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Abstract

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JEL Classification: H11, H57, O31, O32, O38

Keywords: Buyers, Innovation, Management Practices, Procurement, patents, R&D Procurement

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Buyers' Role in Innovation Procurement*

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I Introduction

Public procurement of innovation concerns the acquisition of R&D services and innovative goods. Although it covers only a small share of GDP, it plays an increasingly strategic role in the economy.[1] It can be a means to increase the efficiency of public services in the face of grand societal challenges linked to population ageing and climate change, and an important policy instrument to boost innovation, competitiveness and growth. About 50% of OECD countries have developed an action plan for procurement of innovation (OECD 2017). With globalized competition, effective outsourcing of R&D and innovation has become increasingly important in the private sector as well (Grimpe and Kaiser 2010, Chesbrough 2003). However, ensuring the effectiveness of the procurement of innovation may be difficult. The procurer needs to make an internal and a market assessment to identify its needs and potential supply, translate its needs into functional requirements and design the tender efficiently so as to select the most suitable contractor. If the buyer plays an important role, then ineffective public buyers can be particularly problematic, as they might bolster the risk that public procurement of innovation pushes firms' R&D investment in the wrong direction.

Despite its relevance to today's policy discussion, econometric studies on the performance of procurement of innovation are scarce at best. One reason is the difficulty in quantifying performance. Measures typically used in the procurement of standardized goods, such as prices, or in the procurement of works and services, such as time and cost overruns, have little meaning when the object of a contract is an innovation. In this paper, we seek to fill this gap by making use of an unusually rich dataset that allows us to measure the buyer's role in determining whether public procurement contracts led to patents and their citations.

We try to shed light on the importance of the buyer's role for innovation procurement and on the phases of the procurement process where this role matters by combining four datasets.

First, we use the Federal Procurement Data System (FPDS), which contains information (e.g., awarding bureau, price, product or service code, contract amount, contract type, contractor features, etc.) on every contract awarded by U.S. federal agencies worth more than $3,000. Second, we use the 3PFL Database of Federally Funded Patents (3PFL), as collected by de Rassenfosse et al. (2018). It links information on patented inventions (i.e., the number of patents, their asso-

[1] For the U.S. our data reveal that between 2006 and 2012, U.S. federal governments spent approximately $382 billion in R&D procurement, an average of $54.57 billion per year.

ciated citations and claims) induced by a U.S. federal procurement contract of R&D to the FPDS dataset. While only a small share of contracts involving R&D produce patents (5.34%), a few of them (31.7%) produce more than one patent.

Our identification strategy is based on the unexpected death of federal managers in the six months preceding the contract start date, i.e., precisely in the period during which contractor selection takes place. The intuitive story for why managers' deaths matter is that those deaths induce a temporary shortage of skilled workers in the bureau and this affects procurement performance.[2] To this end, we enrich our set of data with a third dataset which reports fine statistical information on the entirety of the public workforce produced by the Office of Personnel Management and made it publicly available through the Federal Human Resource database (FedScope). As deaths may not be randomly assigned to bureaus (e.g., size may matter), we use a propensity score weighting approach to adjust for possible unbalancedness on observable characteristics.

Finally, to shed further light on the features most relevant to the buyer's role in innovation procurement, we use a fourth dataset, the Federal Employee Viewpoint Survey (FEVS), that measures government employees' perceptions on several characteristics of their agency and specific unit/bureau.

We find a strong negative impact of unexpected manager deaths occurring in the six months before the contract is awarded on all our innovation outcome measures: an increase in managers' deaths equivalent to 1% of bureau-State-specific number of white collars, causes a decline of 4.3% of patents per contract, 3.8% patent citations per contract and 8.6% patent claims per contract. The smaller the workforce size of the bureau, the stronger is this effect. By contrast, we find a considerably weaker, though still positive and significant effect of unexpected managers' deaths occurring during the contract management phase that follows the contract's award. Similarly, no effects are found when the death events involve employees less likely to cover management roles.

The results are robust to the inclusion of bureau and contractor fixed effects and are qualitatively stable across various model specifications and subsamples. This is suggestive that the effect of relevant managers is not merely loaded into the selection of the contractors but involves additional activities that, most likely, take place before the tender, such as the need assessment and the market evaluation.

[2]The author looks at worker deaths in the private sector and studies changes over time within firms around the time they experience the loss of a worker due to an unexpected death.

Consistently with these results, we also find that bureaus where employees perceive a high level of cooperation within the office are associated with better R&D outcomes. This latter effect is only direct and not through an interaction with the deaths of bureau managers, and suggests that cooperative management practices are central to successful innovation procurement. Neither direct nor indirect effects are found instead for the level of skills and incentives within the bureaus.

Overall, these results represent a clear indication of the importance of focusing on buyers when trying to improve the procurement of innovation, and of the potential benefits of investing in them through a greater professionalization of their activity, both in the public and the private sector. The importance of the pre-award phase and the role played by cooperation are consistent with the complexity and highly interdisciplinary nature of procurement design, which requires combining legal, technical and market expertise of multiple subjects. Given the crucial role of innovation in fostering economic growth and the high share of innovation procurement originating from public bodies, these benefits would spill over to the whole economy.

The rest of the paper is organized as follows. Section 2 presents the relevant literature. Section 3 describes the data sources and reports basic summary statistics. Section 4 illustrates the empirical strategy. Section 5 displays the main results and investigates the channels though which buyers affect innovation outcomes. Section 6 concludes.

II Related literature

Since the seminal works of Schumpeter (1942), Schmookler (1962) and Kaldor (1966), economists consider market demand as one of the major drivers of technical change and innovation. More recently, scholars and policy makers started to suggest that public demand, i.e., public procurement, may have a specific and important role in this process (Geroski 1990, Dalpé 1994, Edquist and Hommen 2000, Scotchmer 2004, Cabral et al. 2006, Edler and Georghiou 2007, Cozzi and Impullitti 2010, EU 2010, OECD 2013).[3] The underlying theoretical argument is the ability of a public agency to act as a lead user. Lead users are defined as users that have needs that are not met by products and services available on the market, who are able to identify innovative solutions

[3] Procurement contracts for R&D represent 36% of total federal spending in R&D and about 11% of global spending in R&D. Even if only a few countries, as for example Finland, have historically devoted attention to innovation-oriented demand, public procurement of innovation is currently receiving growing attention also at the national level, especially in emerging economies, see Uyarra (2013).

addressing those needs (Von Hippel 1986, Gambardella et al. 2016). A public agency procuring an innovation could be considered as a particular type of lead user, capable of clearly identifying its needs and the features of the procured solutions. As highlighted by Edquist (2015), success or failure of an innovation-oriented procurement contract may depend on how the procurement agency assesses needs, evaluates potential supply, defines functional requirements and designs and manages contract and tender.

However, due to the lack of high-quality data, the empirical literature has been rather silent on the role of public buyers. Studies on innovation procurement have so far been mainly based on surveys (Aschhoff and Sofka 2009, Guerzoni and Raiteri 2015), administrative meso-level data (Slavtchev and Wiederhold 2016), and micro-level patent data (Raiteri 2018). Within these studies, Aschhoff and Sofka (2009) find that public procurement has a positive effect on firms' innovative output, proxied by the shares of revenues coming from innovated products, whereas Raiteri (2018) shows that U.S. federal procurement contracts that foster the development of technologies are more pervasive than a group of suitable controls. In a similar fashion, Corredoira et al. (2018) show that federally funded patents tend to be associated with larger technological influence.

Other studies analyzed the contribution of different types of public funding in the U.S. Li et al. (2017) provide evidence that about ten percent of the scientific grants awarded by the U.S. National Institutes of Health (NIH) generates at least one patent. Azoulay et al. (2018) show instead that NIH grants foster the development of patents in the private sectors.

The only study investigating the characteristics of the funding agency we are aware of is Bruce et al. (2018). In this work, the authors analyze how the U.S. federal government selects between different contractual forms for the performance of R&D by private-sector firms. Their study focuses on two contractual arrangements used to support R&D in the U.S.: grants and cooperative agreements. The findings of this work suggest that agencies rely on cooperative agreements when they have relevant technical capabilities near the R&D project site.

Unlike in Bruce et al. (2018), we analyze procurement contracts rather than grants and cooperative agreements. According to the U.S. federal regulation (31 U.S. Code, Subtitle V, 63.01-04), public agencies shall use grants and cooperative agreements when they are willing to support a public purpose. Procurement contracts shall instead be used when the principal purpose is to acquire property or services for the direct benefit of the public agency. Only for procurement contracts is the public agency the buyer and the final user of a specific product or service. In this work we explicitly investigate the importance of the role of the public buyer for the innovation outcome of a procurement contract.

More generally, the interest toward innovation procurement is growing. Recent empirical papers focus on the impact of procurement of innovation on the long-term effects on businesses (Howell 2017), on the private R&D investment (Slavtchev and Wiederhold 2016) and on identifying the primitives of multistage R&D contests (Bhattacharya 2018).

Our paper also contributes to the wide and still growing literature on the determinants of public procurement outcomes, and in particular on the recent literature on the role of buyers' characteristics.[4] Among these studies, the closest papers to ours are Decarolis et al. (2018), who study the effects of buyer competence on contracts for works and services other than R&D, using performance measures such as time and cost overrun; and Best et al. (2017) who find that 60 percent of within-product price variation in Russia in 2011-2015 can be ascribed to the bureaucrats and organizations in charge of procurement. Like them, we are interested in the extent to which public procurement is affected by the buyer. Unlike them, we consider complex procurements rather than standardized goods, and measure performance via innovative output instead of purchase price. Other closely related work includes Bandiera et al. (2009), Bajari et al. (2009), Decarolis (2014), Warren (2014) and Bucciol et al. (2017).

Finally, at a more general level, our results contribute to the recent literature on the role of managerial practices (Bloom and Van Reenen 2010, Van Reenen and Bloom 2007), in particular in the public sector (Bloom et al. 2014, 2015). Within this literature, our findings on cooperation square well with the results in Blader et al. (2016) on the benefits of "cooperative" managerial practices relative to high powered individual incentives.

[4] A number of empirical papers have investigated the role of, for examples, bid preferences (Marion 2007, Krasnokutskaya 2011, Athey et al. 2013), scoring auctions (Bajari and Lewis 2011), minimum prices (Chassang and Ortner 2019), contract duration (MacKay 2017), electronic procurement (Lewis-Faupel et al. 2016), subcontracting (Branzoli and Decarolis 2015), transparency (Coviello and Mariniello 2014), discretion (Coviello et al. 2018), contract renewal (Chong et al. 2015), and past performance Banerjee and Duflo (2000), Decarolis et al. (2016).

III Data

The dataset developed for this study combines together several sources. The level of observation is that of individual contracts, as tracked in the U.S. Federal Procurement Data System (FPDS).[5] From this large dataset, we apply a series of filters aimed at selecting R&D procurement contracts.[6] Moreover, we restrict the sample according to the following rules: R&D activity performed within U.S. borders; award amount greater than $14,000; expected termination date prior to end of the sample (to keep only completed projects we include exclusively contracts awarded until the end of 2012); no Small Business Innovation Research contracts and no grants.[7] This leaves us with a sample of 3,430 R&D contracts awarded between 2006 and 2012, with an overall value of $15.0 billion, 22,476 offers submitted and 525 unique winning firms.[8] Table 1 reports how these contracts are split between federal agencies: the vast majority of the contracts in the data are awarded by bureaus belonging to one of the three ramifications of the Department of Defence (DoD).[9]

The main characteristics of these contracts are reported in Table 2, panel (a). Contract amounts are relatively small and highly skewed: 50% of contracts have an awarding price below $240,000, while 10% of contract spending is accounted for by contracts worth more than $1,880,000. The

[5]See: *https://usaspending.gov*. The data covers all federal contracting offices' transactions in excess of $3,000. They have been used extensively in previous research, including studies by Liebman and Mahoney (2017), Warren (2014), Kang and Miller (2017), Giuffrida and Rovigatti (2018), Decarolis et al. (2018).

[6]The R&D code specified in each contract comes from the variable "Product or Service Code" and is composed of two alphabetic and two numeric digits. The first digit is always the letter "A" to identify R&D; the second digit is alphabetic "A to Z" to identify the major R&D category; the third digit is numeric 1 to 9 to identify a subdivision of the major R&D category, and the fourth digit will be 1 to 7, to identify the appropriate stage of R&D with: (1) Basic Research; (2) Applied Research and Exploratory Development; (3) Advanced Development; (4) Engineering Development; (5) Operational Systems Development; (6) Management and Support; (7) Commercialization. The term "research and development" normally encompasses the first six categories. For example, construction of recreational facilities at an installation used exclusively or generally for research and development would not normally be procurement of "research and development" but it is sometimes included in the sixth category in order to classify obligations according to the ultimate purpose of the procurement. Commercialization transactions are excluded from the analysis, accordingly. R&D categories (i.e., second digits) included in the sample are: Community Service/Development; Defense System; Defense Other; Economic Growth; Energy; Environmental Protection; General Science/Technology; Medical; Space; Other R&D.

[7]SBIR contracts are intended to help certain small businesses conduct R&D activities aimed at their subsequent commercialization. This program has been recently analyzed in a series of studies, including Bhattacharya (2018) and Howell (2017).

[8]The number of offers associated to tenders are reported by variable "Number of Offers Received" and is representative for 2,931 contracts. We exclude from the computation of the total number of offers received those observations reporting 99 or 999 bids (467 observations amounting to 13.61% of the working sample). Furthermore, the information was already missing in 32 observations.

[9]We indicate as *bureaus* the sub-units of the U.S. federal government agencies. All federal agencies, whether executive (i.e., analogous to ministers common in parliamentary or semi-presidential systems) - such as DoD - or independent - such as NASA - will be indicated as *agencies* throughout this study. Each agency has its own organizational structure according to which its power is exercised through different sub-units, the bureaus. Bureaus are charged with a specific mission depending on the agencies they are affiliated to. Bureaus undertake different tasks, including procurement, and are located in different U.S. States.

Table 1: U.S. Federal Agencies and R&D Contracts

Agency	Freq. of Contracts	Percent	Contract Value (billion)	Percent
Dep. Air Force	1,034	30.15	8.77	58.47
Dep. Army	819	23.88	1.82	12.13
Dep. Navy	1,103	32.16	3.65	24.33
NASA	323	9.42	0.39	2.6
Others	151	4.40	0.48	2.8

Notes: Contracts are grouped by i) DoD subagencies, ii) NASA, and iii) other agencies. We report the frequency of contracts awarded and their overall amount.

average price is about $1 million, but the total cost, inclusive of any subsequent modification, is more than $4 million on average. Correspondingly, the average contractual duration is 531 days, while the final contract duration inclusive of any delay is 867 days. The substantial increase in cost, paired with relatively small delays, is explained by the cost-plus nature of most of the contracts (73%). The preponderance of cost-plus contracts in DoD procurement is a well known phenomenon (Kang and Miller 2017, Carril and Duggan 2018). It is explained by the interest of the DoD to obtain a timely completion of projects that have highly uncertain costs at the time of bidding.[10] Yet, contrary to other studies we observe that most of the contracts are awarded through open procedures (58%) and are characterized by full and open competition (90%).

The three variables at the bottom of panel (a) are the outcome measures of innovation used in this study. They come from the 3PFL database (de Rassenfosse et al. 2018). This database exploits a feature of the U.S. Federal Acquisition Regulation (FAR) to unambiguously identify patented inventions that were spurred by federal contracts. Under FAR's Subpart 27.3, contractors may retain title to any invention made in the performance of work under a government contract (for experimental, developmental, or research work), under the condition that they file a patent application at the United States Patent and Trademark Office (USPTO) and give a non-exclusive, royalty free license to the U.S. government. To ensure that the government retains the rights to use the patented invention, the FAR requires the contractor to include in the patent a statement acknowledging that the invention was made with government support and the unique identifier of the specific procurement contract underpinning the patented invention.

The 3PFL database covers USPTO patents granted between 2005 and 2015.[12] As panel (a)

[10]See Bajari and Tadelis (2001) for an extensive study of the trade-off between time and cost to completion induced by the contract pricing format.

[12]Having data until 2015 and considering three years at least on average for the patentability process to end, we

Table 2: Summary Statistics

(a) Contract Level

	Mean	50th	S.D.	Obs.	Source
Awarding Price (in $1,000)	988	240	3,770	3,430	FPDS
Final Cost (in $1,000)	4,383	594	71,600	3,430	FPDS
Expected Duration (Days)	531	365	414	3,430	FPDS
Total Duration (Days)	867	731	588	3,430	FPDS
Cost Plus (dummy)	0.73	-	0.44	3,430	FPDS
Negotiation (dummy)	0.42	-	0.49	3,430	FPDS
Competed (dummy)	0.90	-	0.30	3,430	FPDS
# Patents	0.11	0.00	0.86	3,430	3PFL
# Citations	0.13	0.00	1.15	3,430	3PFL
# Claims	0.14	0.00	0.65	3,430	3PFL

(b) Buyer Level

	Mean	50th	S.D.	Obs.	Source
Total Employment	889.5	88.00	1,907.00	789	FedScope
Relevant employment	420.2	39.00	934.85	789	FedScope
Median Age	7.03	7.00	0.17	789	FedScope
Median Salary	8.08	8.00	1.29	789	FedScope
Cooperation	0.76	0.76	0.03	789	FEVS
Skill	0.56	0.56	0.03	789	FEVS
Incentives	0.45	0.45	0.04	789	FEVS

(c) Seller Level

	Mean	50th	S.D.	Obs.	Source
Propensity to patent	0.74	0.37	1.07	525	USPTO
Small (dummy)	0.41	-	0.47	525	FPDS
University (dummy)	0.17	-	0.37	525	3PFL

Notes: Cost plus indicator variable equals to one if the contract pricing format is cost plus (i.e., the supplier is entitled to obtain compensation in proportion to the cost it incurs plus a mark-up) and zero if it is fixed price (i.e., the supplier is paid a fixed price, regardless of the cost incurred). When buyers prefer cost-plus contracts, they are losing effectiveness to incentivize effort of sellers carrying out a contract and, hence, we expect a negative effect on contract outcome; *Awarding Price* - in USD $ - and *Expected Duration* - the expected duration of the contract at the time of award, in days - mean to proxy for the project complexity; *Final Cost* and *Total Duration* represent the actual cost and duration of the R&D projects, respectively; *Small* is an indicator variable equal to one if the seller meets the small business size standard for award to a small business that is applicable to the contract.[11] *Negotiation* is a dummy variable indicating whether the contract uses negotiated procedures (i.e., the contract is awarded on the basis of a direct agreement with a contractor, after solicitation of a number of sources); 1 point S.D. in *Median Age* represents 5 years and category 1 coincides with "Less than 20 years"; 1 point S.D. in *Median Salary* $10,000 and category 1 coincides with "Less than $20,000". Accordingly, sample average *Median Age* and *Median Salary* are 45.15 and 80.800, respectively.

of Table 2 indicates, in addition to the number of patents, the 3FPL data also allows us to mea-

exclude contracts awarded from 2013 onward. This fact is confirmed by the negligible share of contracts associated to at least one patent in the 2013-2015 time span.

sure patent-level bibliographic information, which are recovered from the European Patent Office's Worldwide Patent Statistical Database (PATSTAT). More in detail, using the information contained in the 3PFL database, we build three different performance measures for our sample of R&D contracts: *Number of Patents*, *Number of Citations*, *Number of Claims.* The variable *Number of Patents* reports the total number of patented inventions associated with a specific federal R&D contract.[13] *Number of Citations* reports the number of patent citations received by the patents associated with a specific R&D contract in the five years after the patent application was filed divided by the total number of patents associated with that contract.[14] Patent citations are commonly used in the patent literature as a proxy for the technological impact and the commercial value of the patented invention (Trajtenberg 1990, Jaffe et al. 1993, Hall et al. 2005, Belenzon 2011, Moser et al. 2017). Finally, the variable *Number of Claims* reports the number of independent claims included in the patents associated with an R&D contract divided by the total number of patents associated with that contract. Patent claims delineate the 'metes and bounds' of the patent owner's legal right (Merges et al. 2003) and their count has been used as a proxy for the scope and the value of a patented invention (Harhoff et al. 2003, Lanjouw and Schankerman 2004, Bessen 2008, de Rassenfosse and Jaffe 2018).

The third source of data that we combine is the FedScope database. It contains personnel data on nearly all federal civilian executive branch employees and we use it to construct measures of the contracting officers' and offices' characteristics. Since the data are released at bureau-level, we merge them with the R&D contract-level data by aggregating the latter by their bureau, State of contract execution and year of contract award.[15] Employment data include demographic characteristics

[13]Among the 3,430 R&D contracts in the data, the number of patents is 370. Table 3 reports the number of patents per category of federal R&D.

[14]One can legitimately question whether patents represent a valid measure of the performance of R&D contracts. A first concern relates to the possibility for a contractor to choose secrecy over patenting. The FAR states that the contractor should file a patent application in order to retain title to the invention. If the contractor fails to do so, the government has the right to file a patent application. There are thus strong incentives to apply for a patent. However, not all contractors may be aware of the regulations or may comply. In such case, secrecy would be an issue only if projects subject to unexpected death of managers during selection were more likely to choose secrecy a few years down the road, which is rather unlikely. Finally, if preference for secrecy is a firm-level variable, the fact that we control for the propensity to patent in the regression model should guard against remaining threats of omitted variable bias. A second concern relates to large heterogeneity in quality across patents. The majority of patents are worth little (Trajtenberg 1990) and merely counting patents may not provide an accurate measure of R&D performance. Starting with Trajtenberg (1990) and Albert et al. (1991), a dense body of work has documented that the number of citations that a patent receives correlates with its (technological and economic) importance (see de Rassenfosse and Jaffe (2017) for a comprehensive literature review). To account for the heterogeneity in patent quality, we have estimated the regression models on a citation-weighted patent count. This approach leads to very similar conclusions.

[15]This is possible through an external dictionary which maps the variable "*Contracting Office Agency ID*" in FPDS to the variable *AGYSUB* of FedScope. See Decarolis et al. (2018) for further details.

Table 3: Federal R&D Procurement Categories

R&D Category	# Contracts	# Patents	Award Value (in 1,000,000$)
AB1 - “Community Service/Development: Crime Prevention/Control”	4	0	5
AB9 - “Community Service/Development: Other”	32	2	59
AC1 - “ Defense System: Aircraft”	165	14	1051
AC2 - “Defense System: Missile/Space Systems”	139	30	813
AC3 - “Defense System: Ships”	9	1	7
AC4 - “Defense System: Tank/Automotive”	13	0	22
AC5 - “Defense System: Weapons”	95	0	252
AC6 - “Defense System: Electronics/Communication Equipment”	378	83	3260
AC9 - “Defense System: Miscellaneous Hard Goods”	14	1	35
AD2 - “Defense Other: Services”	379	16	768
AD4 - “Defense Other: Textiles/Clothing/Equipage”	11	1	6
AD9 - “Defense Other: Other”	1186	100	1975
AE3 - “Economic Growth: Manufacturing Technology”	20	7	31
AG9 - “Energy: Other”	7	6	54
AH3 - “Environmental Protection: Water Pollution”	2	0	3
AH9 - “Environmental Protection: Other”	110	3	98
AJ1 - “General Science/Technology: Physical Sciences”	98	18	190
AJ2 - “General Science/Technology: Mathematical/Computer Sciences”	16	1	99
AJ3 - “General Science/Technology: Environmental Sciences”	17	0	24
AJ4 - “General Science/Technology: Engineering”	90	5	517
AJ5 - “General Science/Technology: Life Sciences”	14	6	23
AJ9 - “General Science/Technology: Other”	18	2	38
AN1 - “Medical: Biomedical”	79	17	370
AN7 - “Medical: Specialized Medical Services”	2	0	4
AN9 - “Medical: Other”	4	0	1
AR1 - “Space: Aeronautics/Space Technology”	128	2	124
AR2 - “Space: Science/Applications”	6	18	4055
AR3 - “Space: Flight”	5	0	63
AZ1 - “Other Research and Development”	389	37	1087

Notes: The table shows descriptive statistics for 3-digit R&D categories. We report the associated # of contracts, # of patents and the overall award amount in our sample.

along with information on appointments and tasks (e.g., length of service, occupation category, pay grade, salary level, type of appointment, work schedule, and location of each single employee). Panel (b) of Table 2 reports summary statistics for the subset of white-collar employees: there are on average 890 such employees with an average age of 50 years and salary of $50,000, respectively.

The variable *Relevant employment* indicates the subset of white-collar workers - in each combination bureau-State - who are below the median age but above the median salary.[16] As discussed extensively in the next section, it is crucial for our analysis to identify the death events involving these employees. We argue that they are the most likely to be the active and effective managers whose death is more likely to come as a surprise. Before turning to that discussion, we conclude this section mentioning two additional sets of variables. First, at the bottom of panel (b) we report bureau-level measures of the characteristics of the working environment, as collected from the Federal Employee Viewpoint Survey (FEVS). This survey, administered every year since 2002 by the Office of Personnel Management, is the largest and most well established source of data on federal offices' features. We will return to these data in the final part of our analysis where we discuss some

[16]The landmark distribution hinges on the full set of federal bureaus, whose median salary and age belong to the interval 50,000-59,999$ and 45-49 years, respectively. Hence, our *relevant (white-collar) workers* are those with a salary greater or equal to 50,000$ and strictly lower than 50 years old. Our sample selection, returns us a subsample of bureaus whose overall median salary is higher (see Table 2)

potential channels through which the death of relevant managers might worsen procurement-related innovation contracts. We will focus in particular on the three features listed at the bottom of panel (b), namely *cooperation*, *skills* and *incentives.* These variables measure respondents' perceptions about their bureaus' strengths along these three dimensions of personnel hiring and working.

Finally, panel (c) of Table 2 reports summary statistics at the seller level. An important finding of our analysis will be that the effectiveness of procurement to spur innovation is linked to the selection of the private contractors. Therefore, it will be relevant to control for the contractors' ability to perform R&D. We do so by developing a measure that grasps the technological capacity of a contractor in the technological domain to which the contract is related, at the moment of the award. We thus collect information on all the privately funded patents applied for between 2003 and 2011 by the contractors in our sample.[17] In particular, we need to take into account the fact that different contractors may exhibit different patenting behavior irrespective of the characteristics of the R&D work they conduct for the U.S. government. [18] In order to do so, we construct the variable *Propensity to patent* as the number of privately funded patents filed by a contractor in the period that we consider (2006-2012), divided by the average number of employees working for the contractor over the same period. Finally, *University* is a binary variable that simply reports whether the contractor is a higher-education institution or not.

IV Empirical Strategy

We seek to estimate buyers' role on contract outcomes. In the spirit of the long established literature in economics and management (see Jäger (2017) for a recent overview), we do so by exploiting unexpected death events involving federal bureaus' managers. In particular, within the limit of our data, we try to isolate the death event of relevant public managers, around the time of project

[17]Privately funded here means that these inventions were achieved without the support of the U.S. federal government neither through procurement contracts, nor grants. Federally funded patents were excluded using the 3PFL database. More precisely, for every patent application we recover the patent identifier, the year of application at the USPTO, and the international patent classification (IPC) classes to which the patent application was assigned. We then produce a correspondence table that maps the PSC code assigned to a federal procurement contract into the relevant IPC classes. The IPC is a hierarchical system for the classification of patent applications according to the different technological fields to which they belong. For the task at hand we work at the class level and thus consider 129 different technological fields. For additional information on the IPC see `http://www.wipo.int/classifications/ipc/en/`.

[18]For instance, a specific company might be on average more likely to rely on trade secrets to protect its inventions and hence more likely to forego patent protection even when a patent application can be filed. However, in the context of inventions realized under federal procurement contracts, if a patent application can be filed and the contractor decides not to apply for a patent and keep the invention secret, the government maintains the right to file a patent application for the invention (McEwen et al. 2012, p.52).

selection. The FPDS data do not track the identity of the managers in charge of the contracts. Moreover, albeit we select exclusively bureaus that conduct R&D contract procurement, these bureaus perform a multiplicity of activities so that it would be unreasonable to consider all of their managers as relevant. Furthermore, some of these managers might be quite ineffective, despite being directly involved with procurement activities. Our approach to deal with this concern is to establish as relevant exclusively those white-collar workers whose age and salary is suggestive of their capabilities: we select employees having simultaneously an age below the median age and a salary above the median salary. Evidence presented in Decarolis et al. (2018) indicates how the deaths of these types of workers is indeed associated with a worsening of measures of the quality of the job performed by the office.[19]

Table 4: Relevant Death Summary Statistics

	(1) Mean	1st	50th	99th	S.D.	Obs.
No. Rel. Deaths/Employment	0.0001	0.	0	0.0021	0.00	929

Notes: The table presents summary statistics of the exogenous variable employed in the analysis.

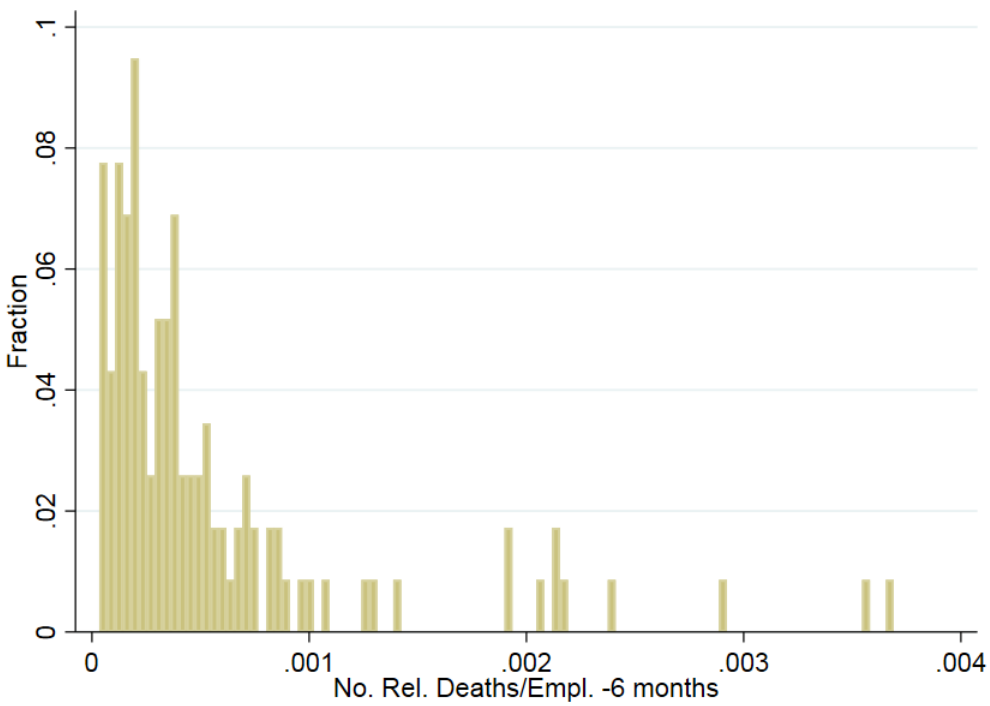
The departure of a manager for reasons related, e.g., to job mobility or retirement might not be random. For that reason, we focus on cases of deaths, which are arguably less predictable than other mobility events—especially for younger individuals. Table 4 reports the distribution of the number of relevant deaths across the sample of bureaus/States/years in the data, divided by the total (white collar) bureau/State/year employment. More in detail, we count the number of deaths occurring in a certain period before (and, as a robustness check, after) the signature of the contracts. As baseline time span, we take a period of six months.[20] According to the managerial literature it takes about six months for newly hired employees to gain full efficiency, so-called "onboarding effect". As shown by Table 4, the majority of bureau/State pairs does not experience any relevant death case.

Conditional on at least one case occurring (13% of observations), Figure 1 shows that the

[19]Note that the identification strategy does not require that we observe contracts that were directly subject to the death of a manager. More generally, we do not need to know which managers were allocated to which contracts. All we need to know is whether a manager unexpectedly passed away in the months preceding contract award. The death of a manager is a painful event that forces a re-organization and a re-allocation of tasks within a bureau. Our identification strategy exploits this temporary shock at the level of a bureau.

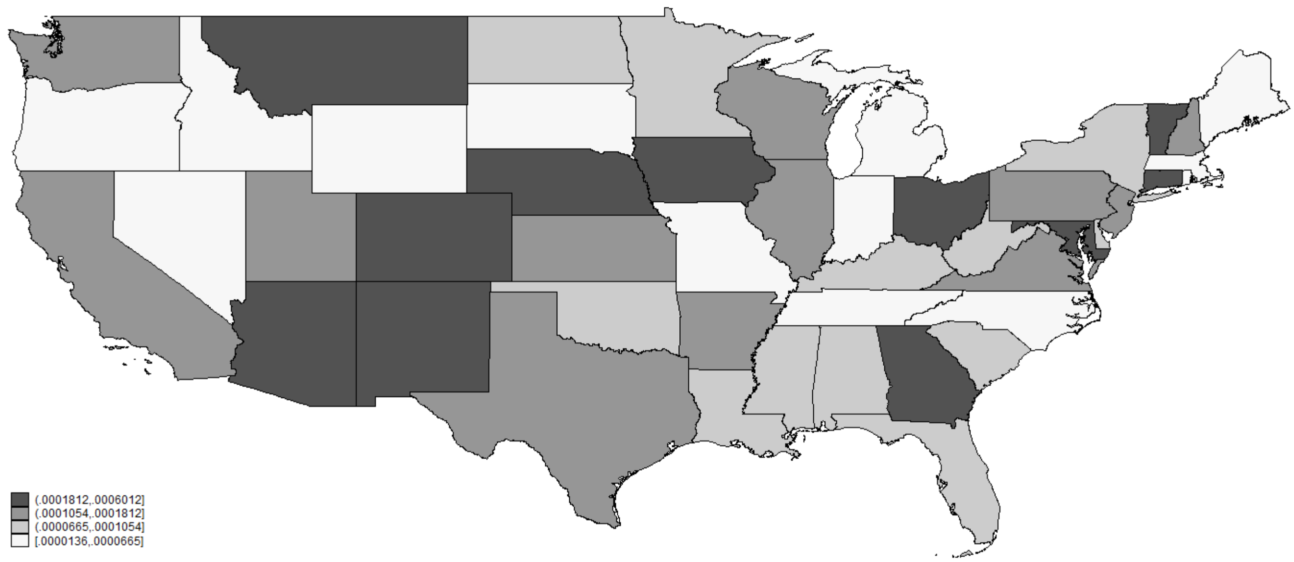
[20]FedScope snapshots are taken in September, while FEVS ones in June. In order to account for any variation in the employment stock owing to the death occurrences before September of the same year, for contracts signed up to September, we substitute the employment stock with its lag that is unaffected by those changes. Death occurrences after June are not affecting the outcome measures, based on FEVS variables, of the current year. Outcome measures based on FEVS variables are adjusted taking their leads.

Figure 1: Distribution of Relevant Deaths



Notes: bins represents the fractions of relevant deaths for the 13% of bureau/State/year triple with at least one relevant death. This figure excludes two outliers (> of 0.5% of deaths), which are *Space and Naval Warfare Systems Command* in Florida for 2008 and *U.S. Army Corps of Engineers* in Arizona for 2012.

Figure 2: Share of Contracts Associated with at least One Relevant Death



Notes: Share of contracts by State associated with at least one relevant death in the six-month period before the award.

variable has a well behaved power-law shaped distribution. It reveals a conceivable right-skewed distribution and a major fraction of deaths lower than 0.0005. From a geographical perspective, the share of deaths does not seem to follow a clear path: Figure 2 shows the share of contracts associated with at least one relevant death.[21]

While death-induced separations are exogenous separations, they may not be randomly assigned across bureaus. To adjust for such unbalancedness, our strategy is to use a propensity score weighting approach. Following the potential outcome literature, consider a Z_i that can take the value of either one or zero depending on whether contract i is awarded by a bureau that (in that State and year) experiences at least one relevant death against none. Then, conditional on covariates X_i, the propensity score describes each subject's probability of being assigned to the treatment that they received given the set of observed covariates.[22]

[21] Note that our sample includes only contracts awarded in States where the awarding bureau has at least one employee. This restriction insures that we can match the locations of the bureaus, local offices and the contracts that they are likely to supervise. In the appendix, Figure 4 reports in detail the location of each bureau by indicating with an "X" the State in which they employ at least one white collar worker.

[22] For causal comparisons, we adopt the potential outcome framework (Rubin 1974). The way in which *Relevant Deaths* are built allows us to rely on the standard Stable Unit Treatment Value Assumption (Rubin 1980), stating that the potential outcomes for each unit are unaffected by the treatment assignments of other units and each unit has potential outcomes $\{Y_i\left(z\right), z=0,1\}$ corresponding to the possible treatment levels, of which only one is observed: $Y_i = Z_i Y_i\left(1\right) + \left(1 - Z_i\right) Y_i\left(0\right)$. Under the unconfoundedness assumption, that is, $Y\left(0\right), Y\left(1\right) \perp Z|X$, we have $Pr\left(Y\left(z\right)|X\right) = Pr\left(Y|X, Z=z\right)$ for $z: 0,1$, so $\tau\left(x\right)$ is the average treatment effect (ATE) conditional on x : $\tau\left(x\right) = E\left[Y\left(1\right) - Y\left(0\right)|X=x\right]$. Estimation of either comparison requires the probabilistic assignment assumption, $0 < e(X) < 1$, which states that the study population is restricted to values of covariates for which there can be both control and treated units.

By matching on propensity scores, we effectively compare bureaus that are equally likely to be assigned to each treatment group. We use the Inverse Probability Weighting approach, which involves weighting the outcome measures by the inverse of the propensity score. Thus, with e denoting the estimated propensity score, the original sample is weighted by: $Z\,e + (1 - Z)\,(1 - e)$. In other words, treated subjects are assigned a weight equal to the reciprocal of the propensity score, while control subjects are assigned a weight equal to the reciprocal of one minus the propensity score. Matching on one variable, the propensity score tends to balance all of the observed covariates and makes the *relevant deaths* random, conditional on bureau features. The propensity score weighting approximates a randomized assignment.

We proceed as follows. To cope with selection on observable characteristics of bureaus, we pair contracts awarded by similar bureaus in terms of median salary, age and number of white-collar employees.[23] We then perform a logistic regression of a dummy for relevant deaths on these characteristics and predict the propensity score $e(\mathbf{z})$. Figure 3 shows the comparison of the propensity score distributions across the treated and the untreated contracts before and after matching. This graph illustrates the successful adjustment of post-matching propensity score distribution for the control group and visually shows that $e(\mathbf{z})$ in our analysis is in fact balanced across treatment and comparison groups.

Then, after weighting the outcome of treated bureaus by $\frac{1}{e(\mathbf{z})}$ and that of control bureaus by $\frac{1}{1-e(\mathbf{z})}$, we estimate the following linear model

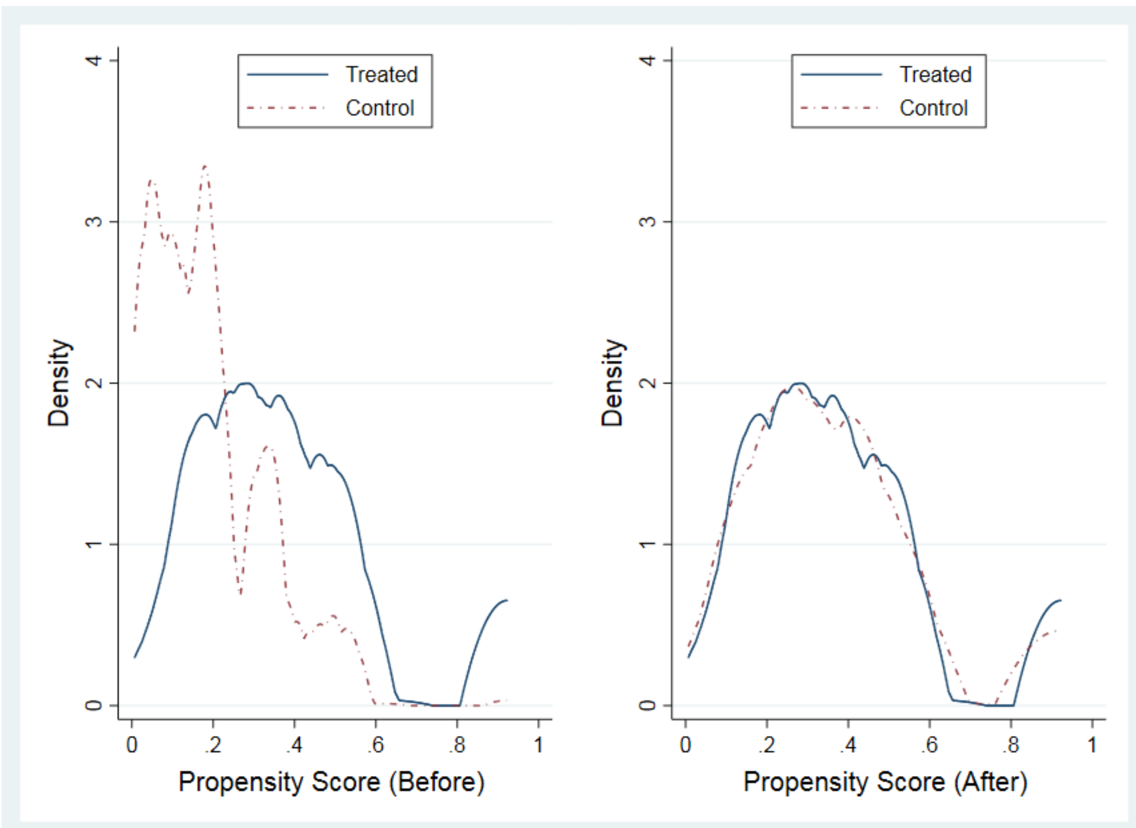
$$Y_{ijtm} = \beta\,\frac{\#RelevantDeaths_{jt}}{TotalEmployees_{jt}} + \theta X_i + \iota_j + \kappa_t + \lambda_m + \epsilon_{ijtm}, \tag{1}$$

where $Y_{ijtm} = [Log - \#Patents; Log - \#Citations; Log - \#Claims]$ stands for our three contract outcomes in logarithmic terms; X_i represents contract and seller characteristics *(Cost Plus, Negotiation, Competed, Small Business, Technological Capacity, Propensity to Patent).* We then include a series of fixed effects: ι_j (bureau fixed effects), κ_t calendar year fixed effects, λ_m: R&D category fixed effects.[24]

[23]Specifically, we generate dummies for the deciles of the distribution of the three variables. Given the distribution of the variables, this provides us with 100 possible combinations. Two quantiles for Median Age, ten for Employment and five for Median Salary.

[24]Other FE included are: stage of R&D and deciles of award price and expected duration distribution.

Figure 3: Estimated Probabilities of Being Treated Before and After Matching



Notes: Distributions of estimated probabilities of being a treated contract (propensity score). The comparison is presented by treatment group (blue line) and control group (red dashed line) prior to and after the matching is implemented.

Table 5: Exogeneity Test for Lagged Deaths

	Relevant Deaths 6m before				Relevant Deaths 6m before			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log Budget	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
log # Contracts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Median Age		-0.15***	-0.15**	-0.13*		-0.12	-0.12	-0.22
		(0.05)	(0.06)	(0.07)		(0.11)	(0.13)	(0.15)
Median Education		0.01	0.01	0.02		0.04	0.05	0.03
		(0.01)	(0.01)	(0.01)		(0.03)	(0.03)	(0.02)
Median LOS		0.04*	0.03	0.04		-0.01	-0.01	0.07
		(0.02)	(0.02)	(0.03)		(0.05)	(0.06)	(0.06)
Median Salary		-0.03	-0.01	-0.01		0.12	0.10	0.03
		(0.02)	(0.02)	(0.03)		(0.08)	(0.08)	(0.04)
Median WF Composition		0.12	0.13	0.05		0.02	-0.04	-0.14
		(0.11)	(0.14)	(0.13)		(0.33)	(0.31)	(0.35)
Accomplishment			-0.36	-1.08*			-1.23**	-1.67**
			(0.35)	(0.56)			(0.47)	(0.62)
Appreciation			0.39	0.45			1.11	-0.02
			(0.31)	(0.31)			(0.69)	(0.35)
Level of Workload			-0.27*	-0.45**			-0.11	-0.09
			(0.15)	(0.19)			(0.31)	(0.35)
Physical condition workplace			0.08	0.16			0.21	0.33
			(0.07)	(0.18)			(0.17)	(0.25)
Integration policy				-0.07				0.41
				(0.19)				(0.39)
Health Security				-0.17				-1.02
				(0.25)				(0.73)
Good Place to work				0.38				1.02*
				(0.44)				(0.51)
Balance work/life				0.38				0.22
				(0.37)				(0.37)
Job Satisfaction				0.46				1.07
				(0.58)				(0.70)
Pay Satisfaction				-0.24				-1.37*
				(0.28)				(0.67)
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bureau FEs	No	No	No	No	Yes	Yes	Yes	Yes
R-squared	0.00	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Observations	788.00	788.00	788.00	788.00	788.00	788.00	788.00	788.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table presents four nested sets of possible predictors (1)-(4) of the bureau-year relevant death variable. OLS estimates include year fixed effects. In addition, columns (5)-(8) include bureau-State fixed effects.

Table 5 offers additional evidence on the effectiveness of the matching strategy. It reports the estimates of a linear probability model for the probability of observing at least one relevant death in the bureau/State/year. There is no observable bureau characteristics that significantly predicts the chances of observing at least one relevant death, with the exception of variables related to age and accomplishment, which are mechanically related to the outcome variable since it measures death occurrences within a specific subpopulation selected precisely on the basis of these variables. Therefore these results are highly suggestive of the random nature of deaths across the set of bureaus that we match.

V Results

Table 6 reports the baseline estimates of equation (1). For each one of the three outcome measures, it presents the estimates for four model specifications that gradually expand the set of covariates. All specifications include bureau fixed effects and R&D categories fixed effects. The first model includes exclusively the share of relevant deaths, whose causal effect we are interested in. The following model includes characteristics of the contractor (propensity to patent, small business and university). The third model controls for features of the contract and awarding procedure (cost plus, negotiated, competed). Finally, the fourth model also includes fixed effects for the stage of R&D activity, calendar year and bins capturing the size and duration of the contract. The latter is our preferred specification.

We observe a similar pattern across all outcome variables: deaths have a negative and highly statistically significant effect. The magnitude of the estimated coefficient declines as the specification becomes less parsimonious, but the qualitative result is stable. The estimated effects imply that an increase in managers' deaths of 1% of bureau-State-specific white collars in the six months before the project award causes a decline of 4.3% of patents per contract, 3.8% patent citations per contract and 8.6% patent claims per contract.

The first step to better understand our findings is to explore how they vary by the bureau workforce size. Reassuringly, we find that the smaller the bureau, the more impactful managers' deaths are. In particular, Table 7 has for each of the three outcomes four sets of estimates: columns 1, 5, 9 correspond to columns 4, 8 and 12 in Table 6; columns 2, 6, 10 exclude all those observations pertaining bureau/State/year at or above the 99th percentile of the distribution of

Table 6: Baseline Estimates

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-5.86***	-5.66***	-5.52***	-4.27***	-4.47	-4.40***	-4.31***	-3.80***	-9.54***	-9.18***	-8.89***	-8.65***
	(0.67)	(0.83)	(0.65)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(1.44)	(1.91)	(1.73)	(2.29)
Small Business		0.025**	0.028	0.033		0.034***	0.037***	0.035***		0.023**	0.024**	0.032**
		(0.012)	(0.017)	(0.035)		(0.007)	(0.009)	(0.009)		(0.009)	(0.009)	(0.014)
Propensity to patent		0.018	0.018	0.020*		0.009	0.009	0.011		0.028**	0.028**	0.030**
		(0.012)	(0.012)	(0.011)		(0.011)	(0.010)	(0.011)		(0.012)	(0.012)	(0.013)
University		-0.025*	-0.023	-0.009		-0.013	-0.009	-0.001		-0.028**	-0.025*	-0.007
		(0.014)	(0.017)	(0.013)		(0.01)	(0.007)	(0.01)		(0.012)	(0.014)	(0.015)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D Category FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract Features	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
R&D Stage FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
Amount&Duration FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
Calendar Year FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.03	0.04	0.04	0.08	0.02	0.02	0.02	0.04	0.03	0.03	0.04	0.07
Observations	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount and Duration FEs represent deciles for contract value and duration.

relevant employees; columns 3, 7, 11 exclude observations at or above the 90th percentile; columns 4, 8, 12 exclude observations at or above the 75th percentiles. In terms of the size of the relevant employees, these three cutoffs correspond to 4241, 1198, 407 employees respectively. There is a trade-off in making the sample more and more concentrated on small offices: as the precision with which we can link the death of a relevant employee to the procurement activity increases, both the chance of observing a death in the smaller offices and the chances that the (fewer) contracts awarded by smaller offices generate a patent decrease. It is therefore remarkable that, across the various subsamples explored in Table 7, the results are qualitatively stable and display a tendency toward higher magnitudes when focusing on smaller bureaus. Indeed, for all three outcome variables the estimates obtained with the smaller subsample are about twice those of the baseline sample.

The next step entails exploring the channels of the effect. In Table 8, we look both at the timing of death events relative to the stage of the contract and at the role of different employees - panel (a) - as well as at the role of firms - panel (b). The estimates in panel (a) show the baseline estimates of columns 4, 8 and 12 in Table 6, but with a different measure of employees' deaths. In the baseline, we look at relevant death occurrences in the six months *before* the contract is awarded. This is aimed at capturing the typical period of the tendering procedure execution, selection of the winning contractor and contract preparation. However, the post awarding phase might also be relevant if monitoring the private contractors can influence the likelihood that patents will originate from

Table 7: Robustness Checks: Subsamples

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-4.27***	-4.38***	-5.04***	-10.8**	-3.80***	-3.85***	-3.76***	-10.2***	-8.65***	-8.73***	-9.41***	-13.4***
	(0.001)	(0.002)	(1.28)	(4.92)	(0.001)	(0.001)	(0.001)	(2.96)	(2.29)	(2.35)	(3.22)	(4.61)
Small Business	0.033	0.034	0.038	0.022	0.035***	0.036***	0.033***	0.044***	0.032**	0.033**	0.035***	0.035**
	(0.035)	(0.042)	(0.036)	(0.017)	(0.0091)	(0.01)	(0.009)	(0.011)	(0.014)	(0.015)	(0.01)	(0.016)
Propensity to patent	0.020*	0.020*	0.022	0.020*	0.011	0.011	0.011	-0.001	0.03**	0.03**	0.032*	0.025**
	(0.011)	(0.012)	(0.017)	(0.012)	(0.011)	(0.011)	(0.014)	(0.005)	(0.013)	(0.013)	(0.017)	(0.010)
University	-0.009	-0.01	-0.019	-0.021***	-0.001	-0.001	-0.012	-0.009	-0.007	-0.007	-0.021	-0.016
	(0.013)	(0.016)	(0.013)	(0.006)	(0.010)	(0.010)	(0.010)	(0.012)	(0.015)	(0.015)	(0.014)	(0.012)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D Category FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D Stage FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract Features	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calendar Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.08	0.08	0.09	0.08	0.04	0.04	0.05	0.06	0.07	0.07	0.08	0.06
Observations	3430.00	3400.00	3024.00	2291.00	3430.00	3400.00	3024.00	2291.00	3430.00	3400.00	3024.00	2291.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: Columns 1, 5, 9 correspond to columns 4, 8 and 12 in Table 6. Then, columns 2, 6, 10 exclude all those observations pertaining bureau/State/year at or above the 99th percentile of the distribution of relevant employees; columns 3, 7, 11 exclude those at or above the 90th percentile; columns 4, 8, 12 exclude those at or above the 75th percentiles. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount and Duration FEs represent deciles for contract value and duration.

the contract. The first row of Table 8, by looking at relevant deaths during the six months *after* the contract is awarded, indicates that there is only weak evidence for this monitoring channel: the estimated coefficient in column (1) is an order of magnitude smaller than that of the baseline and with a lower statistical significance. The second row of the table reports what is the effect of looking for white-collar deaths still in the six-month period before contract award though without conditioning on their relevance: contrary to the case of the relevant deaths, there is no effect on patents or citations and a negative low-significance effect on claims.

To further explore the role of selection, we present in panel (b) of the same table estimates inclusive of firm fixed effects. Relative to the baseline estimates, the smaller sample is due to the requirement of having at least two contracts per firm. Within this sample, the estimates concerning patents and claims indicate a similar effect relative to the baseline. This result implies that, even within the same contractor, being exposed to an office experiencing a relevant death leads to worse procurement outcomes in terms of innovation, as measured by patents or claims (the estimates for citations are, instead, too noisy to be significant). This is suggestive that the effect of relevant managers is not merely loaded into the selection of the private contractors, but involves additional activities that, most likely, take place in the preparation of the contract and the solicitation procedure.

Table 8: Other Robustness Checks

(a) Outcomes on Other Deaths

	Log # Patents		Log # 3Y Citations		Log # Claims	
	(1)	(2)	(3)	(4)	(5)	(6)
# Rel. Deaths /Empl. +6 months	-0.46**		-0.37***		-0.72**	
	(0.20)		(0.009)		(0.33)	
# All Deaths/Empl. -6 months		0.019		0.061		-0.44*
		(0.24)		(0.14)		(0.22)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes
R&D Category FEs	Yes	Yes	Yes	Yes	Yes	Yes
R&D Stage FEs	Yes	Yes	Yes	Yes	Yes	Yes
Contract Features	Yes	Yes	Yes	Yes	Yes	Yes
Firm Features	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes
Calendar Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.09	0.09	0.04	0.05	0.07	0.09
Observations	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00

* $p < .1$, ** $p < .05$, *** $p < .01$

(b) Outcomes on Relevant Deaths - Firm Fixed Effects

	Log # Patents		Log # 3Y Citations		Log # Claims	
	(1)	(2)	(3)	(4)	(5)	(6)
# Rel. Deaths /Empl. -6 months	-4.76***	-5.12***	-3.84***	-0.86	-8.26***	-11.7**
	(1.54)	(0.81)	(0.000)	(3.13)	(2.65)	(4.63)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes
R&D Category FEs	Yes	Yes	Yes	Yes	Yes	Yes
Contract Features	Yes	Yes	Yes	Yes	Yes	Yes
Firm Features	Yes	Yes	Yes	Yes	Yes	Yes
R&D Stage FEs	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes
Calendar Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	No	Yes	No	Yes	No	Yes
R-squared	0.06	0.28	0.04	0.22	0.06	0.26
Observations	3267.00	3267.00	3267.00	3267.00	3267.00	3267.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: Panel (a) shows placebo regressions using six months ahead and non-selected white-collar deaths (all employees, not only relevant employees) six months before. Panel (b) replicates Table 6 in presence of firms' fixed effects. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount and Duration FEs represent deciles for contract value and duration. Firm Features indicates that the model is estimated by controlling for firm characteristics appearing in Table 6.

We conclude this assessment of the channels by looking at how the measure of relevant deaths interacts with the survey measures on bureau characteristics from the FEVS. As discussed above, these measures offer insights on how employees perceive the functioning of their office in terms of several important characteristics. In Table 2, we reported summary statistics for three answers from the block of questions in the survey concerning the employee's bureau/office and that can be easily attributed to cooperation, skills and incentives, respectively. In a related work, Decarolis et al. (2018) used these same variables to try to explain variation in the outcomes of non-R&D contracts in terms of cost overruns and delays. Therefore, it appears plausible that they also affect R&D outcomes.

As a first step, since the block of questions about the bureau contains 8 questions, we employ a principal component analysis (see appendix) to reduce the dimensionality. We obtain two factors that, in essence, partition the variation attributable to questions regarding cooperation (2 questions) from that of the remaining questions (6 questions concerning either skills or incentives). We indicate these two factors as *Cooperation* and *Skill/Incentives*. We then run the same models of Table 6, but enriching all specifications with Cooperation and Skill/Incentives entered both in isolation and as interactions with Relevant Deaths. Table 9 presents the estimates. Across all the specifications, the magnitudes for Relevant Deaths remain significant and large, even above those in Table 6.[25] While the interaction terms are in almost all cases not statistically significant, there is an interesting effect involving Cooperation. Indeed, Cooperation appears to be a positive driver of all three R&D contract outcomes. No direct effect is found for Skill/Incentives. But for this variable, the negative signs of the interaction term that in two specifications is also weakly significant offers some, weak evidence that deaths of the federal bureau's relevant workers negatively affects R&D contract outcomes through a reduction of Skills and Incentives levels within the bureaus.

These findings are interesting as they indicate an additional element through which bureau characteristics influence procurement outcomes, beyond the role of managers. Decarolis et al. (2018) had already stressed the relevance of these FEVS measures of bureaus competence and, especially, of cooperation for successful non-R&D procurement. But our results differ from theirs in important ways: first, the sectors (R&D vs. non-R&D) and the associated outcomes (patents vs. cost overruns and time delays); second, methodologically our longer time span allows using bureau

[25] The larger magnitude might be either an indication of the usefulness of controlling for these bureau characteristics or, on the contrary, a bias introduced by including potentially endogenous variables. Although the presence of bureau fixed effects makes the latter case unlikely, we prefer to consider the more conservative estimates in Table 6 as our main estimates.

Table 9: Workplace Characteristics

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-8.56***	-9.16***	-8.92***	-8.20**	-7.80***	-8.34***	-8.18***	-7.79**	-12.8***	-13.3***	-13.0***	-13.2***
	(2.36)	(1.95)	(1.77)	(3.68)	(1.23)	(1.98)	(2.29)	(3.36)	(1.77)	(2.43)	(2.50)	(4.73)
Cooperation	0.038***	0.037**	0.037***	0.007	0.038***	0.037***	0.037***	0.005	0.031***	0.030***	0.031**	-0.001
	(0.013)	(0.015)	(0.01)	(0.015)	(0.007)	(0.006)	(0.006)	(0.028)	(0.009)	(0.011)	(0.012)	(0.016)
Skill/Incentives	-0.01	-0.01	-0.009	0.01	-0.01	-0.008	-0.006	0.015	0.001	-0.001	0.001	0.016
	(0.014)	(0.019)	(0.012)	(0.018)	(0.014)	(0.014)	(0.012)	(0.017)	(0.017)	(0.017)	(0.013)	(0.023)
Deaths/Empl. -6 months X Cooperation	0.56	-0.22	-1.35	-2.55	0.79	0.15	-1.04	-2.10	0.16	-0.63	-2.10	-4.47
	(3.50)	(3.37)	(3.45)	(4.68)	(3.95)	(3.63)	(3.51)	(3.02)	(4.05)	(4.13)	(3.96)	(5.28)
Deaths/Empl. -6 months X Skill/Incentives	-4.61*	-4.85	-3.63	-2.79	-5.66*	-5.85	-4.60	-3.39	-5.02*	-5.34	-3.89	-1.51
	(2.26)	(3.00)	(4.18)	(7.61)	(3.13)	(3.96)	(4.81)	(5.34)	(2.79)	(3.32)	(4.13)	(8.14)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D Category FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D Stage FEs	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	No
Contract Features	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
Amount&Duration FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
Calendar Year FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.04	0.05	0.05	0.08	0.02	0.03	0.03	0.04	0.03	0.04	0.04	0.07
Observations	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00	3430.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: This table reproduces table 6 by enriching all specifications with Cooperation and Skill/Incentives and the interaction of both variables with Relevant Deaths. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount and Duration FEs represent deciles for contract value and duration.

fixed effects. This is crucial as most omitted variable concerns threatening the identification should be absorbed by these fixed effects. Thus, we do not face the concerns leading Decarolis et al. (2018) to instrument the FEVS measures. With them, however, we share the finding of a significant role for bureau-level cooperation which is a useful confirmation of the arguments presented earlier about the nature of procurement as a complex and interdisciplinary activity requiring effective within-office collaboration.

VI Conclusions

The paper empirically investigates the buyer's role in the procurement of innovation. It shows that buyers play a very significant role in affecting the success of innovation procurement, as measured by the number and quality of the patents generated. It also shows that the buyer's role is particularly important in the pre-award procurement design phase, although to a lower degree it also matters in the following contract management phase. Finally, it stresses that an important factor for the success of an R&D contract performance is a cooperative environment in the buying organization, which squares well the highly interdisciplinary nature of the pre-award phase of the procurement process. Overall, our results represent a preliminary but clear indication of the potential benefits of investing in the quality of buyers through a greater professionalization of this activity, as recently advocated by Saussier and Tirole (2015) for public ones.[26]

As for future research, it would be worth investigating some interesting aspects that our analysis has just touched upon. In particular, we found that the size of the contractors is associated with their propensity to innovate. There is a large debate on programs like the U.S. SBIR that promote innovation among small firms through public procurement. It would thus be important to verify whether, and to what extent, small firms might be affected in a different way relative to large firms by public buyers. Evidence along these lines might help address the question of whether the public procurement of innovation, when handled well, can offer an important opportunity for the growth and competitiveness of SMEs. Given that new initiatives to promote the role of SMEs in public procurement are already taking place (e.g., the European SME instrument), a careful empirical evaluation of this phenomenon could give important suggestions for innovation policy.

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[26] They report a recent study by the *Union des groupements d'achats publics* (UGAP, French Public Procurement Grouping Union) revealing that 63% of French public buyers do not have a legal profile and 61% of public buyers have no prior experience in the field. Only 39% of public buyers undertook some form of course or training resulting in qualification in the field of purchasing.

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A Appendix: To Be Posted on the Author' Web Page

A.1 Sample Selection: Filters

The starting point for the construction of our dataset is the totality of the R&D contracts between 2000 and 2013 available from FPDS. A small fraction of these contracts (around 3%) are at least associated to a patent that we are able to track through the 3PFL dataset. The remaining part is a heterogeneous group of contracts, divided between development contracts that have zero chances to produce patents and research contracts that have a positive probability to generate patents. A meaningful exercise requires to compare contracts that have generated patents with similar research contracts. We proceed as follows. First, we impose a criterion of temporal coherence such that the signature and the final date of each research contract cannot exceed the extreme signature and final date of the sample of contracts with patents. Second, we only keep contracts from bureaus that have a previous history of contracts producing patents to avoid selecting bureaus not involved in research activities. Third, we select contracts belonging to product service categories associated with patents. Finally, we retain contracts signed with suppliers that in the past were able to produce a patent. We check the reliability of our selection through a battery of robustness checks that run the baseline model (estimates of tables 10 to 16) on all the datasets obtained through the combination of the stated filters. The filter that matters the most is relative to the suppliers, table 14. Even in presence of the other filters, enlarging the pool of suppliers entails a null impact of a further death relative to the patent outcomes, but we still have a significant and positive (but smaller) effect on the citation outcome. Moreover, in table 17 we test whether the supplier selection is driven by any bureau characteristics, through two different specifications of a discrete choice model. We find that variables related to the organizational dimension and resources availability of the bureaus are the main drivers explaining the selection of firms capable to produce more patents.

Table 10: No Filters

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-0.37	-0.36	-0.27	-0.26	-0.33*	-0.34**	-0.27*	-0.27*	-0.64	-0.63	-0.53	-0.52
	(0.27)	(0.25)	(0.22)	(0.21)	(0.18)	(0.16)	(0.14)	(0.13)	(0.42)	(0.40)	(0.37)	(0.38)
Cost Plus		0.002	-0.001	-0.001		0.004**	0.003*	0.002		0.002	-0.001	-0.001
		(0.003)	(0.003)	(0.003)		(0.002)	(0.001)	(0.002)		(0.004)	(0.004)	(0.004)
Negotiation		-0.005*	-0.005*	-0.006*		-0.005*	-0.005*	-0.005*		-0.006*	-0.006*	-0.006*
		(0.003)	(0.003)	(0.003)		(0.002)	(0.002)	(0.003)		(0.003)	(0.003)	(0.0032)
Competed		0.006*	0.004	0.005		0.007*	0.005	0.005		0.008**	0.006	0.006*
		(0.003)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)		(0.004)	(0.004)	(0.004)
Small Business			0.001	0.002			0.002	0.003			0.001	0.001
			(0.003)	(0.003)			(0.003)	(0.003)			(0.003)	(0.003)
Tech. Capacity			0.005***	0.005***			0.004***	0.004***			0.006***	0.006***
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.001)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.03	0.03	0.04	0.04	0.01				0.02	0.03	0.04	0.04
Observations	16197.00	16197.00	16197.00	16197.00	16197.00	16197.00	16197.00	16197.00	16197.00	16197.00	16197.00	16197.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table replicates the baseline estimates without conditioning for bureaus, R&D categories and sellers associated with a record of patents in our data. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

Table 11: Filters On: Bureaus

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-0.39	-0.38	-0.30	-0.27	-0.34	-0.34*	-0.28	-0.27*	-0.66	-0.65	-0.55	-0.53
	(0.29)	(0.27)	(0.24)	(0.21)	(0.21)	(0.19)	(0.18)	(0.16)	(0.44)	(0.42)	(0.40)	(0.38)
Cost Plus		0.001	-0.001	-0.002		0.004*	0.002	0.002		0.001	-0.001	-0.002
		(0.003)	(0.003)	(0.003)		(0.002)	(0.002)	(0.002)		(0.004)	(0.004)	(0.005)
Negotiation		-0.006**	-0.006*	-0.007**		-0.005**	-0.005**	-0.006*		-0.007**	-0.006*	-0.007*
		(0.003)	(0.003)	(0.003)		(0.002)	(0.002)	(0.003)		(0.003)	(0.003)	(0.003)
Competed		0.007*	0.005	0.006*		0.008**	0.006*	0.006		0.01**	0.008*	0.008*
		(0.004)	(0.004)	(0.003)		(0.004)	(0.004)	(0.004)		(0.004)	(0.005)	(0.004)
Small Business			0.001	0.002			0.002	0.003			0.00071	0.0016
			(0.003)	(0.003)			(0.004)	(0.003)			(0.004)	(0.004)
Tech. Capacity			0.005***	0.005***			0.004***	0.004***			0.006***	0.006***
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.001)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.03	0.03	0.04	0.04	0.01				0.02	0.02	0.03	0.03
Observations	13934.00	13934.00	13934.00	13934.00	13934.00	13934.00	13934.00	13934.00	13934.00	13934.00	13934.00	13934.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table replicates the baseline estimates only conditioning for bureaus associated with record of patents in our data. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

Table 12: Filters On: Services

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-0.38	-0.37	-0.27	-0.26	-0.35*	-0.35*	-0.27*	-0.28*	-0.65	-0.64	-0.52	-0.52
	(0.29)	(0.27)	(0.23)	(0.22)	(0.21)	(0.19)	(0.16)	(0.15)	(0.44)	(0.42)	(0.39)	(0.39)
Cost Plus		0.002	-0.001	-0.001		0.004**	0.002	0.002		0.002	-0.001	-0.002
		(0.003)	(0.003)	(0.003)		(0.002)	(0.002)	(0.002)		(0.004)	(0.004)	(0.005)
Negotiation		-0.006*	-0.005*	-0.006*		-0.005*	-0.005*	-0.005*		-0.006*	-0.006*	-0.006*
		(0.003)	(0.003)	(0.003)		(0.002)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)
Competed		0.006*	0.005	0.005		0.007*	0.006	0.005		0.009**	0.007*	0.007*
		(0.003)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)		(0.004)	(0.004)	(0.004)
Small Business			0.001	0.002			0.002	0.003			0.001	0.001
			(0.003)	(0.003)			(0.003)	(0.003)			(0.004)	(0.003)
Tech. Capacity			0.005***	0.005***			0.004***	0.004***			0.006***	0.006***
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.001)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.03	0.03	0.04	0.04	0.01				0.02	0.03	0.04	0.04
Observations	14804.00	14804.00	14804.00	14804.00	14804.00	14804.00	14804.00	14804.00	14804.00	14804.00	14804.00	14804.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table replicates the baseline estimates only conditioning for R&D categories associated with a record of patents in our data. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

Table 13: Filters On: Sellers

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-6.64	-5.25***	-5.33***	-5.18***	-5.34	-3.98***	-4.09***	-3.98***	-11.3	-9.84***	-10.0***	-10.1***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.00)	(0.000)	(0.000)	(0.000)	(0.00)	(0.009)	(1.24)	(0.009)
Cost Plus		-0.024*	-0.018	-0.020		-0.012	-0.006	-0.006		-0.036*	-0.027	-0.032*
		(0.013)	(0.012)	(0.013)		(0.010)	(0.01)	(0.01)		(0.019)	(0.017)	(0.018)
Negotiation		-0.017*	-0.017*	-0.019**		-0.015*	-0.016**	-0.017*		-0.016	-0.017	-0.018
		(0.009)	(0.009)	(0.009)		(0.008)	(0.007)	(0.008)		(0.019)	(0.019)	(0.023)
Competed		0.021	0.014	0.014		0.029**	0.022*	0.021*		0.034	0.024	0.024
		(0.017)	(0.017)	(0.017)		(0.012)	(0.011)	(0.010)		(0.027)	(0.028)	(0.034)
Small Business			0.035**	0.039***			0.033**	0.037***			0.046*	0.049
			(0.014)	(0.012)			(0.016)	(0.013)			(0.026)	(0.031)
Tech. Capacity			0.002	0.002			0.001	0.001*			0.001	0.002
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.0014)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.05	0.06	0.06	0.07	0.03				0.04	0.05	0.05	0.06
Observations	4330.00	4330.00	4330.00	4330.00	4330.00	4330.00	4330.00	4330.00	4330.00	4330.00	4330.00	4330.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table replicates the baseline estimates only conditioning for sellers associated with a record of patents in our data. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

Table 14: Filters On: Bureaus and R&D Categories

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-0.41	-0.38	-0.29	-0.28	-0.35	-0.34	-0.27	-0.27	-0.67	-0.65	-0.53	-0.53
	(0.30)	(0.27)	(0.22)	(0.21)	(0.22)	(0.21)	(0.18)	(0.16)	(0.44)	(0.41)	(0.38)	(0.37)
Cost Plus		0.001	-0.002	-0.002		0.004	0.002	0.001		0.001	-0.002	-0.003
		(0.004)	(0.003)	(0.004)		(0.002)	(0.002)	(0.002)		(0.005)	(0.005)	(0.005)
Negotiation		-0.006*	-0.006*	-0.007**		-0.005*	-0.005*	-0.006*		-0.007*	-0.007*	-0.007*
		(0.003)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)		(0.004)	(0.004)	(0.004)
Competed		0.008*	0.006	0.006		0.009*	0.007	0.007		0.011**	0.009*	0.009*
		(0.004)	(0.004)	(0.004)		(0.004)	(0.004)	(0.004)		(0.005)	(0.005)	(0.005)
Small Business			0.002	0.002			0.003	0.003			0.001	0.001
			(0.003)	(0.003)			(0.004)	(0.004)			(0.004)	(0.004)
Tech. Capacity			0.005***	0.005***			0.004***	0.004***			0.006***	0.006***
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.001)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.03	0.03	0.04	0.04	0.01				0.02	0.02	0.03	0.04
Observations	12750.00	12750.00	12750.00	12750.00	12750.00	12750.00	12750.00	12750.00	12750.00	12750.00	12750.00	12750.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table replicates the baseline estimates only conditioning for bureaus and R&D categories associated with a record of patents in our data. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

Table 15: Filters On: Bureaus and Sellers

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-6.52	-4.90***	-5.03***	-5.08***	-5.36	-3.86***	-3.99***	-4.20***	-11.5	-9.76***	-9.99***	-10.4***
	(0.00)	(0.000)	(0.00)	(0.000)	(0.00)	(0.000)	(0.000)	(0.000)	(0.00)	(0.015)	(1.44)	(0.63)
Cost Plus		-0.025*	-0.019	-0.021		-0.013	-0.0066	-0.0067		-0.037*	-0.028	-0.034*
		(0.014)	(0.013)	(0.013)		(0.011)	(0.010)	(0.010)		(0.021)	(0.017)	(0.019)
Negotiation		-0.017*	-0.017*	-0.019*		-0.015*	-0.015*	-0.016*		-0.017	-0.017	-0.019
		(0.001)	(0.009)	(0.009)		(0.008)	(0.008)	(0.009)		(0.023)	(0.020)	(0.036)
Competed		0.021	0.014	0.014		0.029**	0.022*	0.019*		0.035	0.025	0.024
		(0.018)	(0.018)	(0.018)		(0.012)	(0.012)	(0.011)		(0.035)	(0.032)	(0.059)
Small Business			0.036**	0.040***			0.034**	0.038***			0.048*	0.051
			(0.014)	(0.012)			(0.017)	(0.014)			(0.026)	(0.042)
Tech. Capacity			0.001*	0.002			0.001	0.001*			0.001	0.001
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.002)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.05	0.06	0.06	0.07	0.03				0.04	0.05	0.05	0.06
Observations	4179.00	4179.00	4179.00	4179.00	4179.00	4179.00	4179.00	4179.00	4179.00	4179.00	4179.00	4179.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table replicates the baseline estimates conditioning for bureaus and sellers associated with a record of patents in our data. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

Table 16: Filters On: Sellers and R&D Categories

	Log # Patents				Log # 3Y Citations				Log # Claims			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Rel. Deaths /Empl. -6 months	-6.87	-5.39***	-5.36***	-5.49***	-5.58	-4.13***	-4.13***	-4.32***	-11.7	-10.1***	-10.1***	-10.7***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.041)	(1.26)	(1.00)
Cost Plus		-0.023*	-0.017	-0.02		-0.012	-0.006	-0.006		-0.035	-0.026	-0.032*
		(0.013)	(0.012)	(0.012)		(0.01)	(0.01)	(0.01)		(0.021)	(0.017)	(0.018)
Negotiation		-0.017*	-0.017*	-0.018**		-0.015*	-0.016**	-0.017*		-0.016	-0.017	-0.018
		(0.009)	(0.009)	(0.009)		(0.008)	(0.007)	(0.009)		(0.03)	(0.02)	(0.025)
Competed		0.020	0.012	0.013		0.028**	0.021*	0.020*		0.033	0.023	0.022
		(0.017)	(0.017)	(0.017)		(0.012)	(0.012)	(0.011)		(0.044)	(0.030)	(0.038)
Small Business			0.036**	0.040***			0.034**	0.037**			0.047*	0.050
			(0.014)	(0.013)			(0.016)	(0.014)			(0.028)	(0.031)
Tech. Capacity			0.002*	0.002			0.001	0.001			0.0014	0.002
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.001)
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount&Duration FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R&D FEs	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes
R-squared	0.05	0.06	0.06	0.07	0.03				0.04	0.05	0.05	0.06
Observations	4315.00	4315.00	4315.00	4315.00	4315.00	4315.00	4315.00	4315.00	4315.00	4315.00	4315.00	4315.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table replicates the baseline estimates only conditioning for sellers and R&D categories associated with a record of patents in our data. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

Figure 4: Geographic span

	AK	AL	AR	AZ	CA	CO	CT	DC	DE	FL	GA	HI	IA	ID	IL	IN	KS	KY	LA	MA	MD	ME	MI	MN	MO	MS	MT	NC	ND	NE	NH	NJ	NM	NV	NY	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VA	VT	WA	WI	WV	WY
AF0B						x				x	x																														x							x			
AF0J	x	x	x	x	x	x		x		x	x	x	x		x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x		x
AF0M	x	x	x	x	x	x		x	x	x	x	x			x	x	x		x	x	x		x	x	x	x		x		x		x	x	x	x	x	x	x	x		x			x	x	x		x	x	x	
AF0R	x										x	x			x																																	x			
AF1C	x	x	x	x	x	x		x		x	x	x		x	x		x	x	x		x	x			x	x	x	x	x	x		x	x	x	x	x	x	x			x	x		x	x	x		x			x
AF1L	x	x	x		x	x			x	x	x	x			x		x			x	x				x	x		x	x			x		x		x	x				x			x		x		x			x
AF1M	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x				x		x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x	x		x			x
AF1S	x	x		x	x	x		x		x	x	x			x					x	x					x	x	x	x	x	x		x	x		x	x		x		x		x	x	x	x		x			x
ARAC	x	x	x	x	x	x		x		x	x	x			x		x	x	x	x	x			x	x			x				x	x		x		x		x		x		x	x	x	x		x	x		
ARAS	x	x		x	x	x	x	x		x	x	x			x		x	x	x	x	x		x	x	x			x				x	x		x	x	x		x		x		x	x		x		x			
ARAT	x	x		x		x		x		x	x	x					x	x			x		x		x			x				x	x		x		x							x	x	x		x			
ARCE	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ARMC	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x		
ARMM	x	x		x	x	x		x		x	x	x	x		x		x		x	x	x		x		x			x				x			x	x	x		x				x	x		x		x			
ARNG	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CM54	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CM57					x	x		x		x	x	x		x				x		x	x		x				x	x		x		x			x	x					x			x		x		x			
DD63	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
HE38	x	x		x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x		x	x		x		x	x	x	x	x	x		x	
HE39	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HSAC	x	x	x	x	x		x	x		x	x	x			x		x	x	x	x	x	x	x	x	x	x		x				x	x		x	x	x	x	x	x	x		x	x		x	x	x	x	x	
NN10		x			x	x		x		x					x	x		x	x	x	x		x	x	x	x		x				x	x		x	x			x		x			x		x			x	x	
NN21		x	x		x	x		x		x											x		x					x							x	x								x		x		x			
NN22		x			x			x		x													x			x										x								x						x	
NN23		x			x	x	x	x	x	x	x			x						x	x				x	x		x					x			x		x			x			x	x	x					
NN24					x			x		x					x								x		x								x	x	x									x	x	x			x		
NN51					x	x		x		x				x		x				x	x							x			x		x		x	x					x		x			x				x	
NN62		x			x	x				x									x							x		x								x			x					x	x	x					
NN64											x															x										x															
NN72		x			x	x		x		x	x	x			x		x		x	x	x		x	x	x								x			x	x				x		x	x		x	x		x		
NN76		x		x	x	x	x			x					x																					x								x		x					
NV14		x		x	x	x		x		x	x	x			x					x	x					x		x					x		x				x	x	x			x		x		x			
NV19		x		x	x	x	x	x	x	x	x	x			x	x			x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x		x	
NV23		x		x	x		x	x		x	x	x			x	x			x	x	x	x			x	x		x			x	x		x	x		x		x	x	x		x	x		x		x	x		
NV24	x	x	x	x	x	x	x	x		x	x	x		x	x	x		x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x		x	x	x		x	x	x	x		x	x		
NV25			x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x		x	x	x		x	x	x	x		x	x		
NV39		x		x	x	x	x	x		x	x	x		x	x	x			x	x	x	x		x	x	x		x	x	x	x	x	x	x		x	x		x	x	x		x	x		x		x	x	x	
TD03	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Notes: Intersection between bureau (columns) and State (rows) are filled with X when, across our sample, at least one worker within the bureau is settled in the State.

Table 17: Seller selection

	Probit: Selection of sellers				LPM: Selection of sellers			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Budget	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Median Age		0.10	0.07	0.05		0.03	0.02	0.02
		(0.12)	(0.11)	(0.12)		(0.03)	(0.03)	(0.03)
Median Education		-0.02	0.01	0.02		-0.01	0.00	0.01
		(0.04)	(0.05)	(0.05)		(0.01)	(0.02)	(0.02)
Median LOS		-0.04	-0.03	-0.02		-0.01	-0.01	-0.01
		(0.03)	(0.04)	(0.04)		(0.01)	(0.01)	(0.01)
Median Salary		0.06	0.07	0.06		0.02	0.03	0.02
		(0.06)	(0.06)	(0.07)		(0.02)	(0.02)	(0.02)
Median WF Composition		0.98***	0.97***	1.13***		0.30***	0.30***	0.36***
		(0.23)	(0.25)	(0.35)		(0.07)	(0.08)	(0.11)
Iqr Age		-0.09***	-0.11***	-0.10**		-0.02*	-0.03**	-0.03*
		(0.03)	(0.04)	(0.04)		(0.01)	(0.01)	(0.02)
Iqr Education		0.01	-0.00	0.00		0.00	0.00	-0.00
		(0.02)	(0.02)	(0.03)		(0.01)	(0.01)	(0.01)
Iqr LOS		0.04	0.03	0.03		0.01	0.01	0.01
		(0.02)	(0.03)	(0.03)		(0.01)	(0.01)	(0.01)
Iqr Salary		0.02	0.02	0.02		0.01	0.01	0.01
		(0.03)	(0.04)	(0.04)		(0.01)	(0.01)	(0.01)
Iqr WF Composition		0.73***	0.72***	0.76***		0.14***	0.15***	0.16***
		(0.19)	(0.19)	(0.19)		(0.03)	(0.04)	(0.04)
Accomplishment			-0.20	-0.73			-0.05	-0.16
			(0.68)	(0.76)			(0.24)	(0.25)
Appreciation			-0.22	-0.02			-0.12	-0.04
			(0.91)	(0.81)			(0.32)	(0.27)
Level of Workload			-0.60	-0.49			-0.23	-0.20
			(0.43)	(0.45)			(0.14)	(0.14)
Physical condition workplace			0.32*	0.59*			0.13**	0.22**
			(0.19)	(0.31)			(0.05)	(0.09)
Integration policy				-0.11				-0.09
				(0.63)				(0.18)
Health Security				-0.83				-0.25
				(0.53)				(0.17)
Good Place to work				0.47				0.17
				(0.57)				(0.18)
Balance work/life				0.21				0.01
				(0.51)				(0.15)
Job Satisfaction				-0.14				-0.08
				(0.55)				(0.18)
Pay Satisfaction				-0.18				-0.07
				(0.47)				(0.14)
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bureau FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16813.00	16813.00	16813.00	16813.00	16822.00	16822.00	16822.00	16822.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The table reports the estimates of a dummy variable assuming value equal to 1 if a seller is included in the final sample regressed on bureau characteristics. Columns (1)-(4) report the estimates using a probit model and an increasing set of controls. Columns (5)-(8) report the estimates using a linear probability model. Standard errors are clustered by bureau and are in parentheses.

A.2 Workplace Features

As explanatory variables that we use to investigate the channels through which deaths of managers affect the quality of procurement of innovation processes, we consider bureau-level characteristics coming from the Federal Employee Viewpoint Survey (FEVS). Since the early 2000s, the Office of Personnel Management has called on federal employees to provide their opinions on all aspects of their employment, including evaluations of their supervisors, bureaus, agencies and, more generally, of their work experience.[27]

Table 18: Quantiles of Age and Salary

	Managers		Other White-Collar Employees	
	Age	Salary	Age	Salary
1 %	25-29	$30,000 - $39,999	20-24	$20,000 - $29,999
5 %	30-34	$40,000 - $49,999	25-29	$20,000 - $29,999
10 %	35-39	$50,000 - $59,999	25-29	$30,000 - $39,999
25 %	40-44	$60,000 - $69,999	35-39	$40,000 - $49,999
50 %	50-54	$90,000 - $99,999	45-49	$50,000 - $59,999
75 %	55-59	$120,000 - $129,999	50-54	$80,000 - $89,999
90 %	60-64	$140,000 - $149,999	60-64	$100,000 - $109,999
95 %	60-64	$150,000 - $159,999	60-64	$120,000 - $129,999
99 %	65 or more	$180,000 or more	65 or more	$160,000 - $169,999
Obs	2,131,206	2,131,206	11,914,322	11,914,322
Std. Dev.	1.74	3.54	2.34	3.10
Av. # employees	583	583	3,208	3,208
Md. # employees	76	76	322	322
Employees Std. Dev.	1,718	1,718	12,570	12,570
Local Av. # employees	45	45	184	184
Local Md. # employees	6	6	12	12
Local Employees Std. Dev.	151	151	782	782

Notes: The table reports the distribution of age and salary separately for two groups of employees, managers and other white-collar employees during the time window 2006-2012. The sample is taken from the Employment cube of FedScope. Blue-collar workers are expunged. 1 point S.D. in *Age* represents 5 years; 1 point S.D. in salary represents $10,000.

FEVS was run biannually starting with 2002; only since 2010 has it been run on a yearly basis. We focus on the period 2006-2012 and we fill the gaps for years 2007 and 2009 by imputing the mean, respectively 2006 to 2008 and 2008 to 2010.[28] There is a total of 107 bureaus from 20

[27]The goal is to measure government employees' perceptions of whether, and to what extent, conditions characterizing successful organizations are present in their bureaus and agencies and, ultimately, to influence change in their workplace. The beginning of this survey dates back to 2002 when it was first administered under the name "Federal Human Capital Survey" as an essential tool of the President George W. Bush administration's agenda for a managerialization of the public administration. Since then, the survey has been mainly used for internal human resources management recommendations from the Office of Personnel Management to the agencies. This federal agency uses the FEVS to monitor human capital management initiatives and outcomes and to provide guidance, resources, and technical assistance to the entire federal government. Despite the existence of published works based on FEVS data (see the survey review of Fernandez et al. (2015)), ours is only the second one to reconcile them with the procurement data discussed next (Decarolis et al. 2018).

[28]We focus on all bureaus that in a year procure at least one contract. To allow for matching with other datasets,

agencies that are invited to participate accounting for 97% of the executive branch workforce with about half of the employees randomly selected to participate in the survey and an average 47% response rate. The FEVS consists of 85 questions divided into five different sections which appear to respondents in the following order: my work experience, my work unit, my agency, my satisfaction and work/life. The section "my work unit" - presented in Table 19 - begins with eight questions pertaining to different features of the bureau and ends with a ninth question aiming to capture the overall effectiveness of the job done in the office. From the content of the questions, we derive three bureau features - *cooperation*, *incentives* and *skills*. The two-factor principal component analysis, whose weights are reported in the last two columns of Table 19, shows how our "textual classification" is correct and how answers related to skill and incentive characteristics of the office tend to correlate.

Table 19: List of FEVS Questions Composing the "My Work Unit" Section

Q#	**Question**	**Classification**	**PCA Skill/Incentive Factor 1 Weights**	**PCA Cooperation Factor 2 Weights**
My Work Unit:				
20	The people I work with cooperate to get the job done.	Cooperation	<0.01	0.60
21	My work unit is able to recruit people with the right skills.	Skills	0.08	0.04
22	Promotions in my work unit are based on merit.	Incentives	0.16	<0.01
23	In my work unit, steps are taken to deal with a poor performer who cannot or will not improve.	Incentives	0.19	<0.01
24	In my work unit, differences in performance are recognized in a meaningful way.	Incentives	0.22	<0.01
25	Awards in my work unit depend on how well employees perform their jobs.	Incentives	0.17	<0.01
26	Employees in my work unit share job knowledge with each other.	Cooperation	<0.01	0.35
27	The skill level in my work unit has improved in the past year.	Skills	0.14	<0.01
28	How would you rate the overall quality of work done by your work unit?	Competence	-	-

Notes: The complete set of nine questions in the FEVS section dedicated to the employees' assessment of their work unit. The numbering in column one reflects that in the FEVS. The last two columns report the percentage contributions that each variable assumes through the weights calculated by the factor analysis.

For all questions, employees' responses are in five ordered levels of intensity. For a typical question, the possible responses are: very poor, poor, fair, good, very good.[29] We first transform these answers into numerical values from zero to four, then we aggregate answers at the bureau level (by using the FEVS' representative weights), and finally we normalize the resulting variables to be between zero and one.[30]

we i) aggregate the answers to the questionnaire at the bureau level and ii) do not consider the 2002 and 2004 surveys because of the few federal bureaus involved.

[29]The respondent can also report "do not know" or leave the question unanswered, but both occurrences are rare (typically less than 2% of the responses for each of these two cases).

[30]The full-sample weights are developed according to a three-stage procedure. First, base weights are calculated for each sampled employee equaling the reciprocal of each individual's selection probability. Second, the base weights are adjusted for non-response within federal bureaus. Those adjustments inflate the weights of survey respondents to represent all employees in the subgroup, including non-respondents and ineligible employees. Third, the statistical procedure of raking ensures that the weighted distributions matches known population distributions by demographics.

Table 20: Bureau Features - Contract Level

	PCA Skill/Incentive		PCA Cooperation	
	(1)	(2)	(3)	(4)
# Rel. Deaths /Empl. -6 months	-17.0	-12.9**	-15.5	-22.6***
	(12.8)	(5.17)	(9.11)	(3.85)
Small Business		-0.049		-0.016
		(0.041)		(0.021)
Propensity to patent		0.014***		0.0033
		(0.0041)		(0.010)
University		-0.024		-0.019***
		(0.015)		(0.0059)
Bureau FEs	Yes	Yes	Yes	Yes
R&D Category FEs	Yes	Yes	Yes	Yes
R&D Stage FEs	No	Yes	No	Yes
Amount&Duration FEs	No	Yes	No	Yes
Calendar Year FEs	No	Yes	No	Yes
R-squared	0.90	0.95	0.66	0.91
Observations	3430.00	3430.00	3430.00	3430.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: The observation is the contract. Standard errors are two-way clustered by bureau and R&D category and are in parentheses. Amount FEs and Duration FEs represent deciles for contract value and duration.

To further explore drivers of the impact of managers' deaths on innovation procurement processes, in Table 20 we regress *Skill/Incentive* and *Cooperation* on our main explanatory variable (i.e., *Relevant Deaths*). Odd columns only include bureau and R&D category fixed effects while in even columns we add the full battery of baseline fixed effects and controls. The signs of the coefficient are negative, suggesting that managers' deaths disrupt office features. However, the magnitudes of death impact in this model are hard to interpret. First, bureau features are evaluated at bureau-year level while we measure the number of death events by fixing the month of contract award. In other words, the observation in these regressions is the contract while the outcome is the bureau-year pair. This is highlighted by the high R-squared reported. In order to provide a more reliable estimate, in Table 21 we regress the same outcomes on the number of relevant deaths in the bureau-year-State triple in our working sample - still as a fraction of total white-collar workers. While odd columns report a plain regression of bureau features on deaths, even columns augment the model with bureau and year fixed effects, leaving the cross-sectional variation occurring at local level. In a more neat fashion, this latter model displays how events of managers' deaths do worsen the office features as perceived by employees and provide evidence of a concurrent effect going on in the office besides the worsening of outcomes of R&D procurements.

Table 21: Bureau Features - Bureu/Year Level

	PCA Skill/Incentive		PCA Cooperation	
	(1)	(2)	(3)	(4)
# Rel. Deaths/Empl.	0.39***	-0.028	0.30***	-0.025*
	(0.11)	(0.022)	(0.068)	(0.014)
Bureau FEs	No	Yes	No	Yes
Calendar Year FEs	No	Yes	No	Yes
R-squared	0.04	0.91	0.05	0.92
Observations	161.00	161.00	161.00	161.00

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: Observation is the bureau-year-State triple. SE are two-way clustered by bureau and R&D category.