Government Efficiency in Facilitating Innovation

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Abstract

Government's optimal role in facilitating innovation has been well characterized from a theoretical perspective: they should complement private sector spending by subsidizing high risk projects which have large positive externalities, and which firms would not undertake otherwise. However, whether federal R&D funding acts as a complement or a substitute for private funding has remained an open question. The key challenge of the literature on this topic has been to address endogeneity concerns due to selection in which firms become government contractors. I use the state-level retirements of Supervising Contract Officers as an exogenous shock to firm revenue to measure the causal impact of government funding on private investment. I find that an influential employee retiring predicts a \$24 million decrease in contract revenue the next period. Then, I estimate the causal impact of \$1 million in additional contract revenue and find that it increases firm R&D expense by a modest \$4,000. I also find that government funding increases patent applications, but that these patents are of lower quality. This suggests that the complementarity between federal funding and private innovation is likely limited in practice, and that researchers studying government contracting should pay close attention to endogeneity issues.

1 Introduction

While debate about the optimal size and scope of government has regained popularity since the start of the second Trump administration, it is by no means new. Milton Friedman argued on behalf of minimal government as early as the 1960s, with the conversation going back to the founding of the U.S., and even much further. The debate has lasted without resolution due to the complex nature of the problem. Properly addressing it means exploring each function of government separately, and understanding if it could be performed better by the private sector. In this paper, I move towards this goal by examining government's effectiveness in one particular aspect of the economy: facilitation of private-sector innovation through federal R&D contracts. Specifically, I use an instrumental variable to estimate the causal impact of an additional dollar of government funding on firm R&D activity, giving insight into whether government funding is actually increasing innovative activity.

Early theoretical considerations of government's role in innovation, from Arrow (1962) and Nelson (1959), outline some positive impacts that can arise from subsidization of private R&D. Specifically, they argue that government can alleviate market failures associated with "basic research", or research that has positive externalities, but also comes with the risk that the resulting innovation may not be useful in the firm's current operations. Both highlight government's comparative advantage in risk-bearing being a way for firms to offload some of this risk; Nelson (1959) goes further, and discusses how a wide technological base within the firm can also help firms reduce this risk. Restating their arguments in financial terms, there are some high-risk projects with large social benefits, whose costs of capital exceed the firm's required cost of capital, making them negative NPV (from the firm's perspective). In these cases, by sharing some of the risk with the government, the firm decreases its internalized cost of capital, making these projects positive NPV, and increasing its investment opportunity set.

However, the argument in favor of government subsidy of private R&D rests on one primary assumption: that government is successful in financing only the types of risky, high social benefit projects outlined by Nelson (1959) and Arrow (1962). If this assumption holds, then the firms receiving federal funding undertake more projects than they would otherwise. Stated as a testable prediction, receipt of funding should increase firm-level R&D expenditure (complementarity between funding sources). Alternatively, if it does not hold – i.e. they are unsuccessful in targeting the "basic" projects – then the government may be financing projects which the firm would have undertaken on their own, and thus which could have been financed with external capital through the equity or debt markets (substitution). This would also imply that money is being compelled from taxpayers to pay for things that would be financed anyway, but instead by those *already willing* to finance it. This paper seeks to test the validity of this assumption, thereby revealing how closely government adheres to the theoretical motivations for its involvement in the market for innovation.

In the existing work on this topic, there is one central issue that remains unresolved, discussed by David, Hall, and Toole (2000): the endogeneity in who is awarded a government contract. If a firm's likelihood of being a government contractor and its spending on R&D are both related to an omitted variable, then a regression of firm spending on contract revenue may report a positive relationship where none truly exists. The literature has tried several methods to address this, such as matching, regression discontinuity, and structural models. However, to my knowledge, this paper is the first to use an IV approach to properly address this issue, allowing me to explore government's causal impact on private innovation.

I use retirements of senior level contract officers, identified using federal employee data from the Office of Personnel Management, as an exogenous shock to firm contract revenue. I combine this with detailed data on 742,262 federal contract awards for R&D work, sourced from USASpending.gov and linked to Compustat via fuzzy matching for the sample period 2001-2014. With these datasets, I link employee retirements to agency contract allocations at the state-level, allowing for a precise identification of within-state allocations of contracts. At the firm level, I document a significantly negative impact of retirements on firm contract revenue, with a firm receiving an average of $24 million less in contact revenue following the departure of a senior level contract officer. This effect is entirely through the revenue from contract modifications, highlighting these officers' influence over renegotiation terms.

Before correcting for endogeneity, OLS regressions falsely suggest that $1 million in additional government funding increases firm R&D by a statistically significant $38,000[1]. Once the endogeneity is removed, I find that this figure decreases to $4,000, but remains significant. On average, government positively impacts firm innovation spending, but the relatively minor economic magnitude suggests that they are generally ineffective in identifying the correct projects to fund. I also test the impact of government funding on firm patent activity. I find that endogenous estimates also overstate the impact of R&D contracts on patent applications, but that firms do submit more patent applications following an upward shock to their R&D contract revenue. Additionally, I find that these patents are of lower quality, both in terms of how many future citations they receive, and how long it takes for these citing patents to be filed. This suggests that federal contracts incentivize patenting, but do not appear to meaningfully expand the investment opportunity sets or increase the quality of the research outputs of the firms to which they are allocated.

[1]This is likely a lower bound, since the revenue measure I use is technically obligated funding, rather than that actually paid out.

The policy suggestion of this paper is a careful identification of which federal R&D contracts are funding the types of research studied by Nelson (1959) and Arrow (1962), leaving the others to be funded by firms, if they or the capital markets determine they are worth funding. Additionally, this paper suggests that researchers studying the impact of government contracts on firm activity should take endogeneity concerns seriously, and work carefully to address them, as failing to do so can lead to large over-estimations and false conclusions about the efficiency of government investment.

2 Literature

Two of the earliest theoretical considerations of government's optimal role in facilitating innovation come from Nelson (1959) and Arrow (1962). Both highlight the ability of government subsidies to help firms internalize the positive externalities associated with some R&D activities, leading them to increase their investment. Nelson (1959) argues that government should focus on funding basic research, for which the relevant technological field of the innovation could be any of a large number of possibilities. He also suggests that large firms, which have a wide technological base will undertake basic research without need of government subsidy[2]. Arrow (1962) focuses on subsidies as a way for firms to shift risk onto the government. He argues, among other things, that "the most risk-efficient outcome is not necessarily the most technically efficient one", as one effect of the risk, when borne by the inventor, is that it incentivizes more effort.

These theoretical predictions have been the subject of past empirical research, but there has been disagreement among researchers. Many find complementarity between government funding and firm spending on innovation, while many others

[2] Nelson (1959) cites historical anecdotes such as "Eastman Kodak enter[ing] the vitamin business after a research project resulted in a new way to synthesize Vitamin B"

find a crowding out effect. For example, Almus and Czarnitzki (2003) studied a sample of firms in East Germany during the rebuilding after the fall of the Berlin wall, and found evidence that government subsidies do increase private R&D spending, while Wallsten (2000), in a contemporaneous study of the Small Business Innovation Research (SBIR) program, finds evidence of an almost perfect crowding out of private spending by public subsidies.

One of the issues at the center of the literature on this topic, as discussed by David, Hall, and Toole (2000), is controlling for the selection bias in who receives a federal contract. If the government tends to contract with more innovative firms for some unobserved reason that also impacts innovation spending, then a regression of R&D expense onto firm contract revenue may suggest a positive and significant relationship where none exists. Several approaches have been tried to address this problem, including regression discontinuity (Bronzini and Piselli (2016)), structural estimation (Takalo, Tanayama, and Toivanen (2013), González, Jaumandreu, and Pazó (2005), Wallsten (2000)), and matching methods (Lach (2002), Almus and Czarnitzki (2003)). This paper is the first, to my knowledge, to identify a clear exogenous shock to firm revenue, and use it as an instrumental variable to clearly identify the causal impact of government funding.

Other papers which explore the USASpending.gov contract data include Brogaard, Denes, and Duchin (2021), who find that politically connected firms are able to make more competitive bids ex-ante, because they are able to more successfully renegotiate higher payments ex-post. My results are consistent with theirs, as I also document evidence that a firm's relationships with contract officers impact its future revenue from contract renegotiations. Liebman and Mahoney (2017) study intra-year spending patterns, and find that federal agencies engage in wasteful year-end spending to avoid budget cuts in the following period, while Goldman (2019) documents a stabilizing effect of government funding on firms who receive it during the Financial Crisis, with spillovers into the firm's local economies.

3 Conceptual Framework

I will now provide a stylized example to clearly illustrate the mechanism by which government subsidy can positively impact the research and development efforts of the private sector. First, I assume that the firm will opt to undertake any and all projects which it views to be positive NPV. The firm need not have cash on hand to finance these projects, as any positive NPV projects can be successfully funded through capital markets in the absence of informational frictions. The projects will require investment, I, today for uncertain cash flows, C, which are realized with some endogenous probability, p, in one period, and which the firm discounts at its cost of capital, r. The project can fail in one of two ways: it can either fail to generate new technology entirely, or it can generate technology which is not applicable to the firm's current industries, either of which means it pays off 0 next period, making these two outcomes functionally equivalent for the firm. The probability of one of the two failure states occurring is captured by $(1-p)$. Putting these pieces together, the firm estimates the NPV of each available project as:

$$NPV = \frac{p * C + (1-p) * 0}{1+r} - I = \frac{p * C}{1+r} - I \tag{1}$$

and undertakes each one for which $NPV > 0$.

As discussed in Section 2, the theoretical foundations of Nelson (1959) describe the primary role of government subsidy as reducing the risk that new technology will be unusable by the firm in its current lines of business, since the government operates in such a wide variety of industries. This guaranteed cash flow from R&D contracts effectively increases p, thereby increasing the NPV of the project as perceived by the firm.

I will now distinguish between types of projects which the government can subsidize, and characterize for which types this subsidy is efficient (inefficient) and complements (substitutes) private investment. I also show how the ability of government agencies to select these efficient projects can be revealed by how the R&D investment of the firm responds to contract revenue, allowing me to draw conclusions about the real-world efficiency of government investment in the empirical tests that follow.

Consider three types of projects: A, B, and C. For simplicity, assume that without government subsidy, each type has probability of success p_L. The government can offer a subsidy which will cause this probability to increase up to some maximum level p_H, proportionately increasing the NPV of the project. The types differ in two primary ways: (1) whether $NPV(p_L) > 0$, and (2) whether there exists some $p*$ for which $NPV(p*) = 0$. The figure below illustrates the three projects, and how their NPV changes with increases in p.

[*INSERT FIGURE 1 HERE*]

In Figure 1, project A (the green line) is positive NPV even when $p = p_L$. This means that the firm will undertake this project even without government intervention. Therefore, government subsidy of this project will be inefficient, as it will substitute for investment the firm would make anyway. Project C is inefficient for a different reason; there is no amount of subsidy for which this project will be positive NPV for the firm (i.e. even if $p = p_H$, I is large enough that the firm will destroy value by undertaking the project). Because the firm can selectively submit bids, they will avoid bidding on contracts for type C projects, so the analysis can be restricted to considering types A and B. Project B, which I will refer to from now on as the "marginal" project, are those for which the firm will not undertake them unless they are partially subsidized by the government, and thus are those for which government funding is value-increasing and efficient.

3.1 Optimal Subsidy and Testable Predictions

In this framework, the optimal level of subsidy is that which increases p to p^*, or in other words, that which is just enough to make the project positive NPV, at which point the firm views it as worth shouldering the remaining cost itself. Any larger subsidy would be substituting for some private funding, which would be shifting the cost of investment unnecessarily onto taxpayers and away from firms. Stated differently, properly identifying marginal projects and allocating contracts of the correct magnitude will have a positive causal impact on firm investment, as they will spend some of their own funds on projects that otherwise would have gone untouched. This is illustrated in Figure 2. The green circle represents the set of projects of Type A which the firm undertakes regardless of subsidy. The blue ring represents those Type B projects that the firm will undertake if subsidies are given through R&D contracts. Properly structured, subsidies should increase the total amount of investments the firm is making, resulting in a positive causal effect of government contracts on private sector R&D inputs.

[*INSERT FIGURE 2 HERE*]

By relying on this framework, I can infer the efficiency of government investment by the sign of the causal impact of contract revenue on firm R&D expense. If it is positive, then government subsidies are value-increasing. If it is insignificant, that suggests the government is either subsidizing the "wrong" non-marginal projects, over-subsidizing the marginal projects such that the firm is investing on behalf of the government rather than investing alongside the government, or some combination of the two; regardless of which specifically it is, this would suggest government funding of private R&D is inefficient. Identifying the magnitude of this causal impact is the focus of the remainder of the paper.

4 Data

I bring together data from several sources to construct the panel which I use to test the causal impact of federal funding on private innovation. The primary data for my study, is information on United Stated Federal R&D contracts awarded to private-sector firms in the years 1975-2023, which are available for download from the Federal Procurement Data System (FPDS) through USASpending.gov. The data for 2008-2023 can be downloaded through the Award Data Archive[3], while years prior to 2007 must be accessed through a Custom Query[4]. Though the data are technically available as early as 1975, the data earlier than 2001 only contain broad information, as the system was updated to include additional, more detailed fields around this time. The total sample of R&D contracts consists of 742,262 federal R&D awards, totalling $792 billion in obligated funds (inflation adjusted to 2001). The remainder of this section describes how I link the contract data to firm-level spending, and the employee-level data I use to identify an exogenous shock to firm revenue.

4.1 Identifying Government Contractors in Compustat

Among other details, FPDS reports both the name of the firm receiving the award and the name of the recipient's parent company. I extract the unique list of parent names that received a contract in the sample period 2001-2023 (420,228 unique names), and follow the methodology of Brogaard, Denes, and Duchin (2021) to fuzzy match the names to Compustat's *conm*. To prepare the strings for matching, I remove punctuation and common characters or phrases from both sets of names[5].

Next, I calculate the Levenshtein ratio between each possible pair of matches.

[3] https://www.usaspending.gov/download_center/award_data_archive

[4] https://www.usaspending.gov/download_center/custom_award_data

[5] The common characters/phrases I remove are: INC, LLC, CORPORATION, LTD, CORP, COMPANY, CO, INCORPORATED, GMBH, LIMITED, COLTD, LP, LLP, PLC, PLLC

This ratio, LR, is defined as:

$$LR = 1 - \frac{LD}{S_1 + S_2}$$

where LD is the minimum number of single-character edits needed to change one string into the other (the Levenshtein Distance), and S_1 and S_2 are the lengths of the parent company name, and Compustat name, respectively. $LR = 1$ would correspond to a perfect match. After calculating the Levenshtein ratio for each pairwise combination, I keep only those for which $LR > 0.95$, and manually verify the validity of each match. I identify 3,447 unique *gvkeys* in Compustat as having received at least some government contract revenue during the sample, representing roughly 1/4 of public firms. I then create an indicator variable, $GovContractor$, which equals 1 if a firm was identified to be government contractor, and zero otherwise. Figure 3 plots the proportion of Compustat firms which are government contractors over time. Interestingly, government has done business with an increasingly lower share of public firms in the years since the financial crisis.

[*INSERT FIGURE 3 HERE*]

4.2 Firm Contract Revenue and Characteristics

To make my analysis as precise as possible, I would like to know which federal contracts are specifically associated with R&D efforts. Fortunately, the government reports a product classification code for each contract, along with a written description, which is very well-populated. These 4-character codes have a nested structure, with those beginning with "A" corresponding to Research and Development. For example, A is "R&D"; AC is "Defense R&D", and AC21 is "Atomic energy defense activities; Basic Research". Under this definition, an average level of $56B was spent on R&D per year in the sample.

To assess the impact of this funding on firm activity, the ideal measure of contract revenue would be the actual dollar amount that has been paid out to firms each quarter, as this would be the actual cash flow that either substitutes for or complements the firm's R&D spending. The contract data include such a variable (total amount outlayed), but it is missing for the vast majority of contracts. As a next-best alternative, I use a measure of federal funds which are assigned when contracts are awarded. In general, it is intuitive to expect a large positive correlation between obligated and outlayed funds, so this measure should be a reasonable proxy, though it does mean the results should be interpreted as lower bounds.

Finally, I aggregate the total revenue received from federal R&D contracts to the firm-quarter level, while also measuring that from newly initiated contracts separately from renegotiations, as federal employee's may differ in their ability to influence one over the other. From Compustat, I gather annual data on firm R&D expenses, total assets, total revenue, capital expenditures, and net operating cash flow, keeping only observations with non-missing positive total assets. I winsorize all non-indicator variables at the 2.5% level, and inflation-adjust all dollar values to 2001, to maintain comparability across time.

4.3 OPM Contracting Officer Data

To address the endogeneity concerns highlighted by past work on this question, I use retirement events of senior-level contracting officers as a shock to a firm's contract revenue. I measure this using quarterly data on federal employee positions, which is now publicly available through the Office of Personnel Management (OPM) data archive following a series of Freedom of Information Act (FOIA) requests[6]. These data contain information on the employee's name, the agency they work for, and their age and length of service in groups of 5 years (e.g. 30-34),

[6] https://archive.org/download/opm-federal-employment-data/

among other variables. They come in quarterly files for three consecutive samples: 1973Q3 - 2014Q2, 2014Q3 - 2016Q3, 2016Q4 - 2017Q1, though the two shorter samples do not differ in structure in any meaningful way. The early sample, on the other hand, is the only one that includes unique employee id numbers, as the later samples only report names. Because these names are often redacted for employees of certain agencies (mostly the Department of Defense), tracking unique individuals across time is not possible with only the provided employee characteristics. This leads me to use only data from the earlier sample to maintain the validity of the identification.

I rely on some of the additional employee information contained in the OPM data to identify those employees who have the most influence over contract allocations. To determine who these employees are, I refer to the statutes governing the classification of two of the employee-level variables: Occupation Code and Supervisory Status. Occupation codes identify the type of work done by the employee; the associated responsibilities for each are detailed in the "classification standards" found on the OPM website[7]. The documentation for code 1102 - "Contracting" clarifies a few important details about its role. Interestingly, they do not have influence over the extensive margin of contracting. The decision of whether or not procurement is needed to complete a program objective is instead made by one of the multiple program offices within each agency. After procurement is deemed necessary, a request is submitted to the relevant contract office, which is then responsible for "soliciting, negotiating, awarding, terminating, and administering" the contracts. Thus, I focus on the subsample of employees who work in contracting, as they determine how funds are allocated across firms. Because these contractors' influence is isolated to the intensive margin of contract allocation, their impact on renegotiation terms may be larger than on new awards. I provide

[7] https://www.opm.gov/policy-data-oversight/classification-qualifications/classifying-general-schedule-positions/#url=1100

evidence supporting this hypothesis when I test the relevance condition for my instrumental variable in Section 4.

More detail from the OPM website[8] allows me to narrow the set of contracting employees further, to focus on the top-level decision makers who are actually impacting firm revenue. I rely on the government's Supervisory Status codes for information about each employee's place in the hierarchy of the federal workforce. The definition of "supervisor" in this context is defined under the law in 5 U.S.C. 7103(a)(10), which says that employees can only receive this designation (status code = 2 or 4) if one of their primary job functions is "to hire, direct, assign, promote, reward, ... or remove employees". Through their influence on staffing of lower level contracting positions, these managers are in a unique position to exert influence on the distribution of federal contract awards. The final panel of federal employees from which I will construct the instrumental variable defined in Section 5 consists of 9,556 of these Supervising Contracting Officers (SCOs) (of the 62,169 contracting employees), working across 65 federal agencies from 2001 - 2014Q2.

4.4 Research Outputs

By just exploring the impact of government subsidies on firm research inputs, it is not possible to get a complete picture of their effectiveness. A negligible impact of subsidy on firm R&D expenditure may not imply inefficiency, as it is possible that government funding is more efficient in generating research outputs. For example, there may be some information spillovers that come with being a government contractor which allow the same level of expense to generate more patents. In this case, government funding would be efficiently increasing research productivity, even while substituting for private sector funding.

To explore this idea, I rely on a patent dataset constructed by Dyevre and

[8] https://dw.opm.gov/datastandards/referenceData/1578/current?index=S

Seager (2023), who identify Compustat firms in PatentsView data, through firm names, linking the patent identification numbers in USPTO data to Compustat gvkeys. They have graciously made this data available on their GitHub page.[9]. Using these files, I count the number of approved patents that each government contractor in my sample is awarded, by quarter in which the patent is filed. I focus on filing date instead of awarding date, as the filing date better represents when the new technology is discovered. I also retain information on the time-to-approval for each of the firm's patents, which allows me to test if R&D firms with more government backing are able to expedite the approval process.

Next, I construct two forward-looking measures of patent importance to help understand how effective government funding is at generating quality patents, in addition to quantity as defined above. First, I measure the average number of future patents which cite the firm's current patents. Citations should be correlated with the usefulness of the technology, as research outputs with broad technological applications will act as a jumping off point for more future development. Additionally, more important patents are expected to be cited more quickly, as new technological applications will likely be more readily apparent. To capture this idea, I measure the average time-to-citation for the firm's patents. Because patents can be cited once they are published, even if they are still pending, I construct this measure as the difference, in quarters, between the original patent's filing date and the cited patent's filing date. With these two measures, I am able to expand my analysis of the impact of government funding beyond a distinction between substitution and complementarity, and into an exploration of both the quantity and quality of research outputs.

[9]https://github.com/arnauddyevre/compustat-patents

5 Identifying Contracting Officer Retirements

The regulations governing retirement ages for federal employees were defined by Congress in the Federal Employees Retirement System Act in 1986[10]. Within this legislation were rules describing the minimum, early, and immediate retirement ages. Interestingly, they vary with employee tenure: a federal employee can retire with full benefits as early as 55 if they have 10+ years of service. To identify retirement events, I focus on the rules for immediate retirements, as most other options only occur under specific circumstances. For example, early retirement is described as only occurring "in certain involuntary separation cases and in cases of ... major reorganization or reduction in force".

I begin by taking the last quarter that each SCO id appears in the sample as their departure date (while tossing out the last period). Then, I define an indicator, *Retirement*, which flags each event as a retirement if one of two conditions is met: (1) they are at least 60 years old, meeting the minimum age for immediate retirement, or (2) they are at least 55 with 10+ years of service[11]. In total, I identify 5,472 contracting employees that left the sample, 822 of which were supervisors. Of these, 433 are identified as retirement events. I aggregate the indicator to the agency-state level, assigning it a value of 1 in period t if any SCO from a given agency, working in a given state retired in period $t-1$.

Because I can observe the agency and location of both the employee's position and the contract award, I can match the retirement events to the firm's contract revenue at a granular, agency-state level, forming a strong basis for my identification. However, the level of R&D investment from Compustat is only observable at the firm level. To address this mismatch, I reconstruct the indicator such that it is equal to 1 if any SCO retired last quarter from any of the agencies the firm con-

[10]https://www.opm.gov/retirement-center/fers-information/eligibility/

[11]Over 2/3 of departures meet the minimum tenure requirement for retirement at 55

tracts with this quarter. Below, I test the relevance condition for this aggregated instrument and argue that the exclusion restriction holds in this setting.

5.1 Instrumental Variable Conditions

Using measures of firm contract revenue (new, modifications, and total), I demonstrate that the relevance condition is satisfied. Specifically, I run the following panel regression:

$$GovRevenue_{i,t} = \beta_0 + \beta_1 * Retirement_{i,t} + \beta_2 * GovRevenue_{i,t-1} + +\eta_i + \delta_t + \varepsilon_{i,t}$$

where $GovRevenue_{i,a,s,t}$ is the dollar value of R&D contract revenue received by firm i in period t, in millions adjusted for inflation.

The total average impact of a retirement on federal revenue, shown in Table 1, is significantly negative, with a retirement decreasing revenue the following period by \$23.93M (t = -3.36). Past revenue positively predicts current revenue, suggesting some degree of persistence. This can also be interpreted as evidence in support of the instrument, as it suggests that there is some consistency to the distribution of awards which can be disrupted by the SCO retirement.

[*INSERT TABLE 1 HERE*]

However, as discussed previously, the documentation on Contracting Officer responsibilities states that these officers negotiate the content of contracts *after* the determination that procurement is necessary has been made by a separate program office. This leads to a testable hypothesis concerning SCOs differential impact: they may have more influence over renegotiations (intensive margin) than initiations of new contracts (extensive margin). Table 2 tests the above regression for revenue from new contracts and contract modifications separately. The insignificant coefficient on $Retirement_{i,t}$ 0.54 (t = 0.56) in Column (2) suggests that retirements do not decrease a firm's revenue from new contracts. Alternatively, Column (4) suggests that all of the negative impact observed in Table 1 is because of a reduction in firm revenue from contract modifications (62% of federal actions). These finding are consistent with Brogaard, Denes, and Duchin (2021) who find a relationship between a firm's political influence and its contract renegotiation terms.

[*INSERT TABLE 2 HERE*]

In Section 5, I use estimated total revenue, predicted based on the coefficients in Table 1, to test the causal impact of government funding. But, before I can implement the instrument, I must first argue that it satisfies the exclusion restriction. The definition of a retirement event is determined by: the age of the employee, and their tenure with the federal government, both of which are determined by events likely several decades in the past (birth date and start date). While their birth date is more clearly unrelated to firm revenue, it is possible that their departure date will not actually be a shock, if an SCO tends to leave after their influence has deteriorated. However, if employees retire at the first available opportunity, then departure date is linked to birth date, making it more plausibly exogenous. Figure 4 shows the distribution of employee departures by age group. There is a clear grouping around the federal minimum retirement age. It appears that many employees choose to retire at the earliest opportunity, suggesting the departure decision is largely uncorrelated to their degree of influence. For these reasons, the exclusion restriction is likely to be satisfied in this setting.

[*INSERT FIGURE 4 HERE*]

In sum, both the SCO's birth date and initial start date are plausibly uncorrelated with the firm's R&D investment decisions, except through their impact on the firm's receipt of federal funding. In addition, the impact is significantly negative, satisfying the relevance condition. These findings together support the validity of the instrument.

6 Estimating the Impact of Government Funding

This section defines the second-stage regression, and uses it to explore the relationship between government R&D funding and firm R&D expenditures. It presents results both with and without instrumenting for contract revenue, finding evidence that endogeneity does in fact lead to significant overestimation of the impact of government funding. However, while the magnitude of the effect becomes economically small in the IV estimation, it remains positive and significant.

The second stage regression takes the form:

$$R\&DIntensity_{i,t} = \beta_0 + \beta_1 * GovRevenue_{i,t} + \beta_2 * GovRevenue_{i,t-1} + \Gamma \mathbf{X}_{i,t} + \eta_i + \delta_t + \varepsilon_{i,t}$$

where $GovRevenue_{i,t}$ is either the realized value of firm contract revenue, or its expected value as predicted by the first stage regression coefficients in Column (4) of Table 1. $R\&DIntensity_{i,t}$ is firm i's R&D expense in period t, scaled by total assets at the end of the period. $GovRevenue_{i,t-1}$ is the contract revenue the firm received in the previous period, and $X_{i,t}$ is a vector of control variables: Peters and Taylor (2017) Total q, free cash flow (operating cash flow - capital expenditures), other revenue (this includes non-R&D government revenue and other sales), logarithm of firm age and total assets, measured in quarters and millions of dollars, respectively, and number of Compustat business segments. All variables measured in millions are scaled by total assets.

To understand what endogeneity may be present, I first establish a baseline for comparison. I run the above regression, letting $GovRevenue_{i,t}$ equal the realized value of R&D contract revenue. This regression will provide an estimate of government's impact before controlling for any endogeneity. Table 3 shows the results. The impact of government funding appears positive and significant. In dollar terms, an increase of $1 million in funding is associated with spending $38,000 more on R&D. This estimate suggests that the government funding is increasing the firm's R&D activity, and thus that the government is on average successful in complementing private innovation.

[*INSERT TABLE 3 HERE*]

Next, I replace the measure of realized contract revenue with the fitted values implied by Column (1) in Table 1, which will allow me to make a causal statement about the impact of government funding. I find that the magnitude of the impact decreases from 0.038 to 0.0040, though it remains significant. The two coefficients are significantly different from one another, suggesting that endogeneity does bias estimates of government funding impact upward. While statistically significant, the $4,000 increase in expenditure for every $1 million in contract revenue is not economically large. This suggests that the government likely funds many projects for which government funding is not adding value, such that the average impact is small.

[*INSERT TABLE 4 HERE*]

Next, I test the predictions of Nelson (1959) and Arrow (1962) regarding the interaction between the breadth of the firm's technological base and the efficiency of government subsidies. As discussed in Section 2, the primary theoretical mechanism by which subsidy should enhance private investment in R&D is through risk-sharing. Specifically, the government is more equipped to bear the risk associated with basic research – the risk that technology resulting from R&D projects is not usable by the firm in its current industries. This leads Nelson (1959) to postulate that government subsidy should benefit concentrated firms more, as they operate in fewer industries, and thus are more exposed to this risk.

[*INSERT TABLE 5 HERE*]

To explore this idea empirically, I test the interaction between government funding and the breadth of the firm's operations, as measured by the number of distinct Compustat segments they operate in each quarter. Table 5 presents the results for both actual revenue (Columns (1) and (2)), and instrumented revenue (Columns (3) and (4)). The coefficient on $GovRevenue_t$ represents the baseline effect for concentrated firms, while the coefficient on the interaction $GovRevenue_t * NumSegments_t$ is interpreted as how much the effect varies on average as the breadth of the firm's operations increases. Again, the non-instrumented revenue leads to over-estimation of the baseline effect by a factor of 10, with the causal estimate suggesting that only 0.32% of contract allocations flow through to investment by concentrated firms. Interestingly, the interaction coefficient is positive and significant, implying that government contracts allocated to more diverse firms have a larger impact on R&D spending. This evidence counters the theoretical prediction, suggesting that the funding is not actually targeting marginal projects in more concentrated firms, where we would expect them to be most effective in adding value.

Overall, including the instrumented revenue decreases the estimated impact of government funding on firm R&D by a factor of 10, suggesting there is selection in who is awarded government contracts. The corrected causal impact, while statistically significant, is modest, with only 0.43% of every dollar of additional funding flowing through to firm expenditures. Also, the impact is larger for firms which have broader operations, countering what the theory would predict if subsidies were being efficiently targeted. These results suggest that the complementarity between funding sources is limited in practice, but, it is possible that funding from one source is more or less productive than the other in terms of research *output* (patents, publications, etc.). For example, it is possible that government's impact on firm R&D spending is modest, but that their funding is more (less) efficient in terms of productivity, leading to more (less) output for a similar level of expenditures. I explore this idea below.

6.1 Government Funding and Research Outputs

I begin by testing the impact of government funding on research output with a simple measure of patent quantity, as measured by patent applications filed each quarter. As mentioned in Section 4, I focus on patent application dates, as this more closely aligns with when the technologies are generated than do approval dates. I restrict the patent sample to those patents which are ultimately approved, as including applications which are eventually denied may lead to overestimation of the firm's research outputs. For this test in Table 6, I replace the dependent variable in Tables 3 and 4 with the quantity of patent applications. The results in Column (2) suggest that a 100% increase in contract revenue should increase patent applications by 18, though this estimate is only marginally significant (t = 1.86). This contrasts with Column (4) which gives a much more precise, but smaller point estimate, suggesting that a similar increase in contract revenue is associated with a statistically significant 4.4 more patent applications being filed the following quarter (t = 4.39). This suggests that in terms of quantity, government funding does have a positive impact on research outputs, but also underscores the degree to which failure to account for endogeneity can lead to vast over-estimates of the effect.

[*INSERT TABLE 6 HERE*]

Table 7 expands upon these tests by exploring the impact on future patenting activity 2, 3, and 4 quarters into the future. Because patent output may not be immediate following increased investment, it is important to understand the time trend of applications following receipt of government funding. The final three columns present the causal estimates of this impact up to 4 quarters into the future. The impact stays consistently positive and significant, suggesting that government funding does increase patent applications not only immediately, but also for technologies that may take longer to develop.

[*INSERT TABLE 7 HERE*]

Now that I have established an increase in the *quantity* of patents, I will explore the *quality* of those patents. Because government controls both the funding and patent assigning organizations, contractors may have increased incentives to apply for patents on technology that they otherwise may not have. This possibility means that the number of patents alone may lead to an inaccurate portrayal of the impact of subsidies on research outputs. Higher quality patents are those which are able to be used as the basis for future technology, and those which are expounded upon in this way more rapidly. In Table 8, I explore government funding's impact on future patent citations, capturing the first aspect of patent quality. I measure citations as the average number of future citations of the firm's patents this quarter. Column (4) estimates the causal impact of an increase of 100% in R&D contract revenue on the average number of future patents which cite those applied for by the firm this quarter. This estimate is negative and marginally significant, suggesting that while government funding increases firm patent activity, these patents are less useful for generating other technologies going forward, generating 1.4 fewer citations, on average (t = -1.90).

Next, I explore the second aspect of patent quality, by estimating the impact of government funding on the speed with which the technology is expanded on by others. I measure this time-to-citation as the average number of quarters between the patent application date and the analogous date for the citing patents. Table 9 estimates how time-to-approval and time-to-citation change as the firm receives more government contract revenue. I find that government revenue does not shorten the approval process, but that it does increase the time it takes for the patented technology to be used by other patents. Column (4) suggests that an increase in contract revenue of 100% increases the time-to-citation by 1.3 quarters, on average.

[*INSERT TABLE 9 HERE*]

Overall, this evidence suggest that, while contract revenue may increase the number of patent applications, these patents are of lower quality, both in terms of how many patents cite them, and how long it takes before they become the basis for other technology. Taken together with the evidence on the substitution between government and private sector funding, my results suggest a great deal of inefficiency in R&D contract allocation.

7 Conclusion

This paper contributes to the national conversation about the ideal size and scope of government by exploring the effectiveness of government in one specific area:

facilitating private sector innovation. Theoretical foundations suggest a complementarity between government funding and firm innovation spending. In practice, whether government funding acts as a substitute or complement has been the subject of many existing studies. However, this paper is the first to properly address the endogeneity problem in who is awarded a federal contract, which I achieve with a precisely defined IV.

Specifically, I estimate the causal impact of additional government revenue on firm R&D spending by identifying retirements of Supervising Contract Officers as negative shocks to firm contract revenue. I link firms to agency-state level employee departures, and estimate that an SCO retiring reduces firm contract revenue in the following quarter by $24 million, on average. I also find evidence that this impact manifests through contract renegotiations, rather than initiation of new programs.

Endogeneity overestimates the impact of government funding both for research inputs and outputs. Causal estimates suggest that $1 million in additional contract revenue increases R&D expenditures by only $4,300 (t = 6.50), while increasing revenue by 100% leads to the firm submitting 4 more patent applications. However, this increase in revenue predicts fewer citations, and a longer time-to-citation for the additional patents. These results suggest that the government contracts are mostly substituting for firm innovation spending, and that these contracts negatively impact the quality of research outputs. The policy prescription from this paper is a careful identification of the high-risk, socially beneficial projects which are ideal candidates for government funding, leaving others to the private sector. For researchers, this paper also demonstrates the importance of properly controlling for endogeneity when examining the impact of government contracts on firm activity. Failing to do so can lead to large over-estimations and false conclusions about the effectiveness.

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Figure 1: **Illustration of Categories of Projects for Subsidy**

This figure illustrates the three types of projects which firms can encounter for potential investment, and how their NPV scales with the probability of success, p. By offering a subsidy, government can increase p, changing the set of projects that the firm will find attractive. Type A projects are those which the firm would undertake even without subsidy, or those for which government funds would substitute for private investment. Type B projects are the marginal projects for which the subsidy incentivizes the firm to increase its investment, by taking projects they otherwise would not, implying complementarity between government and private sector funding sources. Finally, type C projects are those for which the project is negative NPV even with complete risk-sharing, and for which the firm will decline to submit a bid.

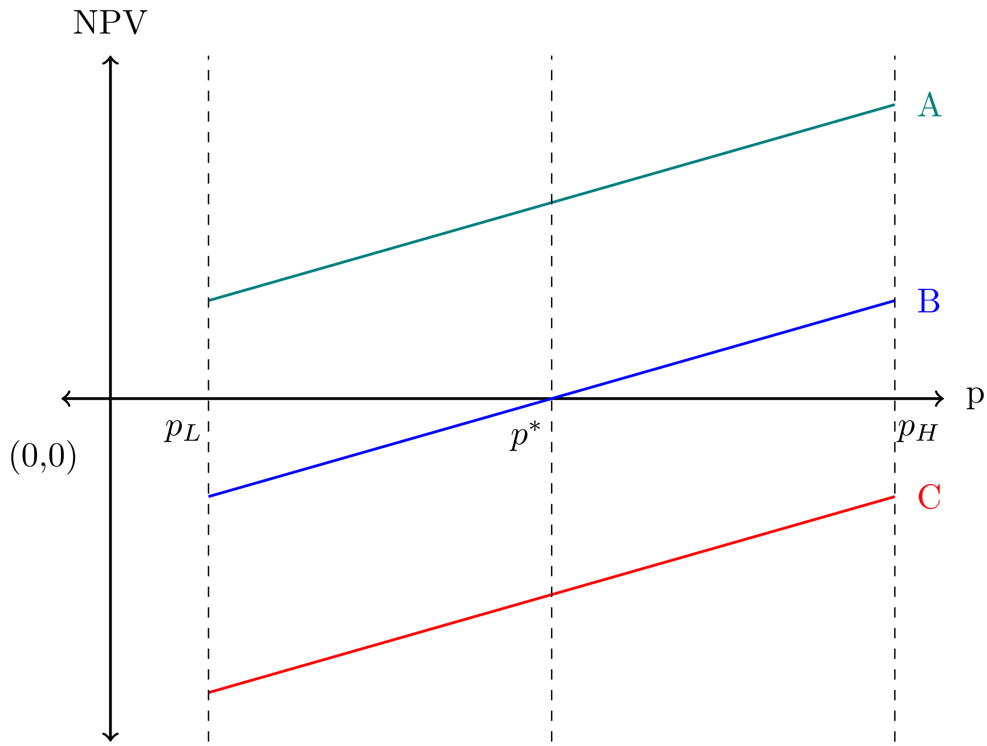

Figure 2: **Illustration of Investment Opportunity Sets**

This figure illustrates how the investment opporunity set of the firm changes when they receive properly targeted government subsidies. The green region represents Type A projects, which the firm will undertake regardless of subsidy, and for which government funding is inefficient. The blue ring represents the marginal Type B projects for which government subsidy incentivizes firms to invest when they otherwise would not have. The investment set with proper subsidy is inclusive of that without subsidy, leading to the testable prediction that the causal impact of contract revenue on R&D inputs should be positive if the contracts are being allocated efficiently.

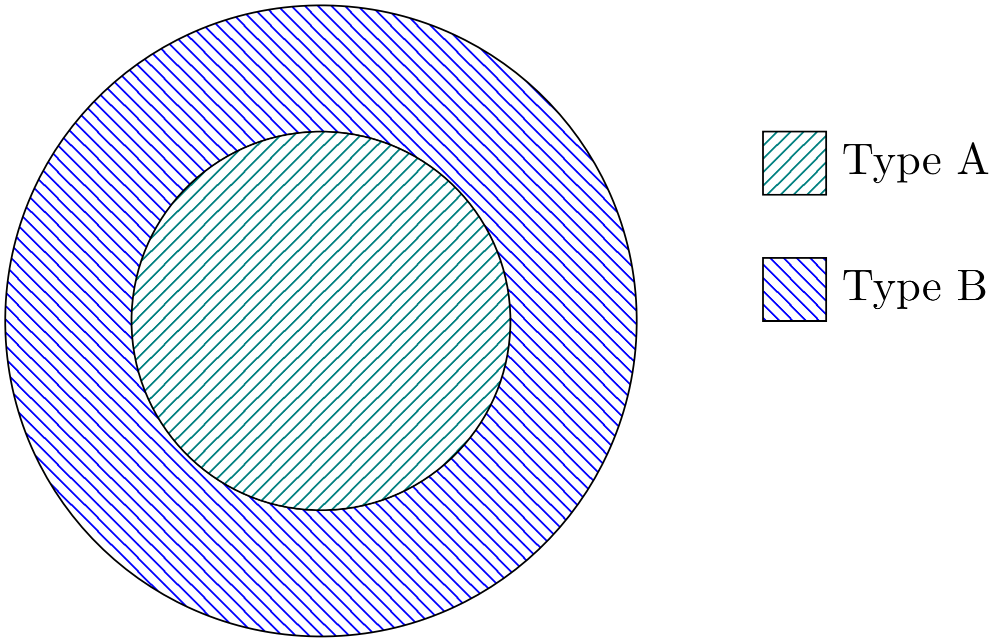

Figure 3: **Share of Public Firms Identified as Government Contractors**

This chart plots the prominence of government contractors among public firms each year. They are identified using the fuzzy matching method described in Section 3. I compute the Levenshtein ratio between each pair of Compustat firm names and contract recipient names, keep the reasonably close matches, and manually verify them. The line shows the number of firms with government revenue from federal contracts as a fraction of the total number of public firms in that year.

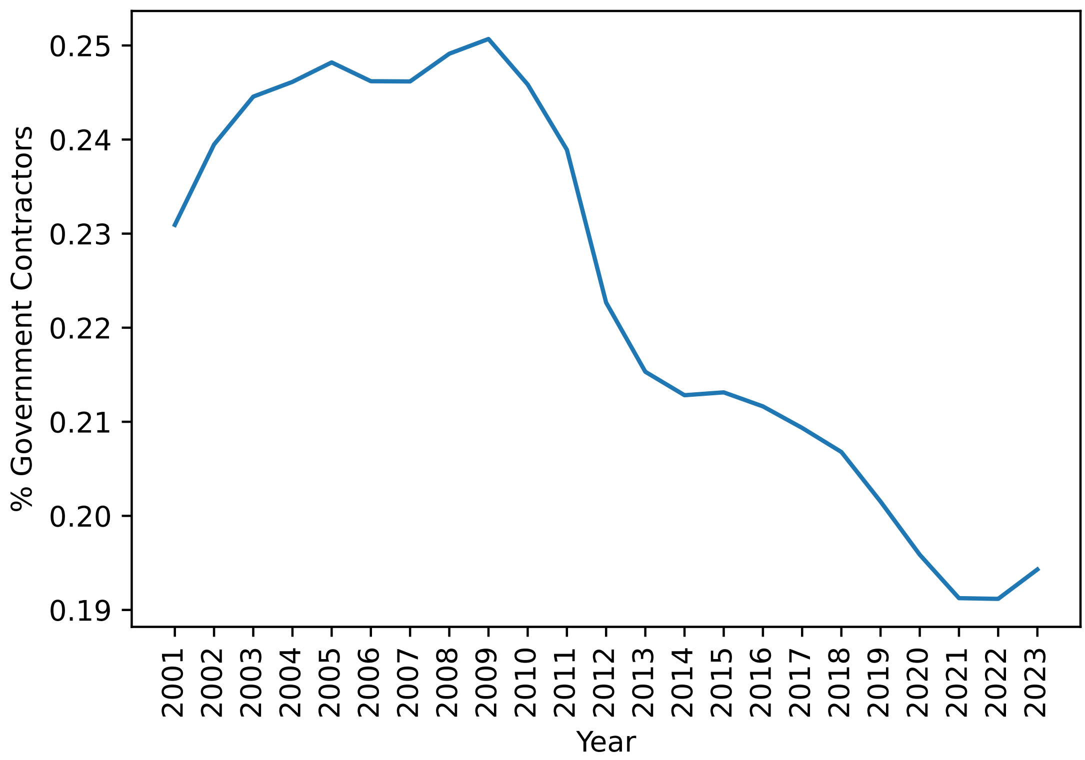

Figure 4: **Departures by Age Group**

This chart is a histogram showing the distribution of employee departures by their age in groups of 5 years. The sample is the group of employees working in contracting (OPM Occupation Code = 1102 described in Section 3). The timing of departures are determined by last quarter each unique employee ID appears in the sample. There is a peak around the federal minimum retirement age of 55, which is interpreted as supporting evidence for retirements as a valid instrument for firm contract revenue.

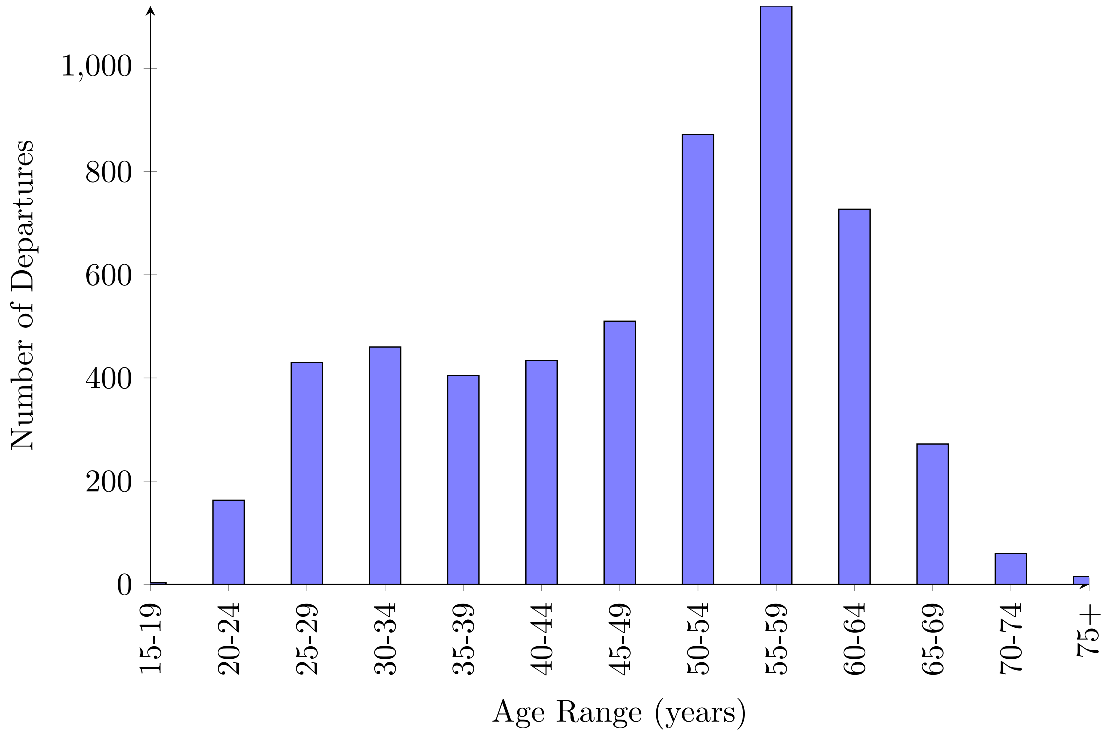

Table 1: **The Impact of Retirement on Firm Revenue**

This table presents the results of the first-stage regression for the instrumental variable constructed in Section 4. GovRev_t is the total dollar amount of R&D contract revenue received by the firm from the federal government, in millions, inflation-adjusted to 2001. $Retirement_{i,t}$ is an indicator equal to 1 if any Supervising Contract Officer at any agency a firm receives revenue from retired in the previous period, $GovRevenue_{t-1}$ measures the total revenue a firm received in the past quarter. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively.

Dep Var: $\text{GovRev}_{i,t}$	(1)	(2)	(3)	(4)
$\text{Retirement}_{i,t-1}$	-23.51***	-24.03***	-24.41***	-23.93***
	(-3.38)	(-3.37)	(-3.43)	(-3.36)
$\text{GovRev}_{i,t-1}$	0.17***	0.17***	0.17***	0.17***
	(12.49)	(12.32)	(12.57)	(12.26)
Total $q_{i,t}$		0.54	0.55	0.41
		(0.74)	(0.76)	(0.56)
$\text{FCF}_{i,t}$			-0.02***	-0.02***
			(-4.08)	(-4.01)
Other $\text{Revenue}_{i,t}$			0.00	0.00
			(0.81)	(1.20)
$\log(\text{Age}_{i,t})$				-7.59
				(-1.02)
$\log(\text{Assets}_{i,t})$				-8.34***
				(-2.47)
# Business $\text{Segments}_{i,t}$				-2.14***
				(-2.43)
Constant	25.09***	25.01***	25.81***	124.88***
	(25.82)	(18.25)	(9.52)	(3.52)
N	5,894	5,742	5,742	5,742
R^2	0.8426	0.8426	0.8431	0.8436

Table 2: **The Heterogeneous Impact of Retirement on Firm Revenue**

This table presents the results of the first-stage regression for the instrumental variable constructed in Section 4. GovRev_t is the dollar amount of R&D contract revenue received by the firm from the federal government, in millions, inflation-adjusted to 2001. Columns (1) and (2) measure revenue from new contracts, while (3) and (4) measure revenue from renegotiations. $Retirement_{i,t}$ is an indicator equal to 1 if any Supervising Contract Officer at any agency a firm receives revenue from retired in the previous period, $GovRev_{t-1}$ measures the total revenue a firm received in the past quarter. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively.

	New Awards		**Modifications**	
	(1)	(2)	(3)	(4)
$\text{Retirement}_{i,t}$	0.50	0.54	-24.89***	-24.81***
	(0.52)	(0.56)	(-3.67)	(-3.67)
$\text{GovRev}_{i,t-1}$	0.03***	0.03***	0.15***	0.15***
	(15.32)	(14.96)	(11.60)	(11.56)
Total $\text{q}_{i,t}$	0.01	0.01	0.53	0.41
	(0.14)	(0.09)	(0.76)	(0.58)
$\text{FCF}_{i,t}$		0.00		-0.02***
		(0.81)		(-4.04)
Other $\text{Revenue}_{i,t}$		-0.00		0.00
		(-0.78)		(1.18)
$\log(\text{Age}_{i,t})$		-0.00		-7.61
		(-0.00)		(-1.07)
$\log(\text{Assets}_{i,t})$		-0.50		-7.55**
		(-1.09)		(-2.35)
# Business $\text{Segments}_{i,t}$		-0.25**		-1.85***
		(-2.07)		(-2.22)
Constant	2.44***	7.08	21.92***	115.33***
	(13.09)	(1.46)	(16.81)	(3.42)
N	5,742	5,742	5,742	5,742
R^2	0.6381	0.6386	0.8162	0.8172

Table 3: **The Non-Instrumented Impact of Government Funding**

This table presents the results from a regression of firm R&D intensity onto *realized* firm revenue from federal R&D contracts in that quarter, along with a vector of control variables. R&D intensity is measured as firm R&D expense scaled by total Assets. $\text{GovRev}_{i,(t,t-1)}$, $\text{FCF}_{i,t}$, and $\text{OtherRevenue}_{i,t}$ measure firm revenue from the government, free cash flow (operating cash flow - capex), and revenue from other sources. All are scaled by total assets. Age is measured in quarters, assets are measured in millions, and Total q is the Peters and Taylor (2017) Total q measure, available through WRDS. All dollar values are inflation adjusted to 2001. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively. These coefficients represent the impact of government funding on firm R&D activity, before correcting for potential endogeneity.

Dep Var: $\text{RDIntensity}_{i,t}$	(1)	(2)	(3)	(4)
$\text{GovRev}_{i,t}$	0.0198***	0.0174***	0.0171***	0.0377***
	(3.35)	(3.17)	(3.11)	(5.98)
$\text{GovRev}_{i,t-1}$	0.0133**	0.0110*	0.0117**	0.0081
	(2.16)	(1.94)	(2.06)	(1.44)
Total $\text{q}_{i,t}$		0.0000	0.0000	-0.0001
		(0.29)	(0.14)	(-0.38)
$\text{FCF}_{i,t}$			-0.0228***	-0.0286***
			(-4.23)	(-5.27)
Other $\text{Revenue}_{i,t}$				0.0251***
				(7.35)
$\log(\text{Age})_{i,t}$				-0.0030**
				(-2.13)
$\log(\text{Assets})_{i,t}$				-0.0029***
				(-4.24)
# Business $\text{Segments}_{i,t}$				0.0003**
				(2.03)
Constant	0.0123***	0.0123***	0.0124***	0.0387***
	(61.61)	(47.27)	(47.47)	(5.39)
N	5,894	5,742	5,742	5,742
R^2	0.7185	0.7474	0.7482	0.7539

Table 4: **The Instrumented Impact of Government Funding**

This table presents the results from a regression of firm R&D intensity onto *fitted* values of firm revenue from federal R&D contracts in that quarter, along with a vector of control variables. $\widehat{GovRev}_{i,t}$ is the value of federal revenue, predicted by the first stage regression shown in Table 1 R&D intensity is measured as firm R&D expense scaled by total Assets. $\text{GovRev}_{i,t}$, $\text{FCF}_{i,t}$, and $\text{OtherRevenue}_{i,t}$ measure firm revenue from the government, free cash flow (operating cash flow - capex), and revenue from other sources in period t. All are scaled by total assets. Age is measured in quarters, assets are measured in millions, and Total q is the Peters and Taylor (2017) intangible-adjusted q measure, available through WRDS. All dollar values are inflation adjusted to 2001. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively. These coefficients represent the impact of government funding on firm R&D activity, after correcting for potential endogeneity using SCO retirements and an instrumental variable.

Dep Var: RDIntensity	(1)	(2)	(3)	(4)
$\widehat{GovRev}_{i,t}$	0.0056***	0.0056***	0.0054***	0.0040***
	(9.68)	(9.69)	(9.37)	(6.03)
$\text{GovRev}_{i,t-1}$	0.0084	0.0083	0.0091	0.0141**
	(1.57)	(1.55)	(1.69)	(2.60)
Total $q_{i,t}$		0.0001	0.0001	0.0000
		(0.58)	(0.45)	(0.17)
$\text{FCF}_{i,t}$			-0.0188***	-0.0238***
			(-3.50)	(-4.39)
Other $\text{Revenue}_{i,t}$				0.0159***
				(5.39)
$\log(\text{Age})_{i,t}$				-0.0018
				(-1.25)
$\log(\text{Assets})_{i,t}$				-0.0019**
				(-2.61)
# Business $\text{Segments}_{i,t}$				0.0003**
				(2.18)
Constant	0.0101***	0.0100***	0.0102***	0.0251***
	(33.17)	(28.04)	(28.27)	(3.21)
N	5,742	5,742	5,742	5,742
R^2	0.7511	0.7510	0.7516	0.7540

Table 5: **Testing Predictions about the Impact of Firm Diversity**

This table presents the results from a regression of firm R&D intensity onto *fitted* values of firm revenue from federal R&D contracts in that quarter, along with a vector of control variables, this time testing the interaction between the contract revenue and the width of the firm's technological base. Columns (1) and (2) use the realized value of contract revenue, and (3) and (4) use the value predicted by the first stage regression shown in Table 1. $\text{GovRev}_{i,t}$, $\text{FCF}_{i,t}$, and $\text{OtherRevenue}_{i,t}$ measure firm revenue from the government, free cash flow (operating cash flow - capex), and revenue from other sources in period t. All are scaled by total assets. Age is measured in quarters, assets are measured in millions, Total q is the Peters and Taylor (2017) intangible-adjusted q measure, available through WRDS, and $NumSegments$ is the number of distinct Compustat business segments in which the firm operates in that period. All dollar values are inflation adjusted to 2001. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively. These coefficients represent the impact of government funding on firm R&D outputs, and demonstrates the over-estimation that occurs when failing to account for endogeneity.

	Actual Revenue		**Fitted Revenue**	
Dep Var: RDIntensity	(1)	(2)	(3)	(4)
GovRevenue_t	0.0145*	0.0359***	0.0046***	0.0032***
	(1.84)	(4.22)	(7.12)	(4.53)
NumSegments_t	0.0002	0.0003*	0.0001	0.0002
	(1.03)	(1.92)	(0.61)	(1.10)
$\text{GovRevenue}_t{*}\text{NumSegments}_t$	0.0015	0.0009	0.0006***	0.0005***
	(0.50)	(0.32)	(3.30)	(3.05)
GovRevenue_{t-1}	0.0112*	0.0083	0.0079	0.0132**
	(1.96)	(1.46)	(1.48)	(2.43)
Totalq_t	0.0000	-0.0001	0.0001	0.0000
	(0.29)	(-0.39)	(0.51)	(0.07)
FCF_t		-0.0287***		-0.0236***
		(-5.28)		(-4.35)
OtherRevenue_t		0.0251***		0.0159***
		(7.34)		(5.40)
$\log(\text{Age}_t)$		-0.0030**		-0.0017
		(-2.13)		(-1.20)
$\log(\text{Assets}_t)$		-0.0029***		-0.0018**
		(-4.23)		(-2.49)
Constant	0.0116***	0.0388***	0.0095***	0.0266***
	(17.42)	(5.39)	(13.04)	(3.40)
N	5,742	5,742	5,742	5,742
R^2	0.7684	0.7745	0.7723	0.7750

Table 6: **The Impact of Government Contracts on Patent Activity**

This table presents the results from a regression of firm patent activity onto firm revenue from federal R&D contracts in that quarter, along with a vector of control variables. Columns (1) and (2) use the realized value of contract revenue, and (3) and (4) use the value predicted by the first stage regression shown in Table 1 Patent output is measure by number of patents. $\text{GovRev}_{i,t}$, $\text{FCF}_{i,t}$, and $\text{OtherRevenue}_{i,t}$ measure firm revenue from the government, free cash flow (operating cash flow - capex), and revenue from other sources in period t. All are scaled by total assets. Age is measured in quarters, assets are measured in millions, Total q is the Peters and Taylor (2017) intangible-adjusted q measure, available through WRDS, and $NumSegments$ is the number of distinct Compustat business segments in which the firm operates in that period. All dollar values are inflation adjusted to 2001. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively. These coefficients represent the impact of government funding on firm R&D outputs, and demonstrates the over-estimation that occurs when failing to account for endogeneity.

	Actual Revenue		**Fitted Revenue**	
Dep Var: # Patent Applications	(1)	(2)	(3)	(4)
$\hat{\text{G}}\text{ovRevenue}_t$	2.2289	18.0237*	0.7902	4.3598***
	(0.27)	(1.86)	(0.88)	(4.29)
GovRevenue_{t-1}	1.3197	3.5808	0.9177	4.0655
	(0.15)	(0.41)	(0.11)	(0.49)
Totalq_t	-0.1737	-0.2586	-0.1669	-0.1960
	(-0.81)	(-1.20)	(-0.78)	(-0.91)
FCF_t	-2.7689	-9.2716	-2.1799	-5.7140
	(-0.34)	(-1.11)	(-0.26)	(-0.69)
OtherRevenue_t		13.4046**		9.6935**
		(2.56)		(2.15)
$\log(\text{Age}_t)$		-5.1388**		-3.8780*
		(-2.38)		(-1.78)
$\log(\text{Assets}_t)$		7.2294***		8.8930***
		(6.89)		(7.86)
NumSegments_t		0.7456***		0.7525***
		(2.92)		(2.95)
Constant	23.3403***	-11.0849	23.0104***	-29.3156**
	(58.47)	(-1.00)	(41.51)	(-2.44)
N	5,742	5,742	5,742	5,742
R^2	0.9094	0.9104	0.9094	0.9107

Table 7: **The Impact of Government Contracts on Future Patent Activity**

This table presents the results from a regression of firm future patent activity onto firm revenue from federal R&D contracts in the current quarter, along with a vector of control variables. Columns (1) and (2) use the realized value of contract revenue, and (3) and (4) use the value predicted by the first stage regression shown in Table 1 Patent output is measure by number of patents. GovRev$_{i,t}$, FCF$_{i,t}$, and OtherRevenue$_{i,t}$ measure firm revenue from the government, free cash flow (operating cash flow - capex), and revenue from other sources in period t. All are scaled by total assets. Age is measured in quarters, assets are measured in millions, Total q is the Peters and Taylor (2017) intangible-adjusted q measure, available through WRDS, and *NumSegments* is the number of distinct Compustat business segments in which the firm operates in that period. All dollar values are inflation adjusted to 2001. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively. These coefficients represent the impact of government funding on firm R&D outputs, and demonstrates the over-estimation that occurs when failing to account for endogeneity.

	Actual Revenue			**Fitted Revenue**		
Dep Var: # Pat. Apps.	2Q	3Q	4Q	2Q	3Q	4Q
GovRevenue$_t$	6.3859	11.0730	-1.1996	5.4892***	5.0831***	3.9707**
	(0.35)	(0.55)	(-0.06)	(3.42)	(3.22)	(2.53)
GovRevenue$_{t-1}$	7.3469	4.2324	3.0761	1.4719	-2.1117	-2.6386
	(0.43)	(0.29)	(0.18)	(0.09)	(-0.14)	(-0.15)
Totalq$_t$	-0.3933	-0.2849	-0.1465	-0.2472	-0.1464	-0.0412
	(-1.25)	(-0.90)	(-0.45)	(-0.78)	(-0.46)	(-0.13)
FCF$_t$	-14.8286	-12.6394	-7.7919	-10.4409	-8.9650	-5.3266
	(-1.22)	(-1.04)	(-0.64)	(-0.86)	(-0.74)	(-0.44)
OtherRevenue$_t$	2.9486	4.9495	-0.5623	4.0142	5.6476	1.5219
	(0.40)	(0.66)	(-0.07)	(0.58)	(0.80)	(0.21)
log(Age$_t$)	-6.1491**	-7.0018**	-5.8859*	-4.1960	-5.6433*	-4.7685
	(-1.97)	(-2.30)	(-1.79)	(-1.32)	(-1.84)	(-1.45)
log(Assets$_t$)	7.2570***	6.9925***	4.4237***	9.2876***	8.9594***	6.1845***
	(4.67)	(4.52)	(2.82)	(5.64)	(5.43)	(3.68)
NumSegments$_t$	1.3954***	1.8384***	2.3729***	1.3918***	1.8351***	2.3458***
	(3.85)	(5.16)	(6.37)	(3.86)	(5.17)	(6.32)
Constant	-5.3873	-1.8805	10.8083	-31.1117*	-24.2034	-8.8717
	(-0.34)	(-0.12)	(0.66)	(-1.80)	(-1.43)	(-0.50)
N	3,811	3,730	3,573	3,811	3,730	3,573
R^2	0.8972	0.8984	0.8950	0.8975	0.8987	0.8952

Table 8: **The Impact of Government Contracts on Patent Citations**

This table presents the results from a regression of firm future patent relevance onto firm revenue from federal R&D contracts in the current quarter, along with a vector of control variables. Columns (1) and (2) use the realized value of contract revenue, and (3) and (4) use the value predicted by the first stage regression shown in Table 1 Patent citations is measured by the average number of future citations the firm's patents received, capturing how influential the patents will be going forward. $\text{GovRev}_{i,t}$, $\text{FCF}_{i,t}$, and $\text{OtherRevenue}_{i,t}$ measure firm revenue from the government, free cash flow (operating cash flow - capex), and revenue from other sources in period t. All are scaled by total assets. Age is measured in quarters, assets are measured in millions, Total q is the Peters and Taylor (2017) intangible-adjusted q measure, available through WRDS, and *NumSegments* is the number of distinct Compustat business segments in which the firm operates in that period. All dollar values are inflation adjusted to 2001. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively. These coefficients represent the impact of government funding on firm R&D outputs, and demonstrates the over-estimation that occurs when failing to account for endogeneity.

	Actual Revenue		**Fitted Revenue**	
Dep Var: Future Citations	(1)	(2)	(3)	(4)
GovRevenue_t	3.1354	3.9134	-1.3622**	-1.4048*
	(0.52)	(0.55)	(-2.10)	(-1.90)
GovRevenue_{t-1}	-3.3739	-3.6625	-0.1639	-1.2717
	(-0.54)	(-0.58)	(-0.03)	(-0.21)
Totalq_t	0.2647*	0.2025	0.2577*	0.1911
	(1.71)	(1.29)	(1.66)	(1.22)
FCF_t	-6.8413	-7.4086	-7.9565	-7.8452
	(-1.15)	(-1.22)	(-1.33)	(-1.29)
OtherRevenue_t		0.1026		-1.3816
		(0.03)		(-0.42)
$\log(\text{Age}_t)$		-4.3444***		-4.7198***
		(-2.76)		(-2.97)
$\log(\text{Assets}_t)$		1.5600**		0.7692
		(2.04)		(0.93)
NumSegments_t		0.1494		0.1552
		(0.80)		(0.83)
Constant	6.8318***	14.3800*	7.4428***	22.5874***
	(23.61)	(1.79)	(18.52)	(2.58)
N	5,742	5,742	5,742	5,742
R^2	0.3755	0.3768	0.3760	0.3772

Table 9: **The Impact of Variables on Average Citation and Approval**

This table presents the results from a regression of firm patent processing times onto the instrumented value of firm revenue from federal R&D contracts in the current quarter, along with a vector of control variables. Columns (1) and (2) measure the average time from application to patent approval, and (3) and (4) measure the average time before citing patents are filed, both measured in quarters. $\widehat{GovRev}_{i,t}$, $\text{FCF}_{i,t}$, and $\text{OtherRevenue}_{i,t}$ measure firm revenue from the government, free cash flow (operating cash flow - capex), and revenue from other sources in period t. All are scaled by total assets. Age is measured in quarters, assets are measured in millions, Total q is the Peters and Taylor (2017) intangible-adjusted q measure, available through WRDS, and $NumSegments$ is the number of distinct Compustat business segments in which the firm operates in that period. All dollar values are inflation adjusted to 2001. *,**, and *** indicate significance at the 10, 5, and 1% levels, respectively. These coefficients represent the impact of government funding on firm R&D outputs, and demonstrates the over-estimation that occurs when failing to account for endogeneity.

	Approval Time		**Citation Time**	
	(3)	(4)	(1)	(2)
$\widehat{GovRev}_{i,t}$	0.65*	0.39	1.78***	1.34**
	(1.73)	(0.98)	(2.83)	(2.03)
GovRevenue_{t-1}	-4.22	-5.46	-4.74	-8.06
	(-0.93)	(-1.19)	(-0.68)	(-1.14)
Total q_t	0.09	0.04	-0.13	-0.19*
	(1.25)	(0.51)	(-1.21)	(-1.76)
FCF_t	1.50	2.19	-0.05	1.57
	(0.57)	(0.83)	(-0.01)	(0.40)
Other Revenue_t		-1.78		-6.73***
		(-1.10)		(-2.78)
$\log(\text{Age})_t$		-2.62***		-2.12**
		(-3.99)		(-2.20)
$\log(\text{Assets})_t$		0.03		-0.65
		(0.12)		(-1.53)
Number of Segments_t		-0.11*		-0.02
		(-1.80)		(-0.21)
Constant	13.55***	26.15***	26.69***	43.29***
	(97.07)	(7.27)	(130.16)	(8.16)
N	2,958	2,958	2,838	2,838
R^2	0.4107	0.4153	0.6050	0.6072