Transparency and the Social Benefits of Government Funded Research*

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Abstract

I investigate the effect of increasing transparency on the social benefits of government funded research. For this purpose, I exploit two laws enacted in the United States related to government funding and improved information provision. Using these, I analyze how the change in information disclosure affects follow-on innovation of government-funded research. The results show an elevated degree of innovation building on federally funded patents after transparency increased due to additional information. I find that this effect could be attributed to a decrease in search costs and asymmetric information. Further results imply that patents funded by procurement contracts show a stronger increase in follow-on innovation compared to those funded by grants. Considering the actual amount awarded, I find a positive relationship and that patents from projects with a medium level of funding benefit in particular. These results imply a positive effect of more transparency on innovation.

Keywords: Innovation, Transparency, Information disclosure, Government funding, Public procurement and grants, Patent citations

JEL classification: D83, I28, L24, O30, O31, O32, O34, O38

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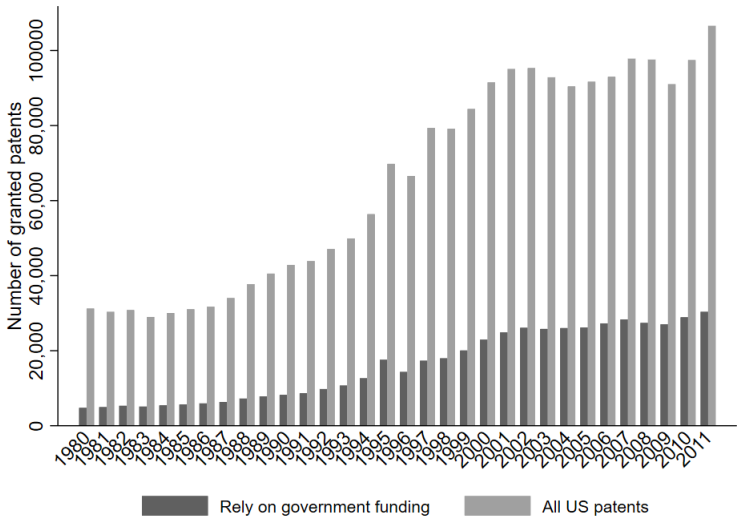
1 Introduction

How does increasing transparency affect the social benefits of government funded research? Analyzing this question is of particular relevance because publicly financed research serves important functions for the society. On the one hand, government funding acts as driver of basic research and therefore provides the foundation for follow-on innovation (e.g., Fleming et al. 2019). On the other hand, public procurement of innovation is considered an important form of public support for private innovation activities (e.g., Cozzi & Impullitti 2010). The importance of government funded research is underlined by the fact that about one third of all patents rely on it (Figure 1). These include innovation related to microchips, information and communication technologies, navigation, and human health. This emphasizes the conclusion that federal funding and cumulative innovation are an important driver for economic development and growth (e.g., Bresnahan & Trajtenberg 1995; Scotchmer 1991).

Although cumulative innovation are welfare increasing, market failures are a common problem in environments where innovation are sequential. Especially asymmetric information could lead to a too low degree of follow-on innovation from a welfare perspective (e.g., Bessen 2004; Bessen & Maskin 2009). First, diminished information transmission between upstream and downstream technology sectors could hamper subsequent research as this information flow is crucial for developing follow-on innovation (e.g., Bresnahan & Trajtenberg 1995; Green & Scotchmer 1995). Besides government support already in early stages, follow-on developments of the microchip, for instance, were realized due to the transmission of information (e.g., Mason 1986). Second, searching for a specific technology is not a trivial task and is connected with costs. In result, these search costs affect incentives for follow-on inventors to rely on existing technologies (e.g., Biasi & Moser 2021; Bryan & Ozcan 2020; Hellmann 2007). Consequently, analyzing mechanism to spur follow-on innovation of government funded patents is particular important from a welfare perspective.

Figure 1: Number of granted patents that rely on government funding



Notes: The data to produce this figure is obtained from Fleming et al. (2019). The figure shows the number of granted patents that rely on government funding. A patent is defined to be reliant on government funding if it is either directly financed by federal funds or rely on a government financed patent.

In this paper, I investigate whether and how increasing transparency about an invention affects subsequent innovation. For this purpose, I exploit two acts related to government funding and information disclosure that have been introduced in the United States. First, I make use of a feature of the 1980 Bayh-Dole Act that allows me to identify government funded patents. Second, as source of variation in the accessibility of additional information, I exploit the introduction of the Federal Funding Accountability and Transparency Act (FFATA) in 2006. The FFATA requires the publication of federal funding information on a publicly accessible website. The published information does not only include details about the award granting institution, but also about the type of award, funding size and project characteristics. Using this information finally allows to compare the change in subsequent innovation for government and non-government funded patents before and after transparency has increased due to improved and better accessible information.

To investigate the impact of transparency on subsequent innovation, I combine baseline patent data with additional information on government funded patents. Utilizing PatentsView bulk data allows to assemble basic patent characteristics and to de-

termine whether a patent is funded by the government or not. Taking this first set of information, I apply a combination of difference-in-differences regressions with a matching approach. First, I test for the difference in subsequent innovation building on government funded patents compared to non-government funded patents, before and after the enactment of the FFATA. Second, the matching approach allows accounting for a potential selection problem as federally funded patents are likewise different from those who are not. For further analyses concerning the impact of the funded award type, amount and general project characteristics, I apply additional data from de Rassenfosse et al. (2019). Combining this rich data set with the baseline patent data allows determining the heterogeneity of the effects according to several patent and award characteristics.

I find that the mandatory increase in transparency spurred subsequent innovation. The pooled baseline effect implies an increase of follow-on innovation of government funded inventions by about 5% in the period after the FFATA was enacted. Thus, the provision of additional information and reduction in search costs for information leads to an increase in patented follow-on inventions. Additional analyses imply that this positive effect is not only found to hold for the probability that a follow-on innovation is realized (extensive margin), but also for the amount of innovation (intensive margin). Analyzing the effect heterogeneity over time, I show that the subsequent innovation pattern of government funded patents compared to non-government funded inventions remains positive and relatively stable in the periods after the FFATA was implemented. Thus, not only short term attention for government funded research drives the results, but continuous information access.

In an additional step, I show that the effect is indeed driven by additional information provision and a reduction in search costs. Thus, when distinguishing patents with searchable awards and those without, I find the following: The impact of the information provision due to the FFATA is found for both, patents that could be directly mapped to awards listed on the public information source and those who are not. How-

ever, the effect is larger for patents that could be searched on the public information source. Finding that the effects are statistically different from each other implies that the baseline effect is indeed driven by the reduction in search costs and increase in information provision.

Further analyzing the role of project heterogeneity, I show that the effects are more pronounced for patents financed by procurement contracts and those with a medium level of funding. Determining the impact of the award type, I find that the effect is stronger for patents financed by procurement contracts compared to those funded by grants. This is likely rooted in the characteristics of the projects funded by the specific award. While a grant is aiming at completing research and offers some kind of flexibility, a procurement contract is legally binding and more emphasis is placed on delivering a final output (e.g., product). Moreover, I show that the funding amount is an additional factor that affects the magnitude of the FFATA's impact on subsequent innovation that build on government-funded patents. Thus, I find that higher funding amounts are indeed related to higher innovation counts after the FFATA. While this holds for the linear case, subsequent tests reveal that the impact of funding size on innovation follows the pattern of an inverted-U. I determine that the effect exists for the aggregated funding size, but also for grants and procurement contracts independently. Both results, concerning type and size of funding, reinforce the conclusion that increased information transmission and the reduction in search costs are particular driver of the results.

The results in this paper contribute to several strands of literature. First, I show that increasing transparency by the disclosure of financial and project related information, but also the reduction in search costs leads to an increase in follow on innovation. The effect size implies that there are spillovers that are not negligible. Thus, I contribute to works that investigate the effects of knowledge accumulation and spillovers (e.g., Furman et al. 2021; Furman & Stern 2011), information disclosure in terms of additional information provision (e.g., Bessen 2004; Murray et al. 2016), reductions in search costs

(e.g., Biasi & Moser 2021; Bryan & Ozcan 2020; Elfenbein 2007; Hellmann 2007; Iaria et al. 2018), financial reporting (e.g., Fu et al. 2020), and patent publications on innovation (e.g., Baruffaldi & Simeth 2020; Kim & Valentine 2021; Romer 1986; Sampat & Williams 2019; Williams 2017).

Moreover, second, the results in this study contribute to the policy discussion on the importance of financing for innovation (e.g., Hall & Lerner 2010; Kerr & Nanda 2015) and particularly the effectiveness of R&D programs (e.g., Howell 2017; Lach et al. 2021). On the one hand, I add to these works by showing that funding R&D and the resulting output fosters subsequent inventions. More important, I determine that increasing information disclosure of publicly funded patents and reducing search costs are valuable mechanisms to reinforce this relationship. On the other hand, the results presented in this paper imply that specifically projects funded by procurement contracts and a medium monetary input particularly benefit. This is in line with the fact that particularly this type of projects needs to be supported (Lach et al. 2021).

The remainder of this article is structured as follows. Section 2 covers a description of the impact of patent information disclosure on subsequent innovation. This is followed by Section 3, which comprises descriptions of the data and empirical strategy. The results are shown and described in Section 4. This includes baseline results and robustness and sensitivity tests. The results when analyzing the role of information access, type of funding and funding size are described in Section 5. The final Section 6 concludes.

2 Information disclosure and subsequent innovation

2.1 Government funding to fix market failures

Almost every technological development can be traced back to earlier innovation and it is greatly acknowledged that cumulative innovation are an important driver for economic development and growth (e.g., Bresnahan & Trajtenberg 1995; Scotchmer 1991).

Yet, market failures are a common problem in environments where innovation are sequential. One main issue is too little incentives to invest in the upstream invention (e.g., Green & Scotchmer 1995). This would not only prevent the first innovation, but also every follow-up development in downstream sectors. Another prevailing problem is that some degree of information transmission from the upstream to the downstream technology sectors is required that allows for subsequent developments (e.g., Bresnahan & Trajtenberg 1995). Thus, a lack of incentives and information could finally impede the development of innovation in either stage.

Public funding is considered an important policy tool to overcome issues related to a too low investment in innovation. Among others, this is rooted in the reduction of uncertainties that are a huge hampering factor in the innovation process (e.g., Hall & Lerner 2010). Thus, public funding of innovation is an important way to generate new knowledge and information about new technologies. While there are many financing options (Edler & Georghiou 2007), grants and procurement contracts are among the most widely used. A grant is aiming at completing research, could be related to early stage research efforts and offers some kind of flexibility regarding the reach of the particular agreed goal or its intended use (e.g., Howell 2017). Procurement contracts in contrast are supposed to stimulate innovation through demand for them (Czarnitzki et al. 2020; Edler & Georghiou 2007; Raiteri 2018) and a high emphasis is placed on delivering a final output (e.g., product). Thus, government funded innovation serve important roles by creating or enlarging the application sector for specific technologies (e.g., Bresnahan & Trajtenberg 1995). In addition to this, they are also bridging the gap between science and markets (e.g., Bresnahan & Trajtenberg 1995). Thus, government funded inventions likely stimulate further research.

2.2 Information provision and subsequent innovation

Although government funding provides incentives for innovation, a lack of information transmission might still constitute a problem for cumulative innovation. Among others, this is related to diminished information transmission between upstream and

downstream technology sectors (e.g., Bresnahan & Trajtenberg 1995; Green & Scotchmer 1995). It is especially the coordination between first inventor and follower which gets difficult under severe asymmetric information (Bresnahan & Trajtenberg 1995). In this case, licensing bargaining failures can results from a high degree of private information (e.g., Bessen 2004). However, it is not only the coordination as such, which becomes more difficult with less information. Also knowledge about what to coordinate about is necessary. Thus, high search costs for specific technologies make it less likely that it is build upon (e.g., Bryan & Ozcan 2020; Hellmann 2007). This is related to both, the technology itself, but also additional characteristics, like its costs. Consequently, additional information provision is a mechanism to overcome this issue.

It is generally acknowledged that information disclosure affects innovation positively. On the one hand, this refers to patent protection itself that is related to the requirement of publishing information (e.g. Murray et al. 2016). On the other hand, disclosing information beyond the patent documents is also beneficial for innovation. Additional information can reduce search costs for firms to find suitable scientific discoveries to build on (e.g., Biasi & Moser 2021; Bryan & Ozcan 2020; Elfenbein 2007; Hellmann 2007; Iaria et al. 2018). Moreover, it can include additional signals about the value of the technology (e.g., Arrow 1962), but also further technological details (e.g., Elfenbein 2007). The latter point refers mainly to the technology itself, (e.g., Zeckhauser 1996), but also the costs for research and development (e.g., Zeckhauser 1996). Although the latter might also be a signal of the value of the technology, the disclosure of R&D costs leads to positive effects on the research efforts of peer firms (e.g., Fu et al. 2020). This positive effect stems from the reduction in asymmetric information problem by disclosing additional information, which speeds up overall research (e.g., Bhattacharya & Ritter 1983). Consequently, additional information provision is generally expected to stimulate follow-on research.

2.3 Increasing transparency of government funded patents

The aim of this paper is to analyze impact of increasing transparency by mandatory information disclosure and better accessibility of information on subsequent innovation. For this purpose, I exploit two different acts to identify federally funded patents and patents affected by better accessible information: the Bayh-Dole Act of 1980 and the Federal Funding Accountability and Transparency Act of 2006.

First, I exploit the the Bayh-Dole Act of 1980. According to 35 U.S. Code § 202(c)(6), a patent which is the result of government funding has to include a statement about the government support awarding agency and the related contract. The origin of this requirement is the Bayh-Dole Act of 1980. Thus, each federally funded patent includes a 'Government interest' statement (e.g., Appendix A, Figure A1). This is part of the pre-grant patent publication, but also issued patent publication. Using this information allows to determine if a patent is federally funded or not. Additionally, the statement reveals the award granting agency and related award numbers.

Second, I utilize the Federal Funding Accountability and Transparency Act of 2006 as source of variation in access to information. Although the government interest statement contains important details about the federally funded patents, the award number leads to important financial details. In the period before 2006, interested persons had to access different sources and possibly crawl large data bases to access, if any, parts of the information behind these numbers. One rationale behind the FFATA is that the American public should get informed about how tax money is spent. To achieve this goal, a central requirement was that the information should be easily accessible via a website (Appendix B, Figure B1). The archived information should include, among others, recipient and funder details, amount and type of award, and general information about the funded projects. The FFATA was signed on September 26, 2006.[1] The first initial website was launched in early 2007, which was followed by pilot website in July 2007 (Appendix C, Figure D1) and the final website `www.USAspending.gov` in

[1] See Appendix C, Figure C1 for a timeline of the events from the signing of the act to the final website.

December 2007 (Appendix C, Figure E1). This allows to search for specific award numbers on the website to retrieve further award specific information. Accessing these via this source is not least possible due to improved data quality and integration into the website. In 2008, the FFATA was amended by the Government Funding Transparency Act.

Taken together, both acts allow to identify federally funded patents and an increase in transparency due to better accessible information. According to the description above, when comparing federally funded and non-federally funded patents, I expect the following: Federally funded patents are cited to a higher degree after the signing of the FFATA compared to similar non-federally funded patents. This is not least rooted in increased disclosure of information and reduced search costs due to the FFATA.

3 Data and empirical setting

3.1 Data and variables

To investigate the effect of mandatory increase in transparency on subsequent innovation that build on federally funded patents, I combine data sets from different sources. The core is build by information that is obtained from the USPTO PatentsView bulk data. This comprises general details for design, utility and plant patents. The PatentsView version as of August 11, 2021 covers information for about 7 million granted patents, patent applications and pre grant publications. Besides baseline details, also additional information as for example, the relation to other patents, the patent assignee and inventor are provided.

I utilize the PatentsView bulk data for utility patents as the core data base of my analysis. Thus, I do not only exploit information on the patent itself, but also additional characteristics. Besides the patent type, this includes the filing and grant date. In addition, I utilize information about the technological origin of the patent. This includes the section and class component of the International Patent Classification (IPC)

code. Utilizing this information allows to control for technology field specific effects. Furthermore, I obtain citation information to construct a citation measure that is the outcome variable of interest.

As outline above, the analysis focuses on the difference between federally funded and not federally funded patents. Thus, I also exploit the information concerning 'Government interest' which is part of the patent publication. The origin of this requirement is the Bayh-Dole Act of 1980. Thus, according to 35 U.S. Code § 202(c)(6), a patent which is the result of a government contract has to include a statement about the government support awarding agency and the related contract. This allows to extract several information. First, it allows to distinguish federally funded patents from those which are not. Second, it allows to determine the award granting agency. Third, from the wording in the statement it is possible to derive the type of award (e.g., contract or grant). Fourth and last, the statement includes the related contract or grant number.

Making use of the award number allows to obtain even further information. I use data from de Rassenfosse et al. (2019) that includes details concerning federally funded patents. The data is obtained by making use of the FFATA requirement that the American public should get information how tax dollars are spend via an easily accessible website. Thus, the data covers funding details starting from the fiscal year 2000 onward. This includes, for example, the specific type of award and size of funding. Thus, from these sources, I extract information about the type and size of the award. Moreover, I use these databases to determine the number of grants and contracts that funded a patent, and in addition to that the average length of the grants and contracts. These information allow to investigate the funding intensity even further.

The sample of patents used for the baseline estimations is build from the application cohorts 2002 to 2004 that are observed in the years 2002 to 2011.[2] The particular choice of this sample is rooted in various reasons. First, it ensures that no patents

[2]Robustness tests addressing the composition of patent cohorts and length of the sample period are discussed and presented in Section 4.4. Descriptive statistics are shown in Appendix F, Figure F1 and Table F1.

are included which are financed by federal awards that have no information on the USAspending.gov website. The federal awards that are accessible through this website are those starting in fiscal year 2000 and later. Moreover, these patents are filed after The American Inventors Protection Act (AIPA) was enacted on November 29, 1999 and after the 2001 recession.[3] Most important is the fact that for patents filed on or after November 29, 2000, the publication time was reduced to 18 months. Thus, the information of these patents is likely publicly available when the FFATA became active. This includes whether the patent is federally financed or not and the related information outlined above. Taking 2004 as last cohort ensures to observe a pre-FFATA period that is long enough to investigate the patent citation pattern before the FFATA was enacted.

3.2 Empirical strategy

The aim of this paper is to analyze the effect of increasing transparency due to additional information disclosure on subsequent innovation. For this purpose, federally funded patents were identified as patents treated by the FFATA and non-federally funded patents as control group, not affected by the new regulation. To determine the effect of the mandatory disclosure requirement on the follow-on innovation development of treated patents, I apply difference-in-differences regressions in combination with a matching approach. While the difference-in-differences estimation allows to determine the treatment effect by accounting for unobserved changes over time, it does not account for a possible selection into the treatment status. For the specific application in this paper, it has to be noted that federally funded patents could be assumed to be different from non-federally funded patents. Among others, this is rooted in the fact that receiving money, for example, from a procurement contract, compensates for risks and uncertainties that usually arise in the innovation process (e.g., Raiteri 2018). In addition, federally funded patents might incorporate a high degree of basic research and could be related to a direct application, but do not necessarily have to. Thus, this selection issue makes it important to account for the difference between federally funded and not government funded patents.

[3] For details about the causes of the 2001 recession see Kliesen (2003).

To consider a potential selection problem, I apply a matching procedure that allows to find suitable control units for each federally funded patent. For this purpose, I utilize a coarsened exact matching approach (e.g., Iacus et al. 2012). The general idea is to define strata per characteristic in which treatment and control observations are weighted according to their presence (e.g., Iacus et al. 2012). Thus, I require the observations to be exactly matched based on the technology section times class combination the patent is assigned to. Moreover, patents are sorted into strata defined by the application years the patents were filed and the grant year. In addition to these characteristics, I require the patents to be sorted in groups according to the size of the patent holder. Besides these static characteristics, I account for the pre-FFATA citation trends. Thus, I apply Scott's rule to coarsen the logarithm of citations for the years 2003 to 2005 (Iacus et al. 2012). Incorporating these variables, the observations are weighted in each strata according to the ratio of matched and total treated and control units (Iacus et al. 2012).

I investigate the impact of the information disclosure due to the FFATA on federally funded patents by performing difference-in-differences estimations and applying the above described weights obtained from the matching procedure. Thus, I estimate the following difference-in-differences equation:

$$\log(\text{Citations} + 1)_{it} = \tau_0 + \tau_1 \text{Government}_i \times \text{FFATA}_t + \alpha_i + \eta_{it} + \varepsilon_{it} \tag{1}$$

where $\log(\text{Citations} + 1)_{it}$ represents the log of citations by other patents in year t. To determine the difference-in-differences estimate, an interaction is included which consists of two parts: First, an indicator variable Government_i that takes the value one if the patent is federally funded and zero else. Second a dummy variable FFATA_t, for which value one is assigned for the time after 2007 and zero for the years before. Consequently, the parameter τ_1 identifies the change in subsequent innovation that build on federally funded patents due to the FFATA compared to non federally funded patents and the time period before the FFATA. In addition, I include patent fixed effects

α_i to account for the impact of time invariant patent characteristics. Moreover, I add a set of year times IPC section-class fixed effects η_{it}. On the one hand, this allows to cover period and technology class effects over time. On the other hand, this ensures that τ_1 determines the intended treatment effect.

I perform further estimations to investigate the heterogeneity of the effect of additional information disclosure on follow-on innovation over time. I apply an adjusted version of equation (1) that allows for yearly varying effects of information disclosure on patent citations. Consequently, I estimate the following equation:

$$\log(\text{Citations} + 1)_{it} = \tau_0 + \sum_{\substack{t \neq 2006 \\ t=2002}}^{2011} \tau_t I_t \times \text{Government}_i + \alpha_i + \eta_{it} + \varepsilon_{it} \tag{2}$$

where I include a set of year dummy variables 'I' interacted with the indicator variable 'Government'. The resulting coefficients τ_t identify the effect of increasing transparency on subsequent innovation in the respective year t, compared to the reference year $t = 2006$. This approach has several advantages. On the one hand, the interaction terms for the years 2005 and earlier inform about the citation difference between federally funded patents and those that are not before the FFATA. This citation pattern should be parallel so that τ_1 in equation (1) reflects a valid difference-in-differences estimate. On the other hand, the interaction terms for the time period after 2006 allow to determine the treatment heterogeneity over time. Thus, the coefficients τ_t for $t \geq 2007$ reflect the yearly changes in citations after the FFATA was enacted.

4 Baseline results

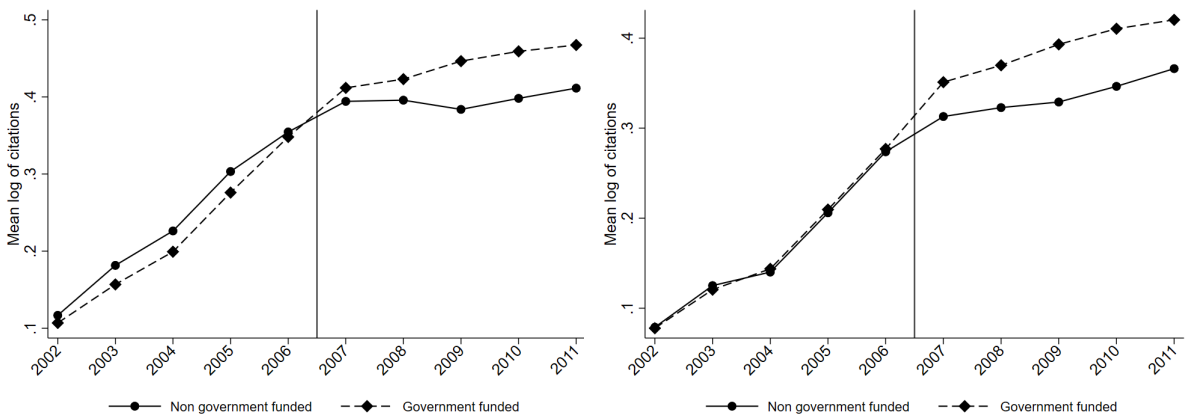
4.1 Descriptive evidence

In a first step, I analyze the pattern of subsequent innovation that build on federally funded and not federally funded patents over time. For this purpose, I use the data in the raw form and after the matching procedure described in Section 3.2. The results are shown in Figure 2. First, the development of citations for the raw data is shown in

panel (a). For the time before the FFATA went active in 2007, the non-federally funded patents show a higher citation count. This pattern changes with the enactment of the FFATA in 2007. The relationship turns around and the federally-funded patents receive a higher degree of citations. While the gap between both types of patents is relatively narrow in the first years, it becomes wider over time. Second, a similar observation could be made for the matched sample in panel (b). The citation pattern before the FFATA became active in 2007 implies that the matching process was successful. After the FFATA became binding, the federally funded patents show a higher citation count. The results from both panels of Figure 2 imply first evidence that the FFATA led to an increase in subsequent innovation that build on federally funded patents.

Figure 2: Citations of federally and not federally funded patents over time

(a) Raw sample **(b) Matched sample**



Notes: The figure shows the development of citations for federally funded and not federally funded patents over time. The outcome variable is the mean of the logarithm of citations for each group of patents per year. The vertical bar indicates the change in time period when the FFATA became active.

4.2 Difference-in-differences estimation results

To determine the baseline impact of the effect of increasing transparency due to mandatory information disclosure on subsequent innovation, I analyze the results of estimating equation (1). These are shown in Table 1, columns (1) to (3). What becomes evident on the first sight is that the effects are positive and significant on the one percent level. This indicates that the FFATA led to an increase in subsequent citations of federally funded patents compared to non-federally-funded patents. Regarding the size

of the impact, the descriptive evidence is reinforced. The estimate in column (1) implies that the FFATA led to a 5.2% increase in subsequent patent citations for government funded patents compared to non-federally funded patents and the time before the FFATA.

In further regressions, I analyze the change in the extensive and intensive margin of citations. These estimates inform about whether the effect is driven by either the amount or probability of citations or both. The results in column (2) imply that the degree of citations (intensive margin) increased by about 4.9 % for federally-funded patents. For the probability to receive a citation, the results are shown in column (3). The positive and significant effect reflects the finding that not only the amount of citations, but also the likelihood to receive a citation increased due to the FFATA for federally funded patents.

Table 1: The impact of mandatory information disclosure on subsequent innovation

	(1) log(Citations + 1)	(2) log(Citations>0)	(3) P(Citations>0)
Government × FFATA	0.052*** (0.004)	0.049*** (0.007)	0.039*** (0.003)
R-squared	0.443	0.491	0.363
Observations	3,844,293	791,314	3,844,293

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the weighted sample of federally funded and non-federally funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in column (1). In column (2) the intensive margin of citations is determined by taking the logarithm of the non-zero values of patent citations. The dependent variable in column (3) is an indicator variable taking unit value if the patent under consideration was cited by any patent in a given year and zero else. The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

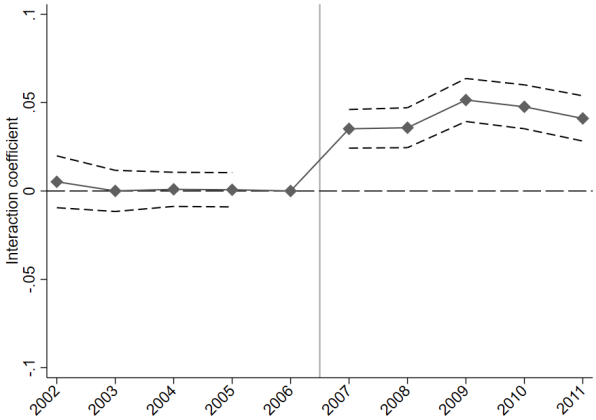
4.3 Heterogeneity of the effect over time

The average effect outline in the previous section is positive and the descriptive evidence in Section 4.1 implies that the effect is varying over time. Thus, in an additional analysis, I run equation (2) to determine the effect of the law change over time. The

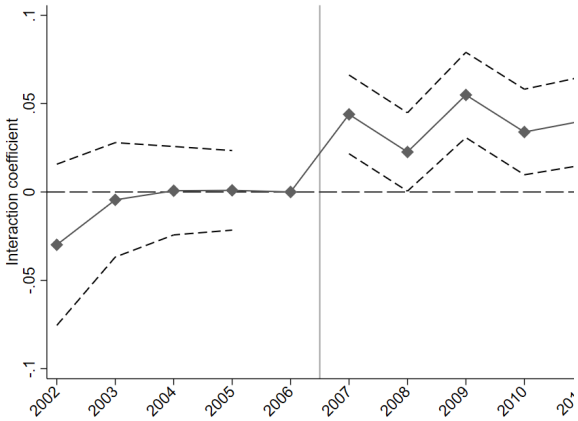
results of this exercise are shown in Figure 3, panels (a) to (c). For the pooled estimate in panel (a) the yearly effects are not significant different from the baseline period 2006 in the time before the introduction of the FFATA in late 2006. This implies that the observation made from Figure 2 – that the common trend assumption likely holds – could be confirmed. For the time period after the FFATA was enacted (2007 and later), the effect is positive and significant different from zero. Moreover, the results in Figure 3, panel (a) imply that the effect increases up the year 2009, and decreases afterwards, but stays positive. Similar patterns are observed in panels (b) and (c). Consequently, also citations at the extensive and intensive margin remain elevated after the FFATA has been enacted in late 2006.

Figure 3: Citations before and after the FFATA

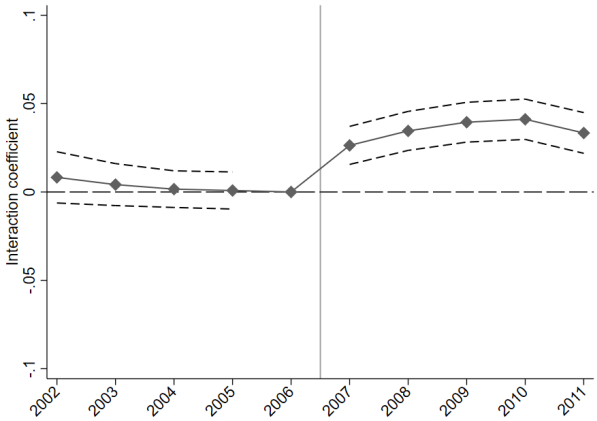
(a) Before and after the FFATA



(b) Intensive margin



(c) Extensive margin



Notes: The figure shows the results of estimating equation (2) for the sample of government and non-government funded patents as described in Section 3. All panels show the development of citations for federally funded compared to not federally funded patents over time with reference to the baseline period ($t = -1$). The outcome variable in panel (a) is the logarithm of citations plus one. The intensive margin is displayed in panel (b): This is expressed by the outcome variable constructed as the logarithm of citations plus one of the patents with at least one citation. For the extensive margin in panel (c), a binary variable is used as dependent variable. This takes unit value if the patent receives a citation and zero else. 95% confidence intervals are indicated by dashed lines.

4.4 Robustness and sensitivity tests

I perform several robustness tests to check for the sensitivity of the results to the assumptions made in Section 3. It might be a valid concern that the results are driven by, for example, the choice of particular patents utilized in the analysis or the specific time horizon applied. Thus, I begin with shedding light on the effects of the patents under consideration in the main analysis.

Individual application year effects. It might be a valid concern that the effect is driven by patents filed in a particular application year. Among others, this reasoning could be grounded in specific technology shocks or developments that affect only specific patents in one cohort. Thus, first I use the single application years 2002, 2003 and 2004 to estimate equation (1). The results in Appendix G, Table G1 look fairly similar for the three years independently.

Extended sample of treatment and control patents. The chosen sample of patents described in Section 3 and the related weighting approach might drive the results. Thus, in a next set of tests, I drop the weighting approach and also extend the number of patents. In a first sub-test in this section, I apply the full not-weighted set of patents from 2002 to 2004 pooled and independently in the analysis. The results are shown in Appendix H, Table H1. They look fairly similar to the baseline results. One rationale for using this sample of patents was that the technology is state of the art, that there is an appropriate pre-FFATA period and that the patents are financed by awards started in fiscal year 2000 or later. In an additional tests, I extend the number of patents even further. This includes two steps. First, using also patents filed in the years 2000 and 2005. Second, applying the weighting algorithm to them. The results for the pooled and independent application year samples, weighted and not weighted are shown in Appendix H, Table H2, panels A and B. It becomes evident that they look, again, similar to the baseline results.

Composition of treatment and control patents. Another concern regarding the results outline above might be that the composition of treatment and control patents is driving them. First, I apply a single control patent for each federally funded patent. For this purpose, I stick to the approach described in section 3.2, but draw one patent out of the population of control patents. The results shown in Appendix I, Table I1, panel A are quite similar to the baseline results. In an additional test, I draw a textual similar patent out of the population of control patents by making use of the data from Arts et al. (2021). The results of this exercise are shown in Appendix I, Table I1, panel B.

Again, they look quite similar to the baseline estimates shown above. In an additional analysis, I restrict the sample of treatment and control patents to those hold by firms. This assignee type holds the largest share of government funded patents. The results are shown in Appendix I, Table I1, panel C. They look fairly similar to the baseline results. In an additional step, I add the patent value to the parameters in the matching process. Thus, I search for patents that are assigned similar values. The results in Appendix I, Table I1, panel D are similar to those presented above.

Origin of citations. It might be also questioned where the follow-on citations might come from. Although the argumentation above implies that these are most likely better informed inventors that also benefit from reduced search costs, other explanations have to be rule out. First, I test whether awareness of government funding might caused examiners to add citations during the patent prosecution. For this purpose, I estimate equation (1) using citations by examiners and applicants as separate outcome variables. The results in Appendix J, Table J1, panel A imply that the effect is largely driven by applicant citations. However, there is also a small but significant increase in examiner citations.

Another concern could be that the citation pattern is driven by the applicant of the focal patent itself. To rule out this possibility, I estimate equation (1) separately for outcome variables that either reflect citations by the entity the patent is assigned to or citations by distinct entities. Although the results in Appendix J, Table J1, panel B show positive and significant effects for both outcomes, the effect for the distinct assignee citations is three times as high as the effect from the own assignee. Moreover, this effect is close to the baseline estimates.

In a last test in this category, I account for a potential issue that could be related to federally funded research itself. Thus, it might be a valid concern that most of the follow-on citations stem from other federally funded inventions. If this would be the case, the effect would shown in Section 4.2 would not be driven by increases in knowledge flows and decreases in search costs of the general public, but by other federal

projects. To rule out this possibility, I estimate equation (1) separately for citations by federally funded patents and citations by not federally funded patents. The results in Appendix J, Table J1, panel C imply that the effect is driven by federally and non-federally funded patents.

5 Information access, type of funding and funding size

5.1 Funded patents with and without information

To provide further evidence for the hypothesis that the increase in subsequent innovation that build on federally funded patents stems from the FFATA, I conduct additional heterogeneity tests. First, I analyze whether the effect could be attributed to the reduction in search costs and the provision of additional information. If these two forces are at work, the impact has to be larger for patents that include an award number that could be found on the website of the government compared to federally funded patents for which this is not the case and compared to patents that are not federally funded. To test for this relation, I make use of the data from de Rassenfosse et al. (2019). This includes patent and award information for patents granted between 2005 and 2015 that are funded by a procurement contract or grant active between 2000 and 2013, which was searchable on the USAspending.gov website.

To test for the different impact of the FFATA on these groups of patents, I refine the data set and estimation strategy in two steps. In a first step, I align the baseline sample with the patent cohorts included in de Rassenfosse et al. (2019). For this purpose, I restrict the sample of treated patents to those that were financed by a procurement contract or grant active between 2000 and 2013, were filed up to 2004, and were granted between 2005 and 2015. Second, I refine the treatment indicator used in equation (1) by distinguishing in federally funded patents granted in this time period, that have award information on the government website and those which have not. The control group now consists of patents that are not federally funded but were filed in the periods 2002 to 2004, and were granted between 2005 and 2015. While the latter group should

not be affected by the FFATA, the federally funded patents with an award number but no easy detectable information on the website of the government should be cited to a lower degree than patents with more information.

The results of this exercise are shown in Table 2. First, I re-estimate the baseline results for the adjusted sample outline above in column (1). The obtained estimate looks fairly similar to the baseline results in Table 1. In columns (2) and (3), I estimate equation (1) separately for patents for which an information can be found on the website (column 2) and patents for which no information can be found (column 3). As comparison group I use the full set of control patents from the adjusted sample in each of the cases. The results directly point towards a larger effect in column (2) compared to column (3). Thus in a second step, I estimate equation (1) and distinguish the treatment variable in two separate indicators to obtain one effect for each group. Again, non-federally funded patents filed between 2002 and 2004 and granted between 2005 and 2015 serve as control patents. The results in column (4) imply that the previously described effect is also found for the this specification. A test on the equality of both coefficients is rejected. Taken together, this exercise reinforces the statement that the impact is stronger for patents for which an information is searchable on the website. This directly points towards an effect of a reduction in search costs and better information transmission.

Table 2: Funded patents with and without information

	(1)	(2)	(3)	(4)
		log(Citations + 1)		
	Baseline	Information vs. No information		
Government × FFATA	0.044***			
	(0.004)			
Funding information × FFATA		0.050***		0.050***
		(0.005)		(0.005)
No funding information × FFATA			0.033***	0.033***
			(0.007)	(0.007)
Test for difference of Information vs. No information coefficients				
p-vlaue				0.002
R-squared	0.432	0.432	0.432	0.432
Observations	2303173	2273400	2247526	2303173

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The adjusted sample is constructed from patents that were filed up to 2004, and were granted between 2005 and 2015. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in columns (1) to (4). In column (1) the baseline estimation of equation (1) is reported for the adjusted sample of patents. The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. In columns (2) and (3), the treated patents are either those with an information on the publicly searchable website or those without. The comparison group is formed from patents that are non-government funded. The 'Government' dummy variable is replaced respectively. In column (4), the treatment indicator is split into two separate variables for each of the previously mentioned types. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

5.2 Type of funding

In a next step, I analyze whether the effect is heterogeneous according to the specific funding types. Especially the fact that different policy tools aim at different innovation types and incentives leads to the expectation that there should be also different effects due to the additional information disclosure. In the particular case of this study, the main types are procurement contracts and grants. A general feature both innovation policy tools have in common is that their design aims at overcoming market failures. Among others, this is related to a reduction in risk and uncertainties for the innovator that lead to an increase in the incentives to innovate. However, the specific design of the policies reveals important differences that could affect the impact of additional information on the degree of subsequent research. First and general, while a grant

is a supply side measure, procurement contract are intended to stimulate innovation through demand for innovation (Czarnitzki et al. 2020; Edler & Georghiou 2007; Raiteri 2018). Thus, a grant is aiming at completing research, could be related to early stage research efforts and offers some kind of flexibility regarding the reach of the particular agreed goal or its intended use (e.g., Howell 2017). In contrast to that, a procurement contract is legally binding as high emphasis is placed on delivering a final output (e.g., product). One of the particular goals of procurement contracts is to overcome market failures in terms of information asymmetries and better diffusion of innovation (e.g., Edler & Georghiou 2007). Thus, procurement contracts lead to a reduction in transaction costs when adapting new products, provide signals to market participants that raise early product awareness, and positively impact the creation of markets (e.g., Edler & Georghiou 2007; Raiteri 2018). These characteristics lead to the conclusion that the effect of additional mandatory information should be more pronounced for procurement contracts than for grants.

To investigate the effect of the different funding types on the degree of follow-on innovation after the FFATA for government funded and non-government funded patents, I apply the following approach: I re-estimate equation (1) and replace the government funding indicator by two different dummy variables that are either 'Procurement' or 'Grant'. While the latter takes unit value if the patent is funded by a government grant, the 'Procurement' dummy takes unit value if the patent was funded by this award type. I estimate equation (1) using these separately or jointly. The results of this exercise are shown in Table 3, panels A and B. The sample in panel A covers the full population of patents and the award type information is directly taken from the government interest statement. In panel B, for the treatment group, the subset of government funded patents with available funding information from de Rassenfosse et al. (2019) is used. This includes patents filed between 2002 and 2004, that were granted between 2005 and 2015. For both panels, the effects are similar. When estimating the effect independently for each funding type in columns (2) and (3), the size of the coefficients is larger for patents financed by procurement contracts compared to those financed by grants. The

comparison of coefficient sizes in column (4) implies that these are statistically different from each other. Consequently, patents financed by procurement contracts benefit more – in terms of subsequent innovation – from the additional information provision.

Table 3: Type of funding

	(1)	(2)	(3)	(4)
	log(Citations + 1)			
	Baseline	Procurement	Grant	Procurement and Grant
Panel A: Full sample with information from government interest statements				
Government × FFATA	0.052***			
	(0.004)			
Procurement × FFATA		0.085***		0.084***
		(0.006)		(0.006)
Grant × FFATA			0.028***	0.029***
			(0.005)	(0.005)
Test for difference of Procurement vs. Grant coefficients				
p-vlaue				0.000
R-squared	0.443	0.442	0.443	0.443
Observations	3844293	3780428	3782184	3844293
Panel B: Adjusted sample with available funding information				
Government × FFATA	0.050***			
	(0.011)			
Procurement × FFATA		0.096***		0.096***
		(0.008)		(0.008)
Grant × FFATA			0.067***	0.064***
			(0.006)	(0.006)
Test for difference of Procurement vs. Grant coefficients				
p-vlaue				0.000
R-squared	0.446	0.446	0.446	0.446
Observations	3311373	3275045	3289737	3311373

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in columns (1) and (2). In column (3) the intensive margin of citations is determined by taking the logarithm of the non-zero values of patent citations. In column (1) the baseline estimation of equation (1) is reported for the full sample (panel A) and the adjusted sample of patents (panel B). The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. In columns (2) and (3), the treated patents are either defined as being financed by a procurement contract or by a grant. The comparison group is formed from patents that are non-government funded. The 'Government' dummy variable is replaced respectively. In column (4), the treatment indicator is split into two separate variables for each of the previously mentioned types. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

5.3 Amount and years of funding

In a next set of tests, I analyze whether the project intensity in terms of funding years and funding size affects the results. It could be expected that differences along both dimensions exists. First, a long contract duration and high funding amount could signal particular value of a project. This could be also reflected in the degree of citations a patent receives. However, it could also be expected that a patent stemming from a high value contract with a long duration receives comparably lower amount of follow-on citations. This might be rooted in the fact that a particular long duration and high funding amount could signal high costs for follow-on inventors to build on the specific patent. From this argumentation it could be expected that the general effect of funding size and duration is positive. However, after a specific optimal point, the effect will decrease so that it will form an inverted-U.

To test for the impact of the amount of funding and the duration of funding, I replace the treatment indicator in equation (1) by a variable that is constructed as the logarithm of the quotient of total funding amount and award duration.[4] I begin by replacing the treatment indicator with a linear term and add a quadratic term subsequently for the total project funding amount, procurement contracts and grants. The results in Table 4 imply that the degree of citations is indeed larger for patents that were financed by a larger funding amount and for a longer duration (columns 1, 3, 5). While this holds for the linear case, adding a quadratic term changes the picture slightly. It becomes evident from the results in columns (2), (4) and (6) that the degree of citations increases with the funding size, but that the effect decreases after reaching a tipping point. Thus, the relationship has the form of an inverted-U. This reinforces the expectation that a too high funding amount and project duration leads to lower appropriation of results and therefore lower citation counts. This result is in line with the conclusion that higher information transmission affects the degree of follow-on innovation positively.

[4]The interpretation of the results remains similar, when the years of funding, the logarithm of funding or the logarithm of the share of funding per patent are applied independently in separate regressions.

Table 4: Amount and years of funding

	(1)	(2)	(3)	(4)	(5)	(6)
	log(Citations + 1)					
	Total		Procurement		Grant	
$\ln\left(\frac{\text{Amount}}{\text{Funding years}}\right) \times$ FFATA	0.009***	0.049***	0.008***	0.047***	0.035***	0.073***
	(0.001)	(0.006)	(0.002)	(0.009)	(0.006)	(0.013)
$\ln\left(\frac{\text{Amount}}{\text{Funding years}}\right)^2 \times$ FFATA		-0.006***		-0.006***		-0.017***
		(0.001)		(0.001)		(0.005)
R-aquared	0.431	0.431	0.431	0.430	0.431	0.431
Observations	1996338	1996338	1996338	1962166	1995994	1975656

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in columns (1) to (6). The interaction term of interest is ' $\ln\left(\frac{\text{Amount}}{\text{Funding years}}\right) \times$ FFATA'. The variable ' $\ln\left(\frac{\text{Amount}}{\text{Funding years}}\right)$' takes the value of the funding share per year if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

6 Conclusion

In this paper I investigate the effect of increasing transparency due to disclosure of additional information on subsequent innovation. To identify the exposure to the additional information requirement, I make use of two legislation introduced in the United States. First, the Bayh-Dole Act of 1980 and second, the Federal Funding Accountability and Transparency Act in 2006. While the first allows me to identify government funded patents, the second led to an increase in transparency due to a better availability and accessibility of information. To test for the effect of this enhanced information transmission, I compare the degree of follow-on innovation building on government funded patents after 2007 to not government funded patents.

I show that increasing transparency due to access to additional information indeed affects the degree of subsequent innovation positively. The average effect could be attributed to a combination of attention for government patents and enhanced information transmission. I show in subsequent tests, that the effect is relatively stable over time and is also found for the likelihood that any follow-on innovation builds on the government funded patent. To determine whether the effect could actually be attributed to the enhanced information transmission, I perform an additional test. For this purpose, I distinguish all government patents in those for which the information can be found on the website and those for which not. The results imply that the increase in follow-on innovation is significantly larger for patents with actually better accessible information. This leads to the conclusion that the increase in innovation building on government funded patents could indeed be attributed to better information transmission and a reduction in search costs.

Considering the heterogeneity of the federally funded patents shows that project characteristics play an important role. On the one hand, I show that patents stemming from procurement contracts benefit particularly. Although this is the case, a positive, but lower effect is also observed for patents funded by grants. For the actual funding

amount, I find that higher funding corresponds to a higher follow-on innovation count after the FFATA. However, additional estimates show that the effect has the shape of an inverted-U. This implies that patents with a medium level of funding benefit particularly.

The results in this paper have important implications for firms and policy makers. First, government funding provides a valuable tool to fix market failures when it comes to innovation. The increasing degree of subsequent innovation due to enhanced transparency implies that providing additional information is helpful to even better fulfill this role. The positive welfare effects are underlined by the increase in subsequent innovation, which points to a spillover effect due to the additional information. Thus, disclosure requirements serve an important role to foster peer firm incentives to innovate, but could be detrimental for firms that have to disclose information (e.g., Fu et al. 2020). This underlines that further support should be provided to increase the transmission of knowledge from basic research to the application sector (e.g., Fleming et al. 2019). An additional finding that patents funded by a medium level of funding benefit particularly is in line with the theoretical finding of Lach et al. (2021). Thus, this paper shows that providing additional information is one important mechanism to increase the dissemination of patented knowledge from this kind of funded projects.

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Appendix - Additional figures

A Bayh-Dole Act of 1980

Figure A1: Government interest statement of patent 9,146,104

JELLYFISH-INSPIRED TILT SENSOR AND ARTIFICIAL MESOGLEA

STATEMENT OF GOVERNMENT INTEREST

This invention was made with government support under Contract No. N00014-08-1-0654 awarded by Office of Naval Research. The government has certain rights in the invention.

B FFATA of 2006

Figure B1: Snippet of the FFATA of 2006

(1) WEBSITE.—Not later than January 1, 2008, the Office of Management and Budget shall, in accordance with this section, section 204 of the E-Government Act of 2002 (Public Law 107–347; 44 U.S.C. 3501 note), and the Office of Federal Procurement Policy Act (41 U.S.C. 403 et seq.), ensure the existence and operation of a single searchable website, accessible by the public at no cost to access, that includes for each Federal award—

(A) the name of the entity receiving the award;

(B) the amount of the award;

(C) information on the award including transaction type, funding agency, the North American Industry Classification System code or Catalog of Federal Domestic Assistance number (where applicable), program source, and an award title descriptive of the purpose of each funding action;

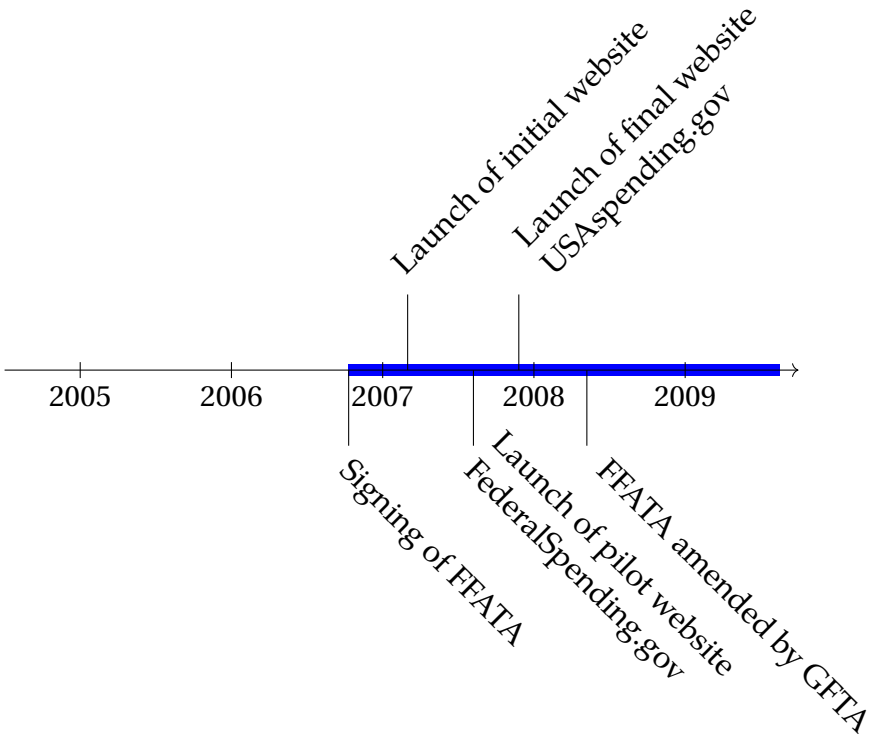
(D) the location of the entity receiving the award and the primary location of performance under the award, including the city, State, congressional district, and country;

(E) a unique identifier of the entity receiving the award and of the parent entity of the recipient, should the entity be owned by another entity; and

(F) any other relevant information specified by the Office of Management and Budget.

C FFATA timeline

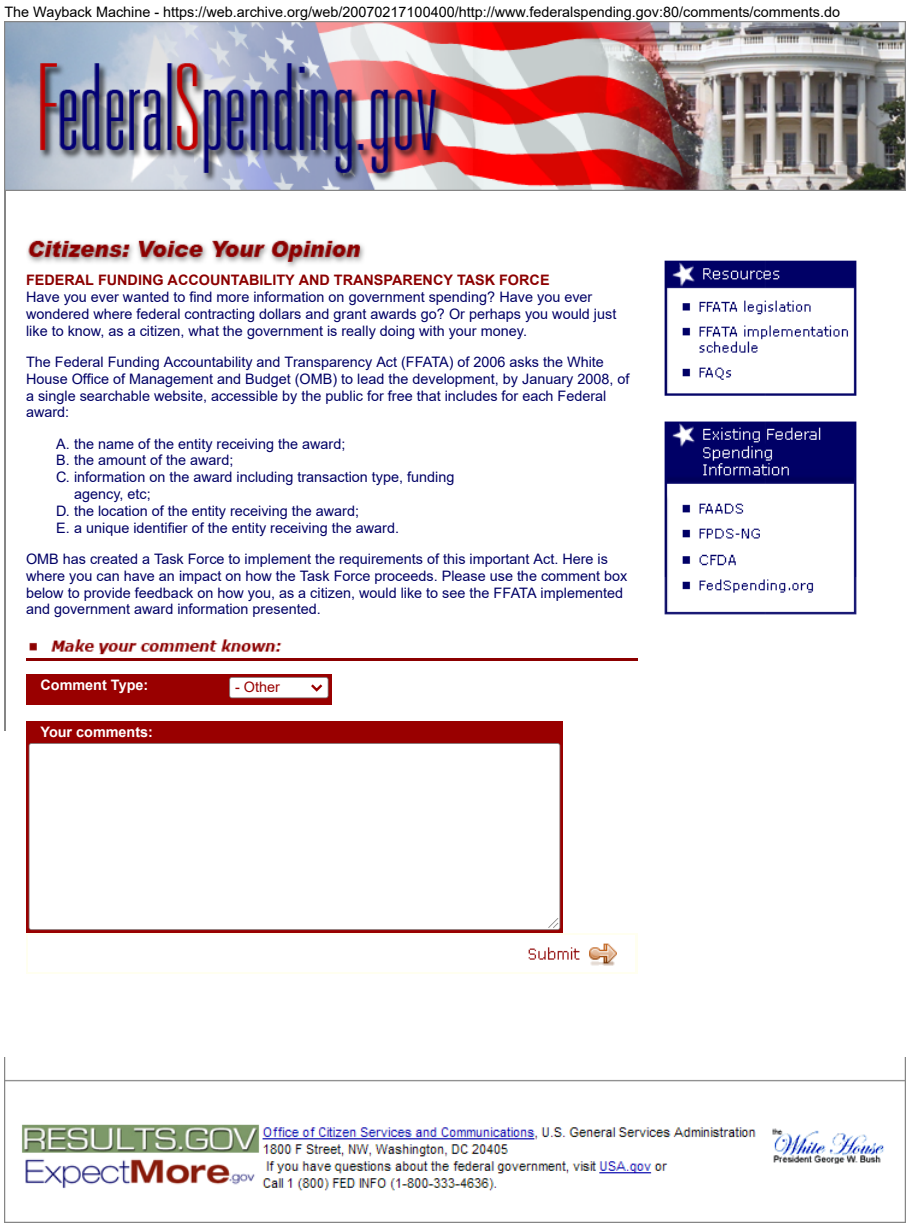
Figure C1: Timeline of the FFATA and the required website



Notes: The figure shows the timeline of the FFATA. The abbreviation GFTA stands for the Government Funding Transparency Act of 2008.

D FederalSpending.gov website

Figure D1: FederalSpending.gov website



Notes: The figure shows a screenshot from the FederalSpending.gov website. The screenshot is obtained from the version archived in The Wayback Machine on February 17, 2007 `https://web.archive.org/web/20070217100400/http://www.federalspending.gov/comments/comments.do`.

E USAspending.gov website

Figure E1: USAspending.gov website

The Wayback Machine - https://web.archive.org/web/20071215152751/http://www.usaspending.gov:80/index.php

About this Site | About the Data | Site Map | Contact Us

USAspending.gov

HOME | CONTRACTS | ASSISTANCE | DATA QUALITY | PROVIDE FEEDBACK

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- Home
- Frequently Asked Questions
- Glossary
- API Documentation

Welcome to USASpending.gov, Where Americans Can See Where Their Money Goes

Have you ever wanted to find more information on government spending? Have you ever wondered where federal contracting dollars and grant awards go? Or perhaps you would just like to know, as a citizen, what the government is really doing with your money. The Federal Funding Accountability and Transparency Act of 2006 (Transparency Act) requires a single searchable website, accessible by the public for free that includes for each Federal award:

1. The name of the entity receiving the award;
2. The amount of the award;
3. Information on the award including transaction type, funding agency, etc;
4. The location of the entity receiving the award;
5. A unique identifier of the entity receiving the award.

Welcome to www.USAspending.gov, a relaunch of www.FederalSpending.gov, that provides citizens with easy access to government contract, grant and other award data.

To begin searching, select either the Assistance or Contracts tab at the top left side of this page. You can easily switch back and forth as you search.

This shows you where your money goes, and provides a summary of federal spending:
Contracts and Other Spending in Billions of Dollars

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
Contracts	$208.8	$219.8	$262.3	$304.1	$342.8	$385.4	$415.0	$146.7
Grants	$294.5	$330.7	$406.2	$493.3	$449.6	$441.0	$488.5	$290.4
Loans	$108.0	$141.8	$216.8	$210.8	$154.8	$118.8	$95.4	
Insurance	$431.3	$492.2	$556.6	$567.2	$603.9	$653.2	$771.3	
Direct Payments (e.g. Social Security)	$768.3	$839.6	$841.5	$947.9	$965.5	$1,004.1	$1,092.7	$15.3
Other	$2.8	$2.7	$0.2	$0.7	$0.4	$0.3	$3.8	
Total	$1,813.7	$2,026.9	$2,283.6	$2,524.0	$2,516.9	$2,602.7	$2,866.7	$452.4

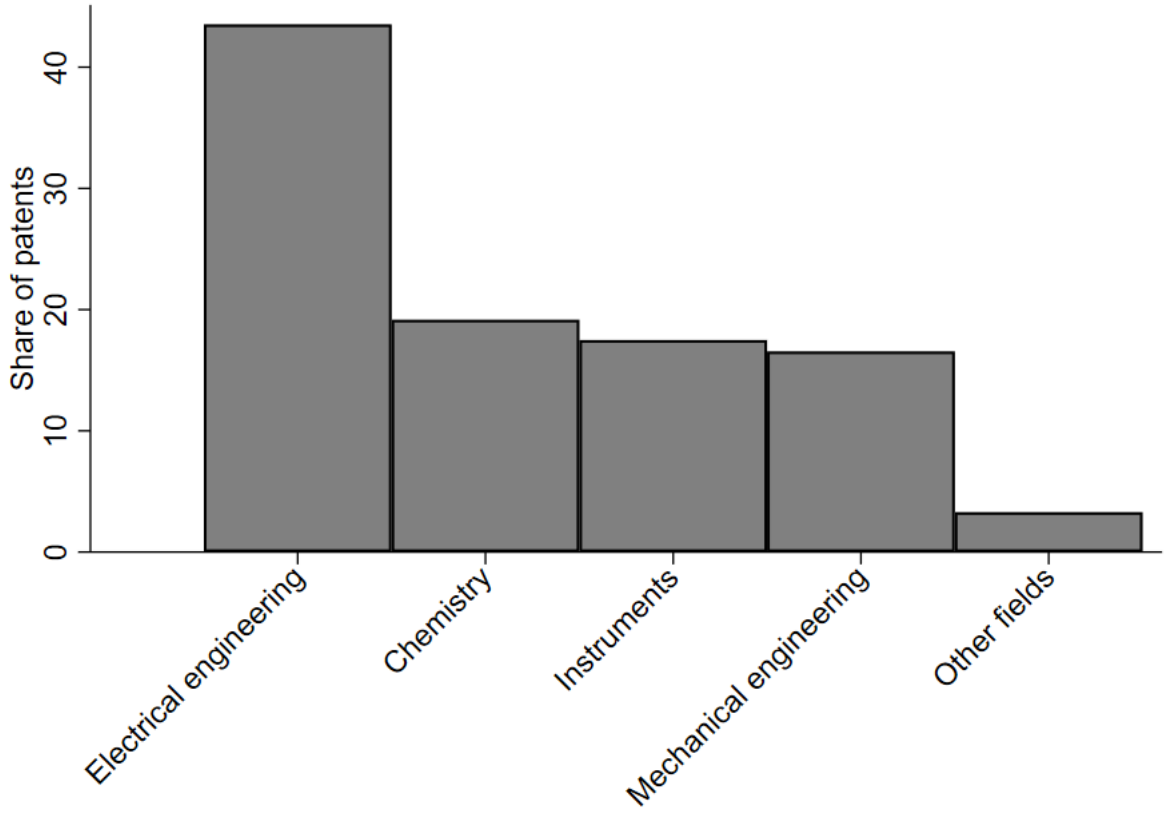
WARNING: This is a United States Federal Government computer system that is "FOR OFFICIAL USE ONLY." This system is subject to monitoring. Therefore, no expectation of privacy is to be assumed. Individuals found performing unauthorized activities are subject to disciplinary action including criminal prosecution. Click here for more information.

Notes: The figure shows a screenshot from the USAspending.gov website. The screenshot is obtained from the version archived in The Wayback Machine on December 15, 2007. `https://web.archive.org/web/20071215152751/http://www.usaspending.gov:80/index.php`

Appendix - Descriptive statistics

F Descriptive statistics

Figure F1: Technology classes



Notes: The figure shows the share of patents in the International Patent Classification section indicated on the x-Axis of the chart.

Table F1: Additional descriptive statistics for applied variables

	Mean	SD	P10	P25	P50	P75	P90	Count
Government funded patent	0.028	0.165	0	0	0	0	0	5135733
Baseline citation measures								
Number of citations	0.515	2.093	0	0	0	0	1	5135733
Any citation	0.245	0.430	0	0	0	0	1	5135733
Funding related variables								
Total funding in million	32.098	795.873	0	0	0	0	0	5070140
Procurement funding in million	31.967	795.847	0	0	0	0	0	5070365
Grant funding in million	0.137	4.579	0	0	0	0	0	5070075
Procurement contract	0.006	0.078	0	0	0	0	0	5021924
Grants	0.010	0.099	0	0	0	0	0	5041403
Procurement contract (Government interest)	0.012	0.108	0	0	0	0	0	5050563
Grant (Government interest)	0.012	0.110	0	0	0	0	0	5052863
Total funding in million	2083.491	6069.715	0.264	0.946	4.592	79.503	5810	78110
Procurement funding in million	2069.121	6064.775	0	0	0	11.971	5810	78335
Grant funding in million	8.875	35.837	0	0	0.476	4.095	16.750	78045
Share of procurement contracts	0.384	0.486	0	0	0	1	1	78512
Number of contracts	1.057	0.282	1	1	1	1	1	30660
Number of grants	1.372	0.755	1	1	1	2	2	50364
Patent characteristics								
Basicness	0.146	0.231	0	0	0	0.200	0.500	5135733
Originality	0.343	0.269	0	0	0.375	0.563	0.693	4972006

Note: The table shows the descriptive statistics for the variables used in the analysis.

Appendix - Results of robustness tests

G Individual application year effects

Table G1: Single application year effects from 2002 to 2004

	(1)	(2)	(3)	(4)
		log(Citations + 1)		
	2002-2004	2002	2003	2004
Government × FFATA	0.052***	0.056***	0.059***	0.045***
	(0.004)	(0.007)	(0.007)	(0.006)
R-squared	0.443	0.437	0.449	0.457
Observations	3844293	1297800	1268037	1278456

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in columns (1) to (4). The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

H Extended sample of treatment and control patents

Table H1: Full raw application cohorts 2002 to 2004

	(1)	(2)	(3)	(4)
		log(Citations + 1)		
	2002-2004	2002	2003	2004
Government × FFATA	0.060***	0.058***	0.061***	0.052***
	(0.004)	(0.006)	(0.006)	(0.006)
R-squared	0.510	0.521	0.509	0.500
Observations	5505533	2101130	1803132	1599944

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in columns (1) to (4). The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

Table H2: Full sample for application cohorts 2000-2005

	(1) log(Citations + 1)	(2) log(Citations>0)	(3) P(Citations>0)
Panel A: Unweighted sample			
Government × FFATA	0.054***	0.051***	0.040***
	(0.003)	(0.005)	(0.002)
R-squared	0.519	0.557	0.369
Observations	11620607	3724393	11620607
Panel B: Weighted sample			
Government × FFATA	0.038***	0.032***	0.028***
	(0.003)	(0.005)	(0.002)
R-squared	0.442	0.474	0.357
Observations	7637653	1662823	7637653

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in column (1). In column (2) the intensive margin of citations is determined by taking the logarithm of the non-zero values of patent citations. The dependent variable in column (3) is an indicator variable taking unit value if the patent under consideration was cited by any patent in a given year and zero else. The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

I Composition of treatment and control patents

Table I1: Composition of treatment and control patents

	(1) log(Citations + 1)	(2) log(Citations>0)	(3) P(Citations>0)
Panel A: Single control patent			
Government × FFATA	0.054***	0.059***	0.040***
	(0.005)	(0.009)	(0.004)
R-squared	0.450	0.492	0.372
Observations	216108	56625	216108
Panel B: Similar matched control patents			
Government × FFATA	0.046***	0.075***	0.023***
	(0.011)	(0.020)	(0.009)
R-squared	0.460	0.490	0.385
Observations	121399	33857	121399
Panel C: Using firm patents only			
Government × FFATA	0.054***	0.049***	0.042***
	(0.004)	(0.008)	(0.003)
R-squared	0.475	0.523	0.379
Observations	3460928	712951	3460928
Panel D: Using the patent value as additional matching variable			
Government × FFATA	0.065***	0.070***	0.048***
	(0.010)	(0.018)	(0.008)
R-squared	0.436	0.518	0.342
Observations	1141683	232949	1141683

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in column (1). In column (2) the intensive margin of citations is determined by taking the logarithm of the non-zero values of patent citations. The dependent variable in column (3) is an indicator variable taking unit value if the patent under consideration was cited by any patent in a given year and zero else. The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.

J Origin of citations

Table J1: Origin of citations

	(1)	(2)
	log(Citations + 1)	
Panel A: Examiner or applicant		
	Examiner	Any applicant
Government × FFATA	0.008***	0.049***
	(0.002)	(0.004)
R-squared	0.283	0.439
Observations	3844293	3844035
Panel B: Assignee or other assignee		
	Same assignee	Other assignee
Government × FFATA	0.015***	0.042***
	(0.002)	(0.004)
R-squared	0.357	0.438
Observations	3844293	3844293
Panel C: Funding type		
	Government	Non-government
Government × FFATA	0.035***	0.031***
	(0.002)	(0.004)
R-squared	0.277	0.439
Observations	3844293	3844263

Notes: The table shows the results of linear fixed effects estimations of equation (1) for the matched sample of government funded and non-government funded patents. The primary outcome variable is 'log(Citations + 1)' – the logarithm of patent citations plus one – in columns (1) and (2). The origin of citations is indicated in the column heading. The interaction term of interest is 'Government × FFATA'. The variable 'Government' takes unit value if the patent is federally funded and zero else. The indicator 'FFATA' has the value one for the years after 2006 and takes value zero else. Each regression includes technology section-class times year fixed effects. Standard errors clustered at the patent level are shown in parentheses. Significance: *, **, *** significant at the 10%, 5%, 1% level.