The Impact of Federal R&D Contracts on Firms' R&D Productivity

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The U.S. government is the world's largest customer, including the world's largest "purchaser" of R&D. While initially the bulk of federal R&D represented industrial contracts, federally-funded R&D to industry has declined 88% (as share of GDP) since its 1960s peak. We examine the impact of this decline on R&D productivity. To do so, we compare firms post federal R&D contract to "commercial only" firms. We find a positive treatment effect of federal R&D contracts on firms' R&D productivity which increases with the duration of federal contracting, but not its scale. Because federal R&D contracts both increase firms' R&D productivity and with it, their optimal level of investment, we estimate that growth from R&D would have been 20% higher per year if the government had maintained R&D contracting at mid-1960s levels.

Keywords: Federal contractors, U.S. government, R&D, innovation, R&D productivity

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I. Introduction

The U.S. government is the world's largest customer, with forecasted procurement of $762 billion in 2024[1]. Its purchases cross almost every industry, from advanced weapons systems, to cloud based software, to lawn maintenance. One of the things it purchases is R&D. In the U.S., R&D represents 1.8% of the federal budget, which corresponds to 0.7% of GDP.

Federal R&D is disbursed in two forms: grants, the most common form for funding university R&D, and procurement contracts, the most common form for funding industrial R&D.[2] Both contracts and grants are typically awarded competitively. The functional distinction is that grants are an assistance mechanism used when the government wants to support a public purpose. In contrast, contracts are the procurement mechanism the government uses when it wants to obtain goods or services.

Interestingly, while historically the majority of federal R&D comprised procurement contracts to firms, the vast majority of academic research on federal R&D examines grants to universities. In EconLit the ratio is 10:1 (558/56), and in Business Scource Complete it is even more pronounced at 44:1 (25372/580). This is unfortunate, because the proportion of federal R&D to universities versus industries has shifted dramatically (Figure 1). While in 1960, 70% of federal R&D went to firms, versus 5.7% to universities (12:1), as of 2018, the ratio had reversed. Firms now obtain 22.1% of federal R&D, while universities receive 35.1% (0.63:1).

[1] https://federalnewsnetwork.com/contracting/2023/11/contract-spending-is-set-to-grow-across-the-board-in-2024/

[2] There is a third funding vehicle, cooperative agreements, which are a hybrid. Like grants they are to achieve a goal rather than to procure a good or service, but like contracts they include substantial involvement between the government and the recipient.

Without greater research on federal R&D contracts to firms, we can't say much about whether this shift is good or bad.

[Insert Figure 1 Here]

A number of factors fueled the decline in federal R&D to firms, though the precipitating event was the end of the Cold War, with the fall of the Berlin Wall in November 1989, which reduced defense spending 50% (from 6% of GDP in 1986 to 3% in 1998)[3]. In an effort to make more effective use of the lower funds, then DoD Secretary, William Perry initiated two efforts: 1) industry consolidation: requesting defense contractors to consolidate to save overhead costs (which reduced the number of prime contractors from approximately 25 to 4) (Mintz 1997), and 2) advocating increased use of commercial technology (Perry 1994). This latter effort was embodied in the Federal Acquisition Streamlining Act of 1994, which shifted procurement towards "off-the shelf" products and services to take advantage of the competition and market forces and pricing.

While initially a solution to a DoD funding shock, this shift has been perpetuated by arguments that "commercial firms" are more innovative, so rather than fund R&D, the government should buy technology off the shelf (Gansler 2011, Srinivasta 2019, Fischetti 2020). As a consequence of Perry's efforts and more recent sentiment, federal R&D funding to firms has decreased more dramatically and over a longer period of time than the decrease in DoD funding.[4] This decline

[3] https://www.whitehouse.gov/omb/information-resources/budget/historical-tables/

[4] DoD funding decreased from 0.61% of GDP in 1987 to 0.11% in 2018.

is potentially important because it coincides with a similar decline in U.S. industrial R&D productivity, and accordingly GDP growth (Figure 2). Thus the decline in federally-funded R&D to industry may contributed to the decline. For that to be the case however, federal R&D contracts must increase the productivity of firms' R&D. Accordingly, we examine the impact of federal R&D contracts on firms' R&D productivity.

[Insert Figure 2 Here]

As mentioned previously, little research has examined federal R&D to firms. There are some exceptions however. One of the earliest is Levy and Terleckyj (1983) which examined both the stimulus and productivity effects of federal R&D contracts. The stimulus effect refers to government contracts causing firms to increase their investments in R&D; the productivity effect refers to government contracts causing firms to become more productive with their R&D. Using aggregate data for the U.S., the authors found that each dollar of federal R&D contracted to industry stimulated twenty-seven cents of private R&D investment. By contrast, they found that federal R&D funding to universities and private labs had a negative but non-significant impact on private investment.

The stimulus finding was reinforced by Lichtenberg (1988), and more recently using firm-level data by Pallante, Russo and Roventini (2023), Moretti, Steinwender, & Van Reenen (2021) and Belenzon and Cioaca (2023). These more recent studies find the stimulus effect of federal contracts to be twice the Levy and Terleckyj estimate.

Regarding the productivity effects, Levy and Terleckyj found that federal R&D contracted to industry increased labor productivity, while federal R&D to universities and labs decreased labor productivity. While Levy and Terleckyj's finding of enhanced labor productivity suggests that federal R&D enhances R&D productivity, Griliches (1986) examined R&D productivity directly. He used panel data to estimate firms' production function treating federal R&D and own R&D as separate inputs. He concluded that the productivity of federal R&D was a small fraction of that for firms' own internal R&D. However, Griliches' data was cross-sectional, and pre-dated the decline in federal R&D contracts to firms. Accordingly, it may have captured a period when the federal government was overinvesting in industrial R&D.

Accordingly, we examine the productivity effects of federal R&D with panel data over a more recent period. To conduct our test, we compare the R&D productivity of federal R&D contractors (publicly-traded firms who receive at least one R&D contract during our observation window) to that of commercial firms (publicly-traded firms who receive no federal R&D contracts within that window). Using a dynamic difference in differences (DiD) estimation relative to the time of first federal R&D contract, we find that federal R&D contracts have a significant positive treatment effect on firms' R&D productivity, which increases over time but not with the scale of federal R&D.

We then explore why federal R&D contracts might increase R&D productivity. One possible explanation is artifactual: the government issues R&D contracts to firms from whom it expects to procure the ultimate good/service. Given that, increases in R&D are structurally linked to later increases in procurement revenue. We test the extent to which this structural R&D-procurement link explains the higher R&D productivity of federal R&D contractors by exploiting a shock to federal funding—the Budget Control Act of 2011 (BCA), also known as sequestration, which dramatically decreased federal spending. If the structural link explains the higher productivity of federal contractors, their R&D productivity should decrease following BCA, because firms become less likely to receive procurement contracts. We find instead that firms' productivity increases following BCA. Thus, it doesn't appear the higher R&D productivity of federal contractors is artifactual.

Given that the treatment effect of federal contracts appears to be non-artifactual, we next explore substantive mechanisms through which federal R&D contracts might increase firms' R&D productivity. We consider two dimensions of a firm's innovation, its expansiveness and its impact. We find that federal R&D causes firms innovation to be more expansive (diverging more from prior innovation), but it appears to have no significant impact on its impact (patent citations)

Digging deeper into the expansiveness effect, we examine one potential mechanism through which federal contracts might make firms' R&D more expansive—more direct access to university research that precedes and/or enables the technology underpinning firms' R&D contracts. We find no evidence consistent with that. Federal contractors and commercial firms are equally likely to cite university patents.

Given that links to university research failed to explain greater expansiveness of innovation in firms with federal R&D contracts, and that we could find no other public data that might explain it, we interviewed an R&D manager, with experience on both sides of federal R&D contracts. He indicated that the government only funds R&D programs to solve problems for which no solution exists, or for which existing solutions are no longer sufficient. This helps to explain why firms' R&D trajectory would tend to diverge following a federal R&D contract. As to why that divergence would lead to higher R&D productivity, he pointed out that while R&D contracts are initially funded for purposes of solving government problems, often the new technology leads to commercial products, so called "dual-use" technologies.

Taken together our results indicate that federal R&D contracts increase firms' R&D productivity. The higher productivity cannot be explained by the fact these contracts are pre-cursors to subsequent procurement contracts. Rather it appears that federal R&D contracts enhance the character of firms' R&D, by taking it in new directions.

These results have implications for theory as well as practice. For theory, our results help to explain prior empirics showing that firms increase internal R&D when they recieve federal R&D contracts (the stimulus effect of federal R&D). Prior authors argue the increased R&D stems from firms' efforts to ensure future procurement contracts. We offer an additional explanation—that federal R&D contracts increase the productivity of firms' R&D, which increases their optimal investment level. Thus, our results with firm-level data over a more recent period and with micro-level data reaffirm Levy and Terleckyj (1983) results: federal R&D contracts both increase R&D productivity.

This result in turn has implications for policy—allowing us to estimate the impact of the decline in federal R&D contracts to firms. Back of the envelope analysis of the likely growth that would have occurred had the U.S. maintained funding of federal R&D to industry at its early 1960s level of 1% of GDP indicates that aggregate growth from R&D might have been 20% higher per year over the past decade (Appendix A).

The paper proceeds as follows. We first describe our empirical approach. Next we present our results. Finally we discuss implications.

II. Empirical Approach

We test the impact of federal R&D contracts on firm innovation, by comparing the R&D productivity of federal R&D contractors with that of commercial firms. We define firms as being federal contractors if they receive at least one federal R&D contract during our observation window (2001 to 2021), and define commercial firms as ones without any federal R&D contracts during that window.

We begin by modeling R&D productivity of firm *i* in year *t*, as a function of whether the firm had begun receiving federal R&D contracts ($post\ contract_{it}$), while controlling for firm fixed effects (η_i) and year effects (λ_t). To do so, we drop firms who were federal R&D contractors in our first observation year (2001).

$$R\&D\ productivity_{it} = \beta_1 (post\ contract)_{it} + \eta_i + \lambda_t + \varepsilon_{it} \qquad (1)$$

One concern with estimating Equation 2 is endogeneity in federal agencies' choice of firms to grant R&D contracts. The concern is that firm characteristics might jointly cause federal agencies to choose particular firms, and for those firms to become more productive. We deal with this through dynamic difference in differences (DiD) (event study) estimation of the federal contract treatment.

Our dynamic DiD estimation models R&D productivity of firm *i* in year *t*, relative to the year of first federal R&D contract. The need for dynamic DiD stems from the fact that a) our data have staggered adoption times, and b) firms may differ in their treatment effects. These conditions (staggered timing and heterogeneous treatment effects) have been shown to produce unreliable estimates in pooled DiD, because later-treated (and earlier-treated) units effectively serve as comparison units (Baker, Larker and Wang 2022). By carrying all years for the treated firms in a single equation, the dynamic DiD prevents treated firms from serving as comparison units. We employ the augmented inverse-probability weighting (AIPW) estimator, outlined in Callaway and Sant'Anna (2021) to estimate the average treatment effects on the treated (ATETs), while using the set of commercial firms and not-yet-treated firms as the control group. The AIPW estimator fits a model for the outcome as well as the treatment, which allows one of the models (outcome or treatment) to be misspecified and still get consistent estimates, a property called double robustness.

Variables

Our measure of R&D productivity is based on the total stock market value of a firm's R&D (*tsm*) (Kogan, Papanikolaou, Seru, and Stoffman 2017). *Tsm* is the sum of the stock market responses to announcements of the firm's patent grants in a given year. To convert *tsm* to a productivity measure, we divide *tsm* in year t by lagged total R&D (own R&D plus federal R&D contracts in year t-1) to form *tsm intensity*. *Tsm intensity* therefore captures the increase in firm value from a firm's patent grants per dollar of prior year R&D.

. We utilize two independent variables, *federal contractor*, and *post contract*. *Federal contractor* is a dummy variable, which takes on the value 1 if a firm has any federal R&D contract during our observation window (2001-2021), and is 0 otherwise. *Post contract* is a dummy variable, which takes on the value 1 for all years after a firm receives its first federal R&D contract, including the first contract year. In DiD estimation, we delete observations where the firm had a federal contract in 2001, since we aren't able to observe the treatment for those firms.

In subsequent analyses that examine how federal contracts might affect the character and conduct of firms' R&D, we utilize four additional variables. The first variable, *federal R&D intensity*, is the share of a firm's R&D funded by federal contracts. It is computed as federal R&D contracts in year t divided by *total R&D* in the same year (the sum of R&D contracts plus interal R&D). The second variable, *trajectory distance*, is the cosine distance in a firm's patent vector from one year to the next, where the vector in each year is formed by aggregating the technology classifications of the firm's patents filed in that year (Kluppel and Cummings 2019). The measure is intended to capture widening or narrowing of research over time. Finally we measure the number of *patents* filed by the firm in a given year (and ultimately granted), and the number of *citations* to patents received by the firm in a given year. *Patents* captures the extent to which the firm creates innovations it wants to protect through intellectual property; *citations* capture the extent to which those patents spawn additional innovation, and are therefore more impactful.

Data

Our data comprise all publicly traded U.S. firms who conduct R&D and have at least one patent during our 20-year observation window (2001-2020). While the number of publicly traded firms is small relative to the population of all U.S. firms, they capture almost the entirety of U.S. industrial R&D. In 2021 for example, publicly-traded firms comprised 98.6% of industrial R&D ($593.8 billion of $602.5 billion total).

Data for the study come from three sources. The data on firms' federal R&D contracts comes from the USAspending.gov website.[5] Data for *tsm intensity* and the patent variables come from the extended patent database for Kogan et al (2017).[6] Finally, data on firms' trajectory distance (Kluppel and Cummings, 2019) come from the authors.

Table 1 presents summary statistics for the entire sample period, as well as for the 2010 cross section, decomposed by federal R&D contractors and commercial firms. The table reveals that approximately 6.6% of public firms who conducted R&D in 2010 received federal R&D contracts during the twenty-one year window 2001-2021. These federal R&D contractors tend to be larger (Revenues of $4.6

[5] In response to the Federal Funding Accountability and Transparency Act of 2006, the publicly accessible website USASpending.gov discloses details on federal contracts of more than $3,000 beginning with fiscal year 2001.

[6] https://github.com/KPSS2017/Technological-Innovation-Resource-Allocation-and-Growth-Extended-Data

billion vs $1.0 billion), and slightly more R&D intensive than commercial firms (internal R&D represents 3.5% of revenues versus 3.2%). Commerical firms are more likely to file patents for their innovation (0.54 patents per million dollars of R&D versus 0.40 for federal contractors, and their patents are slightly more likely to receive citations (7.2 citations per patent versus 6.5).

[Insert Table 1 Here]

III. Results

We begin by reviewing results for estimating Equation 2. These results, which capture the impact of federal R&D contracts on firms' R&D productivity, are presented in Table 2. Model 2 is the fully specified fixed effects model. However, we first present OLS results to provide additional insight. Model 1 is an OLS regression with year effects that decomposes the selection (*federal R&D contractor*) and treatment (*post first contract*) effects of federal R&D contracts. The coefficient estimates suggest that federal R&D contractors are not significantly different from commercial firms, absent federal contracts, but that federal R&D contracts increase firms' market value per dollar of R&D on average $560 thousand per year, though the effect is only mildly significant.

[Insert Table 2 Here]

Model 2 is equivalent to Model 1, though in a fixed effects specification. As such, the selection effect (*federal R&D contractor*) is subsumed by the firm fixed effects. Again, the *post first contract* treatment effect is positive, though only mildly significant. The coefficient magnitudes indicate that firms increase the market value per dollar of total R&D by approximately $760 thousand dollars per year. Thus federal contracts appear to make firms more productive with their R&D. This is in addition to the fact that federal R&D contracts are also increasing a firm's total R&D by the amount of the contracts. We withhold discussion of Model 3 until the mechanisms discussion.

Equation 2 ignores issues of endogeneity. To address endogeneity issues, we employ dynamic DiD estimation, where we model R&D productivity of firm *i* in year *t*, relative to the year of first federal R&D contract. Results for this strategy are presented in Figure 3. The figure indicates that the treatment effect of federal R&D contracts begins in year 1 and increases through year 15 of federal R&D contracting, where *tsm intensity* reaches a peak of 5.4 dollars of firm martket value per dollar of total R&D. Thus the coefficient estimate for *post contract* of 0.76 (Table 2, Model 2) represents the mean *tsm intensity* over the years in which firms in our sample receive federal contracts.

[Insert Figure 3 Here]

One important question with regard to the DiD estimates is whether the treatment effects for both the treatment and control groups are zero prior to treatment (the parallel trends assumption). Figure 3 suggests that the parallel trend assumption is supported, since the mean ATET for years prior to treatment year is not significantly different from zero (mean = -0.21 (0.62)).

If federal contracts themselves are more productive, then the impact of federal contracts on firms' R&D productivity should increase in *federal R&D intensity* (federal R&D/total R&D). Thus as a supplemental test, we estimate a version of

Equation 2 which models R&D productivity as a function of *federal R&D intensity*. Again, we include firm fixed effects and year effects.

$$R\&D\ productivity_{it} = \beta_1(federal\ R\&D\ intensity)_{it} + \eta_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Results from that exercise, shown in Table 3 (Model 3) indicate that R&D productivity decreases with the federal share of a firm's total R&D. This suggests that having federal R&D contracts is beneficial in a way that is negatively affected by scale.

Mechanisms

The set of results indicates that federal contracts increase the productivity of firms' R&D. The question is how? One explanation is mechanical or artifactual—the government funds R&D for products and services it ultimately intends to procure. We examine the extent to which this link explains the higher R&D productivity of federal contractors by exploiting an external shock to funding, the Budget Control Act of 2011 (BCA), also known as sequestration. Faced with a debt ceiling, Congress enacted the BCA to reduce federal spending by more than $1 trillion dollars over the subsequent 10 years. The bill came into effect in FY 2013 (March 2013) and immediately reduced federal outlays by nearly $90 billion. The logic of this identification strategy is that sequestration made it less likely that firms with federal R&D would obtain follow-on procurement contracts. Accordingly, if the the structural link between R&D and subsequent procurement explains the higher productivity of federal contractors, then R&D productivity should decline post BCA, as the subsequent contracts become less likely.

We first check whether and how BCA affected federal contracts. Figure 4a indicates that the most dramatic impact of BCA was a 45% decrease in the share of firms with federal R&D contracts (from 22% to 12%). Interestingly, the number of contracts and the dollar value of contracts remain constant (through 2017) for those firms who continued to receive them.

[Insert Figure 4 Here]

Having characterized how federal R&D contracts changed following BCA, we next examine whether BCA affects the treatment effects of federal R&D contracts. To do so, we employ results from the dynamic DiD estimation discussed previously. Figure 3 captured the most important aspect of the estimation: the mean treatment effect for a firm as a function of time since treatment (receiving the first federal R&D contract). An alternative depiction of results captures the mean treatment effect over calendar time for all firms who have been treated by a given year. That depiction is presented in Figure 4b. The figure indicates that the ATET of federal R&D contracts increased rather than decreased following BCA. The mean ATET prior to 2011 is 0.80, whereas the mean ATET post 2011 was 2.11. Thus the mechanical link between federal R&D and subsequent revenues for procurement contracts fails to explain the treatment effect of federal R&D on firms' R&D productivity.

Having ruled out the artifactual explanation for the impact of federal R&D contracts on firm R&D productivity, it appears that federal R&D contracts enhance firms' R&D productivity in a substantive way. The question is how. We consider two avenues.

The first avenue through which federal contracts may affect firms R&D productivity is by shaping the direction of firms' innovation—taking into new technological domains. We test that via a novel measure developed by Kluppel and Cummings (2019) which captures a firm's innovation direction—measured as the cosine distance in the firm's patent vector from year to year: how far is the centroid of this year's cluster of patent classes from the prior year's centroid? Firms whose R&D is becoming more entrenched over time will have decreasing values for cosine distance, while firms whose R&D is becoming more expansive will have increasing values.

We model cosine distance between this year and the prior year as a function of years since first contract. Results for those tests (presented in Table 3) indicate that while the coefficient on years since first federal contract is insignificant in simple OLS regression, it becomes significant in Model 2 with firm fixed effects. These results suggest that federal R&D takes firms in new technological directions, which may open up new opportunities for growth.

[Insert Table 3 Here]

Additional avenues through which federal R&D contracts might change the nature of firms' R&D is through generativeness (more innovation) and the potency of that innovation—greater technological impact. We examine generativeness and impact by estimating the effect of federal contracts on *patent counts* and *citation counts,* respectively. We examine both selection and treatment effects of federal R&D. Results for those tests are presented in Table 4. Models 1-3 examine *patent counts*; models 4-6 examine *citation counts*. The main model in both cases is with firm fixed effects and year effects (Model 3 for *patent counts* and Model 6 for *citation counts*). Results indicate that the coefficients on *post first contract* in both models, while positive, are not significant. Thus federal R&D contracts appear to have no effect on either the generativenes or impact of their innovation.

[Insert Table 4 Here]

Thus the main mechamism which seems to explain the higher R&D productivity of federal contractors appears is that research becomes more expansive—taking it in new directions. Again, the question is why? One potential answer is that the government provides a conduit from precedent research which it has funded at universities to the follow-on R&D at firms. We test that informally by comparing federal contractors to commercial firms on their reliance on university research. Our measure is the share of backward citations in the firm's patents to university patents (backward citations to academic patents/total backward citations). That comparison, shown in the bottom row of Table 2 (Panel A) reveals the academic ratio for federal R&D contractors is indistinguishable from that of commercial firms, though we only have this measure for five years (2001-2005). Thus federal R&D contracts do no appear to be a knowledge conduit from university research to industrial development.

Given that links to university research failed to explain greater expansiveness of innovation in firms with federal R&D contracts, and that we could find no other public data that might explain it, we interviewed an R&D manager, with experience on both sides of federal R&D contracts. He is currently an R&D director within a firm, but had previously worked as a program manager within DARPA, responsible for an R&D contract with industry. He indicated that the government only funds R&D programs to solve problems for which no solution exists, or for which existing solutions are no longer sufficient. This helps to explain why firms' R&D trajectory would tend to diverge following a federal R&D contract. As to why that divergence would lead to higher R&D productivity, he pointed out that while R&D contracts are initially funded for purposes of solving government problems, often the new technology leads to commercial products, so called "dual-use" technologies. These technologies grow firm revenues beyond the follow-on federal procurement, as in the case of iRobot. Initially it robotics technology was used to navigate to and defuse explosive devices (Kerr 2013), but it was redeployed to create Roomba, the autonous vaccum, for the commercial market. His remarks suggest that the productivity affects of federal R&D contracts stem from creating new sources of commercial revenue.

IV. Discussion

Federally funded R&D to firms has declined 88% (as share of GDP) since its 1960s peak. We examined whether this has contributed to the decline in aggregate R&D productivity, and attendant GDP growth To do so, we compared the R&D productivity of federal R&D contractors to that of commercial firms (firms who never receive federal R&D contracts during our observation window). Using dynamic difference in differences (DiD) estimation relative to the time of first federal R&D contract, we find that federal R&D contracts have a significant positive treatment effect on firms' R&D productivity.

We next explored what mechanisms might underpin that. We looked first at an artifactual explanation--the government issues R&D contracts to firms from whom it expects to procure the ultimate good/service. We tested that by exploiting a shock to contracting (BCA) which should sever the link between R&D contracts and subsequent procurement. We found that the R&D productivity of federal R&D contractors increased (rather than decreased) following BCA. Thus the higher R&D productivity of federal contractors does not appear to be an artifact of the contracts being structurally linked to subsequent procurement contracts.

Having ruled out the artifactual explanation, we next explored substantive mechanisms through which federal R&D contracts might increase firms' R&D productivity. We looked at three dimensions of a firm's innovation, its expansiveness, its generativeness and its impact. We found that federal R&D contracts are associated with firms' innovation becoming more expansive (diverging more from prior technological domains). However federal R&D contracts have no significant effect on the rate of patenting or the impact of patents (citations).

One reason federal R&D might make firms' innovation more expansive is that the government provides a conduit between research it has funded at universities and the follow-on R&D at firms. While we only examined that for the subset of years in which we had patent citation data, we found no dfference between commercial firms and federal R&D contractors in the tendency to cite academic patents.

Taken together our results indicate that federal R&D contracts increase firms' R&D productivity. The higher productivity cannot be explained by the fact these contracts are pre-cursors to subsequent procurement contracts. Rather it appears that federal R&D contracts cause firms to do different R&D (take it in new directions).

Our results have implications for theory as well as practice. For theory, our results help to explain prior empirics showing that firms increase internal R&D when they recieve federal R&D contracts (the stimulus effect of federal R&D). Prior authors argue the increased R&D stems from efforts to ensure the anticipated future procurement contracts. We offer an additional explanation. Federal R&D increases the productivity of firms' R&D, which increases their optimal investment level (the level at which the marginal dollar of R&D equals marginal gross margin). Thus firms increase internal R&D because it is now profitable to do so.

Thus our results with firm-level data over a more recent period and with micro-level data reaffirm Levy and Terleckyj (1983) results: federal R&D contracts increase R&D productivity.

This in turn has implications for policy—allowing us to estimate the impact of the decline in federal R&D contracts to firms. Back of the envelope analysis of the likely growth that would have occurred had the U.S. maintained funding of federal R&D to industry at its early 1960s level of 1% of GDP indicates that aggregate growth from R&D might have been 20% higher per year over the past decade (Appendix A).

REFERENCES

Argyres, N. and B. Silverman (2004) "R&D, organization structure, and the development of corporate technological knowledge" *Strategic Management Journal*, 25(8): 929–958.

Arora, A., S. Belenzon and L. Rios (2011) ""The Organization of R&D in American Corporations: The Determinants and Consequences of Decentralization". *NBER Working Paper 17013*

Arora, A., S. Belenzon and A. Patacconi (2018) "The decline of science in corporate R&D," *Strategic Management Journal*, 39(1):3-32.

Baker, A., D. Larcker and C. Wang (2022) "How much should we trust staggered difference-in-differences estimates?" Journal of Financial Economics, 144(2): 370-395.

Belenzon, S. and L. Cioaca (2023) Guaranteed Markets and Corporate Scientific Research, *NBER Working Paper 28644* http://www.nber.org/papers/w28644

Bloom, N., C. Jones, J. VanReenan and Webb (2020) "Are Ideas Getting Harder to Find?" *American Economic Review*, 110 (4): 1104-44.

Cooper, M., A.M. Knott and W. Yang (2022) "R&D productivity Innovative Efficiency and Firm Value", *Journal of Financial and Quantitative Analysis,* 57(5): 1649-1694

Cummings, T. (2019) Cummings, T. "Innovation Strategy and R&D Structure: The Effect of Long-Term Institutional Ownership on R&D Structure". *working paper* (2019).

Fischetti, M. (2020) Challenges Facing Non-traditional Contractors: Communicating With a Redefined Industrial Base, *Defense Acquisition*, April-May 2020: 47-52

Gansler, J. (2011) *Democracy's Arsenal: Creating a Twenty-First-Century Defense Industry,* MIT Press.

Griliches, Z. (1986) "Productivity, R&D, and the Basic Research at the Firm Level in the 1970's," *American Economic Review*, 76(1): 141-54.

Gruber, J and S. Johnson (2019) *Jump-Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream* New York, NY: Public Affairs.

Hall, B. Mairesse and Mohnen (2010) Hall, B. and J. Mairesse and P. Mohnen. “Measuring the Returns to R&D in *Handbook of the Economics of Innovation*”. B. H. Hall and N. Rosenberg (eds.), North-Holland (2010).

Jones, C. (1995) “R&D-Based Models of Economic Growth”, *Journal of Political Economy*, 103(4): 759-784

Jones, B. (2008) The Burden of Knowledge and the "Death of the Renaissance Man": Is Innovation Getting Harder? *The Review of Economic Studies*, 76(1): 283-317

Josephson, B. W., J.-Y. Lee, B. J. Mariadoss, and J. L. Johnson (2019). “Uncle Sam Rising: Performance Implications of Business-to-Government Relationships,” *Journal of Marketing*, 83(1): 51-72.

Kerr, J. (2013) “The History of the Roomba”, *Fortune Magazine*.

Kluppel, L. and A. Knott (2023) “Are Ideas Being Fished Out” *Research Policy*, 52: 1-8.

Knott, Anne Marie (2023) “Do Inventions Drive Firm Growth?” Available at SSRN: https://ssrn.com/abstract=4555106

Kogan, L., D. Papanikolaou, A. Seru, and N.Stoffman, (2017). “Technological Innovation, Resource Allocation, and Growth,” *Quarterly Journal of Economics*, 132(2), pp. 665-712.

Kluppel, L. and T. Cummings, (2019) “A New Direction or Lack of Direction? The Story of Innovation with Outsider CEOs,” *Academy of Management Annual Meeting Proceedings*. 2019 (1): 1-1.

Levy, D. and N. Terleckyj (1983) “Effects of Government R&D on Private R&D Investment and Productivity: A Macroeconomic Analysis,” *Bell Journal of Economics*, 14(2): 551-561.

Lichtenberg (1988) The Private R&D Investment Response to Federal Design and Technical Competitions *American Economic Review*, 78(3): 550-59

Moretti, E., C. Steinwender and J. Van Reenan (2021) “The Intellectual Spoils of War? Defense R&D, Productivity and International Spillovers”, *NBER Working Paper 26483*

Pallante, G., E. Russo and A. Roventini (2023) "Does public R&D funding crowd-in private R&D investment? Evidence from military R&D expenditures for US states," *Research Policy*, 52(8).

Romer, P (1990) Romer, P. “Endogenous Technological Change”. *Journal of Political Economy* 98(5): 71–102.

Singer, P. (2014) *Federally Supported Innovations: 22 Examples of Major Technology Advances that Stem from Federal Research Support*, MIT Information Technology and Innovation Foundation.

Srinivasta, T. (2019) *Innovating in a Secret World: The Future of National Security and Global Leadership*, Potomac Books.

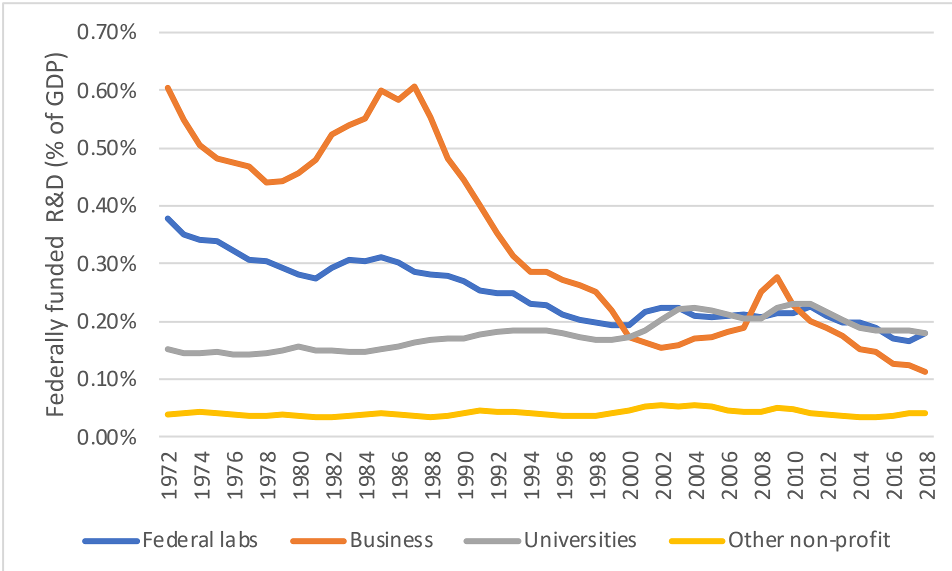

FIGURE 1. TRENDS IN ALLOCATION OF US FEDERALLY-FUNDED R&D

Source: National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series). Get link from email to Nick Argyres

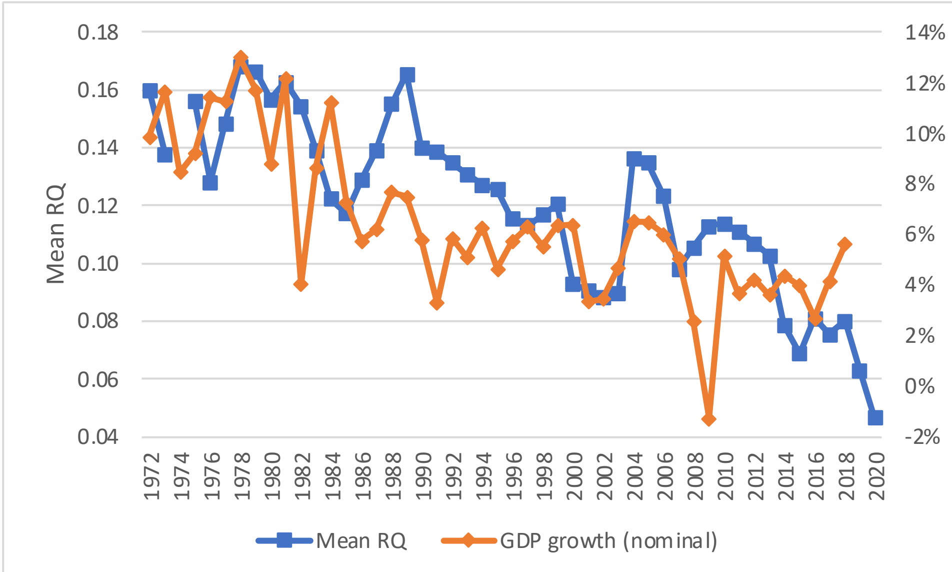

FIGURE 2. THE DECLINE IN RESEARCH PRODUCTIVITY TRACKS THE DECLINE IN FEDERAL DEVELOPMENT

Source: GDP: st louis fed; R&D productivity: Wharton R&D productivity data set

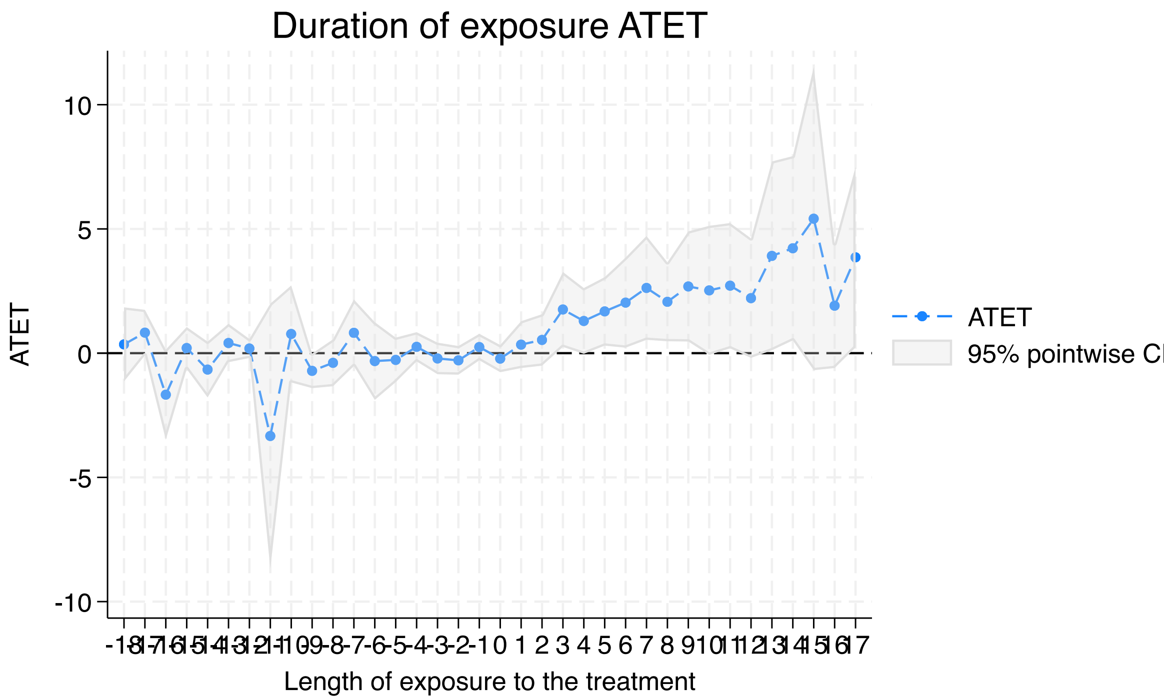

FIGURE 3. DYNAMIC DIFFERENCE IN DIFFERENCES ATET ON R&D PRODUCTIVITY FROM DATE OF FIRST FEDERAL R&D CONTRACT

Notes: ATET estimates from AIPW estimator relative to a control group of firms who have not yet received treaatment. Xthdidregress allows for heterogeneity in treatment time and treatment effects. Length of exposure is with respect to first year of a federal R&D contract. Firms who received a federal contract prior to 2002 are dropped.

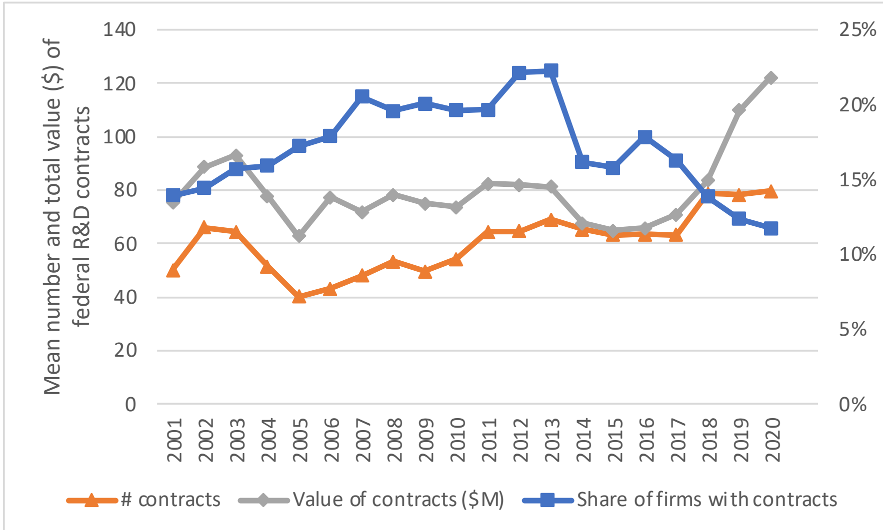

FIGURE 4A. IMPACT OF SEQUESTRATION ON FEDERAL R&D CONTRACTS

Notes: This figure plots evolution in federal R&D contracts leading up to and following sequestration (The Budget Control Act of 2011), which imposed mandatory cuts to agency budgets: share of publicly traded R&D firms with federal R&D contracts, mean number of R&D contracts (and total dollar value) per firm with R&D contracts.

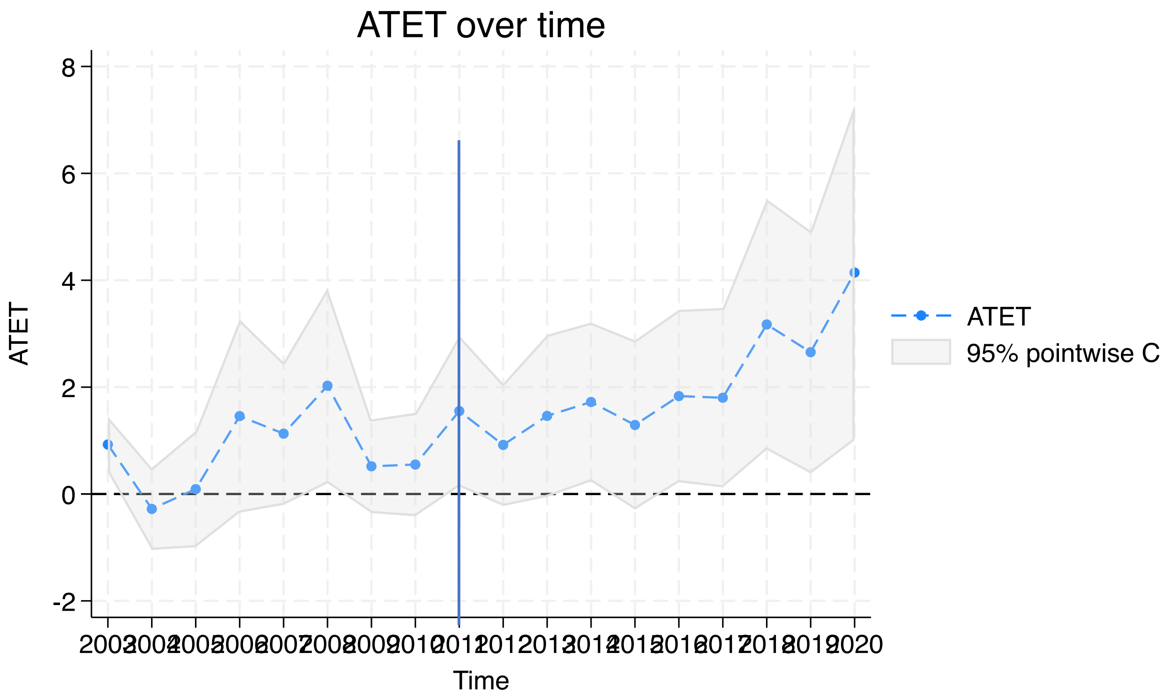

FIGURE 4B. EVENT STUDY OF IMPACT OF THE BUDGET CONTROL ACT OF 2011 (SEQUESTRATION)

Notes: This figure presents ATET estimates of the impact of sequestration on the R&D productivity of firms with federal contracts relative to a control group of firms who have not yet received a federal R&D contract in the data window (2001 to 2020).

TABLE 1 —SUMMARY STATISTICS

A. ALL R&D PRODUCTIVITY YEARS (2001-2021)

	Commercial (No Federal R&D) Firm					Federal R&D Contractor				
Variable	Obs	Mean	StDev	Min	Max	Obs	Mean	StDev	Min	Max
Revenue ($million)	54737	913.9	4509.5	-475.4	182133.0	2964	6171.1	23869.0	0.0	386064.0
R&D ($million)	54737	35.0	209.5	0.0	10895.0	2964	302.4	1821.2	0.0	42740.0
TSM intensity	11955	2.9	7.2	0.0	272.5	1481	3.1	6.5	-8.7	123.9
Federal R&D contracts	54737	0.0	0.0	0.0	0.0	2964	2.0	21.2	0.0	681.0
Federal R&D amount ($Million)	54737	0.0	0.0	0.0	0.0	2964	1.9	18.8	0.0	638.0
Patent count	11408	17.2	54.2	1.0	1218.0	1493	63.5	224.5	1.0	2197.0
Citation count	11408	181.6	831.4	0.0	21155.0	1493	403.4	1839.6	0.0	34235.0
Academic share of backward citations	227	0.06	0.12	0.00	1.00	16	0.06	0.09	0.00	0.25

B. FISCAL YEAR 2010 CROSS SECTION

	Commercial (No Federal R&D) Firm					Federal R&D Contractor				
Variable	Obs	Mean	StDev	Min	Max	Obs	Mean	StDev	Min	Max
Revenue ($million)	2,281	1000.3	4620.8	0.0	132872.0	152	4656.5	16572.1	0.0	135592.0
R&D ($million)	2,281	31.7	163.0	0.0	4934.2	152	161.1	699.1	0.0	6962.0
TSM intensity	557	2.1	3.3	0.0	27.5	68	2.3	4.0	0.0	18.4
Federal R&D contracts	2,281	0.0	0.0	0.0	0.0	152	0.7	1.7	0.0	9.0
Federal R&D amount ($Million)	2,281	0.0	0.0	0.0	0.0	152	0.5	2.1	0.0	17.8
Patent count	513	17.0	54.0	1.0	772.0	75	64.1	204.4	1.0	1347.0
Citation count	513	122.8	807.2	0.0	17147.0	75	418.4	1172.6	0.0	7479.0

Notes: These are summary statistics for our primary dataset to test the impact of federal R&D contracts on R&D productivity. The dataset includes all U.S. publicly-traded firms reporting R&D . We present means for all-years in Panel A, and for the 2010 cross-section in Panel B (for greater comparability)

TABLE 2—TEST OF IMPACT OF FEDERAL R&D CONTRACTS ON FIRM R&D PRODUCTIVITY (TSM INTENSITY)

	OLS	FE	FE
	(1)	(2)	(3)
Federal R&D Contractor	-0.207		
	0.422		
Post First Contract	0.579	0.757	
	0.301	0.414	
Federal R&D Intensity			-0.520
			0.193
Observations	13436	13436	13419
		2205	2199
R-squared	0.213		
Within		0.029	0.030
Between		0.001	0.000
Overall		0.015	0.012
F	.	11.41	11.71
Prob>F	.	0.000	0.000
Industry (3 digit SIC) FE	Yes		
Year FE	Yes	Yes	Yes
Firm FE	No	Yes	Yes

Notes: Robust standard errors clustered at the firm level are below coefficients

TABLE 3 —IMPACT OF FEDERAL R&D CONTRACTS ON FIRMS' PATENT TRAJECTORY DISTANCE

	Trajectory Distance	
	(1)	(2)
Contract years	0.002	0.014
	0.002	0.003
Observations	3414	3414
		430
R-squared	0.011	0.003
Within		0.021
Between		0.005
F		3.13
Prob>F	0.179	0.000
Year FE	Yes	Yes
Firm FE	No	Yes

Notes: Test of the impact of federal contracts on firms' patent trajectory distance, Robust standard errors clustered at the firm level are below coefficients

TABLE 4— IMPACT OF FEDERAL R&D CONTRACTS ON FIRMS' PATENTING

	Patent Count			Citation Count		
	(1)	(2)	(3)	(4)	(5)	(6)
Federal R&D Contractor	45.46			299.84		
	20.37			154.21		
Post First Contract	-0.03	14.26	8.45	-41.45	52.84	62.28
	3.98	7.49	5.95	37.25	39.32	118.24
Observations	12901	12901	12901	12901	12901	12901
			2082			2082
R-squared	0.029	0.01	0.029	0.027	0.020	0.061
Within			0.000			0.002
Between			0.004			0.020
F	2.640	0.00	4.100	5.380	5.430	3.850
Prob>F	0.000	92.72	0.000	0.000	0.490	0.000
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	Yes	No	No	Yes

Notes: Test of the impact of federal contracts on firms' patent importance, where importance is defined as citation intensity (the mean number of citations per patent). Robust standard errors clustered at the firm level are below coefficients.