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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. 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.

1. Introduction

National defense spending in the US accounts for more than 15% 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.

Our main analysis leverages micro-level data from DoD contracts and exploits 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, we identify the causal effect of increased concentration on a series of procurement outcomes, such as the level of competition, the choice of

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[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] Appendix Table A1 presents budgetary and contract spending data for major agencies of the US federal government.

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contractual form, product level spending, and proxies for post-award contract transaction costs.

We also perform a complementary analysis focusing 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. 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 7 percentage points. It would have also increased the share of dollars in cost-plus contracts by 5 percentage points. Robustness checks to our preferred specifications as well as placebo tests using either a failed (announced but ultimately blocked by federal regulators) merger or a series of hypothetical mergers 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 *fell* in relative terms in product markets that experienced higher concentration due to the cited mergers. Second, markets that became more concentrated saw a *decrease* in measures of post-award transaction costs (proxied by the amount of contract modifications and terminations), relative to less affected markets. Third, 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.

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 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. Also related to our study is Kang and Miller (2017), who study the determinants of the extent of competition in US federal procurement. Rather than focusing on the principal agent structure within the government, we emphasize the role of market structure in determining the level of competition for procurement contracts.

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 of Bhattacharya (2018), who studies the economics of R&D contests, focusing on the case of the DoD's Small Business Innovation Program.

[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.

[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 et al., 2011), health insurance (Dafny et al., 2012), mortgages (Allen et al., 2014), breweries (Ashenfelter et al., 2015), and hospitals (Cooper et al., 2019).

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

[6] Bajari et al., (2009) 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), Decarolis et al. (2018).

Finally, Hensel (2010) studies our same research question focusing on changes in major acquisition programs' procurement costs following contractors' mergers. We improve on Hensel (2010)'s 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. Second, these richer data allow 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 our complementary analysis of major programs, 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 3 describes the main data set that we utilize, while Section 4 describes our empirical methodology. In Section 5 we present our main empirical results, which are complemented by further analyses and a set of robustness checks in Section 6. In Section 7 we discuss and interpret our key results. Section 8 concludes.

2. Background

2.1. 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 on 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 3000 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 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]

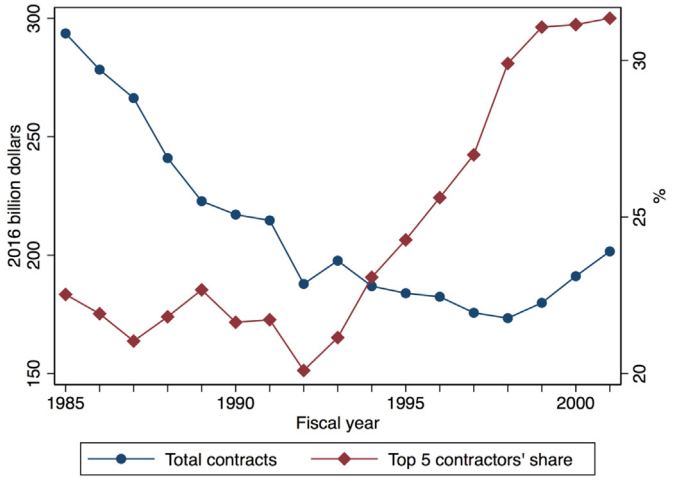

Fig. 1. Aggregate contract spending and concentration Notes: The data source is the Defense Contract Action Data System. "Total contracts" means the sum of all contract dollars obligated in a given fiscal year. "Top 5 contractor's share" is calculated as the sum of contract dollars awarded to the five 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).

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.

2.2. Period of study: defense budgets, industry concentration, and procurement reform

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. Fig. 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 experienced a stark change in trajectory: after nine years of staying roughly constant, the top five share started increasing rapidly in 1994.

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.[10] Among the many M&A operations, four stand out as the largest ones: Northrop's purchase of Grumman

[8] See Appendix Table A1.

[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 types of contracts.

[10] 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."*

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 *	2316	6.0	13.9	6.4	26.3	63.5
2	General Dynamics	2441	4.2	10.3	4.8	27.6	54.6
3	General Electric	3114	3.0	9.4	4.3	43.3	63.4
4	Raytheon ♦	1484	4.6	6.9	3.2	41.2	58.4
5	Lockheed ♠	1690	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 ♦	1457	3.9	5.6	2.6	45.2	52.6
8	United Technologies	486	1.9	4.8	2.2	24.8	78.6
9	Grumman ♣	1326	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 *	2013	2.0	4.0	1.8	39.7	52.2
12	Westinghouse Electric	1171	3.2	3.8	1.8	49.7	62.5
13	Rockwell International	1780	2.1	3.7	1.7	38.3	69.9
14	Honeywell International	3802	0.9	3.5	1.6	47.1	69.8
15	Litton Industries	1210	2.2	2.6	1.2	44.9	78.5
16	Northrop ♣	1540	1.6	2.4	1.1	47.2	49.9
17	Unisys	3564	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	1065	2.0	2.1	1.0	65.4	76.9
20	Textron	1075	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.

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 show, 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 support from DoD. We use all of the approved mergers as a source of variation in

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 ♠	6011	3.6	21.9	11.4	51.8	40.6
2	Boeing *	3952	4.6	18.0	9.4	31.7	53.7
3	Raytheon ♦	5342	1.8	9.6	5.0	49.5	46.5
4	General Dynamics	3163	1.9	6.0	3.2	65.0	63.9
5	Northrop Grumman ♣	4182	1.1	4.4	2.3	61.8	42.8
6	Litton Industries	2931	1.3	3.9	2.0	76.3	49.3
7	United Technologies	2216	1.4	3.0	1.6	25.1	90.7
8	TRW	1527	1.9	2.9	1.5	78.1	32.5
9	General Electric	1975	1.2	2.4	1.2	32.8	90.0
10	Science Applications Intl.	3402	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	1921	0.9	1.7	0.9	97.3	26.8
14	GEC	1581	0.9	1.4	0.7	67.7	43.2
15	Honeywell International	2274	0.6	1.4	0.7	39.3	81.8
16	EDO	1255	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	Date announced	Date effective	First FY in effect (t^*)	Approved by DoJ?
Northrop–Grumman	03/10/1994	05/18/1994	1994	Yes
Lockheed–Martin Marietta	08/30/1994	03/15/1995	1995	Yes
Boeing–McDonnell Douglas	12/17/1996	08/01/1997	1997	Yes
Raytheon–Hughes Aircraft–Texas Instruments	01/16/1997	12/18/1997	1998	Yes
Northrop Grumman–Lockheed Martin	07/03/1997	07/17/1998*	1999**	No

Note: This table lists key merger deals between defense contractors during the decade of 1990. We identify the five listed mergers from the Thomson ONE database. We filter M&A transactions between 1987 and 1999 where: (i) both the acquiror and target were classified in the "Aerospace and Defense" Industry; and (ii) both firms were within the top 30 DoD contractors in 1990. We then sort by the value of the deal and select the top 5 transactions. The first four listed 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.
* Date officially cancelled.
** Based on the date in which we assume that the deal would have been finalized.

industry concentration and the rejected merger for a set of placebo tests. Table 2 summarizes these four mergers along with the one rejected merger. [11]

Finally, our period of study coincides with some significant reforms to the federal procurement system enacted during the Clinton administration, including the Federal Acquisition Streamlining Act of 1994 and the Federal Acquisition Reform Act of 1996. These laws sought to significantly deregulate the procurement system and increase the flexibility and discretion of public agencies, facilitating the procedures for small awards and for the purchase of commercially available products. While these reforms coincide with the timing of consolidation in the defense industry, their focus on small awards and commercially available technology makes them significantly less relevant for the particular context that we study. In fact, arguably the most significant innovation introduced by these laws were the so-called simplified acquisition procedures. These allowed contracts below $100,000 to be awarded using a streamlined process subject to much more flexibility and discretion on the part of the contracting officer. While these were important policy changes, contracts below the simplified acquisition threshold accounted for only 0.7% of the contract dollars awarded in that same year. As we will see in Section 4, the key outcomes that we analyze are shares in terms of contract dollars (share of non-competed or single-bid dollars, and share of fixed-price dollars), which means that these changes are unlikely to affect our analysis in a quantitatively meaningful way. Similarly, while we do not have specific data on the commercial availability of the products in our sample, we expect the overwhelming majority of DoD contract dollars do not fall in that category (as opposed to what we could expect with other federal agencies). Taken together, this implies that there is likely little scope for these reforms to bias our main results.

3. The defense contract action data system (DCADS)

3.1. 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.[12] The data are maintained by the U.S. National Archives and Records Administration and are 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.[13]

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 5000 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.

3.2. 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

[11] To select these mergers and identify their effective dates, we use data from the Thomson ONE database, which contains detailed records of M&A transactions. To focus attention on the most significant mergers, we filtered transactions between 1987 and 1999 (in order to leave at least two years of pre- and post- data) where: (i) both the acquirer and target were classified in the "Aerospace and Defense" Industry; and (ii) both firms were within the top 30 DoD contractors in 1990. We then sort by the value of the deal and select the top 5 transactions. This process yields the four materialized mergers and the announced but never completed merger between Lockheed Martin and Northrop Grumman.

[12] While we are unable to observe any details about classified contracts, we still observe the dollar value of classified contract obligations. Across sample years, classified contract actions account for only 1.4% of annual contract obligations, with a maximum classified share (in year 1996) of 2.5%. For this reason, we drop all classified contract actions from our analysis, noting that this is unlikely to affect our analysis in a quantitatively meaningful way since most of the empirical analysis will consider dollar-weighted shares at the market level.

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

Table 3
Top product categories

Rank		Average spending, 1985–2001 (2016B$)
	Goods	
1	Aircraft and Airframe Structural Components	21.15
2	Communications, Detection and Coherent Radiation	10.96
3	Guided Missiles	10.51
4	Ships, Small Craft, Pontoons, and Floating Docks	7.71
5	Fuels, Lubricants, Oils, and Waxes	7.17
6	Engines, Turbines, and Components	6.67
7	Ground Vehicles, Motor Vehicles, Trailers, Cycles	3.79
8	Ammunitions and Explosives	3.72
9	ADP Equipment Software, Supplies, Equipment	3.7
10	Aircraft Components and Accessories	3.37
	Services	
1	Research and Development	32.51
2	Professional, Administrative and Management Support	10.99
3	Maintenance, Repair, and Rebuilding of Equipment	8.81
4	Construction of Structures and Facilities	7.69
5	Maintenance, Repair or Alteration of Real Property	5.16
6	Utilities and Housekeeping Services	4.24
7	Operation of Government Owned Facilities	3.97
8	Transportation, Travel and Relocation	3.46
9	Modification of Equipment	2.16
10	Medical Services	1.64

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.

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 $826 K (in 2016 dollars). Regarding contract terms, 71% of the contract actions correspond to competitively awarded contracts,[14] 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, 46% through contracts with a single bid, and 72% 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.

3.3. Limitations

The DCADS is a comprehensive dataset that allows us 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. In our main analysis, our only measure of procurement costs will be market-level spending, which is a combination of prices and quantities and that could, therefore, be partially driven by demand. Because of this limitation, in Section 6 we provide complementary analyses looking at other measures of procurement costs.

4. Empirical framework

We study the impact of industry consolidation on public procurement leveraging the sharp increase in market concentration generated by the four approved mergers among top DoD contractors listed in Table 2. The analysis exploits the heterogeneous impact of these mergers across product markets. In this section we describe our empirical strategy in detail.

4.1. Market definition and sample construction

Our 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 et al. (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 1649 observations. We explore the robustness of our results to alternative market definitions in Section 6.

For each market-year, we compute the level of concentration, as measured by the Herfindahl-Hirschman index (HHI). This will be our key explanatory variable, and equals the sum of squared market shares within the product category.[15] A product market where one firm has a monopoly would have a value of 1. Alternatively, if there are N firms and each has an equal 1/N market share, then the value of the HHI would be 1/N. In Section 6 we assess the robustness of our results to a different measure of product market concentration.

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 product 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 4 Panel B presents summary statistics on our product market-level analysis sample.

[14] An additional 2% correspond to follow-on to competed actions.

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

Table 4
Summary statistics.

Panel A: Defense contract action data system

	Mean		s.d.	p10	p50	p90
	(Raw)	(Weighted)				
Dollars obligated (2016K$)	825.5	-	13,875.2	41.9	60.4	113.3
Competed (0,1)	0.71	0.54	0.45	0	0	1
Competed or follow-on (0,1)	0.73	0.65	0.45	0	0	1
One offer received (0,1)	0.34	0.46	0.47	0	0	0
Fixed-price (0,1)	0.78	0.72	0.42	0	1	1
No. of observations (contract actions)	4,324,249					
Sample years	1985–2001					

Panel B: Product market analysis sample

	Mean		s.d.	p10	p50	p90
	(Raw)	(Weighted)				
Total dollars ($M)	1952.0	-	4683.3	12.4	225.3	5487.4
HHI	0.1280	0.0645	0.1421	0.0292	0.0788	0.2859
Number of firms	333.5	974.6	523.1	29.0	156.0	893.0
Number of firms (>1% market share)	16.3	6.0	6.2	7.0	17.0	23.0
Number of actions	2003.1	6479.6	3877.4	69.0	573.0	5927.0
Average action dollars ($K)	975.3	1246.0	1522.5	123.6	381.1	2642.4
Median action dollars ($K)	124.5	53.2	113.5	69.4	99.8	186.9
Share of competed actions (%)	61.7	24.1	27.2	23.3	64.4	95.3
Share of follow-on to competed actions (%)	4.7	8.5	10.3	0.0	0.4	14.4
Share of fixed price contract actions (%)	87.1	23.8	22.8	51.2	98.8	100.0
Share of single-offer contract actions (%)	43.0	23.9	26.8	7.0	43.1	79.1
Number of observations (market-years)	1649					
Number of markets	97					
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 of our market level analysis sample. 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" = 10th, 50th and 90th percentile, respectively.

While Fig. 1 documented the rise in concentration at the aggregate level, we can now do the same using our market-level data. Fig. 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.

4.2. Econometric specification and identification

Our main empirical specification is of the form:

$$Y_{it} = \alpha_i + \lambda_t + \beta \cdot HHI_{it} + \varepsilon_{it} \quad (1)$$

where Y_{it} is an outcome variable and HHI_{it} is the Herfindahl-Hirschman index of product market i in fiscal year t. This specification also includes product market fixed effects to account for baseline differences across product categories in the share awarded competitively and in the other outcome variables of interest. 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 Eq. (1). To do this, we follow DDR and implement an instrumental variables (IV) 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. DDR 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:

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

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^*.

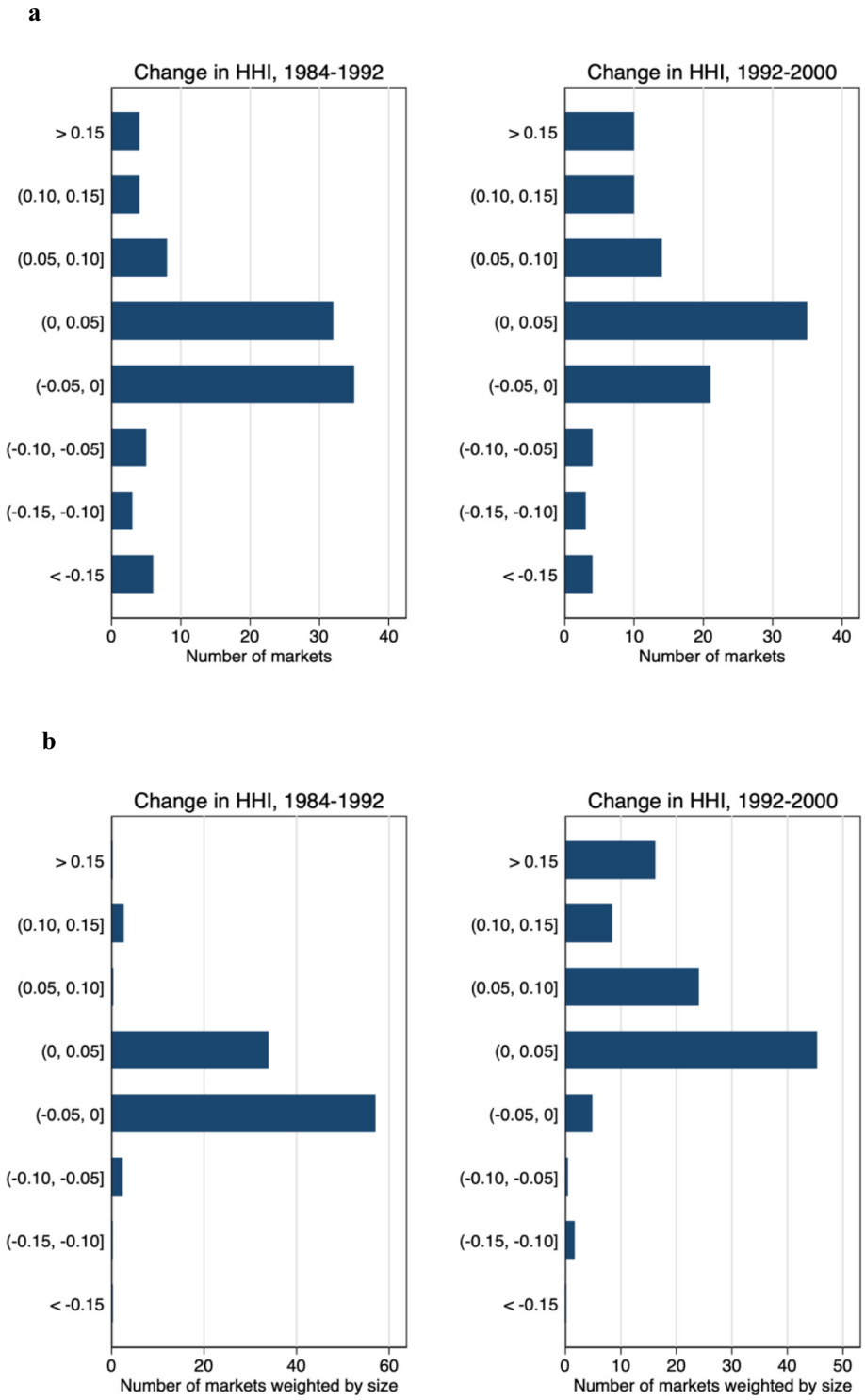

Fig. 2. a. Change in market-level HHI (unweighted). b. Change in market-level HHI (weighted). Notes: The data source is the Defense Contract Action Data System. Observations for this figure are obtained by aggregating individual contract actions at the product category level (market) in selected fiscal 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 between 1984 and 1992, and between 1992 and 2000. In b, the distributions are weighted using each market's average number of contracts in FY1980–FY1984.

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 $simΔHHI_{it}$ is increased by an amount equal to the simulated change in HHI associated with that particular merger.[16] In all specifications, we cluster standard errors by product market.

One potential concern with our 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. We address this issue in several ways. First, we use a merger that was blocked by the U.S. Department of Justice as a "placebo test" in our main specifications. 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] Second, to go beyond this particular merger, we conduct an exercise that expands on this idea and derive inference based on many randomly-generated placebo mergers. Third, we show that our results are robust to controlling for pre-existing trends in our outcomes at the product market level.

4.3. 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:

$$simΔHHI = (0.2068 + 0.0002)^2 - 0.2068^2 - 0.0002^2 \approx 0.0001.$$

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 0.02. 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 0.04 in guided missiles and 0.03 in R&D, while it increased by just 0.006 in the market for weapons.

5. Main results

5.1. First stage

We start by assessing the relevance of our instrument. Recall that our main specification is Eq. (1), where we instrument HHI_{it} with $simΔHHI_{it}$, as defined by Eqs. (2) and (3). Table 5 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 Eq. (3). Here we include the placebo in the combined instrument $simΔHHI_{it}$, 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 $simΔHHI_{it}$. 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 columns (3) and (4) respectively, except that we weight all observations equally.[18]

Overall, the results indicate a significant first stage relationship between our instrument and market-level concentration.[19] 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 slightly above what would be expected from taking the pre-merger market shares of the consolidated firms and assuming no other changes.

It is worth noting that the magnitude of this coefficient was ex-ante ambiguous. If there are participation costs in procurement auctions, we could have expected that consolidation increases entry into auctions by rival (i.e. non-merging) firms. This is because their probability of winning might increase due to the mechanical reduction in the number of potential bidders. In turn, this would have generated an offsetting effect on concentration that would have been translated into a coefficient below 1. On the other hand, the merged firm may be a more formidable competitor that could "scare off" potential bidders who would have participated in the absence of the merger. This could lead to a coefficient estimate of more than 1. Our point estimates suggest that, on net, the second type of force may have been more relevant, although we note that we cannot reject a value of 1 in any of our specifications.

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 product markets 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 $simΔHHI_{it}$ 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 summarized in this table strongly suggests that the approved mergers provide a plausibly exogenous source of variation in market concentration.

[16] For example, consider the case of a single product market i affected by two mergers: in 1995, two firms with 10% market share each merge; in 1997, two firms with 20% market share each merge. The value of the instrument will be 0 in years 1994 and earlier, equal to 0.02 ($=2*0.1*0.1$) in 1995 and 1996, and equal to 0.1 ($=0.02+2*0.2*0.2$) in 1997 and later.

[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.

[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.

[19] In Section 6 we return to the issue of first stage strength and demonstrate that our results are robust to considering inference adjustments for the presence of weak instruments.

Table 5
First stage regressions.

DV: HHI_{it}	(1)	(2)	(3)	(4)	(5)	(6)
$simΔHHI_{it}^{NG}$	9.1136***					
	(1.3515)					
$simΔHHI_{it}^{LM}$	1.9764***					
	(0.3695)					
$simΔHHI_{it}^{BM}$	0.2175					
	(0.8371)					
$simΔHHI_{it}^{RTH}$	0.9120***					
	(0.2247)					
$simΔHHI_{it}^{LMNG}$	−0.6969*	−1.8411***				
	(0.3971)	(0.4374)				
$simΔHHI_{it}$		1.3912***	1.2689***	1.1704**	1.6414***	1.7055***
		(0.3493)	(0.3874)	(0.4749)	(0.4867)	(0.5280)
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	1649	1649	1649	1632	1649	1632
R^2	0.7253	0.7139	0.7135	0.7150	0.5941	0.5964
Mean D.V.	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645

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). Clustered standard errors at the market level are shown in parentheses. Asterisks denote p-value < .10 (*), < .05 (**), or < .01 (***).

Table 6
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}	0.4323*					3.4119***	4.0138**
	(0.2196)					(1.2749)	(1.7049)
$simΔHHI_{it}$		4.3292***	4.6977***	4.5557***	4.9665***		
		(0.7004)	(0.5735)	(0.7104)	(0.5292)		
$simΔHHI_{it}^{LMNG}$				−5.3880***	−6.1214***		
				(1.3485)	(1.3123)		
Category group by year FE?	No	No	Yes	No	Yes	No	Yes
$simΔHHI_{it}$ includes placebo?	No	No	No	Yes	Yes	No	No
Observations	1649	1649	1632	1649	1632	1649	1632
R^2	0.7923	0.8023	0.8200	0.8024	0.8202	-	-
Mean D.V.	0.420	0.420	0.420	0.420	0.420	0.420	0.420

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). Clustered standard errors at the market level are shown in parentheses. Asterisks denote p-value < .10 (*), < .05 (**), or < .01 (***).

5.2. The effect of concentration on procurement competition

Now we consider the effects of concentration on procurement competition. We are interested in the estimation of Eq. (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[20] or through a competitive procedure in which only a single offer was received.

The results are presented in Table 6. In the first column we present the OLS estimate of β from Eq. (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 Eq. (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 product 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.[21]

[20] For example, via direct negotiation with a single firm.

[21] Recall that for this we classify product categories in three groups: goods, services and R&D.

We see from column (1) that higher concentration is positively correlated with the award of noncompetitive contracts, although the coefficient is small and marginally significant (0.43 with a standard error of 0.22). 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 3.41.

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 0.065. 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 6.8 percentage points ($\approx 0.02 \times 3.41$). This would represent a 16% increase given the mean share of 42%.

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 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.

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 increases in product market-level concentration caused the procurement process to become less competitive. We provide further robustness checks to our main specification in Section 6.

Finally, it is worth mentioning that these effects are driven by an increase in *both* noncompetitive awards and single-bid competitive contracts. Appendix Tables A2 and A3 present results separating between these two types of awards, showing consistently positive estimated effects.

5.3. 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 7 presents the results, following the same structure as Table 6.

The OLS results indicate that product market level concentration is negatively correlated with the use of fixed-price contracts (coefficient of −0.25). As with the level of competition, the results using our instrument suggest a much stronger effect. Our preferred IV estimate of −2.56 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 5.1 percentage points. That in turn means that the use of cost-plus contracts increases by that same amount, which represents a substantial 34% increase relative to a mean of 15.1%.

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.

Table 7
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}	−0.2492***					−2.5596**	−1.9103*
	(0.0943)					(1.1392)	(1.0580)
$sim\Delta HHI_{it}$		−3.2477**	−2.2358**	−2.8827**	−1.9723**		
		(1.2886)	(0.8790)	(1.3512)	(0.8675)		
$sim\Delta HHI_{it}^{LMNG}$				1.5411	0.8401		
				(2.2224)	(1.8014)		
Category group by year FE?	No	No	Yes	No	Yes	No	Yes
$sim\Delta HHI_{it}$ includes placebo?	No	No	No	Yes	Yes	No	No
Observations	1649	1649	1632	1649	1632	1649	1632
R^2	0.9389	0.9445	0.9251	0.9448	0.9253	-	-
Mean D.V.	0.849	0.849	0.849	0.849	0.849	0.849	0.849

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), $sim\Delta HHI_{it}$ 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), $sim\Delta HHI_{it}$ 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). Clustered standard errors at the market level are shown in parentheses. Asterisks denote p-value < .10 (*), < .05 (**), or < .01 (***).

Taken together, the results summarized in Table 7 indicate that consolidation-driven increases in market concentration led to a significant shift from the use of fixed-price to cost-plus contracts.

5.4. 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 8 presents the results following the same format of Table 6 and Table 7. 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*. Evaluated at mean concentration levels, the preferred IV specification implies an elasticity of market spending with respect to HHI of 0.31 ($= -4.78 \times 0.065$).

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.

5.4.1. 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. In the next section we provide two complementary strategies to examine further the effects of concentration on procurement costs. We leave the interpretation and discussion of the implications of our results for Section 7.

6. Complementary analyses and robustness

We now complement the main results presented in Section 5 and assess their robustness. We perform two sets of analyses to further investigate whether increased concentration affected procurement costs. First, we estimate specifications for the effect of concentration on proxies of post-award transaction costs. Second, we assess the effect of the mergers on acquisition costs for a small subset of large defense contracts (Major Defense Acquisition Programs). We then conclude the section with a series of robustness checks on our key specifications.

6.1. Post-award transaction costs

We have highlighted that a limitation of our DCADS data is that we do not observe unit procurement costs directly. However, we can rely on the important idea from the procurement literature that a significant portion of procurement costs is realized post-award, related with costly renegotiation and adaptation of procurement contracts (e.g., Crocker and Reynolds, 1993; Bajari and Tadelis, 2001). We construct two proxies of market-level post-award transaction costs: the share of contract actions that correspond to contract modifications, and the share of actions that are contract terminations. The idea is to test whether, as a result of plausibly exogenous increases in concentration, procurement contracts are more likely to be modified and terminated after the award.

We do this by estimating variations of Eq. (1), as in Section 5. The results are presented in Appendix Table A4 for contract modifications and Appendix Table A5 for terminations. Both the reduced form and IV results suggest that higher concentration led to fewer modifications and terminations. In the case of modifications, the results are highly significant, while in the case of terminations, we cannot reject a value of zero in some of the specifications. Taken together, these results provide further evidence that increased concentration did not lead to higher procurement costs.

Table 8
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}	1.5562***					−4.7768*	−4.9738
	(0.4896)					(2.5508)	(2.9994)
$sim\Delta HHI_{it}$		−6.0611**	−5.8212*	−5.1410	−5.6338*		
		(2.9028)	(3.0073)	(3.3736)	(2.9890)		
$sim\Delta HHI_{it}^{LMNG}$				1.7596	4.8288		
				(6.6240)	(7.3815)		
Category group by year FE?	No	No	Yes	No	Yes	No	Yes
$sim\Delta HHI_{it}$ includes placebo?	No	No	No	Yes	Yes	No	No
Observations	1649	1649	1632	1649	1632	1649	1632
R^2	0.9702	0.9695	0.9705	0.9696	0.9705	-	-
Mean D.V.	21.28	21.28	21.28	21.28	21.28	21.28	21.28

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), $sim\Delta HHI_{it}$ 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), $sim\Delta HHI_{it}$ 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). Clustered standard errors at the market level are shown in parentheses. Asterisks denote p-value < .10 (*), < .05 (**), or < .01 (***).

6.2. Analysis of major acquisition programs

We conduct a second complementary analysis of the effect of consolidation on procurement costs by focusing on a subset of high-profile multi-year programs: Major Defense Acquisition Programs (MDAPs), An MDAP is a program for which it is estimated that total expenditures for research, development, and test and evaluation (RDT&E) will exceed $480 million or that procurement expenditures will exceed $2.79 billion (figures in 2014 constant dollars).

We take advantage of the fact that DoD is required to submit periodic reports to Congress about the acquisition costs of these programs, highlighting deviations relative to baseline cost estimates. We therefore investigate whether consolidation led to systematic changes in the acquisition costs of these programs. Here we briefly describe the main empirical specification and discuss the key results. In Appendix C, we provide much more detail on the institutional background of MDAPs, the data used, and the motivation for the empirical framework.

We gather data for 194 MDAP programs that were active for at least three consecutive years on FY1986–FY2001, generating an unbalanced panel with 1267 program (i) – year (t) observations. For each program, we identify the prime contractor and distinguish between programs run by contractors participating in the large mergers of Table 2 – which we refer to as "treated" – and the rest of the programs – which we call "control" programs. There are 118 treated and 76 control programs in our sample. The difference-in-differences (DD) specification is:

$$Y_{it} = \gamma_i + \tau_t + \delta \cdot Merge_{it} + \nu_{it}, \tag{4}$$

where 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 approved 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 use the estimated full cost of program i in fiscal year t (in logs), which is updated annually. Second, we use the estimated real annual cost growth *adjusted by quantity changes*.[22] Third, we 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 percent.

Table 9 presents results from the estimation of variants of Eq. (4) for the three different outcome variables. Our 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% and 2%. 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 than 10%) 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.

Appendix C also presents results from an additional event study analysis, where we randomly assign placebo merger dates for control programs and analyze the year-by-year evolution of acquisition costs for treated and control programs, relative to their merger dates. The results are broadly consistent with the DD results of no differential change in acquisition costs levels or growth rates.

Our results from the MDAP analysis should be interpreted with caution. To the extent that mergers have market-wide effects, they could have affected both merging and non-merging firms. This would imply that the comparison between treated and control firms would be contaminated by potential spillovers, making the DD coefficient an invalid estimate of the causal effect of mergers on acquisition costs. While we

Table 9
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. Clustered standard errors at the program level are shown in parentheses. Asterisks denote p-value < .10 (*), < .05 (**), or < .01 (***).

[22] This measure of cost growth reflects an attempt by DoD to isolate cost changes that are due to supply-side factors, as opposed to changes in demand. We provide more details on how this measure is estimated in Appendix C.

acknowledge this possibility, we still think that the null results are informative. Our DD estimates and raw event study graphs indicate that acquisition costs from merged and non-merged contractors evolved in parallel after the mergers. Further, Appendix Figure B4 suggest that this is not explained by large increases in both treated and control firms, but rather by no big changes in either group. The data seem, therefore, *a priori* inconsistent with consolidation leading to rising industry-wide procurement costs. So while we do not take our MDAP results as a definitive causal test, we think it provides an additional piece of descriptive evidence that points in the same direction of our previous results: consolidation does not appear to have generated substantial increases in procurement costs.

6.3. Robustness checks

We finalize this section by presenting a series of robustness checks to the main results discussed in Section 5.

6.3.1. Pre-existing trends

A first exercise to test the validity of our IV approach is to check that our results are not driven by differential underlying trends in markets that were more affected by the key mergers. Note that we already partially addressed this in our main results by including a separate set of year fixed effects for each product category group. Yet because these category groups are coarsely defined (R&D, goods, and services), it is still possible that we did not fully control for differential product market-specific pre-trends.

We therefore implement a two-step procedure to control for the potentially confounding effect of pre-existing trends. First, we estimate 97 product market-specific linear time trends using only data prior to the first of the observed mergers (i.e. FY 1985–1993). That is, we estimate:

$$Y_{it} = \psi_i + \rho_t + \eta_i \cdot t + \xi_{it} \tag{5}$$

on pre-1994 data and obtain 97 slope coefficients $\hat{\eta}_i$ that measure the pre-existing trend in each of the 97 markets just prior to the first merger. We then include the product of the slope coefficient for each product market and the year (minus 1985) as a regressor when estimating specifications of the following type using data for the entire period (1985 through 2001):

$$Y_{it} = \alpha_i + \lambda_t + \beta \cdot \Delta simHHI_{it} + \phi \cdot \hat{\eta}_i \cdot t + \epsilon_{it} \tag{6}$$

This two-step approach is preferred to simply controlling for market-specific time trends in the main specifications, as this would not reliably distinguish between time-varying treatment effects and pre-existing trends (Lee and Solon, 2011; Goodman-Bacon, 2018).[23] We obtain standard errors by bootstrap, sampling 97 product markets with replacement in each of B = 1000 replications. The results are presented in Appendix Table A6 and show that the key reduced form coefficients are relatively robust to the inclusion of these pre-existing trend controls.

6.3.2. Placebo mergers and randomization inference

In Section 5 we highlighted how the evidence from the announced but eventually withdrawn merger between Northrop Grumman and Lockheed Martin supports a causal interpretation of our estimates. While we think this evidence is reassuring, one concern is that this particular merger was special, which is why the government opposed it.

To test how general these results are, we produce a series of randomly generated placebo mergers, and assess the stability of our key coefficients to their inclusion in the combined *simΔHHI* (along with the corresponding placebo *simΔHHI* as implemented with the blocked merger). We also use random placebo mergers to reflect on inference: how unusual are our IV results, relative to a distribution obtained with many placebo mergers? Full details on these exercises are provided in Appendix D, while we briefly discuss the results here.

First, we find that our key reduced form coefficients in the main specifications are very stable to the inclusion of randomly generated mergers between top contractors. This is in stark contrast to the case where a real consummated merger is treated as a placebo. We illustrate this with the Lockheed and Martin Marietta merger in 1995 (see Appendix Figs. B7 and B8).

Second, we show that the T-statistic of our main IV estimates correspond to relatively extreme events in the distribution of T-statistics generated via placebo mergers. The implied p-values for our baseline T-statistics (i.e., the probability that a T-statistic based on a random placebo merger is greater in absolute value than our baseline estimate) are 0.040 for the IV estimate on competition, and 0.076 for the IV estimate on contractual form (see Appendix Figs. B9 and B10).

6.3.3. Market definition

We also explore the sensitivity of our results to our definition of product markets. Recall that we use the Federal Supply Classification (FSC) codes as a basis for our market definition. These codes provide standardized definitions of goods and services that all contracting offices use for classifying their solicitations. They are also the way in which potential vendors can identify opportunities that are relevant to them. However, a legitimate concern is how much our results depend on the particular level of aggregation of FSC codes that we use to define markets.

Recall that the raw product and service codes that we observe have 4 (alphanumeric) digits. These are commonly aggregated into 2-digit (numeric) codes for goods and 1-digit (letter) codes for services, which constitutes our baseline market definition.[24] We construct two alternative definitions to our baseline of 97 categories. First, we deaggregate service categories to the 2-digit level. This increases the total number of product categories from 97 to 128, and the total number of observations from 1,649 to 2,176 (= 128*17). Second, we deaggregate both product and service categories to the narrower 4-digit level. This increases the total number of product categories from 97 to 937, and the total number of observations from 1649 to 15,929 (= 937*17).

The results are presented in Appendix Tables A7, A8 and A9. All of the key reduced form coefficients maintain their sign and, except for some of the columns in the market spending regressions (A9), their statistical significance. Since the means of the dependent and independent variables change with each new market definition, we compute implied effect sizes at the mean, by normalizing the reduced form coefficients by the ratio between the mean of the instrument and the mean of the dependent variable. These implied effects can be interpreted as elasticities evaluated at the mean, and for all three outcome variables are very stable across specifications with different market definitions.

6.3.4. Measure of concentration

Throughout the analysis we use the HHI as a proxy of market concentration. To show that our conclusions do not depend on this choice, Appendix Tables A10, A11 and A12 present specifications in which concentration is instead measured as the share of market dollars going to the top 5 firms. As with the HHI, higher values of this measure imply

[23] Examples of other studies that use this approach include Bhuller et al. (2013), Goodman-Bacon (2016), and Duggan et al. (2019).

[24] For example, the FSC 15 category corresponds to "Aircraft and Airframe Structural Components", which is an aggregation of several more narrow categories: 1510 – "Aircraft, Fixed Wing", 1520 – "Aircraft, Rotary Wing", 1540 – "Gliders", 1550 – "Drones", and 1560 – "Airframe Structural Components". Similarly, the FSC C service category corresponds to "Architect and Engineering Services - Construction". This is an aggregation of 24 different 4-digit codes. From these 24 narrow categories, 15 of them start with "C1" and are related to construction of building and facility structures, or to non-building structures, like roads or bridges. The remaining 9 start with "C2" and relate to architect and engineering services that are not directly construction, like drafting or inspection services.

greater concentration. The key IV coefficients generally conserve their sign and statistical significance for competition and contractual form. For market spending, the conclusion of a zero —or, if anything, a negative effect — is also unchanged.

6.3.5. Inference robust to weak instruments

Finally, we explore in more detail the issue of instrument relevance. From Table 5 we observed that the first-stage coefficient was robustly significant across specifications. However, in Appendix Table A13 we can see that, when we include category group by year fixed effects, the effective F-statistic of the first stage falls below the conventional rule-of-thumb of 10. To explore whether this fact compromises our IV interpretations, we follow Andrews et al., (2019) recommendation and also present Anderson-Rubin confidence sets in Appendix Table A13. In the case of a single endogenous variable and a single instrument, these confidence sets are robust regardless of the strength of the first stage. We see that in all six main IV specifications, the value of 0 lies outside the 95% confidence intervals, supporting our interpretation of statistically significant results.[25]

7. 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.

7.1. Increased use of non-competitive and cost-plus contracts

Our finding that higher concentration leads to less reliance on competitively awarded contracts is consistent with previous research. Bajari et al. (2009) 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. (2009) 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.

In terms of contractual form, 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). Our results are consistent with recent evidence from the hospital industry that shows that in more concentrated markets, hospitals negotiate contracts that load more risk on insurers (Cooper et al., 2019). Similarly, if consolidation increased the bargaining power of defense contractors relative to the government, it may have allowed them to demand more favorable contract terms, shifting cost overrun risks from contractors to the government. This is particularly plausible in an environment that –according to our previous results– was characterized by decreased competitive bidding and increased negotiation.

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 it may imply for procurement costs. This is particularly 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.

7.2. 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 due to contractor mergers. Second, proxies of post-award transaction costs (such as contract renegotiation and termination) *decreased* in markets more affected by consolidation. Third, acquisition programs run by contractors that consolidated did not see a differential change in per-unit acquisition costs. While by themselves none 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. Throughout the text we have discussed the strengths and weaknesses of these different analyses, yet the fact that all three 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 any firm's ability to extract

[25] In fact, relative to the conventional confidence intervals associated with our cluster-robust standard errors, the lower bound of the confidence set is almost unchanged, whereas the upper bound (in absolute value) is much larger. We interpret these findings as robustly supporting the existence of our estimated effects, while implying that their magnitude can be potentially larger than our point estimates.

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.

7.3. 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.

There are two additional considerations that have received significant attention in the procurement and regulation literature, and that could affect the interpretation of our results. We proceed to briefly discuss these two factors, even though we are unable to study their precise quantitative role with our data.

The first consideration is that concentration could have affected the (unobserved) quality of procured products.[26] For example, rather than increasing the price charged for a project, a contractor subject to softer competition may decide to cut back on, say, field testing. If this leads to lower contract performance, then our conclusion that the government did not see an increase in procurement costs would no longer hold once we properly adjust for contract quality. While our results from analyzing proxies of post-award transaction costs are inconsistent with this hypothesis, this is only partially satisfactory in the absence of more systematic performance data.

A second aspect that would modify our conclusions is the possibility that rising concentration could make the procurement process more vulnerable to regulatory capture. [27] The consolidation of a few giant firms with near monopoly power in certain product markets might lead to cronyism in the award procedures, with an increased ability by contractors of extracting private rents from the government. This might be particularly worrisome in an environment that, as our results show, was characterized by less competitive procedures and less reliance on high-powered fixed-price contracts. Again, since we are constrained by the data available for our period of study, we hope that future research will be able to shed light on the relationship between concentration in public procurement markets and regulatory capture.

[26] See Manelli and Vincent (1995) for an analysis of procurement mechanisms in the presence of unobserved quality.

[27] See Dal Bó (2006) for a review.

8. Conclusion

In this paper we show that rising concentration in the U.S. 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 federal 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% in 1990 to 31.3% 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% in 2010 to 30.2% 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.[28] 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.

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Appendix A. Supplementary data

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[28] 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

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