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Innovation for Hire: A Descriptive Study of Federal Acquisitions and Contractor R&D

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Abstract

In 2016, the U.S. Federal government procured goods and services totaling $460 billion, or over two percent of America's gross domestic product. Innovation is a key goal of Federal procurements, but the extent to which the acquisition process cultivates private-sector innovation is unclear. To shed light on this relationship, we explore private-sector innovation over an eight-year period and find that firms increase research and development commeasurate with government contracts. We develop a measure that ranks firms on the intensity of public-sector versus private-sector innovation. Tests deploying this tool show that firms with the most (least) research and development on government (relative to private) contracts produce innovative goods such as missiles (security guards). Taken together, our results suggest that Federal acquisitions appear to motivate innovation at levels that are appropriate to the nature of requisitioned goods or services. These results should be of interest to practitioners and acquisition personnel who serve a common goal of efficiently deploying a finite pool of taxpayer-generated revenues to the most productive use.

1.0 Introduction

"Government's most profound and innovative technological breakthroughs…have resulted from strategic partnerships between agencies [and] private institutions…Building off of past successes and expanding these types of partnerships is vital for increasing the government's collaboration and innovation, and addressing the nation's most pressing challenges."[1]

In 2016, the United States Federal government procured over $450 billion of goods and services.[2] Federal procurement exceeded two percent of the nation's gross domestic product, making the government the largest buyer in the nation. Because of its size, the government enjoys unrivaled bargaining power with its suppliers, also known as contractors. In addition to being a major customer of many suppliers, Uncle Sam is also firms' most powerful customer; he employs auditors to monitor firms' performance on contracts and can reclaim monies previously disbursed.[3] Given the government's unequaled bargaining power, they are in a unique position to incentivize private-sector innovation in novel technologies, goods, and services. However, the extent to which Federal acquisitions successfully achieve their objective of cultivating innovation remains unclear. We explore this question and find that private-sector partners increase investment in innovation with the extent of governement business. However, we are unable to conclude whether the impact of acquisitions on firm-level innovation (which we proxy using research and development expense) differs from the effect of private sales on firm-level research and development (where private sales are the firm's sales to non-government customers).

We extend the work of scholars who study customers' influence on supplier innovation. Firms with concentrated customer bases deploy fixed assets more efficiently, which frees up

[1] See https://ourpublicservice.org/wp-content/uploads/2016/02/bd747d93412a7f98d10d4e8093193dcc-1454974231.pdf.
[2] See www.usaspending.gov.
[3] The Federal government maintains its own agencies dedicated to auditing contractors' performance and adherence to the government's billing standards, known as the Cost Accounting Standards (CAS). In addition to reclaiming revenues, the government can bar the firm from further work if Federal contract audits identify material issues. For more information on CAS and contract audits, see https://www.acquisition.gov/far/html/FARTOCP30.html and https://www.gao.gov/products/GAO-11-331T.

capital for innovation (e.g., Patatoukas 2011). Consistent with firms investing excess capital in innovation, Krolikowski and Yuan (2017) find that firms do more research and development (R&D) work and have more patent citations when their business partners have strong bargaining power.[4] Both Patatoukas and Krowlikowski and Yuan study private-sector customers of publicly-traded firms. As we noted above, the government enjoys privileges that are not available to private-sector buyers; because of the government's unusual power, it is unclear if prior results generalize to the public procurement setting. Additionally, investing in innovative technologies to meet our nation's strategic challenges is an important objective of acquition activity. Therefore, we find it worthwhile to explore the extent to which the government achieves this goal.

We also extend several recent studies that find a positive association between characteristics of the procurement environment and firm-specific outcomes. For example, Ferraz et al. (2015) find that winning at least one government contract increases the growth of Brazilian firms and motivates such firms to bid on additional contracts and expand into new product markets. Slavtchev and Wiederhold (2016) model returns to innovation as a function of government purchasing and find that private-sector returns to innovation increase with the extent of high-tech goods the government purchases; they conclude that procurement incentivizes private-sector firms to increase their innovation as the government demands more proprietary goods and services. Clemens and Rogers (2020) expand the relationship between characteristics of the government's purchasing and innovation and find that the government's demand function affects incentives to innovate, including incentives to trade off cost verus quality. Finally, Brogaard et al. (2016) and Decarolis et al. (2019) find that the extent and success of patent activity increases with government contracts. Taken together, recent research indicates that the contracting process incentivizes private-sector behavior and outcomes.

We extend this stream of literature in several ways. Firstly, we find an average, cross-sectional positive association between the extent of engagement with the government, measured by the firm's government sales, on their *ex ante* investment in innovation, measured using R&D

[4] Krolikowski and Yuan (2017) also report that supply chain holdups reduce the benefits of customer concentration on innovation.

expense. Patent activity captures the *ex post* success of innovation but does not speak to the firm's incentive to innovate. In contrast, R&D spending measures the firm's *decision to innovate* contemporaneous with receiving government contracts, so proxying innovaton with R&D provides cleaner evidence on the extent to which the government purchases innovation through the procurement process.[5]

Secondly, we provide evidence on the intensity of innovation on government relative to non-government (or private) sales. To measure relative innovation via R&D, we create a measure of the relative intensity of research and development on government versus private sales. Our measure allows us to rank firms and industries on the relative importance of government to private-sector innovation. We validate our measure by showing that those firms with the highest (lowest) rank sell the government high tech (low tech) products such as missile systems (fuel). Similarly, we rank three-digit North American Industry Classification System (NAICS) industries and find that industries with the highest (lowest) ratio of government to private research and development manufacture products such as missile systems (kidney dialysis). To the best of our knowledge, our measure is new and we foresee broad applicability for scholars who need to rank firms or industries based on the relative intensity of various activities. Our results should also be of interest to acquisition practitioners, one of whose key responsibilities is efficiently allocating taxpayer-generated revenues to the most productive use.

2.0 Overview of Government Contracting and Hypothesis

It is critical to understand government procurement (the process through which the Federal government obtains goods and services) in order to understand the potential impact of this process on firms' incentives to innovate. Our summary draws heavily from Hermis (2020), who provides a more detailed explanation of government contracting. The procurement process begins when a government agency identifies a needed good or service, known as a requirement. The agency issues a formal document, called a request for proposal, which contains a detailed explanation of the government's need and instructions for how firms should submit their

[5] Our results, derived from archival data, are necessary but not sufficient to establish causality. We cannot say government sales cause innovation, but our results are the first step toward proving causality.

responses, which are known as contractor proposals. The Federal Acquisition Regulation (FAR) and supplemental agency-specific rules legislate the government's procurement activities, including providing guidance on making award decisions.[6] The average contract is awarded based on a combination of factors which may include the bidder's technical knowledge (for example, experience providing similar items to other customers), history of successfully working for the government, and price. Of course, technical expertise, history with the government, and price vary in importance depending on the contract.[7]

The government purchases a wide array of items. While agencies like the Department of Defense procure specialized goods such as proprietary weapons systems, they also purchase commodities (including toilet paper, laptop computers, and coffee). The extent to which the contracting firm innovates on the contract is obviously contingent on the nature of the government's need. We would expect Raytheon, who builds missiles, to invest heavily in innovation, but we would be surprised (albeit, pleasantly) if OfficeMax displayed exuberant innovativeness in its provision of pens and pencils. The extent to which the average contractor invests in innovation likely reflects whether the government purchases more fighter jets or more packages of socks. Even holding constant what the government purchases, firms have different incentives to innovate. For example, firms who shift costs from private (commercial) to public-sector contracts may innovate more as they engage further with the government because the government subsidizes their commercial work (e.g., Chen and Gunny 2015). However, these same firms plausibly have incentives to shirk if government oversight is lax, leading to a potential negative association between government sales and research and development. Ex ante, we are agnostic as to whether doing business with the Federal government is associated with higher or lower levels of firm-specific investment in research and development, which leads us to state our first hypothesis in the null form.

H1: There is no association between the extent of the firm's sales to the Federal government and the firm's investment in innovation.

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[6] See http://farsite.hill.af.mil/hierarchy.htm for codification of the FAR.

[7] To clarify our understanding of the procurement process, we spoke with a former Contracting Officer for the Department of Defense as well as a retired employee with contracting experience at several publicly- and privately-held defense contractors.

Even if we find a statistically significant association between the extent of the firm's government business and its innovation as measured by R&D spending, such a result would naturally raise the question regarding whether non-government sales similarly impact R&D spending. That is, for a given increase in government sales, what is the impact on R&D relative to the same increase in private sales? For the reasons described above, it is *ex ante* uncertain whether government contracts will lead to increased or decreased innovation relative to commercial sales with non-government customers. We state our second hypothesis as follow:

H2: There is no difference in the firm's innovation for government relative to private, non-government sales.

We now turn to the research design.

3.0 Research Design

3.1 Data and sample selection

In order to test our hypotheses about the effect of government contracting on firm innovation, we compiled a sample of government contractors and comparable non-contractors with financial statement data sufficient to create a robust set of controls. We relied on two databases to identify such firms: the Compustat Fundamentals Annual file found in WRDS and usaspending.gov.[8] We selected a sample period beginning in 2009 to avoid mixing observations prior to the 2008 fiscal crisis with those from the post-crisis period, and we ended our sample period in 2016 to allow a sufficient time lag for firms' financial statement information to be uploaded to Compustat. Table 1 Panel A describes the sample selection and Panel B of the same table displays the number of observations per year, split into the contractor and non-contractor observations.

[8] Usaspending.gov is a repository of Federal spending activity. Usaspending.gov pulls government contract award data on a daily basis from the Federal Procurement Data System Next Generation. Federal agencies submit contract award data at least twice monthly to be published on usaspending, and contract award data is linked directly from the agency's financial system to usaspending's awards data quarterly. Each agency's senior accountable official certifies the quarterly data. Federal agencies are required to report contract awards within 30 days, with the exception of the Department of Defense, who reports awards within 90 days. The longer award reporting window is designed to protect national security. For more details on how usaspending.gov aggregates and verifies data, see https://www.usaspending.gov/#/about.

Our model requires substantial information about control variables and we began our sample creation by downloading the full Compustat Fundamentals Annual File pertaining to our sample period. After dropping duplicates and observations missing control and lagged control variable data, we were left with a sample of 28,065 unique firm-years between 2009 and 2016. Let us call this dataset A.

To identify government contractor firms, we first downloaded all Federal contract prime awards from usaspending.gov during the sample period. On average, each year of usaspending.gov data contained about four million unique contract awards.[9] After eliminating duplicate contracts and contracts missing the recipient contractor name, the contract award amount, or the year in which the contract was awarded, we had a sample of approximately three million unique contractor-years between 2009 and 2016. Let us call this dataset B.

We intersected observations with full Compustat data (dataset A) with observations with government contractor data (dataset B) to create the government contractor dataset, which we will call dataset C. The contractor firms consist of 2,248 firm-year observations from 714 unique firms.

We then generated a set of private sector control firms in several steps. Removing all government contractor firms from dataset A generated an initial set of 25,817 observations on firms with only private sector sales. We then used propensity score matching, described in greater detail in section 3.3, to reduce the set of control firms to 1,737 observations from 1,159 unique firms. These control firms are called dataset D. Our final sample combines contractor dataset C and private sector control firm dataset D.

Table 1 about here

3.2 Model specification

[9]We collected prime contract awards but not sub-contract awards to better answer how direct interactions between the firm and government impact firm-level innovation.

To test our first hypothesis that government contracts are unassociated with firm innovation, we begin with the model of Brown et al. (2009), who find that innovation (proxied using R&D) is a function of sales, cash, and prior investment in innovation. We also chose R&D as our measure of innovation and extend their model by separating total sales into government sales (*GovSales*) and non-government (or private sector) sales (*PrivSales*).[10] Brown et al's parsimonious model omits factors correlated with the firm's lifecyle stage and characteristics of the Federal procurement process, so we augment their empirical specification by adding controls for the firm's age, presence in a high tech industry, market valuation, and a series of year dummies (*Year*). As in Brown et. al, we log continuous variables to normalize the distribution, leading to our main model:

$$LogR\&D_{i,t} = \beta_0 + \beta_1\, Age_{i,t} + \beta_2\, HiTech_{i,t} + \beta_3\, LogMVE_{i,t} + \beta_4 LagLogR\&D_{i,t-1} + \beta_5 (LagLogR\&D_{i,t-1})^{\wedge}2 + \beta_6 LogCash_{i,t} + \beta_7 LagLogCash_{i,t-1} + \beta_8 LogGovSales_{i,t} + \beta_9 LagLogGovSales_{i,t-1} + \beta_{10} LogPrivSales_{i,t} + \beta_{11} LagLogPrivSales_{i,t-1} + \beta_{12} Year10 + \ldots + \beta_{18} Year16 + e_{i,t} \quad (1)$$

where *i* indicates the firm, *t* indicates the year, and *e* is a normally-distributed disturbance term with a mean of zero.

We include lagged R&D and contemporaneous and lagged sales and operating cash flows (scaled by size) because Brown et al. document that these variables predict current levels of innovation. We include a control for the firm's age (*Age*, measured as the number of years since the firm first appeared in Compustat) to capture the higher bargaining power and efficiencies of scale to investment enjoyed by older firms. We identify firms in high tech industries with a dummy variable because such firms are *ex ante* more likely to engage in innovation by nature of their operating environment (Slavtchev and Wiederhold 2016). We specify *HiTech* as being equal to one if the firm falls in high technology three-digit NAICS codes as specified by the Bureau of Labor Statistics (2016); zero otherwise. The firm's market value of equity, *MVE*,

[10] We chose R&D in lieu of patent information because we wished to measure the association between government contracts and *ex ante* innovation; patent activity captures the *ex post* success of innovation.

captures the firm's lifecycle stage and any associated competitive advantages or informational efficiencies. We measure the market value of equity as the number of common shares outstanding multiplied by price, all scaled by total assets. For contractors, *GovSales* is the firm's sales from usaspending.gov scaled by total sales from Compustat, while *PrivSales* is the difference between Compustat sales and *GovSales*, scaled by total sales. For non-contractors, we set *GovSales* equal to zero and equate *PrivSales* to total sales scaled by total assets. Finally, *Year* is a series of dummy variables intended to capture time variation that applies to all firms in a given year. Continuous variables are logged to normalize their distribtion, where the log transformation is (natural logarithm of one plus the variable), and we use robust standard errorss. Appendix A contains the definitions of all variables.[11]

3.3 Creation of control firms by propensity score matching.

If contractor and non-contractor firms systematically differ, this omitted variation may drive our empirical results. We used propensity score matching (PSM) to create an improved set of control observations that matches the contractor sample on observed and unobserved characteristics. PSM has a long history in accounting research and is appropriate when observations share predictable but unobservable group variation that may bias estimators if left untreated (e.g., Armstrong et al. 2010, Shimpman et al. 2017). We executed the PSM as follows.

We ran a year-by-year logistic regression of a contractor dummy on all of the control variables in equation (1), with the exception of *GovSales*, which we can only observe for contractors. We then used each year's fitted model to generate a propensity score for every firm-year observation. We matched each contractor observation with the control (non-contractor) observation with the closest propensity score using replacement. Our final sample consists of 2,248 contractor firm-year observations matched with 1,737 non-contractor firm-years.

As a check on the quality of the matching, we pooled all yearly data into one sample and re-ran the original logistic regression. Given the way the sample was constructed, this new

[11] An anonymous referee rightfully noted that doing business with a large, powerful government agency and working on development contracts share a strong theoretical link to contemporaneous firm innovation. Usaspending.gov reports both awarding agency and codes that allow researchers to identify development type contracts. Unfortunately, these are contract-level variables that exhibit no within variation in our firm-year level analyses. In lieu of controls for large agency and development contracts, we executed sensitivity analyses with firm fixed effects which, arguably, should capture both of these underlying constructs. These results are discussed in section 4.0.

logistic regression should have a poor fit. Table 2 presents the results. The low chi^2 probility (p=0.0446) indicates that we have a reasonable control sample.

Table 2 about here

4.0 Results

4.1 Testing hypotheses 1 and 2

Table 3 reports descriptive statistics for the contractor and non-contractor samples; all variables in Table 3 are unlogged to facilitate interpretation. Panel A compares the contractor and non-contractor firms, while Panel B reports on *GovSale*s for only the contractor firms. Both contractor and non-contractor firms display skewness in *R&D*, *Cash*, *MVE,* and sales values (*GovSales* and *PrivSales*). The skewness of key variables supports our decision to log continuous controls in our specification of model (1) to ensure that extreme observations are not contaminating our results and clouding our inferences.

Table 3 about here

To test our first hypothesis, we estimate the OLS regression specified in equation (1) for the full sample of 3,985 firm-years and report the results in Table 4 Panel A. The coefficients on *LogGovSales* and *LogPrivSales* are both positive and significant (coefficients=0.0747 and 0.1213, p-values=0.000 and 0.000, respectively), indicating that both government and private sales are associated with contemporaneously positive levels of R&D spending. Interestingly, the lags of both government and private sales (*LagLogGovSales* and *LagLogPrivSales)* are negative and significant (coefficients=-0.0836 and -0.1128, p-values=0.000 and 0.000, respectively), implying that last year's sales to both government and private customers are associated with lower investment in innovation in the current year. A one-percent increase in government sales in the full sample is associated with a 7.5% increase in R&D, rendering the impact of government contracting on innovation both positive and economically meaningful. Taken together, these results allow us to reject the null hypothesis that government contracts are unassociated with firm-specific innovation.

Other significant coefficients in Panel A of Table 4 include *HiTech* (coefficient=0.0073, p-value=0.025), *LagLogR&D* (coefficient=0.8314, p-value=0.000), *LogCash* (coefficient=-0.0865, p-value=0.000), and *LagLogCash* (coefficient=0.0485, p-value=0.000). The significance of these coefficients implies that being in a high-tech industry and high levels of prior R&D spending are positively associated with current innovation. Unsurprisingly, lagged cash levels (*LagLogCash*) are positively associated with subsequent R&D one year ahead; in contrast, current cash levels (*LogCash)* are negatively associated with the dependent variable.

After observing that government sales encourage innovation, we naturally wonder whether this effect differs from that of private sales. In other words, we surmise from Panel A of Table 4 that R&D increases significantly for every one percent increase in government contracts, but we do not know if the magnitude of the increase is different from a one percent increase in private sector sales.[12] To answer this query and provide evidence for our second hypothesis, we do an F-test for the primary regression (Table 4 Panel A) on the null hypothesis that *LogGovSales* = *LogPrivSales*; Panel B of Table 4 contains the results. As we can see, we can confidently reject the null hypothesis that government and private contracts have an equal impact on firm innovation (p = 0.0009). While a one percent increase in government sales is associated with a 7.5 percent increase in R&D, the same magnitude increase in private sales contemporaneously increases R&D spending by 12.1 percent. We interpret Panels A and B of Table 4 as providing evidence that contracting with the Federal government encourages firms to innovate by investing in R&D, but the extent to which government contracts incentivize this innovation is less than the incentives provided by private (non-government) contracts. The mechanism through which government contracts promote innovation remains an open empirical question; in section 5.0, we examine the cross-sectional variation in government and commercial R&D spending to help illuminate this issue. Before proceeding to these tests, let us discuss the robustness of the primary result reported in Table 4.

[12] Greene (2000) and Woolridge (2012) demonstrate that the estimated logarithmic coefficients are cross-elasticities.

Table 4 about here

4.2 Sensitivity tests

If contractors systematically differ from non-contractors on unobservable factors correlated with the propensity to innovate and the probability of receiving a government contract (such as the firm's bargaining power), it is possible that the results in Table 4 are driven by correlated omitted variables. To help mitigate this possibility, we estimate an extension of equation (1) that includes firm fixed effects. As we can see from the results reported in Table 5 Panel A, *LogGovSales* remains statiscally significant and shares the same directional association with the dependent variable as previously documented (coefficient=0.0766, p-value=0.000). *LogPrivSales* also remains positive and significant (coefficient=0.0963, p-value=0.000). Given that firm-level financial controls such as government sales are fixed within a given year, the inclusion of firm fixed effects likely absorbs some of the variation in which we are interested, particularly in *LogGovSales* and *LogPrivSales*. The strength of these coefficients in Table 5 Panel A likely represents a conservative estimate of the effect of government contracts on firms' innovation, providing greater comfort that our results reflect a real phenomenon and not an artifact of our particular sample or methodological choices.[13] In Panel B of Table 5, we again estimate an F-test of joint equality on *LogGovSales* and *LogPrivSales*. Unlike in Table 4, we are unable to reject the null hypothesis when our model includes firm fixed effects. The inability to reject the null in Table 5 Panel B may arise from the firm fixed effects absorbing variation of interest, but we cannot make a definitive statement.

Table 5 about here

In addition to correlated omitted variables, it is possible that lagged values of the covariates specified in equation (1) are correlated with the error term. If strict exogeneity is violated, then the estimators reported in Table 4 may be biased.[14] To mitigate this concern, we employed Arellano

[13] For parsimony, we omit discussion of controls variables in sensitivity analyses.
[14] We thank an anonymous referee for bringing this point to our attention.

Bond estimators; Arellano Bond estimators are a GMM estimator that is appropriate when lagged covariates are plausibly correlated with the error term in dynamic panel data. Rather than taking a simple first-difference, the Arellano Bond estimator combines both differences and levels to restore the assumption of strict exogeneity. To implement the Arellano Bond estimators, we took the first-difference of equation (1) to eliminate individual effects then used three lags of *LogR&D* to instrument for differenced lags of the potentially endodenous dependent variable.[15] The results of the Arellano Bond estimator are reported in Table 6 Panel A. The coefficients on *LogGovSales* and *LogPrivSales* remain positive and significant (coefficients=0.1086 and 0.1215, p-values=0.000 and 0.000, respectively), giving some comfort that endogeneity does not explain the previously documented positive association between government contracting and firm-specific innovation. Similar to Table 5 Panel B, we are unable to reject the null hypothesis of the equivalence of *LogGovSales* and *LogPrivSales* with respect to *LogR&D* in Table 6 Panel B.

Table 6 about here

5.0 Measuring the Intensity of Government Relative to Private-Sector R&D

Do certain firms innovate more on their government relative to private-sector contracts? Does the intensity of government relative to private R&D correspond with the uniqueness of the firm's products? That is to say, do firms that produce fighter jets innovate more than firms that supply cans of soda? To answer these questions, we use equation (1) to create an empirical measure of predicted R&D on government contracts, scaled by predicted R&D on non-government contracts. Of course, this measure applies only to firms with both government and commercial business.

To begin, we use the estimated coefficients on *LogGovSales* and *LagLogGovSales* [β_8 and β_{9}) from equation (1)] to generate a forecast of the firm's investment in R&D for its next dollar of government contracts (which we call *ForGovR&D).* Because government sales are

[15] Our STATA estimation also used three lags for all control variables except *LogR&D^2*, for which we used two lags.

volatile, we estimate *ForGovR&D* for every firm-year in our contractor sample and take the *average value* over the sample period to generate one fitted value per firm.

$$ForGovR\&D_{i,t} = \beta_8 LogGovSales_{i,t} + \beta_9 LagLogGovSales_{i,t-1} \quad (2)$$

Similarly, we use the estimated betas from the coefficients for private sector sales and generate a forecast of incremental R&D on the firm's private contracts (*ForPrivR&D)*.

$$ForPrivR\&D_{i,t} = \beta_{10} LogPrivSales_{i,t} + \beta_{11} LagLogPrivSalesi_{,t-1} \quad (3)$$

Dividing the firm-specific result of equation (2) by equation (3) generates a measure of R&D intensity of government contracts relative to private sales. A high value of (2)/(3) indicates the firm innovates more on its government contracts relative to private sales; a low ratio suggests the opposite. We use our measure of R&D intensity to rank firms *and* industries on government relative to commercial innovation and believe the measure has potential for subsequent studies.

After calculating R&D intensity for all the firms in the contractor sample, we sort firms into the highest and lowest ratios. Table 7 Panel A (Panel B) contains the ratio and NAICS three-digit industry for the ten firms with the most (least) innovation on government relative to private contracts. We also report the product the firm provides to the government on its largest contract (taken from usaspending.gov). We expect R&D intensity to be high for firms who provide scarce products to the government and low for firms that provide commodities. For example, Raytheon and Lockheed Martin (in the top ten firms) provide air missile and defense systems and R&D, while Sentry Technology (Panel B, bottom ten firms) provides painting. Presumably, producers of missiles and defense systems innovate more than contractors who paint the government's buildings, so Panels A and B support our new measure's validity.

To further validate our meaure, we expand our analysis to sub-industries. Specifically, we calculate R&D intensity for three-digit NAICS containing at least ten firms and average each constituent firm's measure of R&D on government relative to private contracts to obtain an industry average. We report this analysis in Panel C of Table 7. For each sub-industry, we randomly select one firm and collect the representative government product from the firm's largest government contract on usaspending.gov. As we intuitively expect, industries with high R&D intensity produce products like avionics (NAICS 334) and low-ratio industries purvey less customizable goods such as lodging (531). Imagine our surprise to observe that NAICS 336 (Transportation Equipment Manufacturing) ranks relatively low in R&D intensity. Representative products in this industry include aircraft. Evaluating the optimal level of innovation required in aircraft relative to consulting services is beyond the scope of this paper, but we sincerely hope suppliers in this industry apply whatever innovation they possess to commercial airliners.

Table 7 about here

6.0 Conclusion

In 2016, U.S. Federal government contracts totaled $460 billion or about two percent of gross domestic product. The government is uniquely powerful in its ability to extract concessions from and enforce punishments against firms with whom it conducts business. When Uncle Sam goes shopping, he enjoys virtually limitless bargaining power. Despite the enormity of government spending and the fathomless depths of Federal power over suppliers, we know surprisingly little about how government acquisitions affect private-sector partner behavior, including innovation. As the American economy increasingly rewards innovative firms, firms face ever-mounting pressures to invest in future growth through strategic research and development. Our paper adds to a growing body of literature on the association between Federal acquisitions via contracting and firms' investment in innovation.

Using a sample comprised of both contractor and non-contractor firms, we analyze whether firms' R&D expenditures vary with the extent of sales to the government. We find that government sales positively predict firm-level R&D; this result is robust to sensitivity analyses including firm fixed effects and Arellano Bond estimation. However, the effect of government relative to private contracts on R&D is sensitive to the empirical specification, so we are unable to draw inferences regarding whether the demand on government contracts differs from that on non-government, private contracts. Additionally, we develop a novel measure of R&D intensity that allows us to rank individual contractors and entire industries on the relative importance of public and private sector innovation. This measure is simple to calculate and displays construct validity. We hope fellow researchers find it useful.

Why do government sales share a positive association with investment in R&D? Is this effect more pronounced in certain firms? Are there circumstances under which government and private sales *do* differ in their impact on firm innovation? These queries represent a natural extension of our results and would shed much-needed light on the relatively underexplored impact of acquisitions on our country's collective innovativness.

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Appendix A. Variable Definitions

Variable	Definition (source in parentheses)
Year	A series of dummy variables for year; 2009 excluded (Compustat)
Age	The number of years since firm *i* first appeared in Compustat as of year *t* (Compustat)
HiTech	A dummy equal to one if the contractor is in a high technology industry; zero otherwise (Bureau of Labor Statistics 2016)
MVE	The firm's total shares outstanding multiplied by closing price per share, scaled by total assets (Compustat: prcc_f*csho/at)
R&D	Research and development expense for firm *i* in year *t* scaled by total assets (Compustat: xrd/at)
LagR&D	Research and development expense for firm *i* in year *t-1,* scaled by total assets (Compustat)
LagR&D^2	Squared research and development expense for firm *i* in year *t-1*, scaled by total assets (Compustat)
Cash	Operating cash flows for firm *i* in year *t*, scaled by total assets (Compustat: oancf/at)
LagCash	Operating cash flows for firm *i* in year *t-1*, scaled by total assets (Compustat)
GovSales	Total sales to the federal government for firm *i* in year *t* scaled by total sales (usaspending.gov and Compustat: government sales/sales)
LagGovSales	Total sales to the federal government for firm *i* in year *t-1* scaled by total sales (usaspending.gov and Compustat)
PrivSales	For non-contractors, total sales for firm *i* in year *t-1* scaled by total assets (Compustat: sales/at). For government contractors, total sales for firm *i* in year *t* less government sales, scaled by total sales (usaspending.gov and Compustat: (sales-govsales)/sales))
LagPrivSales	For non-contractors, total sales for firm *i* in year *t-1* scaled by total assets. For government contractors, total sales for firm *i* in year *t-1* less government sales, scaled by total sales (usaspending.gov and Compustat)
Log	The natural logarithm of (variable plus one).

Table 1. The Sample
Panel A. Sample Creation

A. Compustat information for both contractor and private firms

	Observations
Compustat annual file	83,329
Less missing controls	
Less missing lags	
Total Observations	28,065
B. Usaspending.gov contractor information	
usaspending.gov	40,000,000*
Less missing controls	
Combined into firm-years	
Number of observations	3,000,000*

*Contract data files are large. * indicates an approximation.

C. Contractor firms, intersection of A. and B.	
Number of Observations	2,248 / 714 unique firms
D. Non-contractor control firms, A. minus C.	
Initial Set	25,817
After Propensity Score Matching	1,737 / 1,159 unique firms.

Panel B. Observations by year

Year	Contractors	Non-Contractors	Total
2009	492	277	769
2010	474	373	847
2011	221	187	408
2012	225	187	412
2013	220	188	408
2014	215	185	400
2015	221	182	403
2016	180	158	338
Total	2,248	1,737	3,985
	714 firms	1,159 firms	

Table 2. Logit Regression on Government Contractor Dummy after Propensity Score Matching (n = 3,985)

Variable	**Coefficient (p-value)**
Constant	1.3168** (0.042)
Age	1.0029 (0.203)
HiTech	0.9554 (0.562)
LogMVE	0.9121 (0.193)
LagLogR&D	1.7436 (0.339)
LagLogR&D^2	1.0453* (0.072)
LogCash	1.2022 (0.418)
LagLogCash	0.5990* (0.077)
LogPrivSales	0.8056 (0.443)
LagLogPrivSales	1.1095 (0.717)
Pseudo R^2	0.0036
Prob > Chi2	0.0466

Table 3. Descriptive Statistics
Panel A. Contractors (n=2,248 firm-years) and non-contractors (n=1,737)

Variable		*Mean*	*Std. Dev*	*Min*	*25%*	*50%*	*75%*	*Max*
Age								
	Contractor	28.314	15.462	3	16	24	45	55
	Non-Contractor	27.685	15.344	2	15	24	42	55
HiTech								
	Contractor	0.7482	0.4341	0	0	1	1	1
	Non-Contractor	0.7478	0.4344	0	0	1	1	1
MVE								
	Contractor	1.6161	1.5942	0.0015	0.7165	1.1911	1.9911	25.387
	Non-Contractor	4.9460	105.83	0.0058	0.7080	1.1493	1.9294	4347.6
R&D								
	Contractor	0.0713	0.0928	0	0.0175	0.0451	0.0931	0.8921
	Non-Contractor	0.0683	0.1117	0	0.0087	0.0323	0.0937	2.0331
LagR&D								
	Contractor	0.0713	0.0928	0	0.0175	0.0451	0.0932	0.8921
	Non-Contractor	0.0681	0.1114	0	0.0086	0.0322	0.0937	2.0331
LagR&D^2								
	Contractor	0.0007	0.0062	0	4.1E-8	1.5E-6	2.4E-5	0.1913
	Non-Contractor	0.0076	0.1786	0	1.4E-8	4.9E-7	1.9E-4	6.9000
Cash								
	Contractor	0.0648	0.1432	-0.9610	0.0409	0.0876	0.1304	0.8500
	Non-Contractor	0.0719	0.1591	-0.9377	0.0383	0.0903	0.1369	0.3257
LagCash								
	Contractor	0.0649	0.1431	-0.9610	0.0409	0.0876	0.1304	0.8500
	Non-Contractor	0.0723	0.1586	-0.9377	0.0383	0.0904	0.1370	1.7500
PrivSales								
	Contractor	0.8832	0.5540	0.0025	0.5444	0.7590	1.0718	5.3100
	Non-Contractor	0.9402	0.7229	0	0.5276	0.7894	1.1822	9.4508
LagPrivSales								
	Contractor	67.456	1271.9	1.1E-6	0.4461	0.7317	1.2726	50689
	Non-Contractor	0.9407	0.7228	0	0.5283	0.7896	1.1833	9.4508

Table 3. Continued
Panel B. Contractors only (n=2,248)

Variable	*Mean*	*Std. Dev*	*Min*	*25%*	*50%*	*75%*	*Max*
GovSales	0.0390	0.1378	0	0.0002	0.0024	0.0137	2.2639
LagGovSales	1.5158	49.936	0	0.0002	0.0023	0.0155	2319.3

Table 4. Panel A. OLS Regression of Logged R&D on Logged Government Sales and Controls (n = 3,985)

Variable	Coefficient (p-value)
Constant	0.0059 (0.190)
Age	-0.0002 (0.132)
HiTech	0.0073** (0.025)
LogMVE	-0.0005 (0.933)
LagLogR&D	0.8314*** (0.000)
LagLogR&D^2	0.0024 (0.205)
LogCash	-0.0865*** (0.000)
LagLogCash	0.0485*** (0.000)
LogGovSales	0.0747*** (0.000)
LagLogGovSales	-0.0836*** (0.000)
LogPrivSales	0.1213*** (0.000)
LagLogPrivSales	-0.1128*** (0.000)
Adjusted R^2	0.8336

*Year dummy coefficients not reported; ***/**/* indicates statistical significance at <0.001, 0.05, and 0.10, respectively. Standard errors are robust. Variables are defined in Appendix A.*

Table 4. Panel B. F-Test of Joint Equality of Coefficients on *LogGovSales* and *LogPrivSales* with Respect to *LogR&D*

F(1, 3966)	11.00
Prob > F	0.0009

Table 5. Panel A. OLS Regression of Logged R&D on Logged Government Sales and Controls with Firm Fixed Effects (n = 3,190)

Variable	Coefficient (p-value)
Constant	-0.0014 (0.876)
Age	-0.0065*** (0.000)
HiTech	-0.0022 (0.794)
LogMVE	0.0132*** (0.001)
LagLogR&D	0.3080*** (0.000)
LagLogR&D^2	0.0143*** (0.001)
LogCash	-0.0828*** (0.000)
LagLogCash	-0.0038 (0.799)
LogGovSales	0.0766*** (0.000)
LagLogGovSales	-0.0114 (0.356)
LogPrivSales	0.0963*** (0.000)
LagLogPrivSales	-0.0285*** (0.006)
Adjusted R^2	0.9467

*Year dummy coefficients not reported; ***/**/* indicates statistical significance at <0.001, 0.05, and 0.10, respectively. Standard errors are robust. Variables are defined in Appendix A*

Table 5. Panel B. F-Test of Joint Equality of Coefficients on *LogGovSales* and *LogPrivSales* with Respect to *LogR&D*

F(1, 2282)	1.88
Prob > F	0.1699

Table 6. Panel A. Arellano Bond Regression of Logged R&D on Logged Government Sales and Controls, Three Lags, No Constant (n = 565)

Variable	**Coefficient (p-value)**
LogMVE	0.0044 (0.359)
LagLogR&D	0.2923 (0.146)
LagLogR&D^2	-0.0108 (0.142)
LogCash	-0.0802*** (0.000)
LagLogCash	-0.0264 (0.168)
LogGovSales	0.1086*** (0.000)
LagLogGovSales	-0.0131 (0.441)
LogPrivSales	0.1215*** (0.000)
LagLogPrivSales	-0.0043 (0.835)
Wald Chi2(27)	127.22
Prob > chi2	0.0000

*Group variable is firm ID (GVKEY); time variable is fiscal year. ***/**/* indicates statistical significance at <0.001, 0.05, and 0.10, respectively. Robust standard errors are used. Variables are defined in Appendix A.*

Table 6. Continued

Panel B. F-Test of Joint Equality of Coefficients on *LogGovSales* and *LogPrivSales* with Respect to *LogR&D*

Chi2(1)	1.82
Prob > chi2	0.1769

Table 7. Ratio of Forecast Government R&D to Forecast Private-Sector R&D
Panel A. Ratio of Forecast Government R&D to Forecast Private-Sector R&D for the Top Ten Contractors

Company Name	Three-Digit NAICS	Ratio of Forecast Government R&D to Forecast Private-Sector R&D	Representative Government Product
Raytheon	334	223.27	Air and Missile Defense Systems
Lockheed Martin	336	5.9533	Defense R&D
Optical Cable Corp	335	5.2355	Optical Wire Manufacturing
Quantum Corp	334	4.5361	Defense R&D
American Biomedical Corp	325	3.8818	Surgical Appliances
Cubic Corp	333	3.0873	General R&D
MCS Industrial	423	2.6557	HVAC Design
Theragenics Corp	339	2.0329	Medical Instruments
Textron Inc	336	1.6928	Shipbuilding
Ophthalmic Imaging	339	1.4980	Defense R&D

Table 7. Panel B. Ratio of Forecast Government R&D to Forecast Private-Sector R&D for the Bottom Ten Contractors

Company Name	Three-Digit NAICS	Ratio of Forecast Government R&D to Forecast Private-Sector R&D	Representative Government Product
Liberty Property Trust	531	-44.911	Lease Management
Fresenius Medical Care	621	-14.200	Kidney Dialysis
General Dynamics	336	-9.1192	Engineering Services
Electromed	334	-8.2084	Surgical Supplies
NVE	334	-7.8647	Security Guards
Law Enforcement Associates	334	-6.7812	Equipment Repair
Unisys	541	-5.9371	Computer System Design
Aware	511	-5.1905	Software Publishing
Axion	335	-4.1335	Plate Work
Sentry Technology	334	-4.0549	Painting

Table 7. Panel C. Representative Sub-Industry Descriptions, Products, and Average Ratio of Forecast Government R&D to Forecast Private-Sector R&D for Sub-Industries with at Least Ten Firms

Three-Digit NAICS	Sub-Industry Description	Number of Firms in Sub-Industry	Ratio of Forecast Government R&D to Forecast Private-Sector R&D	Representative Government Product
334	Computer and Electronic Product Manufacturing	166	1.2271	Avionics
423	Merchant Wholesalers, Durable Goods	13	0.2416	Motor Vehicle Parts
339	Miscellaneous Manufacturing	43	0.2398	Medical Machines
335	Electrical Equipment, Appliance, and Component Manufacturing	25	0.0942	Power Distribution Manufacturing
333	Machinery Manufacturing	54	0.0668	Rough Terrain Forklifts
325	Chemical Manufacturing	74	0.0366	Alternative Fuels
541	Professional, Scientific, and Technical Services	29	-0.0346	Consulting
519	Other Information Services	13	-0.0804	Television Programming
336	Transportation Equipment Manufacturing	27	-0.1580	Aircraft, Tanks
511	Publishing Industries (except Internet)	51	-0.1592	Database Access
517	Telecommunications	11	-0.1749	Satellite Communications
621	Ambulatory Health Care Services	13	-1.1904	Ambulance Services
531	Real Estate	24	-1.9791	Lodging