of its contracts to this firm, either because the firm wins when contracts are awarded competitively or because the government skips the bidding process because this firm is obviously superior to the others. This and other outside factors could simultaneously influence both procurement outcomes and our measure of market concentration, which would bias our estimates for the effects of concentration on procurement outcomes.

Because of this and related possible sources of omitted variable bias, it is important to isolate a plausibly exogenous source of changes in market concentration to reliably estimate β in equation (1). To do this, we follow DDR and implement an instrumental variables strategy, in which HHI_{it} is instrumented by the change in HHI that would have been observed given a specific merger and absent any other change. The authors refer to this instrument as the *simulated change in HHI* associated with the merger. Formally, suppose that a subset C_m of contractors indexed by f decide to merge in year t_m^*. The simulated change in HHI associated with merger m is given by:

$$sim\Delta HHI_{it}^{m} = \left[\left(\sum_{f \in C_m} s_{i0}^{f} \right)^2 - \sum_{f \in C_m} \left(s_{i0}^{f} \right)^2 \right] \times \mathbf{1}(t \geq t_m^*) \qquad (2)$$

where s_{i0}^{f} is contractor f's market share in market i in a reference period previous to the merger. As this reference period, we use the average of the three years preceding the merger year t_m^*.

The instrument measures the mechanical increase in HHI that one would expect from a merger absent any other changes. By doing this, it isolates the variation in market concentration that comes from the distribution of pre-merger market shares. That means that we should expect larger increases in concentration in markets where merging contractors had larger and more equally distributed market shares. Below we discuss a particular example to illustrate this point. Note that each merger m has its

own associated $sim\Delta HHI_{it}^{m}$ in each product market. Since we exploit four different mergers, our instrument will combine them, leveraging their differential timing. Our instrument will be:

$$sim\Delta HHI_{it} = \sum_{m} sim\Delta HHI_{it}^{m} \tag{3}$$

so that each year after a new merger occurs, the $sim\Delta HHI_{it}$ is increased by an amount equal to the simulated change in HHI associated with that particular merger.

One potential concern with this approach is that defense contractors may merge in response to expected changes in purchasing strategies used by the government or in response to expected changes in market concentration (e.g. the entry or exit of another competitor). If this were true, this would bias our estimates of the effect of concentration on procurement outcomes. To address this issue, we use a merger that was blocked by the U.S. Department of Justice as a "placebo test". As shown in Table 2, the Lockheed Martin-Northrop Grumman merger deal was announced towards the end of our sample period but was ultimately blocked by federal regulators.[17]

Example: Lockheed-Martin merger

To further illustrate how the instrument works, consider the case of the merger between Lockheed Corporation and Martin Marietta Corporation. The deal was announced on the last day of FY1994, so we treat FY1995 as the first year after the merger. The idea of the instrument is that the average effect of this merger on the concentration level of different product markets varied substantially depending on the initial market shares. To see this, consider the variation across three different product markets: weapons (product code 10), guided missiles (product code 14) and Research and Development (service code A).

While Martin Marietta was a significant player in the market for weapons, accounting for 20.68% of the contract dollars in FY1992-FY1994, Lockheed was essentially irrelevant, with a market share of just 0.02%. This asymmetry implies that the simulated change in the HHI for this market would be very small:

$$sim\Delta HHI = (20.68 + 0.02)^2 - 20.68^2 - 0.02^2 \approx 1$$

[17] This is analogous to the approach taken in DDR, where the authors contrast the effect of one merger in geographic markets where federal regulators blocked it with the corresponding effect in markets where the merger was allowed.

with HHI measured on a scale from 0 to 10,000. In the market for guided missiles, however, the asymmetry was less extreme. While Lockheed had 21.62% of the contract dollars prior to the merger, Martin Marietta had a market share of 4.86%. The simulated change in HHI in this case is around 200 points. That is almost identical to the simulated change in HHI that we expected for the R&D market, were firms had smaller combined market shares, but were more equally distributed (Lockheed had 10.56% and Martin had 8.95%).

Our identifying variation comes from the fact that we should expect a higher increase in concentration in the guided missiles and R&D markets, relative to the weapons market. Indeed, in the year following this merger, the actual HHI increased by approximately 400 points in guided missiles and 300 points in R&D, while it increased by just 60 points in the market for weapons.

Analysis of major acquisition programs

Sample construction

For the second part of our analysis, we restrict attention to Major Defense Acquisition Programs (MDAPs). While these consist of a much smaller subset of defense contracts, the benefit is that we can observe acquisition costs directly from the Selected Acquisition Reports (SARs). We consider 194 MDAPs programs that were active for at least three consecutive years on FY1986-FY2001, generating an unbalanced panel with 1,267 program (i) – year (t) observations.

Note that we observe the identity of the prime contractors of each program. Key for our identification strategy below, we distinguish between programs run by the contractors participating in the large mergers of Table 2. We will refer to these programs as "treated" and to the rest of the programs as "control".

Each program has a baseline year, which is typically the year in which the program started, and when initial acquisition costs estimates are recorded. Every year after that, we observe updates of these cost estimates, which start to be partially realized. The DoD also computes measures of cost growth based on the difference between the current and baseline estimates of program cost, adjusting for both inflation and any changes in quantity procured. This is important because these adjustments occur frequently and can imply large changes in the overall level of expenditure without necessarily being related to underlying cost changes. From this information we construct acquisition cost variables that we describe below.

Panel B of Table 5 presents summary statistics on the MDAP analysis sample. Note that we present separate statistics for the 118 "treated" and 76 "control" programs.

Difference-in-differences strategy

Our approach relies on combining the time variation in the mergers of Table 2 with variation across acquisition programs, depending on whether they were directly affected by the mergers. In other words, we implement a difference-in-differences (DiD) strategy, in which we compare the evolution of acquisition costs for programs whose prime contractor experienced a merger relative to those programs that did not, before and after the consolidation. We will refer to the former as "treated" programs, while we will call the latter "control" programs. The DiD specification is:

$$Y_{it} = \gamma + \eta_i + \tau_t + \delta \cdot Merge_{it} + \nu_{it} \quad (4)$$

in which Y_{it} is some measure of acquisition costs, $Merge_{it}$ is an indicator equal to one if program i's main contractor is involved on the mergers listed in Table 2 (i is a treated program), *and* $t \geq t^*$ (the year of the merger). This specification also controls for program fixed effects (to account for baseline differences across programs) and year fixed effects (to account for the effects of common changes across all programs in procurement policies, expenditures, or related factors). We are especially interested in δ, the estimated effect of a firm's merger on the cost of procuring from them. The identifying assumption is that absent any merger, the acquisition costs of programs awarded to firms like Lockheed or Northrop that were both involved in mergers would have evolved in a parallel way with respect to those run by firms like General Dynamics or Litton Industries that were not.

We use three specific measures of acquisition cost as dependent variables. First, we will use the estimated full cost of program i in fiscal year t (in logs), which is updated in every new SARs. Second, we will use the estimated real annual cost growth adjusted by quantity changes. Third, we will generate an indicator from the (corrected) annual cost growth variable that will take the value of 1 if in a given year the annual cost growth exceeds 10%.

Simple event study

The DiD specification from above is estimated using all 194 programs in our sample. But while using all available programs maximizes the statistical precision of the estimation, the identification of our main coefficient of interest δ is driven primarily by treated programs for which we observe activity both before and after the merger of their contractor, as well as from control programs of similar ages that are active in similar years. Given this, we complement our DiD analysis with a simple event study, which focuses only on the programs that drive the estimation of δ, and which provides us with transparent graphical evidence on the relative evolution of acquisition costs for treated and control groups.

We implement our event study in the following way. We first restrict attention to treated programs for which we have at least one observation on the year preceding *and* one observation on the year following the merger. At the bottom of Table 5 we can see that these correspond to 30 programs (the other 88 treated programs are observed either only before or only after the relevant merger).

We then build a comparable control group by selecting programs that were active between the same fiscal years as the subsample of treated programs. For these control programs, we assign placebo merger dates at random, with the condition that the distribution of merger years across both groups looks similar. We let event time to be fiscal years relative to the one in which the merger (real or placebo) occurred. With this approach we can perform our event study by plotting the different measures of acquisition costs over event time for both treated and control programs.

V. RESULTS

We now present the results of our empirical analyses. Like in the previous sections, we proceed in two steps. First we discuss the results of our market-level analysis, in which we exploit variation across product markets to measure the effect of concentration on procurement outcomes. Then we present the results of our analysis of major defense acquisition programs, when we test for differential changes in acquisition costs for programs run by consolidated contractors relative to other programs.

Market-level analysis

First stage

We start by assessing the relevance of our instrument. Recall that our main specification is equation (1), where we instrument HHI_{it} with $sim\Delta HHI_{it}$, as defined by equations (2) and (3). Table 6 shows the results of this first stage, where HHI_{it} is regressed on variants of the instrument and a set of market and fiscal year fixed effects.

In column (1), we include as separate explanatory variables each of the simulated changes in HHI associated with the mergers of Table 2 (including the placebo merger). In column (2), we combine all of them into a single measure, as defined by (3). Here we include the placebo in the combined instrument $sim\Delta HHI_{it}$, and we also include it as a separate regressor. Column (3), our preferred specification, and all subsequent specifications exclude the placebo from the definition of $sim\Delta HHI_{it}$. In column (4) we check the robustness of our estimate by including a different set of fiscal year fixed effects for each of three product category groups: goods, services and R&D. Columns (5) and (6) repeat the specifications in (3) and (4) respectively, except that we weight all observations equally.[18]

Overall, the results indicate a strong first stage relationship between our instrument and market-level concentration. When considered separately, the simulated changes in HHI associated with all four of the approved mergers in Table 2 have positive coefficients, three of which are statistically significant at the one percent level. Interestingly, when combined into a single measure, the coefficient on our instrument is positive, statistically significant, and slightly above 1. This means that, on average, markets experience changes in concentration levels that are roughly equal to what would be expected from taking the pre-merger market shares of the consolidated firms and assuming no other changes. The relevance of our instrument is robust to introducing more flexible controls for category group specific year effects, that is, separate fiscal year fixed effects for goods, services and R&D. Likewise, the first stage remains strong when ignoring the large differences in the size of the different markets, and therefore weighting all observations equally. Finally, it is reassuring that the coefficient associated with the placebo merger of Lockheed Martin and Northrop Grumman does not follow the same pattern. In fact, the significantly negative coefficient in column (2) that is of roughly equal magnitude to the significantly positive estimate for the coefficient on the combined $sim\Delta HHI_{it}$ measure suggests there was no significant change in concentration in markets that would have been differentially affected by this rejected merger. Taken together, the evidence in this table strongly suggests that the approved mergers provide a plausibly exogenous source of variation in market concentration.

[18] Recall that in our baseline specifications we weight each observation it by market i's average number of contracts in the pre-sample period of FY1980-FY1984.

The effect of concentration on procurement competition

Now we consider the effects of concentration on procurement competition. We are interested in the estimation of equation (1). The main outcome of interest for this part is the share of obligated dollars in a given market-year that were either awarded noncompetitively[19] or through a competitive procedure in which only a single offer was received.

The results are presented in Table 7. In the first column we present the OLS estimate of β from equation (1). In columns (2) through (5) we estimate the reduced form of our model, in which we regress the outcome measure directly on the instrument and the relevant fixed effects. In columns (2) and (3), the instrument includes only the approved mergers. In columns (4) and (5), the instrument includes the simulated change in HHI associated with the placebo merger, which we also include in the regression separately. Columns (6) and (7) present the IV estimates of β in equation (1), where the HHI is instrumented by the combined simulated change in HHI of the approved mergers. Columns (2), (4) and (6) correspond to the baseline specifications with market and fiscal year fixed effects. Columns (3), (5) and (7) respectively replicate these specifications with the additional inclusion of category-group specific year effects.[20]

We see from column (1) that higher concentration is positively correlated with the award of noncompetitive contracts, although the coefficient is small and statistically indistinguishable from zero (0.27 with a standard error of 0.17). However, when we use the variation in concentration coming from the consolidation of large defense contractors, the positive relationship becomes much stronger. Our preferred estimate of β, given by the instrumental variable specification in column (6), corresponds to 3.77.

To get a sense of what the magnitude of our coefficient estimates imply, recall that the HHI is scaled between 0 and 1 in all our specifications, and that the mean value of this concentration measure is 0.07. An increase in HHI of 0.02 (say, generated by the merger of two firms with 10% market share each), would cause the share of noncompetitive or single-bid contract dollars to increase by 7.5 percentage points ($\approx 0.02 \times 3.77$). This would represent an 18% increase given the mean share of 42.1%.

The two-stage least squares coefficients in columns (6) and (7) are substantially larger than the OLS coefficient in column (1), suggesting the presence of significant downward bias on the latter

[19] For example, via direct negotiation with a single firm.
[20] Recall that for this we classify product categories in three groups: goods, services and R&D.

specification. At least two distinct forces may be contributing to this bias. First, the fact that we do not observe the universe of contracts (either confidential contracts or those below the reporting threshold) introduces measurement error in our key explanatory variable. Second, reverse causality will tend to net out the positive effect of concentration on noncompetitive awards: a rising share of noncompetitive awards will attract more firms to a particular market, which will result in reduced concentration.

One concern with our identification strategy is that firms may decide to merge in response to expected increases in noncompetitive awards. If that is the case, then our estimates would be confounding this fact with the causal effect of concentration. Reassuringly, the evidence from the placebo merger seems to contradict this explanation. In the reduced form specifications in columns (2) through (5), we see that the inclusion of the placebo merger does not significantly affect the positive coefficient on the instrument, and that the separate coefficient on the placebo merger is in fact *negative* and of roughly equal magnitude to the main estimate. This strongly supports a causal interpretation of our key results since there is no evidence that noncompetitive awards increased in markets that would have been differentially affected by the blocked merger of Lockheed Martin and Northrop Grumman.

Finally, columns (3), (5) and (7) show that all of these results are robust to more flexible controls by category groups and years. We therefore interpret these results as evidence that rises in product market-level concentration caused the procurement process to become less competitive.

The effect of concentration on contractual form

We now turn our attention to the question of whether and to what extent changes in product market concentration affect the choice of contract type, in particular between fixed-price and cost-plus contracts. The analysis resembles that from the previous section, although we focus on the share of dollars awarded via fixed-price contracts as the main outcome variable. Table 8 presents the results, following the same structure as Table 7.

The OLS results indicate that product market level concentration is negatively correlated with the use of fixed-price contracts (coefficient of -0.28). As with the level of competition, the results using our instrument suggest a much stronger effect. Our preferred IV estimate of -2.76 implies that an increase of 0.02 in HHI (generated, for example, by a merger between contractors with 10% market share each) causes the share of fixed-price contract dollars to decrease by 5.5 percentage points. That in turn means that the use of cost-plus contracts increases by that same amount, which represents a substantial 36% increase relative to a mean of 15.2%.

As with the previous table, comparing the IV with the OLS results suggests the presence of substantial downward bias. This can be explained by a combination of measurement error and reverse causality (less use of fixed-price contracts may attract more firms, which results in lower concentration).

Again, the placebo test further supports the causal interpretation of our estimates. The coefficient on the reduced form is stable when we introduce the placebo, and the separate coefficient on the placebo simulated change in HHI has the opposite sign (though it is not statistically significant). Additionally, the introduction of category group by year fixed effects does not change our results by much, although it makes the IV estimate in the final column of the table marginally insignificant.

Taken together, the results in Table 8 indicate that consolidation-driven increases in market concentration led to a significant shift from the use of fixed-price to cost-plus contracts.

The effect of concentration on market level contract spending

Finally, we consider spending at the product market level as an outcome variable. The preceding results suggest that the merger-induced increases in market concentration reduced the competitiveness of the procurement process and induced a shift from fixed-price to cost-plus contracts. One possible concern with these changes is that it may have increased spending on government contracts above what it otherwise would have been. Firms may have bid less aggressively knowing that there were fewer potential competitors. The shift to cost-plus contracting may have allowed firms that were awarded contracts to opportunistically push spending higher. On the other hand, the merged firms might have been more efficient than their predecessors and consequently submitted bids with lower prices. Similarly, government officials may be well-positioned given their significant (current and future) buying power to constrain cost increases.

Table 9 presents the results following the same format of Table 7 and Table 8. From the OLS regression in column (1) we see that concentration is positively correlated with market level spending. However, our reduced form and IV specifications imply that when market concentration is shifted exogenously by mergers among contractors, spending at the market level actually *decreases*. The preferred IV specification implies that the same increase in HHI of 0.02 that we have considered above led to a reduction of 6.5% in spending.

As with the previous results, we are reassured by the placebo test using the blocked Lockheed Martin – Northrop Grumman merger. As before, the coefficient is of the opposite sign (though it is not statistically significant). This suggests that our estimates are not simply driven by firms merging in

response to expected declines in government spending. Our key coefficient estimate is qualitatively similar when we include flexible category group by year fixed effects.

Summing up

Taken together, our results indicate that merger-induced increases in concentration at the product market level caused the federal government's procurement process to become less competitive and to rely more on cost-plus contracts. In other words, concentration led to an increase in the use of contracts that the authority considers as "high risk" in terms of generating wasteful spending. While we cannot test directly whether unit acquisition costs respond to the levels of concentration with these data, our analysis is inconsistent with the hypothesis that concentration caused market-level spending levels to rise. If anything, our results suggest the opposite. We leave the interpretation and discussion of the implications of these results for section VI.

Analysis of Major Acquisition Programs

We now discuss the results of our analyses that investigate whether and to what extent consolidation affected the procurement costs of major acquisition programs. To the extent that merging firms acquired additional market power following the mergers, it is possible that they would try to exercise it by increasing the costs of their projects or extending the duration of the contract. We first present the estimation results of our difference-in-differences specification, given by equation (4). We follow this by presenting evidence of a simple event study of cost growth.

Difference-in-differences

Table 10 presents results from the estimation of variants of equation (4) for three different outcome variables. In Panel A, the dependent variable is the log of total program cost.[21] In Panel B, we instead focus on programs' *annual* cost growth, in percentage terms.[22] Finally, in Panel C, the dependent variable is an indicator equal to 1 if a program's annual cost growth exceeds 10%. Our

[21] This corresponds to an estimate of the total acquisition cost of a given program *over its full life* (in constant dollars). This estimate is revised on each new Selected Acquisition Report (SAR).
[22] This is the change with respect to the previous year, of the difference (in percentage points) between the baseline and the current total cost estimates of a program, adjusting for both inflation and quantity changes.

coefficient of interest is the one on the variable $Merged_{it}$, which we interpret as the causal effect of a contractor's merger on the acquisition costs of their existing programs.

All columns of the table include fiscal year fixed-effects. In the first column we control for the military branch to which the program belongs (Army, Navy, Air Force or Other/Joint). In columns (2) and (3) we introduce linear and quadratic controls for a program's age, which is the difference between year t and the program's base year. In column (4) we control for program fixed effects, which we repeat in column (5) while adding a full set of age fixed-effects.

From Panel A we conclude that consolidation did not significantly affect total acquisition costs. Once we control for the wide differences in cost levels between programs by introducing program fixed effects, we estimate a small causal effect of a contractor's merger on total program cost of between 1 percent and 2 percent. Note that total costs may vary in response to unit cost changes, or due to changes in demand. That is why a more informative measure of costs is the annual *growth* in total program costs, which adjusts for changes in quantity and is presented in Panel B. Again, we estimate treatment effects that are statistically indistinguishable from zero. Our point estimates in fact indicate a *decrease* in the growth rate of acquisition costs of approximately 2 percentage points. This is confirmed in Panel C, where the probability of a high (larger that 10 p.p.) increase in annual cost growth decreases for merged programs by 10 percentage points in our specification with full controls. Again, this change is not significantly different from zero.

Event study

We now complement the regression analysis from the difference-in-differences specification with graphical evidence from a simple event study. Recall that for treated programs, event time is defined relative to their contractor's merger year. For the control group, event time is defined relative to a randomly generated merger date, such that the distribution of merger dates in treatment and control groups is the same.

Figure 3 presents the results of this analysis. We plot the mean annual cost growth for treated and control programs as a function of event time.[23] This graphical evidence is consistent with our previously presented null result, since we see the annual cost growth of treated and control programs evolve in a roughly parallel trend.

[23] Since in this exercise we are not controlling for the large differences between program sizes, the means presented are computed by weighting each program by their baseline total program cost (in constant dollars). Results are qualitatively unchanged when we weight all programs equally.

Taken together, the results from our analyses of the major acquisition programs suggest that consolidation among top contractors did not lead to an increase in procurement costs, at least for these large programs that were already underway at the time of the mergers.

VI. DISCUSSION

Our main results can be summarized as follows. Higher product market concentration –induced by a wave of consolidation between defense contractors during the 1990s– caused the defense procurement process to become less competitive, and more reliant on cost-plus contracts. But although the federal authorities have deemed noncompetitive and cost-plus contracts as more prone to result in wasteful spending, we find no evidence that consolidation led to increased procurement costs. In this section we discuss the implications and possible mechanisms behind these results.

Increased use of non-competitive and cost-plus contracts

Our finding that that higher concentration leads to less reliance on competitively awarded contracts is consistent with previous research. Bajari, McMillan and Tadelis (2008) argue that this is a relatively straightforward implication of standard auction theory: as fewer potential bidders are available (a direct result of industry consolidation), the attractiveness of auctions relative to direct negotiation decreases. While Bajari et al. (2008) show that there is a positive correlation between the availability of bidders and the use of competitive bidding in the context of private procurement contracts, we provide evidence of a causal relationship in the case of public procurement contracts.

The above justification, however, implies that the reduced use of competition is an optimal response on the government's part to the smaller number of competitors. Another possibility is that the government was simply constrained to award less competitively as a result of the market structure changes. For instance, consolidation makes it mechanically more likely that a unique source exists for a particular product (a valid reason to award noncompetitively) or that a single bid is received in a competitive solicitation. That the use of noncompetitive contracts reflects a constraint rather than an optimal choice is plausible in the context of public procurement, since government officials have less flexibility to choose the awarding mechanism than in the private sector.

A similar argument can be made to rationalize the shift from fixed-price to cost-plus contracts. Existing theories emphasize that fixed-price contracts provide strong incentives for efficient cost reduction, while cost-plus contracts provide a flexible way to adapt to unexpected contingencies and

ex post renegotiation (Bajari and Tadelis 2001). That suggests that the optimal choice of contract can be affected by things like the underlying project's complexity, uncertainty regarding *ex post* costs, *ex post* observability of quality, and the length of relationship between buyer and sellers.[24] But these elements do not seem directly affected by changes in market structure, so we should not necessarily expect the buyer's optimal choice of contract pricing to change in response to consolidation. If, however, consolidation increased the bargaining power of the firms in this market, it is possible that this allowed them to demand more favorable contract terms, shifting cost overrun risks from contractors to the government.

Understanding the determinants of procurement competition and contractual form has its own relevance, as proven by the existence of a large theoretical and empirical literature on this topic. However, it is also of special interest because of what these may imply for procurement costs. This is especially relevant in our setting, where it is the taxpayer's money that finances the purchases. Furthermore, for many of the products that we consider in our analysis, the federal government is the only customer.

In March 2009, President Obama signed a memorandum that declared that *"sole-source contracts, contracts with a limited number of sources and cost-reimbursement contracts create a risk that taxpayer funds will be spent on contracts that are wasteful, inefficient, subject to misuse, or otherwise not well designed to serve the needs of the Federal Government or the interests of the American taxpayer."* If this association between procurement terms and cost efficiency is correct, then our previous discussion should imply that consolidation also led to higher procurement costs.

No evidence of increased procurement cost

Despite the previous discussion, our second set of results are inconsistent with this concern. First, contract spending did not increase in product markets that experienced higher increases in concentration. Second, acquisition programs run by contractors that consolidated did not see a differential change in per-unit acquisition costs. While by themselves neither of these results constitute a perfect test, we believe that in combination they provide suggestive evidence that consolidation did not cause the federal government's procurement costs to rise significantly. The first result concerns the near universe of contract spending, but has the problem that, since we only observe total spending, the

[24] Empirical explorations of these arguments can be found in Corts and Singh (2004), Kalnins and Meyer (2004), and Bajari, McMillan and Tadelis (2008).

effect may confound changes in unit procurement costs with demand decisions that are endogenously taken by the government. On the other hand, the latter result relies on a small subset of very high-profile contracts, but benefits from the use of accurately measured unit costs. With these strengths and weaknesses in mind, the fact that both analyses yield qualitatively similar results is reassuring.

How can we rationalize the absence of increased procurement costs? We think that there are multiple forces at play that operate in opposite directions, so that the total effect of consolidation-induced industry concentration on procurement costs is *ex ante* ambiguous. Some of these forces have long been recognized as the key inputs for evaluating the effects of horizontal mergers (Williamson 1968; Whinston 2007). However, we argue there are additional elements to consider in this particular context.

Two clear forces contribute to a positive effect of consolidation on acquisition costs. We have already mentioned the first one: that the shift away from competitively awarded and fixed-price contracts could contribute to increase procurement costs. A second force is that consolidation may have increased the market power of contractors, allowing them to charge higher markups and therefore extracting higher rents from the government.

But there are at least two other forces that can counter the above upward pressure on procurement costs. One is that the mergers generated cost efficiencies. If this is the case, then the ability to charge higher markups can be offset by lower production costs, leaving procurement costs for the government unchanged.

A second, and perhaps more relevant explanation for the absence of increased acquisition costs, is that the government has significant buyer power that can be exerted to curb firm's ability to extract rents. This buyer power is explained by two facts that are particularly relevant for this context. First, the government is a monopsonist, or at least the biggest costumer in many of these product markets. An illustration of this is that sales to the U.S. government represent approximately 70% of the revenue for the Department of Defense's largest contractor, Lockheed Martin Corporation. This is reinforced by a second fact: the dynamic incentives introduced by the repeated nature of the procurement process. In this context, contractors would find it optimal to consider not only the profits accruing from their current portfolio of contracts, but also the expected future contracts that they may obtain from the government. To the extent that reputation is an important factor in this repeated game, contractors thinking of increasing prices will trade off a short-term profit opportunity against a potentially lower stream of future profits coming from new contracts. This mechanism is particularly salient when it comes to the programs we analyze in the second part of our analysis: high-profile major acquisition programs that receive constant public scrutiny and that have higher reporting requirements. Large cost

overruns can cause not only the cancellation of a current program, but the inability of a given contractor to win future equivalent contracts.

Open questions and future research

Some combination of all of these forces can explain our null result of consolidation on procurement costs. And while we favor the explanation that the federal government's substantial buying power explains the inability to exert market power on the contractor's side, we think that more research is needed to obtain a definitive answer. A fruitful avenue for future studies would consist of developing theoretical models tailored to the institutional particularities of public procurement: a buyer with significant market power, with various institutional constraints that interacts with sellers from imperfectly competitive industries. This would not only back some of the qualitative explanations that we have provided here, but would likely generate additional testable implications. These could be taken to the data and could also illuminate a way to distinguish between the different mechanisms that we have proposed here. An important challenge to overcome is to obtain new and more detailed sources of data that can provide a more comprehensive analysis of procurement costs above and beyond major acquisition programs.

VII. CONCLUSION

In this paper we show that rising concentration in the US defense industry during the 1990s made the procurement process less competitive and changed the contractual form away from fixed-price contracts and towards cost-plus contracts. Despite these findings, we find no evidence that this led to an increase in the federal government's procurement costs. We hypothesize that the government's buyer power, particularly relevant in this context, prevented firms from exercising any market power gained by consolidating.

While understanding the effects of this 1990s merger wave is of interest in and of itself, we think that this study has practical implications for current policy discussions. One of the motivating facts we started our analysis with was that the share of contract dollars awarded to the five largest DoD contractors rose from 21.7 percent in 1990 to 31.3 percent in 2000 (Table 1A and Table 1B). In more recent years, the concentration of spending among top contractors has experienced a very similar trend, from 23.8 percent in 2010 to 30.2 percent in 2016. On the other hand, merger and acquisition activity in the defense industry is on the rise again, with several recent announcements of major deals between

large contractors.[25] In the near future, defense and antitrust authorities may be facing once again similar decisions to those made 20 years ago. This will happen in a context were public funds spent on this market will likely achieve an all-time high, as defense budgets are expected to continue to expand in future years. We believe that this paper can shed light on the tradeoffs involved in these difficult policy decisions that are on the horizon.

[25] According to a recent article in the Washington Post, these M&A operations are *"still subject to review by Pentagon officials, who are closely watching the defense industry as it undergoes a wave of consolidation"* https://www.washingtonpost.com/news/business/wp/2017/10/05/boeing-takes-another-step-into-the-pilotless-plane-market/?utm_term=.e4e768abbbd6

REFERENCES

Allen, J., Robert Clark, and Jean-François Houde. "The Effect of Mergers in Search Markets: Evidence from the Canadian Mortgage Industry." *American Economic Review* 104, no. 10 (2014): 3365-3396.

Ashenfelter, Orley, Daniel Hosken, and Matthew Weinberg. "Efficiencies brewed: pricing and consolidation in the US beer industry. " *The RAND Journal of Economics* 46, no. 2 (2015): 328–361.

Ashenfelter, Orley, and Daniel Hosken. "The Effect of Mergers on Consumer Prices: Evidence from Five Mergers on the Enforcement Margin." *The Journal of Law & Economics* 53, no. 3 (2010): 417-66.

Autor, David, David Dorn, Lawrence Katz, Christina Patterson, and John Van Reenen. "The Fall of the Labor Share and the Rise of Superstar Firms." NBER Working Paper No. 23396, (2017).

Azar, Jose, Ioana Marinescu, and Marshall Steinbaum. "Labor Market Concentration." NBER Working Paper No. 24147, (2017).

Bajari, Patrick, Robert McMillan, and Steven Tadelis. "Auctions Versus Negotiations in Procurement: An Empirical Analysis." *Journal of Law, Economics, and Organization* 25, no. 2 (2009): 372-399.

Bajari, Patrick, Steven Tadelis. "Incentives versus Transaction Costs: A Theory of Procurement Contracts." *The RAND Journal of Economics* 32, no. 3 (2001), pp. 387–407.

Bandiera, Oriana, Andrea Prat, and Tommaso Valletti. "Active and Passive Waste in Government Spending: Evidence from a Policy Experiment." *American Economic Review* 99, no. 4 (2009): 1278-1308.

Best, Michael, Jonas Hjort, and David Szakonyi. "Individuals and Organizations as Sources of State Effectiveness, and Consequences for Policy." NBER Working Paper No. 23350, (2017).

Bhattacharya, Vivek. "An Empirical Model of R&D Procurement Contests: An Analysis of the DOD SBIR Program." *Mimeo, Northwestern University,* (2018).

Borenstein, Severin. "Hubs and High Fares: Dominance and Market Power in the U.S. Airline Industry." *The RAND Journal of Economics* 20, no. 3 (1989): 344-65.

Borenstein, Severin. "Airline Mergers, Airport Dominance, and Market Power." *The American Economic Review* 80, no. 2 (1990): 400-04.

Bresnahan, Timothy, and Peter Reiss. "Entry and Competition in Concentrated Markets." *Journal of Political Economy* 99, no. 5 (1991): 977-1009.

Corts, Kenneth, and Jasjit Singh. "The Effect of Repeated Interaction on Contract Choice: Evidence from Offshore Drilling." *The Journal of Law, Economics, and Organization* 20, no. 1 (2004): 230–260.

Coviello, Decio, and Stefano Gagliarducci. "Tenure in Office and Public Procurement." *American Economic Journal: Economic Policy* 9, no. 3 (2017): 59-105.

Coviello, Decio, Andrea Guglielmo, and Giancarlo Spagnolo. "The Effect of Discretion on Procurement Performance." *Management Science* 64, no. 2 (2018): 715-738.

Dafny, Leemore, Mark Duggan, and Subramaniam Ramanarayanan. "Paying a Premium on Your Premium? Consolidation in the US Health Insurance Industry." *The American Economic Review* 102, no. 2 (2012): 1161-185.

Draca, Mirko. "Reagan's Innovation Dividend? Technological Impacts of the 1980s US Defense Build-Up." *Mimeo, University of Warwick,* (2012).

De Loecker, Jan, and Jan Eeckhout. "The Rise of Market Power and the Macroeconomic Implications." NBER Working Paper No. 23687, (2017).

Focarelli, Dario, and Fabio Panetta. "Are Mergers Beneficial to Consumers? Evidence from the Market for Bank Deposits." *The American Economic Review* 93, no. 4 (2003): 1152-172.

Hensel, Nayantara. "Can Industry Consolidation Lead to Greater Efficiencies? Evidence from the U.S. Defense Industry." *Business Economics* 45, no. 3 (2010): 187-203.

Goldberg, V. "Competitive Bidding and the Production of Precontract Information. " *Bell Journal of Economics* 8, no. 1 (1977): 250–261.

Guthrie, Susan, and James Hines. "U.S. Defense Contracts during the Tax Expenditure Battles of the 1980s," *National Tax Journal* 64, no. 2 (2011): 731-751.

Hosken, Daniel, Louis Silvia, and Christopher Taylor. "Does Concentration Matter? Measurement of Petroleum Merger Price Effects." *The American Economic Review* 101, no. 3 (2011): 45-50.

Kalnins, Arturs, and Kyle Mayer. "Relationships and Hybrid Contracts: An Analysis of Contract Choice in Information Technology." *Journal of Law, Economics, and Organization* 20, no. 1 (2004): 207–229.

Lewis-Faupel, Sean, Yusuf Neggers, Benjamin Olken, and Rohini Pande. "Can Electronic Procurement Improve Infrastructure Provision? Evidence from Public Works in India and Indonesia." *American Economic Journal: Economic Policy* 8, no. 3 (2016): 258-83.

Lichtenberg, Frank. "Economics of defense R&D," in: Keith Hartley & Todd Sandler (ed.), Handbook of Defense Economics, edition 1, volume 1 (1995): chapter 15, pages 431-457 Elsevier.

Lichtenberg, Frank. "The Private R&D Investment Response to Federal Design and Technical Competitions," *The American Economic Review* 78, no. 3 (1988): 550-559.

Nakamura, Emi, and Jón Steinsson. "Fiscal Stimulus in a Monetary Union: Evidence from US Regions." *American Economic Review* 104, no. 3 (2014): 753-92.

Rogerson, William. "Economic Incentives and the Defense Procurement Process." *Journal of Economic Perspectives* 8, no. 4 (1994): 65-90.

Warren, Patrick. "Contracting officer workload, incomplete contracting, and contractual terms." *The RAND Journal of Economics* 45, no. 2 (2014): 395–421.

Whinston, Michael. "Antitrust Policy Towards Horizontal Mergers," in: Mark Armstrong and Robert Porter (ed.), Handbook of Industrial Organization, vol. 3 (2007): 2369-2440, Elsevier.

Williamson, Oliver. "Economies as an Antitrust Defense: The Welfare Tradeoffs." *The American Economic Review* 58, no. 1 (1968): 18-36.

Table 1A: Top Defense Contractors in FY1990

Rank	Contractor	No. of contract actions	Average dollars (2016$M)	Total dollars (2016B$)	Share of total spending (%)	Share competed (%)	Share fixed-price (%)
1	McDonnell Douglas ∗	2,316	6.0	13.9	6.4	26.3	63.5
2	General Dynamics	2,441	4.2	10.3	4.8	27.6	54.6
3	General Electric	3,114	3.0	9.4	4.3	43.3	63.4
4	Raytheon ♦	1,484	4.6	6.9	3.2	41.2	58.4
5	Lockheed ♠	1,690	3.8	6.5	3.0	45.8	40.2
6	Martin Marietta ♠	904	6.5	5.9	2.7	56.4	59.6
7	Hughes Aircraft ♦	1,457	3.9	5.6	2.6	45.2	52.6
8	United Technologies	2,486	1.9	4.8	2.2	24.8	78.6
9	Grumman ♣	1,326	3.4	4.6	2.1	24.4	78.6
10	Newport News Shipbuilding	366	10.9	4.0	1.8	39.9	66.9
11	Boeing ∗	2,013	2.0	4.0	1.8	39.7	52.2
12	Westinghouse Electric	1,171	3.2	3.8	1.8	49.7	62.5
13	Rockwell International	1,780	2.1	3.7	1.7	38.3	69.9
14	Honeywell International	3,802	0.9	3.5	1.6	47.1	69.8
15	Litton Industries	1,210	2.2	2.6	1.2	44.9	78.5
16	Northrop ♣	1,540	1.6	2.4	1.1	47.2	49.9
17	Unisys	3,564	0.7	2.3	1.1	83.7	87.5
18	GTE Government Systems	631	3.4	2.2	1.0	56.1	74.8
19	IBM	1,065	2.0	2.1	1.0	65.4	76.9
20	Textron	1,075	1.9	2.0	0.9	27.8	76.3
	All contractors	232,843	0.9	217.1	100	70.5	76.3
	Top 5 contractors	11,045	4.3	47.0	21.7	36.4	57.3

Note: This table lists the 20 defense contractors with most contract dollars awarded in FY1990. The first column corresponds to the number of contract actions. The second column is the average dollars obligated by their contract actions. The third column presents the sum of all dollars obligated by their contract actions. The fourth column presents the same as the third column, but as a share of total contract spending in FY1990. The fifth and sixth column indicate the share of contract actions awarded to each contractor that were part of competitively solicited and fixed-price contracts, respectively. The symbols ∗, ♣, ♦, and ♠ indicate that the contractor was involved in one of the mergers of Table 2. Two contractors with the same symbol merge with each other.

Table 1B: Top Defense Contractors in F2000

Rank	Contractor	No. of contract actions	Average dollars (2016$M)	Total dollars (2016B$)	Share of total spending (%)	Share competed (%)	Share fixed-price (%)
1	Lockheed Martin ♠	6,011	3.6	21.9	11.4	51.8	40.6
2	Boeing ∗	3,952	4.6	18.0	9.4	31.7	53.7
3	Raytheon ♦	5,342	1.8	9.6	5.0	49.5	46.5
4	General Dynamics	3,163	1.9	6.0	3.2	65.0	63.9
5	Northrop Grumman ♣	4,182	1.1	4.4	2.3	61.8	42.8
6	Litton Industries	2,931	1.3	3.9	2.0	76.3	49.3
7	United Technologies	2,216	1.4	3.0	1.6	25.1	90.7
8	TRW	1,527	1.9	2.9	1.5	78.1	32.5
9	General Electric	1,975	1.2	2.4	1.2	32.8	90.0
10	Science Applications Intl.	3,402	0.6	2.2	1.1	94.9	17.1
11	United Defense Industries	904	1.9	1.7	0.9	62.1	23.1
12	Textron	596	2.8	1.7	0.9	25.5	81.5
13	Computer Sciences	1,921	0.9	1.7	0.9	97.3	26.8
14	GEC	1,581	0.9	1.4	0.7	67.7	43.2
15	Honeywell International	2,274	0.6	1.4	0.7	39.3	81.8
16	EDO	1,255	1.0	1.3	0.7	72.5	47.5
17	Dyncorp International	792	1.4	1.1	0.6	98.6	21.5
18	Newport News Shipbuilding	486	2.1	1.0	0.5	14.6	31.5
19	Bechtel	157	6.3	1.0	0.5	95.5	-
20	Canadian Commercial	475	2.0	0.9	0.5	55.2	91.6
	All contractors	308,371	0.6	191.1	100	77.4	68.5
	Top 5 contractors	22,650	2.6	59.9	31.3	51.4	47.9

Note: This table lists the 20 defense contractors with most contract dollars awarded in FY1990. The first column corresponds to the number of contract actions. The second column is the average dollars obligated by their contract actions. The third column presents the sum of all dollars obligated by their contract actions. The fourth column presents the same as the third column, but as a share of total contract spending in FY1990. The fifth and sixth column indicate the share of contract actions awarded to each contractor that were part of competitively solicited and fixed-price contracts, respectively. The symbols ∗, ♣, ♦, and ♠ indicate that the contractor was involved in one of the mergers of Table 2. Two contractors with the same symbol merge with each other.

Table 2: Major mergers among DoD contractors

Merging contractors	Year of announcement (t^*)	Approved by DoJ?
Northrop – Grumman	1993	Yes
Lockheed – Martin Marietta	1995	Yes
Boeing – McDonnell Douglas	1997	Yes
Raytheon – Texas Instruments – Hughes Aircraft	1997	Yes
Northrop Grumman – Lockheed Martin	1998	No

Note: This table lists the largest merger deals between defense contractors during the decade of 1990. The first four mergers were approved by the authority and materialized. The last listed merger was challenged by the Department of Justice, and was later abandoned by the firms.

Table 3: Top product categories

Rank	Goods	Average spending, 1985-2001 (2016B$)
1	Aircraft and Airframe Structural Components	23.16
2	Communications, Detection and Coherent Radiation	11.70
3	Guided Missiles	11.10
4	Ships, Small Craft, Pontoons, and Floating Docks	8.41
5	Fuels, Lubricants, Oils, and Waxes	8.09
6	Engines, Turbines, and Components	7.20
7	Ground Vehicles, Motor Vehicles, Trailers, Cycles	4.10
8	ADP Equipment Software, Supplies, Equipment	4.03
9	Ammunitions and Explosives	3.99
10	Aircraft Components and Accessories	3.75

Rank	Services	Average spending, 1985-2001 (2016B$)
1	Research and Development	35.27
2	Professional, Administrative and Management Support	13.21
3	Maintenance, Repair, and Rebuilding of Equipment	9.92
4	Construction of Structures and Facilities	9.42
5	Maintenance, Repair or Alteration of Real Property	7.59
6	Utilities and Housekeeping Services	5.56
7	Automatic Data Processing and Telecommunication	4.95
8	Operation of Government Owned Facilities	4.49
9	Transportation, Travel and Relocation	3.69
10	Architect and Engineering - Construction	2.94

Notes: This table lists the top product categories in terms of their average contract awards in the 1985-2001 period. We present separate lists for goods (top panel) and services (bottom panel). The data source is the Defense Contract Action Data System. Numbers are obtained by adding the dollars obligated by individual contract actions at the product category by fiscal year level, and then by averaging over years. Product categories are defined by the Federal Supply Classification (FSC), aggregated at the two-digit for goods, and at the one-digit (letter) for services.

Table 4: Summary statistics of the two data sources

Panel A: Defense Contract Action Data System

	Mean (raw)	Mean (weighted)	s.d.	p10	p50	p90
Dollars obligated (2016K$)	830.2	-	14,109.4	41.9	113.3	890.5
Competed (0,1)	0.71	0.54	0.45	0	1	1
Competed or follow-on (0,1)	0.74	0.65	0.44	0	1	1
One offer received (0,1)	0.34	0.36	0.47	0	0	1
Fixed-price (0,1)	0.78	0.68	0.42	0	1	1
No. of observations (contract actions)	4,329,311					
Sample years	1985-2001					

Panel B: Selected Acquisition Reports

	Mean	s.d.	p10	p50	p90
Program-level variables					
Baseline Cost (2016 $M)	10,782	15,451	1,348	4,913	28,801
Number of years	6.5	3	3	6	10
Number of programs	194				
Program-year level variables					
Current Cost (2016 $M)	14,048	18,727	1,900	6,794	42,576
Cumulative Cost Growth (2016 $M)	933	5,693	-1,115	319	4,244
Annual Cost Growth (2016 $M)	165	2,118	-487	18	924
Cumulative Cost Growth (%)	16.8	43.1	-14.5	6.7	58.9
Annual Cost Growth (%)	2.5	22.6	-6.6	0.3	12.4
No. of observations (program-year)	1,267				
Sample years	1985-2001				

Notes: Panel A presents summary statistics from the Defense Contract Action Data System dataset, for fiscal years 1985 through 2001. An observation in this dataset is a contract action. Raw means are taken over individual contract actions, while weighted means weight each action by the obligated dollar amount.
Panel B presents summary statistics from the selected acquisition reports summary tables, for all programs active for at least three consecutive years between 1985 and 2001.
Abbreviations: "s.d." = standard deviation; "p10", "p50", "p90" = 10^{th}, 50^{th} and 90^{th} percentile, respectively.

Table 5: Summary statistics of analysis samples

Panel A: product market analysis	Mean (raw)	Mean (weighted)	s.d.	p10	p50	p90
Total dollars ($M)	1967.0	-	4682.9	12.4	225.5	5487.4
HHI (0 - 10,000)	1318.8	671.1	1499.7	292.1	793.4	2963.6
Number of firms	333.5	990.3	523.1	29.0	156.0	893.0
Number of firms (>1% market share)	16.2	17.1	6.3	7.0	17.0	23.0
Number of actions	2006.0	6,711.7	3876.7	69.0	573.0	5927.0
Average action dollars ($K)	988.2	902.6	1534.1	123.6	384.5	2691.1
Median action dollars ($K)	124.6	121.9	113.5	69.4	99.8	188.8
Share of competed actions (%)	61.6	57.3	27.3	23.0	64.3	95.3
Share of competed or follow-on (%)	4.7	5.4	10.5	0.0	0.4	14.5
Share of fixed price contract actions (%)	86.9	84.8	23.2	49.4	98.8	100.0
Share of single-offer contract actions (%)	43.1	45.9	26.9	7.0	43.1	79.4
Number of observations (market-years)		1,649				
Number of markets		97				
Sample years		1985-2001				

Panel B: major acquisition program analysis	All programs	Treated	Control
Current Cost (2016 $M)	14,048	15,231	12,331
Cumulative Cost Growth (2016 $M)	933	857	1,043
Annual Cost Growth (2016 $M)	165	218	90
Cumulative Cost Growth (%)	16.8	19.7	12.7
Annual Cost Growth (%)	2.5	3.0	1.9
Northrop-Grumman (%)	8.2	13.9	0
Lockheed-Martin (%)	18.9	31.9	0
Boeing-McDonnell Douglas (%)	22.9	38.7	0
Raytheon-Texas Instrument-Hughes Aircraft (%)	14.4	24.3	0
Number of observations (program-year)	1,267	750	517
Number of programs	194	118	76
Only pre-merger	-	65	-
Only post-merger	-	23	-
Pre- and post-merger	-	30	-

Notes: Panel A presents summary statistics of our market level analysis sample. The data source is the Defense Contract Action Data System. Observations are generated by aggregating individual contract actions at the product category level (market) by fiscal year. This generates a balanced panel of 97 markets over 17 fiscal years. Product categories are defined by the Federal Supply Classification (FSC), aggregated to two digits for goods, and to one digit (letter) for services. Raw means are taken by weighting each observation equally. Weighted means weight observations according to the market's average number of contracts in FY1980-FY1984. Abbreviations: "s.d." = standard deviation; "p10", "p50", "p90" = 10^{th}, 50^{th} and 90^{th} percentile, respectively.

Panel B presents summary statistics of our major acquisition programs analysis sample. The data source is the Selected Acquisition Reports (SAR) summary tables. An observation is a program-year, and the sample includes all programs that were active for at least three consecutive years between 1985 and 2001, leaving an unbalanced panel of 194 programs. A program is "Treated" if its prime contractor is listed on Table 2 and is "Control" otherwise. In the lower part of the table, we show the number of treated programs that were active only before the merger date of their contractor (only pre-merger), those active only on or after the merger (only post-merger), and those with at least one observation prior and one observation on or after the merger (pre- and post-merger). The merger dates are referred to as t^* in Table 2.

Table 6: First stage regressions

DV: HHI_{it}	(1)	(2)	(3)	(4)	(5)	(6)
$simΔHHI_{it}^{NG}$	8.7324***					
	(1.5339)					
$simΔHHI_{it}^{LM}$	1.7937***					
	(0.4301)					
$simΔHHI_{it}^{BM}$	0.0203					
	(0.8463)					
$simΔHHI_{it}^{RTH}$	0.8350***					
	(0.2563)					
$simΔHHI_{it}^{LMNG}$	-0.7070*	-1.7334***				
	(0.4200)	(0.4416)				
$simΔHHI_{it}$		1.2543***	1.1241***	1.0217**	1.5063***	1.5850***
		(0.3621)	(0.4081)	(0.4991)	(0.4941)	(0.5323)
Weighting?	Yes	Yes	Yes	Yes	No	No
Category group by year FE?	No	No	No	Yes	No	Yes
$simΔHHI_{it}$ includes placebo?	-	Yes	No	No	No	No
Observations	1,649	1,649	1,649	1,649	1,649	1,649
R^2	0.6754	0.6676	0.6674	0.6721	0.5799	0.5841
Mean D.V.	0.0671	0.0671	0.0671	0.0671	0.0671	0.0671

Notes: The data source is the Defense Contract Action Data System. Observations are generated by aggregating individual contract actions at the product category level (market) by fiscal year. This generates a balanced panel of 97 markets over 17 fiscal years. Product categories are defined by the Federal Supply Classification (FSC), aggregated to two digits for goods, and to one digit (letter) for services. Monetary variables are measured in constant 2016 dollars. The dependent variable in all specifications is the Herfindahl-Hirschman index (HHI), scaled between 0 and 1. The simulated change in HHI is the expected change in HHI associated with a merger, based on pre-merger market shares an assuming everything else constant. In all columns except for column (2), $simΔHHI_{it}$ is defined as the sum of the simulated change in HHI associated with the first four mergers listed in Table 2. In column (2), $simΔHHI_{it}$ is defined by also adding the simulated change in HHI associated with the placebo merger of Lockheed Martin and Northrop Grumman. In columns (1) through (4), observations are weighted according to the market's average number of contracts in FY1980-FY1984. All specifications include a set of market and fiscal year fixed-effects. In columns (4) and (6), we also include a separate set of fiscal year fixed-effects for goods, services, and R&D (we refer to these as category groups).

Table 7: The effect of concentration on procurement competition

DV: Share of dollars awarded without competition or in single-offer contracts

	OLS	RF	RF	RF	RF	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHI_{it}	0.2701					3.7734**	4.4955**
	(0.1700)					(1.5870)	(2.2618)
$simΔHHI_{it}$		4.2415***	4.5930***	4.4938***	4.8887***		
		(0.6998)	(0.5709)	(0.7101)	(0.5241)		
$simΔHHI_{it}^{LMNG}$				-5.4213***	-6.1599***		
				(1.3555)	(1.3176)		
Category group by year FE?	No	No	Yes	No	Yes	No	Yes
$simΔHHI_{it}$ includes placebo?	No	No	No	Yes	Yes	No	No
Observations	1,649	1,649	1,649	1,649	1,649	1,649	1,649
R^2	0.7912	0.8030	0.8216	0.8031	0.8218	-	-
Mean D.V.	0.421	0.421	0.421	0.421	0.421	0.421	0.421

Notes: The data source is the Defense Contract Action Data System. Observations are generated by aggregating individual contract actions at the product category level (market) by fiscal year. This generates a balanced panel of 97 markets over 17 fiscal years. Product categories are defined by the Federal Supply Classification (FSC), aggregated to two digits for goods, and to one digit (letter) for services. Monetary variables are measured in constant 2016 dollars. The dependent variable in all specifications is the share of dollars in a given market-year that was awarded either without competitive procedures or with competitive procedures where a single offer was received. The simulated change in HHI is the expected change in HHI associated with a merger, based on pre-merger market shares an assuming everything else constant. In all columns except for columns (4) and (5), $simΔHHI_{it}$ is defined as the sum of the simulated change in HHI associated with the first four mergers listed in Table 2. In columns (4) and (5), $simΔHHI_{it}$ is defined by also adding the simulated change in HHI associated with the placebo merger of Lockheed Martin and Northrop Grumman. In all columns, observations are weighted according to the market's average number of contracts in FY1980-FY1984. All specifications include a set of market and fiscal year fixed-effects. In columns (3), (5) and (7), we also include a separate set of fiscal year fixed-effects for products, services, and R&D (we refer to these as category groups).

Table 8: The effect of concentration on contractual form

DV: Share of dollars awarded through fixed-price contracts

	OLS	RF	RF	RF	RF	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHI_{it}	-0.2830***					-2.7602**	-2.0214
	(0.0618)					(1.3798)	(1.2718)
$simΔHHI_{it}$		-3.1026**	-2.0652**	-2.7730**	-1.8405**		
		(1.2700)	(0.8538)	(1.3301)	(0.8425)		
$simΔHHI_{it}^{LMNG}$				1.5613	0.8748		
				(2.1678)	(1.7576)		
Category group by year FE?	No	No	Yes	No	Yes	No	Yes
$simΔHHI_{it}$ includes placebo?	No	No	No	Yes	Yes	No	No
Observations	1,649	1,649	1,649	1,649	1,649	1,649	1,649
R^2	0.9340	0.9373	0.9451	0.9375	0.9452	-	-
Mean D.V.	0.848	0.848	0.848	0.848	0.848	0.848	0.848

Notes: The data source is the Defense Contract Action Data System. Observations are generated by aggregating individual contract actions at the product category level (market) by fiscal year. This generates a balanced panel of 97 markets over 17 fiscal years. Product categories are defined by the Federal Supply Classification (FSC), aggregated to two digits for goods, and to one digit (letter) for services. Monetary variables are measured in constant 2016 dollars. The dependent variable in all specifications is the share of dollars in a given market-year that was awarded via fixed-price contracts (as opposed to cost-plus contracts). The simulated change in HHI is the expected change in HHI associated with a merger, based on pre-merger market shares an assuming everything else constant. In all columns except for columns (4) and (5), $simΔHHI_{it}$ is defined as the sum of the simulated change in HHI associated with the first four mergers listed in Table 2. In columns (4) and (5), $simΔHHI_{it}$ is defined by also adding the simulated change in HHI associated with the placebo merger of Lockheed Martin and Northrop Grumman. In all columns, observations are weighted according to the market's average number of contracts in FY1980-FY1984. All specifications include a set of market and fiscal year fixed-effects. In columns (3), (5) and (7), we also include a separate set of fiscal year fixed-effects for products, services, and R&D (we refer to these as category groups).

Table 9: The effect of concentration on contract spending

DV: Log of market-level contract spending

	OLS	RF	RF	RF	RF	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHI_{it}	2.0012***					-5.7704*	-6.1170
	(0.4524)					(3.0355)	(3.8030)
$simΔHHI_{it}$		-6.4862**	-6.2498**	-5.5751*	-6.0449**		
		(2.8467)	(2.9763)	(3.2919)	(2.9620)		
$simΔHHI_{it}^{LMNG}$				2.2252	5.1641		
				(6.5460)	(7.4815)		
Category group by year FE?	No	No	Yes	No	Yes	No	Yes
$simΔHHI_{it}$ includes placebo?	No	No	No	Yes	Yes	No	No
Observations	1,649	1,649	1,649	1,649	1,649	1,649	1,649
R^2	0.9699	0.9675	0.9729	0.9676	0.9729	-	-
Mean D.V.	21.29	21.29	21.29	21.29	21.29	21.29	21.29

Notes: The data source is the Defense Contract Action Data System. Observations are generated by aggregating individual contract actions at the product category level (market) by fiscal year. This generates a balanced panel of 97 markets over 17 fiscal years. Product categories are defined by the Federal Supply Classification (FSC), aggregated to two digits for goods, and to one digit (letter) for services. Monetary variables are measured in constant 2016 dollars. The dependent variable in all specifications is the natural logarithm of market-level contract spending (the sum of all dollar obligations in a given market-year). The simulated change in HHI is the expected change in HHI associated with a merger, based on pre-merger market shares an assuming everything else constant. In all columns except for columns (4) and (5), $simΔHHI_{it}$ is defined as the sum of the simulated change in HHI associated with the first four mergers listed in Table 2. In columns (4) and (5), $simΔHHI_{it}$ is defined by also adding the simulated change in HHI associated with the placebo merger of Lockheed Martin and Northrop Grumman. In all columns, observations are weighted according to the market's average number of contracts in FY1980-FY1984. All specifications include a set of market and fiscal year fixed-effects. In columns (3), (5) and (7), we also include a separate set of fiscal year fixed-effects for products, services, and R&D (we refer to these as category groups).

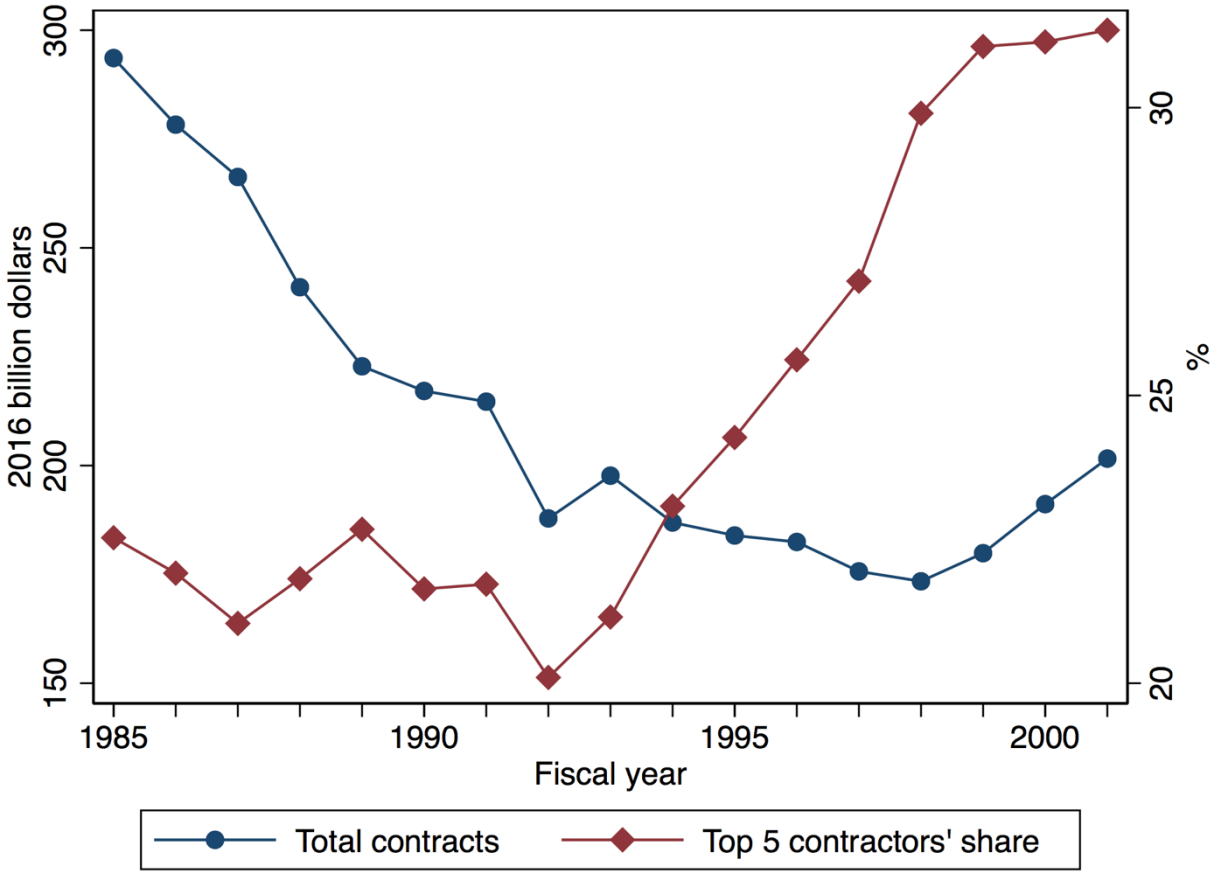
Table 10: The effect of consolidation on procurement costs of major acquisition programs

	Panel A: DV is $logCost_{it}$				
	(1)	(2)	(3)	(4)	(5)
Merged_{it}	0.3384	0.3511	0.3460	0.0099	0.0164
	(0.2331)	(0.2350)	(0.2363)	(0.0549)	(0.0562)
Age_{it}		0.0081	0.0174		
		(0.0133)	(0.0299)		
Age_{it}^2			-0.0005		
			(0.0015)		
	Panel B: DV is $Annual\ Cost\ Growth_{it}$				
	(1)	(2)	(3)	(4)	(5)
Merged_{it}	-2.3318	-2.6630	-2.6442	-1.9504	-2.3620
	(2.7913)	(2.8360)	(2.8483)	(1.9904)	(2.1867)
Age_{it}		-0.2204*	-0.2587		
		(0.1253)	(0.3196)		
Age_{it}^2			0.0019		
			(0.0138)		
	Panel C: DV is $\mathbf{1}(Annual\ Cost\ Growth_{it} > 10\%)$				
	(1)	(2)	(3)	(4)	(5)
Merged_{it}	-0.0112	-0.0223	-0.0190	-0.1225	-0.1064
	(0.0369)	(0.0364)	(0.0367)	(0.0773)	(0.0776)
Age_{it}		-0.0074***	-0.0141*		
		(0.0023)	(0.0076)		
Age_{it}^2			0.0003		
			(0.0004)		
Branch FE	Yes	Yes	Yes	No	No
Age FE	No	No	No	No	Yes
Program FE	No	No	No	Yes	Yes

Notes: The data source is the Selected Acquisition Reports summary tables. An observation is an acquisition program by fiscal year. The sample is an unbalanced panel of 194 programs over the period FY1986-FY2001. Since annual cost growth is a variable computed as a first-difference, regressions in panel B and C have less observations relative to Panel A (one less per program). Number of observations: Panel A = 1,267; Panel B = 1,071; Panel C = 1,071. Mean of dependent variable: Panel A = 21.94; Panel B = 2.53; Panel C = 0.14. $Merged_{it}$ is an indicator that takes the value of 1 if the prime contractor of the program was involved in one of the authorized mergers in Table 2, *and* if the current year is on or after the merger date. All specifications include fiscal year fixed-effects. The age of a program is defined as the difference between the current year and the base year of the program. Branch FE refers to the inclusion of dummies that identify whether the program depends on the Department of the Army, the Department of the Navy, the Department of the Air Force, or other DoD agency.

FIGURES

Figure 1: Aggregate contract spending and concentration



Notes: The data source is the Defense Contract Action Data System. "Total contracts" means the sum of all contract dollars obligated in a given fiscal year. "Top 5 contractor's share" is calculated as the sum of contract dollars awarded to the five contractors with most dollars awarded, divided by "Total contracts" in that year. Total contracts are presented in 2016 constant dollars (left axis), and Top 5 contractor's share are presented in percentage points (right axis).

Figure 2a: Change in market-level HHI (unweighted)

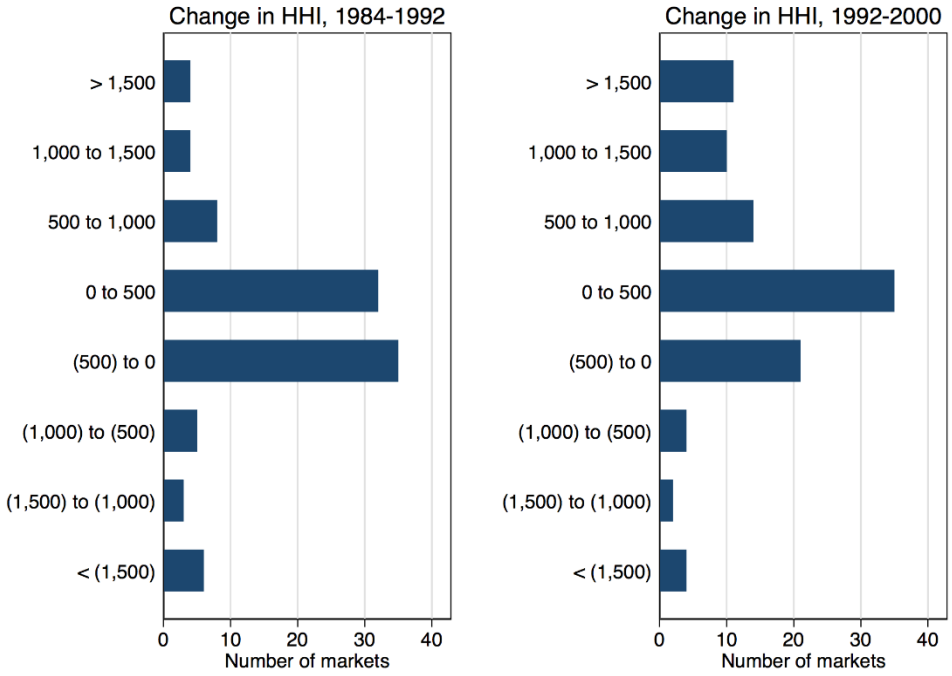
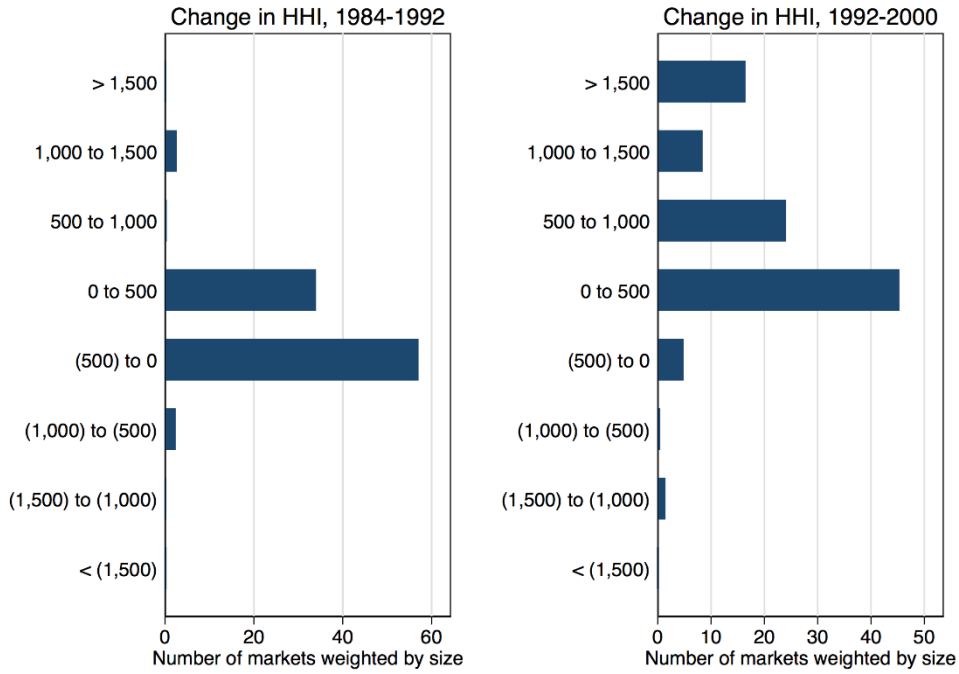
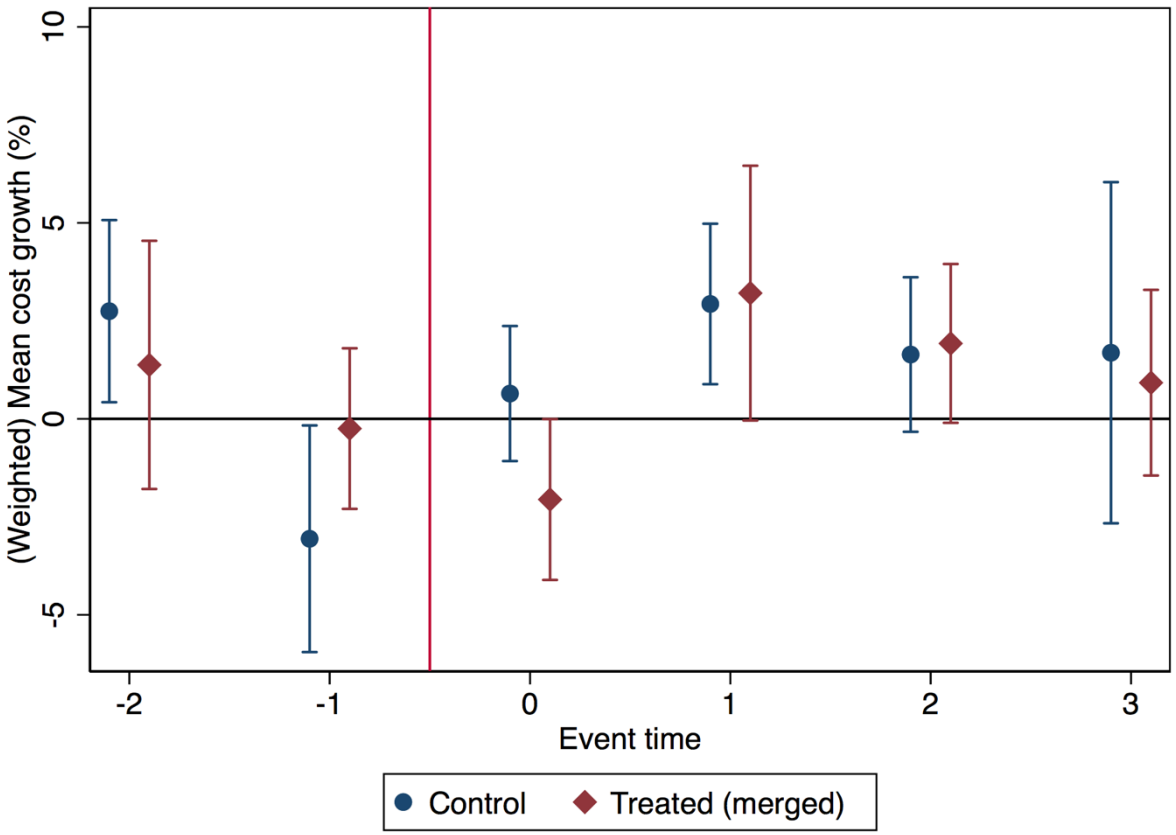


Figure 2b: Change in market-level HHI (weighted)



Notes: The data source is the Defense Contract Action Data System. Observations for this figure are obtained by aggregating individual contract actions at the product category level (market) in selected fiscal years. Product categories are defined by the Federal Supply Classification (FSC), aggregated to two digits for goods, and to one digit (letter) for services. For each market, we compute the change in the Herfindahl-Hirschman index (measured between 0 and 10,000) between 1984 and 1992, and between 1992 and 2000. In Figure 2b, the distributions are weighted using each market's average number of contracts in FY1980-FY1984.

Figure 3: Event study analysis of program cost growth



Notes: The data source is the Selected Acquisition Reports summary tables. The unit of observation is an acquisition program by fiscal year. This figure depicts weighted averages of annual cost growth for each date in "event time", and separately for "merged" and "not merged" programs. We weight each program by their estimated baseline cost. Treated programs are defined as those that have a prime contractor participating in one of the approved mergers in Table 2. The rest are defined as control programs. Event time is calendar years relative to the merger date of a given program (t^* in Table 2). We select treated programs that were observed for at least one year before *and* one year after the merger. Then, we construct a sample of control programs by restricting them to have been active between the same years as the merged sample. Finally, we assign placebo merger dates for control programs at random, following the same distribution of merger dates among treated programs. We use this placebo merger dates to calculate event time for the control sample.

APPENDIX A: ADDITIONAL TABLES

Table A1: Budget authority and contract awards by agency, FY2016

Department or Major Agency	Budget Authority		Contract Awards		Contracts / Budget (%)
	$M	% of total budget	$M	% of total contracts	
Health and Human Services	1,119,006	28.2	23,860	5.0	2.1
Social Security Administration	982,952	24.7	1,534	0.3	0.2
Defense	**661,896**	**16.7**	**304,900**	**64.2**	**46.1**
Treasury	519,865	13.1	6,147	1.3	1.2
Agriculture	168,801	4.2	6,003	1.3	3.6
Veterans Affairs	163,330	4.1	23,200	4.9	14.2
Office of Personnel Management	93,745	2.4	944	0.2	1.0
Education	76,977	1.9	2,472	0.5	3.2
Transportation	75,727	1.9	7,177	1.5	9.5
Housing and Urban Development	48,843	1.2	1,131	0.2	2.3
Labor	46,991	1.2	1,813	0.4	3.9
Homeland Security	46,021	1.2	14,200	3.0	30.9
Justice	32,114	0.8	7,411	1.6	23.1
State	29,828	0.8	8,894	1.9	29.8
All Others	148,198	3.7	51,934	10.9	35.0
Undistributed Offsetting Receipts	(241,362)	-	-	-	-
Total	**3,972,932**	**100.0**	**474,811**	**100.0**	**12.0**

Notes: Budget authority data obtained from the Office of Management and Budget's (OMB) historical tables (https://www.whitehouse.gov/omb/historical-tables/). Data from contract awards come from www.usaspending.gov. We show the 15 departments or major agencies of the Federal Government with most budget authority in FY2016, and group the remaining in the "All Others" category.

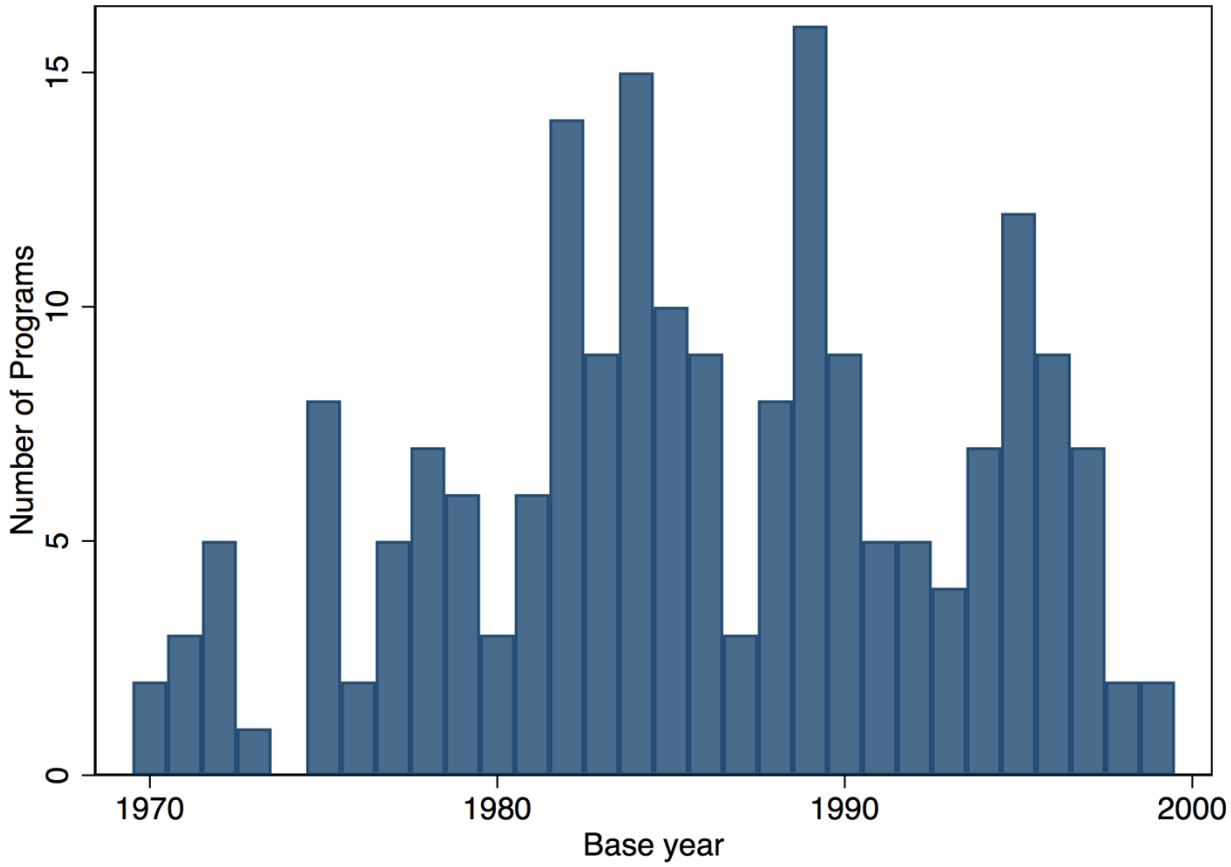
Table A2: The effect of consolidation on procurement costs of major acquisition programs (weighted regressions)

	Panel A: DV is $logCost_{it}$				
	(1)	(2)	(3)	(4)	(5)
Merged_{it}	0.3208	0.3306	0.3254	0.0053	0.0113
	(0.2387)	(0.2404)	(0.2416)	(0.0563)	(0.0574)
Age_{it}		0.0065	0.0158		
		(0.0134)	(0.0301)		
Age_{it}^2			-0.0005		
			(0.0015)		
	Panel B: DV is $Annual\ Cost\ Growth_{it}$				
	(1)	(2)	(3)	(4)	(5)
Merged_{it}	-2.2726	-2.5778	-2.5694	-1.7897	-2.1972
	(2.7077)	(2.7485)	(2.7611)	(1.9374)	(2.1360)
Age_{it}		-0.2124*	-0.2288		
		(0.1235)	(0.3155)		
Age_{it}^2			0.0008		
			(0.0135)		
	Panel C: DV is $\mathbf{1}(Annual\ Cost\ Growth_{it} > 10\%)$				
	(1)	(2)	(3)	(4)	(5)
Merged_{it}	-0.0096	-0.0200	-0.0165	-0.1148	-0.0992
	(0.0364)	(0.0358)	(0.0361)	(0.0758)	(0.0763)
Age_{it}		-0.0072***	-0.0139*		
		(0.0023)	(0.0076)		
Age_{it}^2			0.0003		
			(0.0004)		
Branch FE	Yes	Yes	Yes	No	No
Age FE	No	No	No	No	Yes
Program FE	No	No	No	Yes	Yes

Notes: The data source is the Selected Acquisition Reports summary tables. An observation is an acquisition program by fiscal year. The sample is an unbalanced panel of 194 programs over the period FY1986-FY2001. Since annual cost growth is a variable computed as a first-difference, regressions in panel B and C have less observations relative to Panel A (one less per program). Number of observations: Panel A = 1,267; Panel B = 1,071; Panel C = 1,071. Mean of dependent variable: Panel A = 21.94; Panel B = 2.53; Panel C = 0.14. $Merged_{it}$ is an indicator that takes the value of 1 if the prime contractor of the program was involved in one of the authorized mergers in Table 2, *and* if the current year is on or after the merger date. In all regressions, we weight an observation by the natural logarithm of the program's baseline cost estimate. All specifications include fiscal year fixed-effects. The age of a program is defined as the difference between the current year and the base year of the program. Branch FE refers to the inclusion of dummies that identify whether the program depends on the Department of the Army, the Department of the Navy, the Department of the Air Force, or other DoD agency.

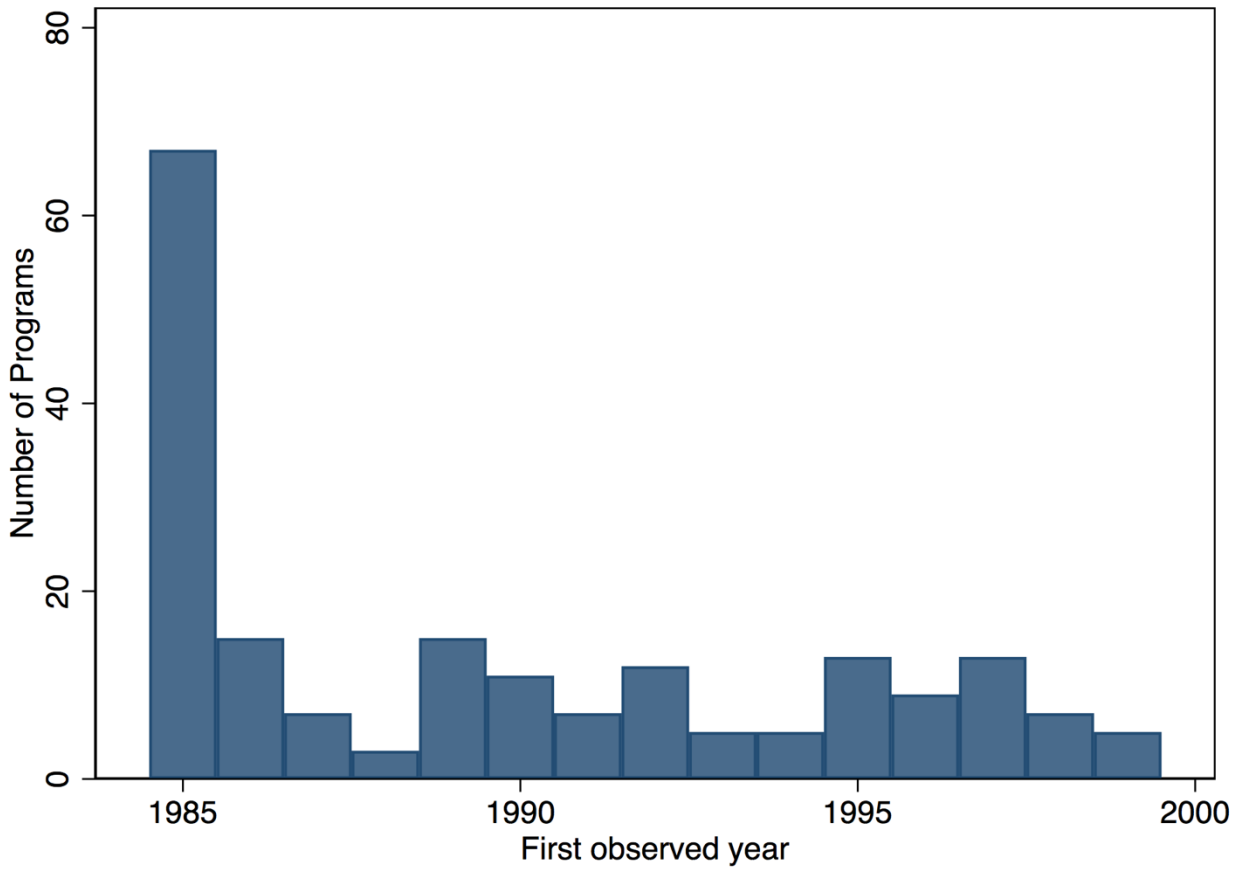
APPENDIX B: ADDITIONAL FIGURES

Figure B1: Distribution of base years of major acquisition programs



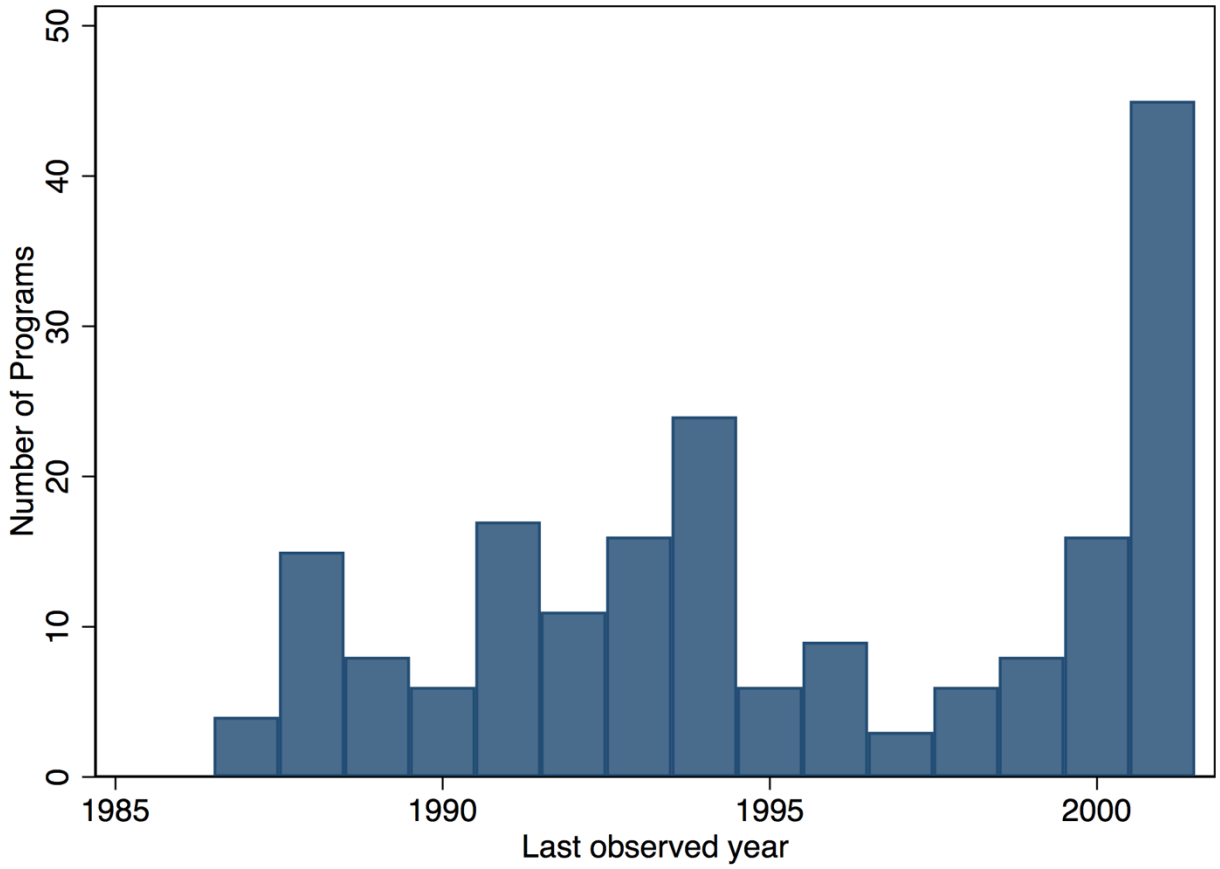
Notes: The data source is the Selected Acquisition Reports summary tables. The analysis sample consists on 194 major acquisition programs that were active for at least three consecutive periods between 1985 and 2001. The figure depicts the distribution of base years of these programs. The base year is typically the year in which the program started, and when baseline cost estimates are computed. Each bar represents the number of programs that have a base year equal to the position in the horizontal axis.

Figure B2: Distribution of first observed years of major acquisition programs



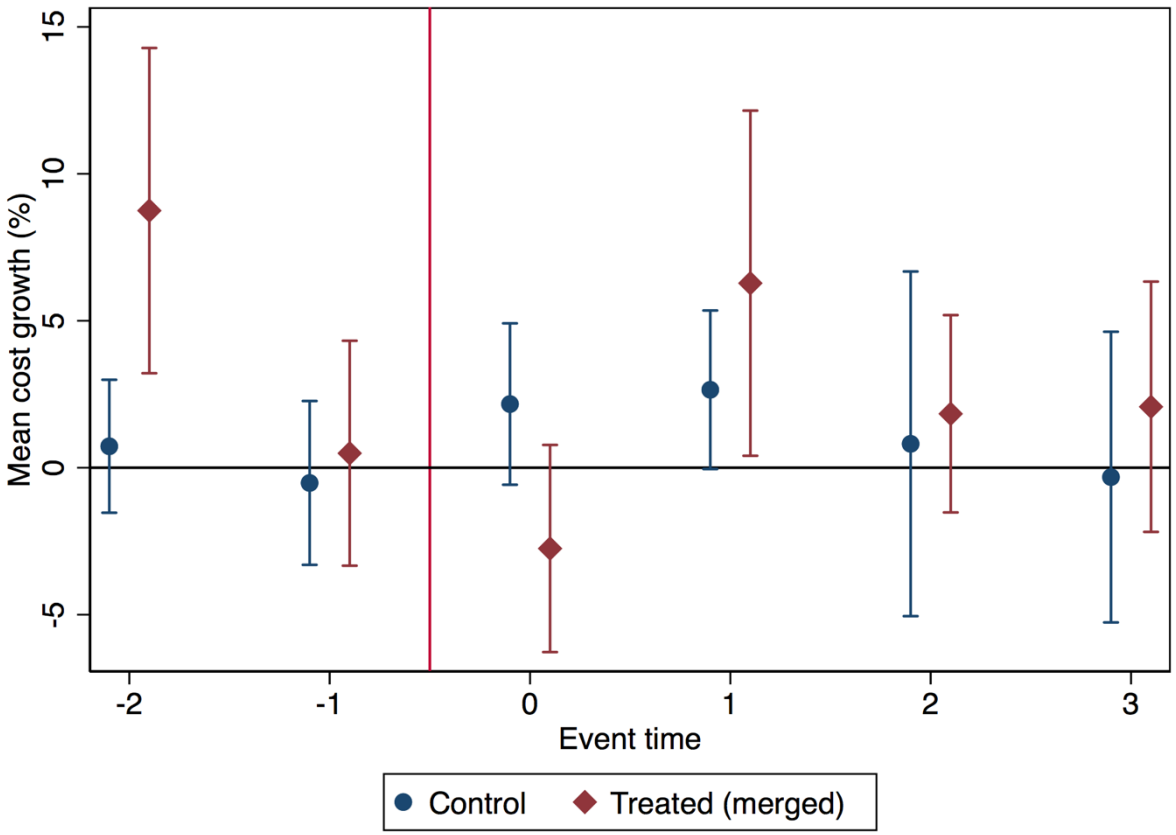
Notes: The data source is the Selected Acquisition Reports summary tables. The analysis sample consists on 194 major acquisition programs that were active for at least three consecutive periods between 1985 and 2001. The figure depicts the distribution of the first observed years of these programs. This variable is truncated at 1985 and 1999 because of our sample definition. Each bar represents the number of programs that we observe for the first time in the year equal to the position in the horizontal axis.

Figure B3: Distribution of last observed years of major acquisition programs



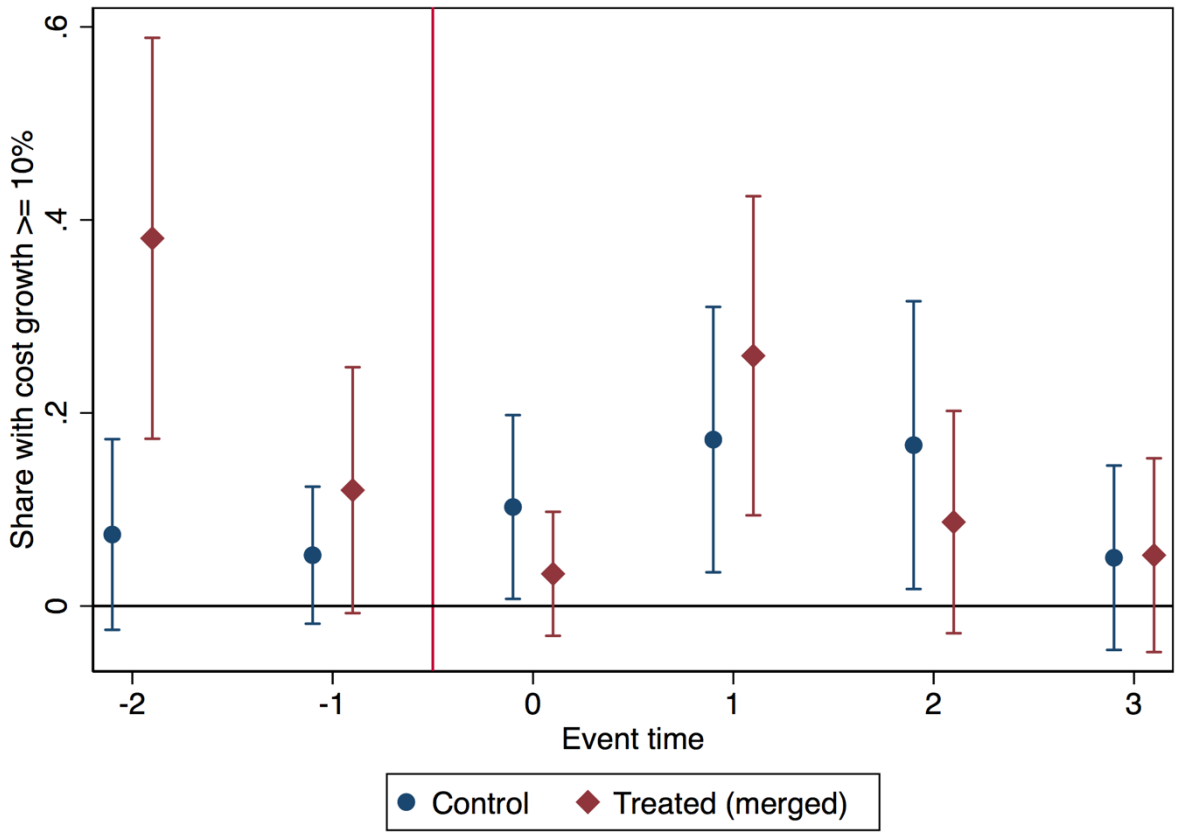
Notes: The data source is the Selected Acquisition Reports summary tables. The analysis sample consists on 194 major acquisition programs that were active for at least three consecutive periods between 1985 and 2001. The figure depicts the distribution of the last observed years of these programs. This variable is truncated at 1987 and 2001 because of our sample definition. Each bar represents the number of programs that we observe for the last time in the year equal to the position in the horizontal axis.

Figure B4: Event study analysis of program cost growth (unweighted annual growth)



Notes: The data source is the Selected Acquisition Reports summary tables. The unit of observation is an acquisition program by fiscal year. This figure depicts (unweighted) averages of annual cost growth for each date in "event time", and separately for treated and control programs. Treated programs are defined as those whose prime contractor was involved in one of the approved mergers in Table 2. The rest are defined as control programs. Event time is calendar years relative to the merger date of a given program (t^* in Table 2). We select treated programs that were observed for at least one year before *and* one year after the merger. Then, we construct a sample of control programs by restricting them to have been active between the same years as the merged sample. Finally, we assign placebo merger dates for control programs at random, following the same distribution of merger dates among treated programs. We use this placebo merger dates to calculate event time for the control sample.

Figure B5: Event study analysis of program cost growth (share of annual cost growth above 10%)



Notes: The data source is the Selected Acquisition Reports summary tables. The unit of observation is an acquisition program by fiscal year. This figure depicts the share of acquisition programs that experienced a cost growth of more than 10%, for each date in "event time", and separately for treated and control programs. Treated programs are defined as those whose prime contractor was involved in one of the approved mergers in Table 2. The rest are defined as control programs. Event time is calendar years relative to the merger date of a given program (t^* in Table 2). We select treated programs that were observed for at least one year before *and* one year after the merger. Then, we construct a sample of control programs by restricting them to have been active between the same years as the merged sample. Finally, we assign placebo merger dates for control programs at random, following the same distribution of merger dates among treated programs. We use this placebo merger dates to calculate event time for the control sample.