Information Transparency in Drug Development: Evidence from Mandatory Disclosure of Clinical Trials

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Abstract

Using Section 801 of the Food and Drug Administration Amendments Act of 2007 (FDAAA) that requires drug developers to disclose clinical trial plans and results publicly, we provide novel evidence for the effect of information transparency on drug development. We find significantly more suspensions in industry-sponsored clinical trials after the FDAAA, which has a causal interpretation based on a difference-in-differences analysis that compares the suspension rates of industry-sponsored and academic clinical trials before and after the FDAAA. Further evidence supports peer learning as a mechanism that helps explain increased suspension decisions after the FDAAA. Finally, we analyze the social welfare implications of increased information transparency; while the FDAAA helps improve drug quality, it leads to more suspensions of potential new drugs that could have reduced mortality and morbidity.

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1. Introduction

The disclosure of a firm's progress with respect to innovative activities is often detrimental to its value due to potential imitation and subsequent learning that its competitors obtain (Arrow, 1972; Horstmann et al., 1985; Levin et al., 1987; Cohen et al., 2000; Anton and Yao, 2004). However, governments may promote and adopt policies (e.g., patent systems) to incentivize and mandate the disclosure of innovation for social welfare due to the public-good nature of innovation.[1] On the other hand, when firms must disclose their innovative activities, they reduce their investment due to the loss of proprietary knowledge and rents (Scotchmer and Green, 1990; Anton and Yao, 1994).[2] Although the patent system has been well studied in terms of its consequences with respect to disclosure effects (e.g., Williams, 2017), little is known about the impact of mandatory disclosure of new drugs' clinical trial outcomes (both successful and unsuccessful), which is what we aim to examine in this study.

The development of new drugs is one of the most costly innovative activities in many dimensions: it involves significant research investment, long hours of laboratory experiments, a large number of animal lives, and many human subjects. Thus, pharmaceutical firms have strong incentives to not publicly disclose information related to clinical trials of new drugs. In the past, these firms only needed to file their clinical trial plans and data to the U.S. Food and Drug Administration (FDA) for regulation and approval. Nevertheless, the development of new drugs greatly serves the public's interest. Hence, timely and accurate information about the outcomes of clinical trials is important for researchers, patients, and the public, for this information facilitates scientific knowledge accumulation, fosters scientific discovery processes, and advocates patient rights, all of which seek to enhance public health (Lehman and Loder, 2012).

Public interest has imposed great pressure on the government and administrative bureaus (FDA and NIH) regarding information disclosure. Patient advocacy groups had long lobbied for access to up-to-date information about potentially life-saving therapies (Gill, 2012). In addition, industry associations and

[1] The patent system exemplifies such an intervention by encouraging individuals or organizations to share their inventions with the public in exchange for exclusive usage rights of their inventions for a certain period (e.g., Judd, 1985; Arora, 1995; Arora et al., 1998; Merges, 2005; Hellmann, 2007; Elfenbein, 2007). Prior studies have documented the social welfare implications by examining the effects of patent disclosure on knowledge diffusion and innovations (e.g., Aoki and Spiegel, 1998; Johnson and Popp, 2001; Budish et al., 2015; Galasso and Schankerman, 2015; Graham and Hegde, 2015; Hedge and Luo, 2017). In addition, the patent system mitigates overlapping R&D efforts that are costly to society (Kamien and Schwartz, 1975; Stephan, 1996).

[2] The literature has highlighted the necessity and associated costs for entrepreneurs when they disclose their innovations to raise external funding and to mitigate information asymmetries (Leland and Pyle, 1977; Bhattacharya and Ritter, 1983, Ferreira et al., 2014). On the other hand, some studies discuss firms' voluntary disclosure of their patenting activities for strategic reasons (Anton and Yao, 2004; Guo et al., 2004; Gill, 2008; James, 2011).

international policies all urge more disclosure of clinical trials (Tse and Zarin, 2009; Zarin et al., 2016; Lassman et al., 2017). As a response to these requests, Congress passed and enacted the Food and Drug Administration Amendments Act (FDAAA) in 2007, in which Section 801 heightened information disclosure requirements with respect to new drug development (we offer more detail in Section 2). This Act basically mandates the disclosure of clinical trials of industry-sponsored new drugs, and the literature confirms substantially enhanced disclosure afterward (Gill, 2012; dos Santos and Atallah, 2015).

To empirically investigate the effect of the FDAAA, we use the BioMedTracker (BMT) database that covers a broad scope of drug projects (i.e., clinical trials) based on multiple sources of information (e.g., ClinicalTrial.gov, press releases, company websites, earning conference calls), especially expert industry analysts who closely monitor companies, clinical trials, deals, and regulatory meetings, to capture and report on the most critical events. In particular, we focus on industry-sponsored clinical trials for new drugs ("projects") that were initiated between 2002 and 2012 as a ten-year event window around the FDAAA in 2007.

We first examine if such mandatory disclosure leads to lower investment by drug developers, as predicted in the prior economics literature. We use the suspension of a new drug to proxy for *divestment*. We find that the project suspension likelihood increases by 4.7% to 17.3% following the enactment of the FDAAA, after we control for many other factors, including the indicator of projects with partners, the number of projects, project diversification, the percentage of matured projects, the percentage of projects with partners, the number of competitors, the industry average failure rate, the percentage of industry matured projects, as well as fixed effects for firms, clinical trial phases, and project indications (i.e., the target disease, illness, or symptom to be treated).

To strengthen a causal interpretation of such an increase in suspension likelihood, we design a difference-in-differences approach with an extended sample that additionally includes academic-sponsored projects. We introduce the joint editorial of the International Committee of Medical Journal Editors (ICMJE) in September 2004, which is a new policy published by several important medical journals that requires submitters to register their projects in any comprehensive, publicly available database before their submissions (De Angelis et al., 2004, 2005). Given university professors' incentive to publish papers, we expect that academic projects have higher incentives to register clinical trials before the FDAAA and can thus work as a control group. Indeed, we find that the post-FDAAA change in suspension likelihood mainly exists for industry-sponsored projects but not academic ones. Our

difference-in-differences result, then, alleviates a concern that our results may be driven by any commingled factor unrelated to the increased information transparency around the FDAAA.

We argue that the post-FDAAA investment reduction, as reflected in higher suspension rates, can be attributed to two mechanisms that may co-exist: learning and competition (see Reinganum, 1984). First, pharmaceutical firms can learn from their peers' public disclosures about the nature of their own clinical trials and update their information sets regarding for the viability and prospect of their own trials. With more frequent information updates, it will be also more likely to suspend a project that is not promising (Fudenberg, Gilbert, Stiglitz, and Tirole, 1983; Harris and Vickers, 1985; Cockburn and Henderson, 1994). Second, when pharmaceutical firms compete to develop new drugs for the same disease, the first new drug to be approved may enjoy market advantages and preempt others, which reduce laggard firms' expected profits and increase their incentives to suspend their related projects (Scherer, 1967; Loury 1979; Dasgupta and Stiglitz, 1980a, 1980b).

Further analyses support the peer learning mechanism: the suspension decision of low-quality firms and the firms without partners is more strongly dependent on peers' failures after the FDAAA. These results conform with information spillovers from peer firms, which allow firms to learn from peers' experience, especially in terms of fundamental difficulties and complications that cause peers' failures. On the other hand, we do not find strong supportive evidence for the competition mechanism: the post-FDAAA increase in suspension is also significant for drugs in a low competition environment.

We also examine the effects of financial constraints and reputational concerns on suspension decisions after the FDAAA. We compare firms that are more vs. less financially constrained for the financial constraint effect, and also compare private vs. public firms for reputation concerns. We predict and find supportive evidence that financially constrained firms are more likely to suspend projects due to scarce resources. Compared to private firms, public firms have higher reputation concerns because they are under greater media coverage and investor monitoring. Thus, public firms' failures or suspensions in new drug development may hurt firm value to a greater extent. However, we find a similar magnitude of the FDAAA effect on suspension between private and public firms; this finding does not support heterogeneous reputation concerns.

In our last set of empirical tests, we attempt to quantify the social welfare implications of the FDAAA. First, we find that the frequency of adverse event reports of clinical trials in which the drug is reported as

a primary suspect significantly reduces by about 50% after the enactment of the FDAAA.[3] Second, the likelihood of clinical trials in delivering serious adverse events in which the drug is reported as a primary suspect decreases by 5% to 10% after the enactment of the FDAAA. These results are consistent with the interpretation that pharmaceutical firms are more likely to suspend high risk projects due to their increased efficiency in making suspension decisions with enhanced information disclosure.

Nevertheless, there are also downsides associated with the FDAAA. The enhanced information disclosure reduces the expected NPV of some future new drug projects, which prevents pharmaceutical firms from initiating such projects. Also, higher transparency in information about on-going new drug development may motivate pharmaceutical companies to give up some projects too early, even though some may be revised and improved with more time and effort.[4] For example, the annual growth rate of active projects is approximately 25% before the FDAAA but becomes negative after the FDAAA. To examine this social welfare implication, we compare Disability-Adjusted Life Years (DALYs) from World Health Organization (WHO) between the two indication groups that experience high and low growth in the number of clinical trials before and after the FDAAA. We find that if the low-growth group receives the same effort as the high-growth group does, then the DALY of the low-growth group may also drop by the same magnitude (8.27%), which is 7.6 million years.[5] These possible drawbacks call for further analysis of the optimal degree of information disclosure with respect to new drug development.[6]

Overall, our investigation highlights the intended and unintended consequences of the FDAAA, which are relevant for pharmaceutical firms, policy makers, and the general public. We first show that more industry-sponsored projects are registered in ClinicalTrials.gov after the Act, which effectively enhances information disclosure. We then find increased project suspensions after the Act, which is novel to the literature; more importantly, such reduction in new drug development can be attributed to firms' learning from their peers' trial results. We also quantify the social welfare implications from the enhanced transparency of clinical trial outcomes: the FDAAA enhances the safety of new drugs as reflected in the

[3] The frequency of adverse event reports is defined as the total number of reports in the Adverse Event Reporting System (AERS) that are designed to monitor drug safety for all approved drug and biologic products.
[4] It is common in the literature that individual firms' profit-maximizing decisions may not be socially optimal. Underinvestment in R&D is a prominent example (Hall and Lerner, 2010).
[5] The potential decline in DALY is estimated at 7.6 million years based on the mean DALY for the low-growth group of 91.9 million years.
[6] Prior studies have examined the optimal design for patent protection (see e.g., Gilbert and Shapiro (1990), Matutes et al. (1996), Goh and Oliver (2002), and Hall (2007)).

reduced frequency and likelihood of adverse event reports after the Act. Nevertheless, the FDAAA also incentivizes pharmaceutical firms to discontinue new projects more often.[7]

More broadly, our study provides new evidence for the effect of information disclosure on innovation competition, which has lacked empirical evidence in the past (Williams, 2017) and has been challenging to capture due to endogeneity issues (Williams, 2013; Hegde and Luo, 2017; Kim, 2019). The enactment of the FDAAA mandates information disclosure of pharmaceutical firms and is found to have a negative effect on firms' investment as measured by the continuation of new projects; these findings are consistent with the model implications of Scotchmer and Green (1990) and Anton and Yao (1994). Our data of clinical trials that contain detailed indication information also allow us to analyse how a firm's peers learn from its disclosure of clinical trials, which adds to recent studies on pharmaceutical firms' reactions to public disclosures on R&D and product details (Krieger, 2017; Krieger et al. 2018).[8]

2. Institutional Background

The Food and Drug Administration Modernization Act (FDAMA, Section 113) that was passed and enacted in 1997 established the ClinicalTrials.gov database,[9] a website that provides patients, their family members, health care professionals, researchers, and the public with easy access to information on publicly and privately supported clinical studies on a wide range of diseases and conditions.[10] The website established the protocols of the records of clinical trials in order to disclose design, methods, objectives, relevant scientific background, and statistical information and is maintained by the National Library of Medicine (NLM) at the National Institutes of Health (NIH). FDAMA Section 113 requires summary information about all publicly- and privately-funded clinical trials of investigational new drugs (and

[7] This result shows that the FDAAA might have unintended consequences of the FDAAA and ought to draw attention from policy makers. A few recent studies examine the consequences of additional disclosure from the FDAAA but focus on an individual firm's information environment, such as reduced information asymmetry (Bourveau et al., 2017) and increased forecast accuracy (Hao et al., 2017). However, none of them examines the consequences on aggregate innovative activities following increased information transparency and social welfare implications.

[8] Prior studies have shown how firms learn from their industry rivals' successes and failures (Madsen and Desai, 2010; Baum and Dahlin, 2007; Kim and Miner, 2007; Ingram and Baum 1997, Haunschild and Sullivan, 2002; Magazzini et al., 2012; Garzon-Vico, 2012). More recently, Bustamante and Fresard (2017) show that firms in imperfect information environments use their peers' investments to update their own estimations about their fundamentals. Prior studies in general show that information disclosure in competitive environments have positive effects on subsequent innovation (Henderson and Cockburn, 1994; Ederer, 2013; Bloom et al., 2013; Boudreau and Lakhani, 2015). However, there are also studies showing negative effects on subsequent innovation: (i) disclosure in technological advance deter R&D competition as rivals are less likely to develop and patent competing innovations (James, 2011); (ii) firms overreact to news about competition and technological failure with an increase in project exit rates (Krieger, 2017); and (iii) negative shocks to a competitor's drug lead competing firms to move resources away from affected areas and into more exploratory projects (Krieger et al., 2018).

[9] The history and evolution of the ClinicalTrials.gov database: https://clinicaltrials.gov/ct2/about-site/history

[10] https://clinicaltrials.gov/ct2/about-site/background

biological products) for serious or life-threatening diseases and conditions (Tse and Zarin, 2009). Voluntary reports from uncovered trials are also accepted.

The most significant change to the disclosure of drug development is Section 801 of FDAAA (FDAAA 801), which was passed and enacted in 2007 (Tse et al., 2009; Tse and Zarin, 2009).[11] This act can be regarded as an advancement in information disclosure, following FDAMA, the International Committee of Medical Journal Editors (ICMJE) joint editorial, the Joint Position on the Disclosure of Clinical Trial Information issued by four pharmaceutical industry associations worldwide, and other relevant U.S. and international policies (Tse and Zarin, 2009; Zarin et al., 2016; Lassman et al., 2017). It responds to the call from patient advocacy groups, which have lobbied to help patients gain access to up-to-date information about possible life-saving therapies and addresses the loss of the public's trust in medical literature due to publication bias (Gill, 2012; dos Santos and Atallah, 2015).

The Act amends the Public Health Service (PHS) Act to require the FDA (i) to mandate the expanded scope and additional information of an "applicable clinical trial" (ACT) to be registered in the ClinicalTrials.gov database within 21 days of enrolling the first patient;[12] in addition, the summary results are required to be filed within a year of a clinical trial's completion date,[13] (ii) to make the database publicly available through the Internet, and (iii) to establish civil penalties for failure to submit required clinical trial information or for the submission of false or misleading clinical trial information to the

[11] https://www.congress.gov/bill/110th-congress/house-bill/3580 Title VIII: Clinical Trials Databases - (Sec. 801) Amends the Public Health Service (PHS) Act to require the Secretary, acting through the Director of NIH, to expand the clinical trials registry data bank. 1. Requires the Director to ensure that the data bank is made publicly available through the Internet. Specifies information required to be submitted for an applicable clinical trial and included in the data bank. 2. Requires the Secretary to ensure that the data bank includes links to results information for those clinical trials that form the primary basis of an efficacy claim or are conducted after the drug or device involved is approved or cleared. 3. Requires the Secretary to further expand the registry and results data bank to provide more complete results information and enhance patient access to and understanding of the results of clinical trials within three years after enactment of this Act. 4. Prohibits the failure to submit required clinical trial information or the submission of false or misleading clinical trial information to the data bank. Sets forth civil penalties for violations. 5. Prohibits a state or political subdivision from establishing or continuing in effect any requirement for the registration of clinical trials or for the inclusion of information relating to the results of clinical trials in a database after the required expansion of the data bank three years after enactment of this Act.

[12] https://clinicaltrials.gov/ct2/manage-recs/fdaaa#WhichTrialsMustBeRegistered Registration is required for studies that meet the definition of an "applicable clinical trial" (ACT) and either were initiated after September 27, 2007, or initiated on or before that date and were still ongoing as of December 26, 2007. ACTs, as defined in section 402(j) of the PHS Act, include (i) controlled clinical investigations (other than phase 1 investigations) of any FDA-regulated drug or biological product for any disease or condition, and (ii) certain studies of FDA-regulated medical devices, excluding small clinical trials to determine feasibility and certain clinical trials to test prototype devices, but including FDA-required pediatric postmarket surveillances of a device product. For more details definition of applicable clinical trials, see: https://prsinfo.clinicaltrials.gov/ElaborationsOnDefinitions.pdf

[13] http://www.atlantclinical.com/compliance-with-fdaaa801 The completion date is the date of the last clinical trial visit of the last patient enrolled in the clinical trial. This deadline, however, can be extended up to 2 years under certain circumstances related to the market's approval of novel products. A certification to delay submission or an extension request must be provided.

database (Tse et al., 2009; Tse and Zarin, 2009). The Act requires sponsors, sponsor-investigators, or sponsor-designated principal investigators of clinical trials to submit information about a clinical study to ClinicalTrials.gov and update that information accordingly. The penalties for noncompliance include the withholding of NIH grant funding and civil monetary penalties of up to $10,000.

Overall, the literature suggests that the FDAAA significantly enhanced the information disclosure of clinical trials. Using a sample of 243 clinical trials of specific biological products, dos Santos and Atallah (2015) find that the rate of ClinicalTrials.gov registration increases from 13.6% before the Act to 70.2% for trials subject to the mandatory reporting under the FDAAA (and 35.6% of trials that are not subject to the FDAAA).[14] Gill (2012) confirms a substantial increase in the number of registered trials in the ClinicalTrials.gov since 2007. On the other hand, some studies suggested that the coverage of the database may not be updated in a timely manner; however, such a criticism is denied by the FDA (Hawkes, 2012; Lassman et al., 2017).[15] All these studies collectively indicate a substantial albeit imperfect coverage of the results of industry-sponsored clinical trials after the enactment of the FDAAA. In fact, all the discussions (including criticisms) on the efficacy and consequence of the FDAAA suggest that the Act and its impact on information disclosure were well-perceived and widely discussed among participants; such attention to and awareness of regulation changes naturally increase the pressure to prepare for mandatory disclosures or those that may be mandatory in the future.

The FDAAA was refined in 2016 with the issuance of 42 CFR Part 11 for Clinical Trials Registration and Results Information Submission (i.e., the "Final Rule"), which took effect in January 2017.[16] The Final Rule aims to clarify the requirements for the regulated parties, interpret ambiguous important

[14] On the other hand, the fact that the registration rate of industry-sponsored trials is not close to 100% can be attributed to several reasons (Miller et al., 2012; Lassman et al., 2017): first, the collaboration among different institutes and the occurrences of mergers and acquisitions make it difficult for the FDA to hold any party responsible for the registration. Second, the coverage of applicable clinical trials of the FDAAA is not well-defined and some descriptions about the registration obligation and deadlines are ambiguous. Third, the delay penalty has not been imposed.

[15] Using a sample of 317 industry-sponsored trials that were completed in 2009 and likely subject to the FDAAA 801, Prayle et al. (2012) find that only 126 (40%) of these had submitted their results to ClinicalTrials.gov on time (i.e., within the one-year period from the completion date). However, the FDA has disagreed with the results reported by Prayle et al. (2012) and pointed out methodological flaws in that study (e.g., including trials not covered by FDAAA, only tracking the on-time registrations) (Hawkes, 2012). In responding to this dispute, the U.S. National Institutes of Health (NIH) implemented an unofficial analysis and reported that 52% of industry-sponsored trials had filed results on time. In addition, Nguyen et al. (2013) examine a sample of 646 cancer-related trials and find that 31% of them posted results in ClinicalTrials.gov within three years after the completion date. Anderson et al. (2015) construct a sample of 8,736 industry-funded trials that are completed after 2008 and are highly likely subject to the FDAAA and find that 41.5% of them reported results at ClinicalTrials.gov by September 2013 (but only 17.0% were reported on-time). Reexamining the data of Miller et al. (2012), Lassman et al., (2017) focus on 15 novel drugs that were sponsored by big firms and were approved in 2012, and they find that almost *all* of them fully complied with the FDAAA.

[16] For details, see Zarin et al. (2016).

statutory provisions, and make decisions about additional reporting requirements necessary (Zarin et al., 2016). In sum, FDAAA 801 essentially requires all clinical trials of new drugs that are in Phases 2 to 4 and are under the FDA jurisdiction to be registered on ClinicaTrials.gov within 21 days of enrolling the first patient and also requires summary results (including adverse events) to be reported within a year of clinical trial completion date (Fassbender, 2018).

3. Data and Variable Construction

3.1.Main sample

We use the BioMedTracker (BMT) database to obtain our primary sample. We obtain the suspension variable and other variables related to drug development such as phase advances, partnered projects, and peer projects in the same indication from the BMT database that covers detailed project-level drug development processes, including clinical trials for all publicly and privately held firms in the drug industry sector. The database catalogues drug developments and related events since the 1950s, drawing from sources that include the FDA approval database, company filings with the Securities Exchange Commission (SEC), conference calls, press releases, news articles, medical conferences, direct communication with companies, and the ClinicalTrials.gov database. Thus, our sample includes a greater breadth of drug project-related events than if we had only used ClinicalTrials.gov. The FDA does publish comprehensive information about approved drugs, including the approval date, but it does not provide in-process information for current individual projects that are under development. Unlike the FDA approval database, the BMT contains information on all drug pipelines, including the specific development phase and outcome for each project phase.

Drug development is regulated by the FDA requirements. The process is divided into parts: pre-clinical research on micro-organisms and animals, and clinical trials—which include phases 1, 2, and 3—on humans. During the pre-clinical stage, laboratories pinpoint new compounds and companies perform safety testing for phase 1. An Investigational New Drug (IND) application is then submitted to the FDA; this application details the effects of the active ingredients and toxicities of a drug. After the IND receives approval, the development advances to the three clinical phases involving human subjects.[17] During phase 1, safety and dosing concerns are addressed with healthy volunteers. During phase 2, the drug's

[17] An institutional review board (IRB) has the authority to approve, require modifications in, or disapprove research to provide a core protection of human subjects of research in accordance with FDA regulations. The requirement of an independent committee review for any human subject research was codified as federal regulation in 1974 by the National Research Act.

effectiveness is tested in a relatively small sample of people up to several hundred with a certain disease or condition. During phase 3, large-scale trials are conducted with 300 to 3,000 people to determine the safety and effectiveness of a drug. At the conclusion of phase 3, a New Drug Application (NDA) or Biologic License Application (BLA) is submitted for FDA review and final approval. The FDA reviews all of the data presented with an NDA or BLA and ultimately approves or denies a new drug for the market. We denote all the remaining clinical study phases that include final FDA reviews and approvals as post-phase 3.

A drug's development can be suspended in the middle of clinical trial phases, for various reasons. Firms can voluntarily suspend or terminate their trials at any point, if their results aren't demonstrating their expected effectiveness, for example. Likewise, firms are not allowed to continue to the next trial phase if trial results are not successful. Further, if regulatory agencies believe that a clinical trial is not meeting applicable regulatory requirements or that the trial poses an excessive safety risk to participants—including significant side effects—they can suspend the project. Although suspended trials can be resumed with a new or revised clinical trial design, the data indicate that resumption is not a common event.

For our primary sample, we use FDA project-level clinical trial phase data that have been covered by the BMT during the sample period from 2002 to 2012. In particular, we focus on industry-sponsored clinical trials and exclude the following clinical trials from our sample: (i) clinical trials for generic drugs, which have low uncertainty and follow different FDA requirements than new drug development; (ii) clinical trials that are not sponsored by industry (i.e., academic drugs), which may have different incentives and pressures with respect to disclosure and compliance; (iii) clinical trials in phase 1, which are not subject to the FDAAA; and (iv) drug projects that were initiated after the FDAAA.

Our final sample encompasses 16,925 new industry-sponsored drug project-year observations; this number includes 7,572 clinical trial-years pre-FDAAA and 9,353 clinical trial-years post-FDAAA. We have 638 unique pharmaceutical firms with 3,595 unique drug projects in our sample. The relevant SIC codes for these firms are 2834 and 2836. Previous studies published in medical journals focus on various types of drugs and different operational definitions for "applicable clinical trials" (ACT) of the FDAAA; unlike these studies, we do not additionally restrict our sample by focusing on trials that are likely ACT, because the literature has found the definition of ACT unclear and relies on discretion and conjectures in selecting ACT samples.[18]

[18] This also explains why the NIH and FDA had to announce the "Final Rule" in 2016 to clearly specify the coverage of the FDAAA. For more details, please see Zarin et al. (2016).

Figure 1-(a) shows that the total number of registered clinical trials has been continuously increasing over time. Figure 1-(b) shows that the total number of progress updates (disclosures) continuously increases over time and increases more strongly in more recent years. The average number of progress updates per projects was around 1.2 before the FDAAA and has significantly increased in the more recent period after the FDAAA regulation change.

[Insert Figure 1 Here]

To study social welfare and policy implications, we use data from the FDA Adverse Event Reporting System (AERS). Appendix A shows examples of adverse event reports for a drug and how we classify different reporting cases. The FDA uses the AERS database to support its own post-marketing safety surveillance program for all approved drugs and therapeutic biologic products, monitoring new adverse events and medication errors that might occur with these products. The FDA receives reports about such events from both health care professionals (e.g., physicians, pharmacists, nurses) and consumers (e.g., patients, family members, lawyers). Health care professionals and consumers can also send adverse event reports to manufacturers, who must then forward reports to the FDA, as specified by regulations. Clinical reviewers in the Center for Drug Evaluation and Research (CDER) and the Center for Biologics Evaluation and Research (CBER) then evaluate the reports in AERS to monitor the safety of products after they have been approved by the FDA. If reviewers identify a potential safety concern, the FDA may take regulatory action based on an assessment of the concern, to improve product safety and serve public health interests; such actions might include updating a drug's labelling information, restricting use of the drug, communicating new safety information to the public, or removing a product from the market. Studying information provided by the AERS database, we use the number of adverse event reports (AER) for each marketed drug as a proxy for drug quality. We classify reports as *serious* when the patient outcome is one of the following conditions: death, life-threatening illness, hospitalization, disability, congenital anomaly, or intervention required to prevent permanent impairment and damage. We classify reports as *primary suspect* when the drug is reported as a primary suspect in an adverse case. This information is found in data fields "ROLE_COD" and "OUTC_COD" of the AERS.

To further examine social welfare and policy implications, we use the Disability-Adjusted Life Year (DALY) metric from the WHO Health statistics and information systems. This measure quantifies the Burden of Disease from mortality and morbidity. One DALY can be considered one lost year of "healthy" life. DALYs for a specific disease or health condition are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people

living with the health condition or its consequences. We use two data points—DALYs from 2000 and 2016—for the top 20 leading causes of DALY globally.[19] These two points are the nearest available data to the FDAAA shock. We then compare the two groups of indications with high-growth of active projects and low-growth of active projects following the FDAAA disclosure shock; thus, we can examine how the shock changes the DALYs between the two data points (2000 and 2016).

3.2. Variable construction

Our main dependent variable of interest, *Suspension*, is a proxy for divestment and is defined as an indicator variable that equals one if an announcement of suspension is made for a project (i.e., clinical trial) in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise.[20] The 90th percentile duration is 5 years for phase 2 and 3 projects and 4 years for post-phase 3 projects. In Figure 2, we illustrate the time-series trend of average suspension rates of projects for each phase. The average suspension rate across all projects in each phase for a given year is calculated as the total number of suspensions in the year divided by the total number of projects in the same year. We find in Figure 2 that suspension rates were stable in all phases before the FDAAA and have increased significantly after the FDAAA, especially for the phase 2 projects.

[Insert Figure 2 Here]

Our main independent variable in our regression analyses is *Post*, which is an indicator variable that takes one after the passage of the FDAAA in 2007 and zero otherwise. We are particularly interested in whether the passage of the FDAAA changes information environments and thus affects pharmaceutical firms' innovation activities.

Panel A of Table 1 presents summary statistics of the variables used in our analyses. The sample is from the clinical trial data that have been covered by the BMT from 2002 to 2012. The sample consists of 16,925 new drug project-year observations with our screening procedures discussed previously. *Suspension* (Indicator) has the mean value of 0.13, which means that on average 13% of the clinical trial projects are suspended in the middle of the development process. On average, 54% of all projects in our sample have partners (measured by an indicator variable, *Project with Partner*), and a firm carries 50% of

[19] The DALY estimates are available at https://www.who.int/healthinfo/global_burden_disease/estimates/en/index1.html for 2000, 2010, 2015, and 2016. However, the indication-level DALYs are available only for 2000 and 2016.

[20] For robustness, we also consider *Disclosed Suspension*, an indicator variable that equals one only if a suspension announcement is made for a project in a given year and zero otherwise. We find qualitatively similar results.

its total projects in a given year with partners (measured by a variable, *Percent of Projects with Partner*). The average of *Log(1+Number of Projects)* is 3.22, which is equivalent to 24 projects.[21]

[Insert Table 1 Here]

The following control variables from the BMT are also included in regressions (and their detailed definitions are provided in Appendix B). The diversification index of a firm's project portfolio has a mean of 0.55 (as denoted by *Project Diversification*). Also, 27% of the projects in a firm's pipeline are matured (i.e., post-clinical trial phases) projects (as denoted by *Percent of Matured Projects*). The average total number of both private and public firms with new drug development in each indication group in a given year is 17.73 (*Log (1+Number of Competitors* = 2.93)). *Industry Failure Rate*, the industry average of firm failure rate in a given year, is 8% on average, and *Industry Percent of Industry Matured Projects*, the industry average of the percentage of firms' matured projects in a given year, is 12% on average.

For our analyses that explore possible mechanisms, we consider the measures of peer firm suspensions and advances as well as the measures of competition. *Peer Suspension Rate* is the average suspension rate (i.e., the number of suspensions divided by the total number of projects) of projects in the same indication as a given project in a given year, excluding the own project's suspension rate. *Peer Advance Rate* is the average phase advance rate (i.e., the number of phase advances divided by the total number of projects) of projects in the same indication as a given project in a given year, excluding the own project's advance rate. The average peer suspension and advance rates are both lagged and 9% and 11%, respectively, during our sample period. *High Competition* represents drug projects with higher than the median number of projects in the indication. In addition, 82% of the drug projects in our sample are not designated as FDA-expedited programs (*Non-Expedited Drugs*).

For our analysis of social welfare, we consider the following variables based on adverse event reports (AER). Log of one plus the number of AER Primary Suspect and Serious AER Primary Suspect are 3.83 and 3.34 respectively. These numbers are equivalent to 45 AER and 27 Serious AER with a given drug being a primary suspect. Among approved drugs, 92% have at least one AER with the drugs being a primary suspect, and 88% of them are considered a serious AER.

In Panel B of Table 1, we compare the variables used in our baseline regression analyses between pre- and post-FDAAA periods. The suspension rate is higher for the post-FDAAA period, which indicates that

[21] The mean and median numbers of total projects per firm for a given year are 10.1 and 3, respectively. The numbers in the summary statistics of Table 1 are calculated at the project-year level and are thus greater than the mean and median calculated at the firm-year level. We cluster standard errors by firm later in all our regression analyses.

pharmaceutical firms are more likely to suspend their ongoing projects after the FDAAA regulation change. Firms on average have greater numbers of total projects, fewer diversified pipelines, smaller percentages of matured projects, fewer projects with partners, and greater numbers of competitors in the post-FDAAA period than in the pre-FDAAA period. Industry failure rate has increased from 5% to 12%, which is consistent with the increased suspension rate, while the percentage of industry matured projects has decreased from 14% to 10%.

4. The Effect of Enhanced Disclosure on Drug Development

In the literature, information transparency is often regarded as a first-order concern when a new mandatory disclosure requirement is proposed. However, researchers have yet to conclusively identify the effects of improved transparency on investment decisions. In this section, we explore how increased information transparency for clinical trials alters pharmaceutical firms' drug development decisions.

4.1. Baseline regressions

In Table 2, we present the results from our baseline regressions that examine the effects of increased mandatory disclosures (and ongoing pressure on possible disclosures) through the FDAAA on suspension rates of drug projects. For all columns in Table 2, the dependent variable is *Suspension (Indicator)*, which equals one if the project has been suspended in a given year and zero otherwise.[22] We estimate a linear probability model in Columns 1 and 2 and a probit model in Columns 3 and 4. Our sample consists of 16,897 new drug project-year observations.

[Insert Table 2 Here]

In Columns 1 and 3, we regress the project suspension measure on the dummy variable, *Post*, that indicates the post-FDAAA period starting from 2008 without controlling for any other variable in the regression except multiple fixed effects based on firms, indications, and clinical trial phases.[23] The significant positive coefficient of *Post* implies that the passage of the FDAAA is associated with an increase in the likelihood of project suspension. In Columns 2 and 4, we show that the positive association between the passage of the FDAAA and the project suspension likelihood is robust when we control for characteristics of drug developers and their industries. For the control variables, we consider whether the

[22] When a project is suspended or finally approved by the FDA in year t, it is dropped from our regression sample from year t+1.

[23] It is noteworthy that we cannot include project fixed effects in our models because projects that have never been suspended or have been approved will be dropped from our regression sample.

project has outside partners, the total number of projects for a given firm, the intensity of project diversification, the percentage of matured projects, the percentage of projects that have outside partners for the firm, the number of competitors in the same indication, the industry failure rate, and the percentage of matured projects in the same industry (all defined in Appendix B). The effect of the passage of the FDAAA on project suspension is economically significant. Specifically, the passage of the FDAAA appears to increase the likelihood of suspension by 4.7% as estimated from the linear probability model in Column 2.

In Appendix Table A.1, we consider a regression model analogous to Table 2 but using a more stringent definition of project suspension. We replace *Suspension (Indicator)* with *Disclosed Suspension (Indicator)* that equals one only if a suspension announcement is made for a project in a given year and zero otherwise. Our results are robust to this replacement. This alleviates a concern that the increased suspension rates after the FDAAA can be driven by the increased duration between progress updates.

4.2. Difference-in-differences regressions: Industry vs. academic projects

Next, we extend our baseline regressions in Table 2 and compare the effect of the FDAAA on suspension rates between industry-sponsored vs. academic projects using a difference-in-differences (DID) approach in Table 3. We argue that the clinical trials of academic projects have been disclosed to the public before the FDAAA due to the joint editorial of the International Committee of Medical Journal Editors (ICMJE) issued in September 2004. The new policy of the ICMJE aimed at promoting the disclosure of all clinical trials and explicitly mandates submitters to register their clinical trials beyond phase 1 in one comprehensive and publicly available database before journal submissions. We deliberately focus on the effect of the FDAAA on drug development in 2007 rather than that of the ICMJE joint editorial for two reasons. First, the ICMJE joint editorial may not affect pharmaceutical firms that do not allow or encourage scientists to submit to academic journals. Second, due to the high investments and expected payoffs from successful new drugs, pharmaceutical firms have a much stronger incentive to comply with the FDA and thus bear much higher reputation costs for losing the public's trust.

We limit our sample period from 2004 to 2010 for this analysis, because academic clinical trial data are not from the BMT and only available from ClinicalTrials.gov from 2004, which is the start year of the new policy of the ICMJE. The sample in the DID analysis consists of 12,171 new drug project-year

observations that include 564 and 170 unique industry-sponsored and academic drug developers, respectively.[24]

In Panel A of Table 3, we first report descriptive statistics for the different nature of drug projects by sponsor. The sample is divided into two groups of industry-sponsored and academic projects. *Industry-Sponsored Project (Indicator)* is one if the project is funded by industry sponsors and zero if the project is funded by academic sponsors (e.g., university, public hospital, NIH). On average, industry-sponsored projects appear to suspend more than academic ones (0.10 vs. 0.04) during the sample period (2004 to 2010). In the pre-FDAAA period, the suspension rates of industry-sponsored and academic projects are 0.06 and 0.08. In the post-FDAAA period, the suspension rates of industry-sponsored and academic projects are 0.13 and 0.03. We observe that the academic projects are suspended more often before the FDAAA, which confirms the effect of ICMJE on disclosures and our design of DID. Industry-sponsored projects are, on average, less likely to have partners, and the percentage of projects with partners in the pipeline of industry sponsors is also lower. Industry-sponsors have a greater total number of projects and a more diversified project portfolio, while their projects are less matured and their industry has a smaller percentage of matured projects.

[Insert Table 3 Here]

Panel B reports the results from the DID regressions. We focus on the linear probability model for the rest of our analyses because it generates a consistent (unbiased) estimate, even if the dependent variable does not follow a logistic or normal distribution (Wooldridge, 2002). In Column 1, we regress the project suspension measure on the interaction term between *Post* and *Industry-Sponsored Project* dummy variables. We include year, phase, and indication fixed effects. The standalone variable, *Post*, is subsumed due to the year fixed effects. We find that the coefficient on the interaction term between *Post* and *Industry-Sponsored Project* is significantly positive. This indicates that the effects of the increased mandatory disclosures on suspension rates mainly appear in industry-sponsored projects. Results are robust after we control for characteristics of drug developers and their industries in Column 2. We additionally include entity (academic institutions and firms) fixed effects in Column 3 to alleviate a concern that the result is driven by different characteristics of projects chosen by entities. Our results are still robust when we include entity fixed effects.

[24] The number of different indications of academic projects is smaller than that of industry-sponsored projects. We exclude industry-sponsored projects that have no matched-indication in academic projects. Also, the majority of academic projects are initiated after the FDAAA. Thus, one of our sample restrictions that exclude drug projects that initiated after the FDAAA reduces the sample size of academic projects significantly.

In Columns 4 and 5, we examine the dynamic effects of the FDAAA in the DID setting. Column 4 and 5 are with and without control variables for the characteristics of drug developers and their industries, respectively. Year dummy variables include Year $_{t-1}$, Year $_{t}$, Year $_{t+1,}$ Year $_{t+2,}$ and Year $_{t+3}$. Year $_{t}$ is the indicator for the year 2007, in which the FDAAA is enacted. We find that the coefficients on the interaction term of the industry-sponsored project dummy with Year $_{t-1}$ are insignificant in both columns, which confirm that there is no pre-trend before the passage of the FDAAA and support that the parallel trend assumption is satisfied. In addition, the coefficients on the interaction terms with Year $_{t}$ to Year $_{t+3}$ in Column 4 and Year $_{t+1}$ to Year $_{t+3}$ in Column 5 are significantly positive and monotonically increasing. This suggests that the effect of the increased disclosure requirement on suspension decisions of industry-sponsored projects starts with the enactment of the FDAAA and becomes stronger afterwards. Our results with this DID approach mitigate a concern that our findings are merely driven by a temporary increase in disclosures of overdue suspension events. Because both academic and industry sponsors are subject to compliance with the FDAAA requirements, our results support the conclusion that industry-sponsored drug developers appear to make suspension decisions differently from those of academic drug developers.

In Appendix Table A.2, we show analogous DID results that include more stringent fixed effects of indication and year together, rather than separately including them, which capture the time-varying technology opportunities or demand in each indication. The results in Appendix Table A.2 are robust and qualitatively similar to the results in Panel B of Table 3. These robust results from the regressions that include the indication and year fixed effects particularly alleviate concerns that changes in fundamental conditions in each indication over time drive our results.

Overall, our baseline regression results in Table 2 and DID results in Table 3 collectively support that the passage of the FDAAA significantly influences the investment decisions of pharmaceutical firms by requiring them to disclose more—and more detailed—information.

4.3. Robustness: Financial crisis

We note that there is a potential concern that the enactment of the FDAAA in 2007 is adjacent to the 2008-2009 financial crisis. Although our previous DID approach with the year fixed effects mitigates that concern, we attempt to rule out the concern further with multiple robustness tests in this section. Specifically, we consider a more refined sample that completely excludes observations in the five-year event window, [-2, +2], that contains the financial crisis period (i.e., observations in 2005, 2006, 2007, 2008, and 2009) or that excludes crisis-period observations in 2008 and 2009.

Table 4 presents the results from these robustness tests. Columns 1 and 2 present the results of a regression specification in Column 2 of Table 2 using the same sample except that it excludes the five-year event window, [-2, +2] (Column 1) and the observations in 2008 and 2009 (Column 2). Column 3 reports the DID results using the same sample from Panel B of Table 3 except that it excludes observations in 2008 and 2009.

[Insert Table 4 Here]

We find that the results are robust to using the more refined samples that exclude the financial crisis period. For both Columns 1 and 2, *Post* indicator variables are positive and statistically significant at the 5% and 1% level, respectively. Especially in Column 1, the sample only includes 2002-2004 and 2010-2012 observations that are least affected by the financial crisis, and we find consistent results. In Column 3, we confirm that our DID results hold after we exclude the financial-crisis period observations. These results effectively rule out the concern that the increase in suspension rates after the FDAAA can be simply attributed to the 2007-2009 financial crisis.

5. Mechanisms

We now explore possible explanations for the increased suspension likelihood following the FDAAA that we find in the previous tables. In particular, we focus on two possible mechanisms: peer learning and competition (see Reinganum, 1984).

5.1. Learning from peers

For the peer learning mechanism, we examine the effects of peer disclosures on suspensions (bad news) and phase advances (good news) on focal firms' suspension decisions. This argument suggests that the suspension likelihood will be associated with peer firms' disclosures, and differently so for good vs. bad disclosures. We also examine differential effects by firm quality and whether the project has outside partners; we predict that high-quality firms (based on the history of advance and suspension events) and firm with outside partners will show different reactions to peer firm disclosures. Table 5 reports the regression results for these predictions.

[Insert Table 5 Here]

We measure peer disclosures on suspensions (*Peer Suspension Rate*) with the fraction of projects with suspension events in the same indication as a given project's indication in a given year. Analogously, we measure peer disclosures on advances (*Peer Advance Rate*) with the fraction of projects with phase

advance events in the same indication as a given project's indication in a given year. We exclude the own project's suspension and advance events when we calculate those fractions. These variables are also lagged for one year to ensure that the information about peer innovation activities is known by the focal firm in advance. In addition, we define high-quality firms as firms with the total number of advance events greater than the total number of suspension events up to the year prior to a given year. Approximately 39.5% of the observations in our sample are regarded as high-quality firm observations.

In Column 1 of Table 5, we find that the coefficient estimate of the interaction term between *Peer Suspension Rate* and *Post* dummy is positive and significant at the 1% level. The economic interpretation is that a one-standard-deviation increase in the peer firm suspension rate in the prior year is associated with a 17% increase in suspension likelihood in the current year from its unconditional mean. Also, we find that the coefficient estimate of the interaction term between *Peer Advance Rate* and *Post* dummy is negative although the significance is weaker at the 10% level. This implies that a one-standard-deviation increase in the peer firm advance rate in the prior year is related to a 7% decrease in suspension likelihood of focal firms from the unconditional mean. These results together are consistent with the peer learning mechanism in that the increased information disclosure after the FDAAA enables firms to learn from their peers about drug development experience and market prospects and make investment decisions in the same direction. On the one hand, peers' failure can reveal some fundamental difficulties and complications in the same indication; on the other hand, firms can learn from peers' successful experiences with clinical trials.

In Columns 2 and 3, we further split the sample for low-quality firms and high-quality firms and examine the differential effects for the two groups. The coefficient estimate for the interaction term between peer firm suspension rate and the post dummy is still positive and statistically significant at the 1% level for low-quality firms in Column 2, whereas the coefficient estimate for the interaction term is no longer significant for high-quality firms in Column 3. This result is consistent with the interpretation that suspensions increase only for low-quality firms after their peer firms disclose suspensions. While low-quality firms are more likely to rely on information from peer suspension disclosures, high-quality firms that might already have sufficient information for their project's prospect and progress are less likely to respond to information revealed by peer suspension events. In Columns 4 and 5, we consider the differential effects by the existence of partners. Although we find the positive and significant effect of peer suspension disclosures on a focal firm's suspension for both project groups with and without external partners in Columns 4 and 5, the magnitude and the significance of the effect are greater for projects

without outside partners in Column 4. The contrast presented in Columns 4 and 5 is consistent with the interpretation that projects with outside partners are more likely to have better knowledge with respect to the prospect of its own projects, because advising on project prospects is one of the roles that outside partners fulfill.

Collectively, Table 5 provides supportive evidence to the peer learning mechanism. Projects are more (less) likely to be suspended when more of their peer projects have been suspended (advanced). Such a pattern is more pronounced among low-quality firms that have been less successful in drug development and projects that have no outside partner.

5.2. Competition

In Table 6, we examine the competition mechanism alternatively. We test for the prediction that the increase in perceived competition due to the FDAAA leads to the increase in suspension decisions. For this test, we consider the following two measures of competition. For Columns 1 and 2, we split the sample into High Competition and Low Competition groups based on the total number of drug projects for each indication. A project is included in the High Competition group if the total number of drug projects in the same indication as a given project in a given year is greater than the sample median and in the Low Competition group otherwise. For Columns 3 and 4, we use an indicator for whether the project is designated as an FDA-expedited program (i.e., fast track, breakthrough therapy, or orphan drug). If the project is designated as an FDA-expedited program, then it is likely that an abnormally small number of entities are currently developing new treatment for the indication, and competition is thus less severe for these projects.

[Insert Table 6 Here]

We run analogous tests to our baseline regression specification in Column 2 of Table 2. The results in Table 6 show that the effect of FDAAA on suspension presents for both high and low competition groups. We find that the coefficients on the *Post* indicator in the Low Competition group (Columns 2 and 4) are statistically significant and their magnitude is not far from their counterparts in the High Competition group (Columns 1 and 3). These results do not support the competition mechanism that predicts that projects in the low competition group should be less affected by the FDAAA.

Overall, our results from Table 6 in combination with the results in Table 5 that focal firms make investment decisions in the same direction as their peers consistently support the conclusion that increased

learning from peers, rather than increased competition, after the FDAAA leads to an increase in suspension decisions.

5.3. Further analyses

In this section, we examine two additional effects that may supplement the learning explanation for the FDAAA effect. First, we examine the effect of financial constraints on our main findings. Second, we investigate the effect of reputational costs.

In Table 7, we examine the relation between financial constraints and the FDAAA effect. In the previous sections, we show that the passage of the FDAAA increased the suspension likelihood mainly through the peer learning mechanism and that our result is not driven by the 2007-2009 financial crisis. Now, we examine the role of financial constraints by splitting firms into subsamples based on financial constraints. For public firms, we split the sample using Altman Z scores (Columns 1 and 2). For private firms, we split the sample based on whether the project is backed by venture capital investors instead (Columns 3 and 4), because financial statement variables that are required to compute Altman Z scores are not available for private firms.

[Insert Table 7 Here]

In Columns 1 and 2 of Table 7, our main variable of interest, *Post*, is positive and statistically significant, regardless of the degrees of financial constraints for public firms. The magnitude of the effect, however, is more than two times greater for the financial constrained firms in Column 1. In Columns 3 and 4, we find that *Post* is significantly positive only for private firms that are likely financial constrained without venture capital investments. Therefore, it appears that the effect of the increased information after the FDAAA on suspension decisions exists for both financially constrained and unconstrained groups, but is stronger for more financially constrained groups.[25] This is consistent with the explanation that firms with financial constraints are more sensitive to available information from peers in making efficient suspension decisions.

In Table 8, we examine the role of reputational costs for the effects of the FDAAA on suspension decisions. We use public and private firm status to capture reputational costs; when compared to private firms, public firms have higher reputation concerns because they are under greater media coverage and investor monitoring. Thus, public firms' failures or suspensions with respect to new drug development

[25] The results for public firms in Columns 1 and 2 are also robust when we include other firm-level control variables (e.g., leverage, Tobin's Q, asset tangibility, profitability).

may hurt firm value to a greater extent. If reputational concerns explain increased suspensions after the FDAAA, we expect the magnitude of the FDAAA effect to be different between public and private firms. We split our sample into public firms (Columns 1 and 2) and private firms (Columns 3 and 4) and run analogous tests to our baseline regression in Column 2 of Table 2.

[Insert Table 8 Here]

We find that *Post* indicator variables for all columns are positive and statistically significant at the 1% level for the first three columns and at the 10% level for the last column. We additionally include available financial characteristics variables in Columns 2 and 4, which include firm size and R&D expenses for public firms and the amount of venture capital financing for private firms. Our results remain unchanged. Regarding the magnitudes of the effect, we find that coefficient estimates are comparable between public and private firms and slightly larger for private firms. Overall, Table 8 suggests that the FDAAA effect exists in both public and private firm samples, which does not support a reputational cost explanation for our main results.

6. Social Welfare Effects

In this section, we examine social welfare implications of the higher suspension likelihood driven by the FDAAA. We examine both quality and quantity aspects of drug development before and after the FDAAA. We do not analyze price effects, however, due to the lack of drug price data. Although a final conclusion for social welfare implications is hard to draw without knowing price effects, our analysis on quality and quantity of drug development is informative, as it offers new evidence and insight on the consequences of mandatory disclosures in terms of innovation activities.

6.1. Drug quality

We first examine whether the overall quality of drug projects has changed after the increased disclosure pressure through the passage of the FDAAA. We use adverse event reports (AER) from the FDA to analyze the quality change of each FDA-approved and thus marketed drug. We expect the quality of drugs to improve because firms know that their drug development is disclosed to the public and peers, and thus firms have stronger incentives to pursue safer projects and weaker incentives to continue projects without promising clinical outcomes that could send bad signals to the market. Table 9 reports the results from the tests that examine this prediction based on drug project-year observations. The main variable of interest

is an indicator variable, *Project Initiation After FDAAA*, that is one if the drug project is initiated after the passage of the FDAAA and zero otherwise.

[Insert Table 9 Here]

For our analysis in Table 9, we merge the approved and marketed drugs from our primary sample with the FDA Adverse Event Reporting System (AERS) data provided by the FDA by drug names.[26] The sample period of the AERS data starts in 2004, and thus the sample in Table 9 covers the period from 2004 to 2012. If an approved drug in our primary sample has no match with the AERS data, then we assume the number of AER that the drug has received in a given year is zero. In Columns 1 and 2, we use the total number of AER that a given drug has received as a primary suspect in a given year for a measure of the drug's quality. We also consider an alternative measure by focusing on whether a given report is about serious patient outcomes in Columns 3 and 4. Appendix A illustrates how we classify different AER cases. Columns 1 and 3 only include *Years from Approval* and firm, indication, and year fixed effects. In Columns 2 and 4, we control for characteristics of drug developers and their industries.

Throughout all columns in Table 9, the coefficient estimates of *Project Initiation After FDAAA* are significantly negative at the 10% level, consistent with our prediction. This effect translates into approximately a 50% decrease in the number of AER if the clinical trial of a drug project is initiated after the passage of the FDAAA. Considering the average number of total AER and serious AER per year are 45 and 27, respectively, from Table 1, this 50% decrease is equivalent to receiving 23 and 14 less total AER and serious AER per drug per year. The effects are still significantly negative in Columns 2 and 4 when we add control variables used in our baseline regression in Table 2. It is worth noting that the inclusion of *Years from Approval* and year fixed effects in our regressions alleviates concerns that older drugs are more likely to receive a larger number of AER than newer drugs in a given year, or conversely that older drugs are safer for some omitted reasons and, thus, likely to receive fewer AER than newer drugs.

We next examine the likelihood that a given drug project will deliver any adverse event after the enactment of the FDAAA in Table 10. The dependent variables of the first two columns and the last two columns in Table 10 are indicator variables that are one if the drug is a primary suspect of an AER in a given year and one if the drug is a primary suspect of an AER with serious adverse outcomes in a given year, respectively. Columns 1 and 3 only include *Years from Approval* and firm, indication, and year fixed

[26] We restrict our sample to FDA-approved drugs that are initiated and approved in and after 2000, considering that the AERS data start in 2004.

effects. In Columns 2 and 4, we control for characteristics of drug developers and their industries. The coefficient estimates of *Project Initiation After FDAAA* in all columns in Table 10 are negative and significant, suggesting that drug projects developed under the increased disclosures from the FDAAA are less likely to deliver any adverse events. The effects are robust in Columns 2 and 4 when we add control variables used in our baseline regression in Table 2. The coefficient estimates in Columns 2 and 4 translate into 5.3% and 9.3% decreases in the likelihood of receiving an AER and a serious AER as a primary suspect, respectively.

[Insert Table 10 Here]

The results in Tables 9 and 10 collectively suggest that drug projects under increased disclosure pressure due to the FDAAA show lower frequency of adverse outcomes on the intensive margin and also the likelihood of delivering any adverse outcome on the extensive margin. These results are consistent with our conjecture: pharmaceutical firms pursue safer projects and discontinue projects without promising clinical outcomes due to the increased information disclosure pressure given that the costs of adverse events and bad outcomes are now transparent to the public.

6.2. Clinical trials and Burden of Disease

We now examine the quantity effect, specifically whether the negative effect of the increased disclosure pressure on the number of active projects has any effect on the Burden of Disease.[27] Previous evidence in Sections 4 and 5 indicates that the FDAAA and increased disclosure pressure lead to greater suspensions of active projects. Also, the mandatory and potential information disclosure requirement not only reduces the economic rents and advantages of first-movers and innovative firms but also reduces the incentives for firms to follow and imitate. The society may lose potential remedies for critical diseases if firms avoid taking risk and give up their projects earlier or more often. Therefore, we expect that a decrease in active projects can result in an increase in the Burden of Disease and, thus, negatively influence social welfare.

We first calculate the average annual growth in the number of active projects (i.e., the number of total projects minus the number of suspended projects) for pre- and post-FDAAA periods for each indication and then take the difference between the pre- and the post-FDAAA growth rates. Figure 3 visualizes this difference, in which we plot the average number and growth rate of active projects over time. We find that

[27] The Burden of Disease is the impact of a health problem as measured by financial costs, mortality, morbidity, or other indicators, and is often quantified with Disability-Adjusted Life Years (DALYs), which means the number of years lost due to a given disease.

the average number of active projects continuously increases in the pre-FDAAA period, but sharply drops after the FDAAA. The time trend for active project growth also confirms that the FDAAA in 2007 appears to slow down the growth rate of active clinical trials significantly. The pre-FDAAA average growth rate is approximately 25%, but this growth collapses nearly to zero and even becomes negative after the FDAAA. Together with prior results, Figure 3 points to a significant drop in new drug development after the FDAAA.

[Insert Figure 3 Here]

We then focus on indications that intend to take care of the top 20 leading causes (diseases) of the globally measured Disability-Adjusted Life Years (DALYs) for the two snapshots of 2000 and 2016 by the WHO. These two years are the closest data points available around the FDAAA with detailed indication information. A disease's DALYs combine the years lived with disability and the years of life lost due to that disease. To further quantify the social welfare loss in DALYs due to the slowdown in drug development for those critical conditions, we compare the reduction of DALY in a high-growth indication group to that in a low-growth indication group, and we then use the difference as social loss due to the slowdown. Based on the difference between the pre- and post-FDAAA growth rates of active projects for each indication, we split indications into two groups: (a) the low-growth indication group if the difference is less than the sample median and (b) the high-growth indication group otherwise. For the two indication groups, (a) and (b), we examine the following statistics in Table 11. In Panel A, we examine the differences between pre- and post-FDAAA active projects' growth rates and suspension rates, and then show these differences between the two indication groups. Because the division of the two indication groups is based on the first set of statistics presented in Row 1, we see the clear difference between the two groups. In the low-growth indication group, the active project growth rates decreased by 46% after the FDAAA, while the growth rates increased by 5% in the high-growth indication group. We attribute the decrease in active projects growth, especially in the low-growth group, to the increased suspensions associated with the FDAAA. We confirm this conjecture with the statistics presented in Row 2. We find that in the low-growth indication group, the average suspension rate is indeed higher than that in the high group by 4%, and this difference is significant at the 5% level.

[Insert Table 11 Here]

We then quantify the social costs associated with new drugs based on DALY in Panel B. In Rows 1 and 2, we show DALY statistics for the two indication groups for a pre-FDAAA year. As we discussed previously, the detailed DALY data are only available from the WHO for two years, 2000 and 2016. We

therefore use the former for the statistics representing the pre-FDAAA period and the latter for the post-FDAAA period. In Row 1, we find that DALY for the diseases related to the low- and high-growth indication groups in 2000 are 91.900 million years and 100.542 million years, respectively, but that the difference between the two statistics is not statistically significant. Results are similar for the other measure of DALY that uses % in Row 2. DALY (%) represents the fraction of DALY attributable to a given disease in DALY for any. In Rows 3 and 4, we consider the difference between 2000 and 2016 for the same statistics and find that the decrease in DALY from 2000 to 2016 is significantly greater for the high-growth indication group than for the low-growth indication group. The difference is approximately 19 million years. In sum, in Row 5 the percentage changes in DALY from 2000 to 2016 are -8.27% for the high-growth group and +4.21% for the low-growth indication group. These statistics suggest that if the low-growth indication group receives the same efforts as that of the high-growth group, then the DALY of the low-growth group may also drop by the same magnitude (8.27%, or 7.6 million years). This finding, together with those findings in Table 2 and Figure 3, suggests that the increased disclosure requirements and on-going pressure result in greater suspensions of active projects and, in turn, possibly an increase in the burden of disease for our society. These results reflect potential unintended consequences of the FDAAA and thus have important policy implications.

7. Conclusion

The role of information disclosure in innovation activities has been an important research topic in the literature; however, there is a paucity of empirical evidence. To address this gap, we use a unique policy change, the enactment of Section 801 of the Food and Drug Administration Amendments Act in 2007 (FDAAA 801), to examine how mandatory disclosure of pharmaceutical firms' clinical trials influences their investment decisions as captured by suspension decisions. Specifically, we find higher suspension probabilities after the FDAAA, suggesting that increased information transparency reduces pharmaceutical firms' innovative investments. This relation has a causal interpretation based on a difference-in-differences analysis showing that, in comparison with academic projects, industry-sponsored projects are suspended more often after the FDAAA. Moreover, we provide evidence that supports a learning-based explanation for our findings by showing that a firm's suspension decision is positively associated with peers' detailed suspension disclosures after the FDAAA. As a result, the mandatory disclosure of the FDAAA indeed creates information diffusion to peer firms and enables pharmaceutical firms to learn from their peers' experiences.

Our empirical investigation has policy and social welfare implications, as it highlights both the intended and unintended consequences of the FDAAA. On the one hand, the original goal of enhancing transparency and safety has been achieved. We indeed find fewer Adverse Event Reports (AER) per drug after the FDAAA, suggesting an improvement with respect to drug quality. On the other hand, due to reputation concerns and disclosure costs, pharmaceutical firms become less motivated to initiate and continue risky projects and are more likely to cut projects that do not deliver good outcomes in earlier stages. Such risk-averse approaches result in fewer new drug projects, which lowers the life quality of the public in the long run.

Appendix A. Examples of the FDA Adverse Event Reports

This appendix presents examples of the FDA adverse event reports for a drug named *Androgel*. *Androgel* is a supplement for testosterone. The field, *Outcomes*, in the table indicates whether the reported outcome is *Serious*. The outcome categories include congenital anomaly/birth defect (CA), death (DE), disability (DS), hospitalization (HO), life-threatening (LT), other serious important medical event (OT), and required intervention to prevent permanent impairment/damage (RI). A report can state multiple outcomes. If the field is missing, the report is classified as *non-Serious*. The field, *Role*, indicates whether the reported drug is *Primary Suspect*. Suspect (S) identifies products that the initial reporter deemed most likely to be associated with the event, and Concomitant (C) identifies products taken at the same time as the suspect product but not deemed as being associated with the event. The *Suspect* field can be further classified as *Secondary Suspect* when needed. In the following four adverse event reports, for *Androgel,* the Number of AER is four, both the Number of AER Suspect and the Number of AER Primary Suspect are four, the Number of Serious AER is three, and both the Number of Serious AER Suspect and the Number of Serious AER Primary Suspect are three. For *Zocor* which is reported as a concomitant drug, the Number of AER is two, both the Number of AER Suspect and the Number of AER Primary Suspect are zero, the Number of Serious AER is two, and both the Number of Serious AER Suspect and the Number of Serious AER Primary Suspect are zero.

FDA Adverse Event Reporting System (FAERS)
Freedom of Information Act (FOIA)
Detailed Report

FDA Received Date	Case #	Case Type	Health Professional	Outcomes	Manufacturer Control #	Age	Sex	Country
05-Feb-2010	7271740	EXPEDITED (15-DAY)	Y	DE	US-SOLVAY-00310000680		Male	USA

Preferred Term	Product	Role	Route	Dosage Text	Duration	Manufacturer
Myocardial infarction	ANDROGEL	S	TRANSDERMAL	Daily dose: unknown	1 YR	
Off label use	UNKNOWN DIABETIC MEDS	C	ORAL	Daily dose: unknown		
	ZOCOR	C	ORAL	Daily dose: unknown		

FDA Received Date	Case #	Case Type	Health Professional	Outcomes	Manufacturer Control #	Age	Sex	Country
05-Feb-2010	7271758	EXPEDITED (15-DAY)	N	OT	US-SOLVAY-00210000660	59 YR	Male	USA

Preferred Term	Product	Role	Route	Dosage Text	Duration	Manufacturer
Prostate cancer	ANDROGEL	S	TRANSDERMAL	Daily dose: 5 gram(s)		
Cataract	METOPROLOL TARTRATE	C	ORAL	Daily dose: unknown		

FDA Received Date	Case #	Case Type	Health Professional	Outcomes	Manufacturer Control #	Age	Sex	Country
17-Feb-2010	7195451	EXPEDITED (15-DAY)	N		US-SOLVAY-00209007046	53 YR	Female	USA

Preferred Term	Product	Role	Route	Dosage Text	Duration	Manufacturer
Hirsutism	ANDROGEL	S	TRANSDERMAL	Daily dose: 2.5 gram(s)	19 MTH	
	VIVELLE DOT	C	OTHER	Daily dose: unknown, As used: 0.075 milligram, frequency: Twice a week, route: transdermal		

FDA Received Date	Case #	Case Type	Health Professional	Outcomes	Manufacturer Control #	Age	Sex	Country
22-Feb-2010	7252209	EXPEDITED (15-DAY)	Y	DE	US-SOLVAY-00210000159		Male	USA

Preferred Term	Product	Role	Route	Dosage Text	Duration	Manufacturer
Myocardial infarction	ANDROGEL	S	TRANSDERMAL	Daily dose: 5 gram(s)	16 MTH	
	ZOCOR	C	ORAL	Daily dose: unknown		
	UNKNOWN DIABETIC MEDS	C	ORAL	Daily dose: unknown		

Appendix B. Variable Definitions

- Suspension (Indicator): An indicator that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase, and zero otherwise.
- Disclosed Suspension (Indicator): An indicator that takes the value of one if a suspension announcement is made for the project in a given year and zero otherwise.
- Post (Indicator): An indicator that takes the value of one after the passage of FDAAA in 2007 and zero otherwise.
- Project with Partner (Indicator): An indicator that takes the value of one if the project has partners in a given year and zero otherwise.
- Log(1+Number of Projects): The log of the total number of drug projects for a given firm in a given year.
- Project Diversification: The firm-year level diversification measure calculated by one minus the sum of the squared project share of each disease group in a given year.
- Percent of Matured Projects: The percentage of matured projects (post-clinical phases) in the firm's pipeline in a given year.
- Percent of Projects with Partner: The percentage of the projects in the firm's pipeline that have partners in a given year.
- Log(1+Number of Competitors): The log of one plus the total number of both private and public firms with new drug development in each industry (indication-level) in a given year The entire industry- and academic-sponsored projects from the preclinical stage to the final FDA approval stage are considered for the variable construction.
- Industry Failure Rate: The industry average of suspension rates in a given year. The entire industry- and academic-sponsored projects from the preclinical stage to the final FDA approval stage are considered for the variable construction.
- Percent of Industry Matured Projects: The industry percentage of matured projects (post-clinical phases) in a given year. The entire industry- and academic-sponsored projects from the preclinical stage to the final FDA approval stage are considered for the variable construction.
- Peer Phase Advance Rate (Lagged): The average phase advance rate (number of phase advances divided by total number of projects) of projects in the same indication as a given project in the prior year, excluding the firm’s own projects.
- Peer Suspension Rate (Lagged): The average phase suspension rate (number of disclosed suspensions divided by total number of projects) of projects in the same indication as a given project in the prior year, excluding the firm’s own projects.
- High Competition (Indicator): An indicator that takes the value of one if the total number of drug projects in the same indication as a given project in a given year is greater than the sample median and zero otherwise.
- Non-Expedited Drugs (Indicator): An indicator that takes the value of one if the drug project is not designated as an FDA-expedited program, which includes fast track, breakthrough therapy, and orphan drug and zero otherwise.
- Log(1+Number of AER Primary Suspect): The log of one plus the total number of AER in which the drug is reported as a primary suspect.

- Log(1+Number of Serious AER Primary Suspect): The log of one plus the total number of AER in which the patient outcome is one of the following serious conditions: death, life-threatening, hospitalization, disability, congenital anomaly, or required intervention to prevent permanent impairment and damage and the drug is reported as a primary suspect.
- Project Initiation After FDAAA (Indicator): An indicator that takes one if the drug project is initiated after the passage of the FDAAA in 2007 and zero otherwise.
- Primary Suspect in AER (Indicator): An indicator that takes the value of one if the approved drug is one of the primary suspects in AER and zero otherwise.
- Primary Suspect in AER Serious Reports (Indicator): An indicator that takes the value of one if the approved drug is one of the primary suspects in AER with serious patient outcomes and zero otherwise.
- Disability-Adjusted-Life-Years (DALY) (years): Sum of the years lived with disability and the years of life lost due to that disease.
- Disability-Adjusted-Life-Years (DALY) (%): The fraction of DALY attributable to a given disease in DALY for any disease.

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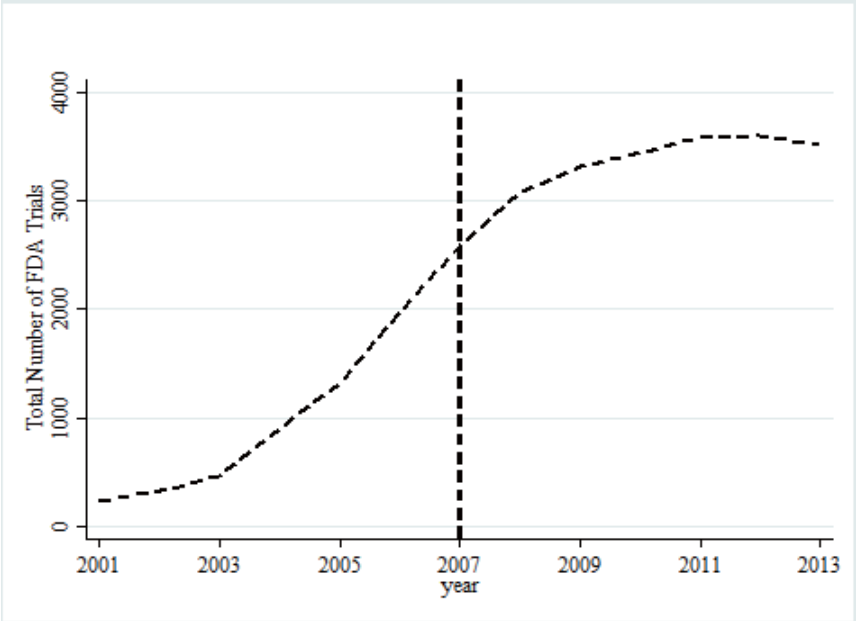
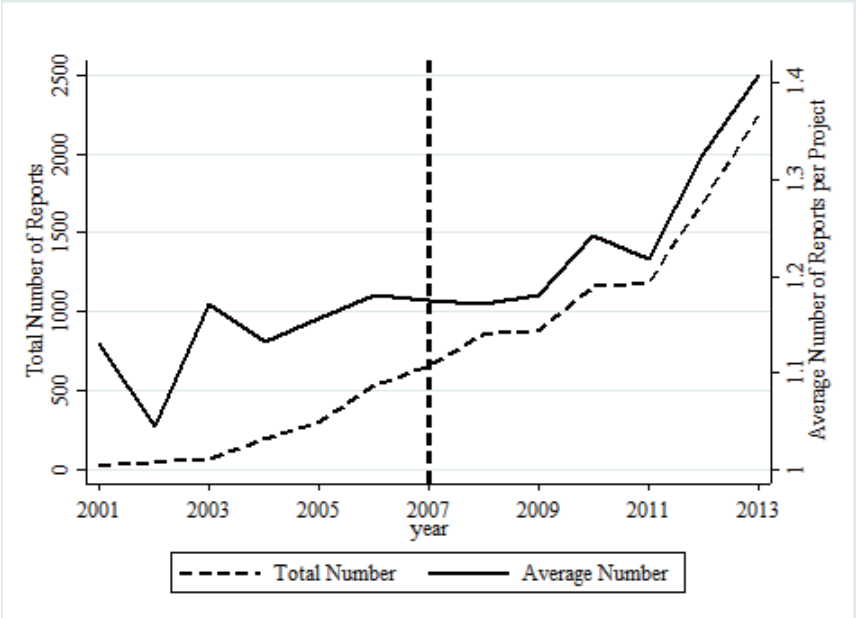
Figure 1. Pre- and Post-FDAAA Trends of Clinical Trials and Disclosures

The figures present the aggregate time trends of clinical trials from 2001 to 2013. Figure (a) shows the total number of clinical trials. The number of clinical trials includes all on-going projects that are not publicly disclosed as terminated. Figure (b) shows the total number of progress updates (e.g., trial initiation, progress update, trial progressing, updated results) and the average number of progress updates per project. The frequency of progress updates can vary across trials.



(a) The number of clinical trials



(b) Disclosure intensity

Figure 2. Pre- and Post-FDAAA Trends of Project Suspension Rates

The figure presents the aggregate time trends of clinical trials from 2001 to 2013. Each line shows the average suspension rate (i.e., the total number of suspension events divided by the total number of projects in a given year) for each phase.

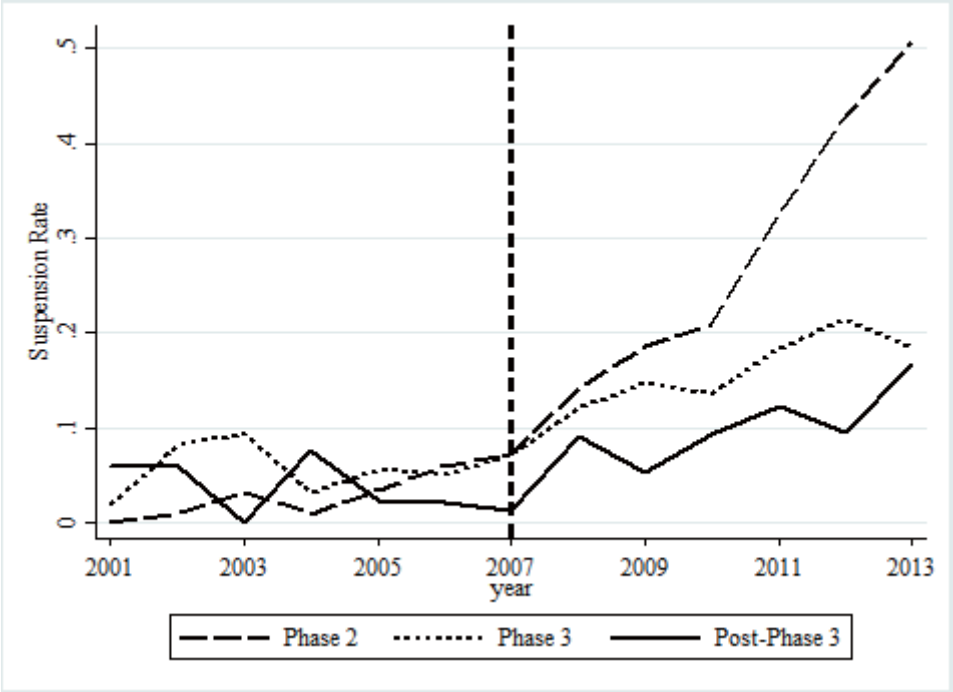


Figure 3. Pre- and Post-FDAAA Number and Growth of Active Projects

The figure presents the time trends of the average number and growth rate of active projects within indication from 2001 to 2013. The number of active projects is the total number of projects minus the number of suspended projects in a given year for a given indication. The active project growth is the percentage growth in the number of active projects for a given indication, which is the number of active projects in the prior year divided by the number of active projects in a given year minus one.

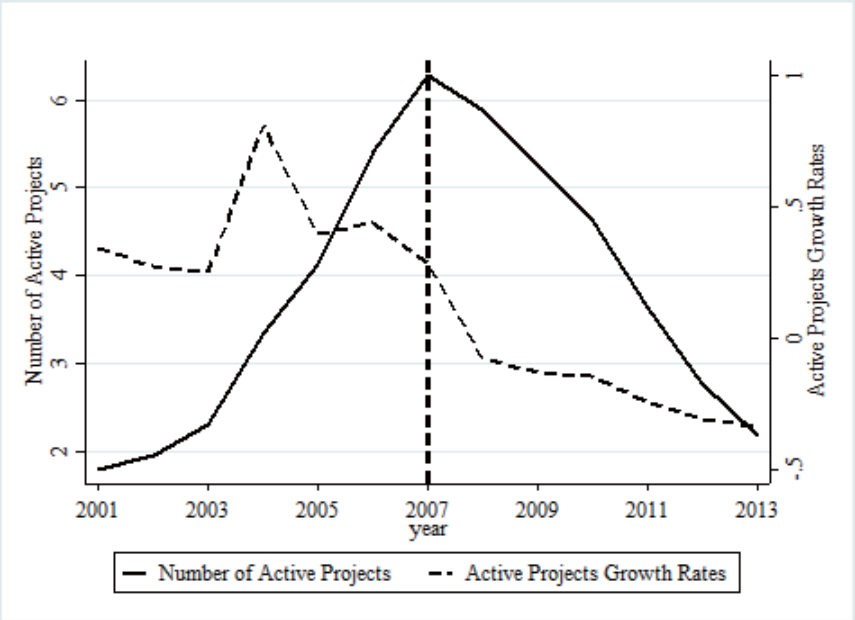


Table 1. Descriptive Statistics

The table presents summary statistics for our primary sample in Panel A and compare variables used in regressions between pre- and post-FDAAA in Panel B. The sample consists of 16,925 new drug project-year observations from the BioMedTracker database for our sample period from 2002 to 2012. We exclude the following clinical trials from our sample: (i) clinical trials for generic drugs; (ii) clinical trials that are not sponsored by industry (i.e., academic-sponsored drugs); (iii) phase 1 trials, which are not subject to the FDAAA; and (iv) trials initiated in the post-FDAAA period. Suspension (Indicator), our main dependent variable, is an indicator variable that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. The detailed descriptions of other variables are available in Appendix B.

Panel A. Summary Statistics

	Mean	SD	Min	Median	Max	Obs
Suspension (Indicator)	0.13	0.33	0.00	0.00	1.00	16,925
Project with Partner (Indicator)	0.54	0.50	0.00	1.00	1.00	16,925
Log(1+Number of Projects)	3.22	1.60	0.69	3.09	6.06	16,925
Project Diversification	0.55	0.32	0.00	0.67	0.90	16,925
Percent of Matured Projects	0.27	0.25	0.00	0.26	1.00	16,925
Percent of Projects with Partner	0.50	0.29	0.00	0.50	1.00	16,925
Log(1+Number of Competitors)	2.93	1.10	0.69	3.04	5.19	16,925
Industry Failure Rate	0.08	0.10	0.00	0.08	1.00	16,925
Percent of Industry Matured Projects	0.12	0.18	0.00	0.05	1.00	16,925
High Competition (Indicator)	0.47	0.50	0.00	0.00	1.00	16,925
Non-Expedited Drugs (Indicator)	0.82	0.39	0.00	1.00	1.00	16,925
Peer Suspension Rate (Lagged)	0.09	0.10	-1.00	0.07	1.00	13,433
Peer Advance Rate (Lagged)	0.11	0.13	0.00	0.08	1.50	13,433
Log(1+Number of AER Primary Suspect)	3.83	2.30	0.00	3.85	10.30	6,906
Log(1+Number of Serious AER Primary Suspect)	3.34	2.22	0.00	3.30	9.95	6,906
Primary Suspect in AER Reports (Indicator)	0.92	0.28	0.00	1.00	1.00	6,906
Primary Suspect in AER Serious Reports (Indicator)	0.88	0.32	0.00	1.00	1.00	6,906

Panel B. Univariate Analysis

	Pre-FDAAA			Post-FDAAA			
	Mean	Median	Obs	Mean	Median	Obs	Diff
Suspension (Indicator)	0.05	0.00	7,572	0.19	0.00	9,353	-0.14***
Project with Partner (Indicator)	0.55	1.00	7,572	0.52	1.00	9,353	0.03***
Log(1+Number of Projects)	3.07	3.09	7,572	3.34	3.14	9,353	-0.27***
Project Diversification	0.56	0.69	7,572	0.55	0.64	9,353	0.01**
Percent of Matured Projects	0.33	0.33	7,572	0.22	0.22	9,353	0.11***
Percent of Projects with Partner	0.51	0.50	7,572	0.48	0.48	9,353	0.03***
Log(1+Number of Competitors)	2.51	2.56	7,572	3.26	3.40	9,353	-0.76***
Industry Failure Rate	0.05	0.00	7,572	0.12	0.11	9,353	-0.07***
Percent of Industry Matured Projects	0.14	0.04	7,572	0.10	0.06	9,353	0.04***

Table 2. Effects of the FDAAA on Project Suspension Rate

This table presents results from the OLS regressions (Columns 1and 2) and the Probit regressions (Columns 3 and 4) using clinical trials data from the BioMedTracker database for our sample period from 2002 to 2012. The sample consists of 16,897 new drug project-year observations. The dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Suspension (Indicator)			
	Linear Probability Model		Probit Model	
	(1)	(2)	(3)	(4)
Post (Indicator)	0.173***	0.047***	1.036***	0.106*
	(0.007)	(0.008)	(0.042)	(0.060)
Project with Partner (Indicator)		-0.038***		-0.232***
		(0.007)		(0.043)
Log(1+Number of Projects)		-0.023*		0.169
		(0.014)		(0.120)
Project Diversification		0.091***		0.828***
		(0.033)		(0.274)
Percent of Matured Projects		0.066**		0.834**
		(0.032)		(0.362)
Percent of Projects with Partner		-0.009		-0.038
		(0.035)		(0.265)
Log(1+Number of Competitors)		0.069***		0.712***
		(0.010)		(0.091)
Industry Failure Rate		1.222***		7.790***
		(0.035)		(0.256)
Percent of Industry Matured Projects		0.132***		0.758***
		(0.016)		(0.237)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes
Observations	16,897	16,897	14,882	14,882
R-squared	0.118	0.212		
Adjusted *R*-squared	0.060	0.160		
Pseudo *R*-squared			0.141	0.275

Table 3. Effects of the FDAAA on Suspension Rate: Difference-in-Differences

This table presents results from the difference-in-differences tests using clinical trials data from the BioMedTracker database and the ClinicalTrial.gov database for the sample period from 2004 to 2010. The sample consists of 12,171 new drug project-year observations that include both industry-sponsored projects and academic-sponsored (non-industry-sponsored) projects. We exclude industry-sponsored projects that have no matched-indication in academic projects. In Panel A, we divide the sample into two groups with industry-sponsored and academic sponsored projects and compare summary statistics. Industry-Sponsored Project (Indicator) is one if the project is funded by industry sponsors and zero if the project is funded by non-industry sponsors (e.g., university, public hospital, NIH). In Panel B, the dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A. Univariate Comparison by Sponsors

	Industry-Sponsored Projects			Academic-Sponsored Projects			Difference
	Mean	Median	Obs	Mean	Median	Obs	
Suspension (Indicator)	0.11	0.00	11,194	0.03	0.00	979	0.08***
Project with Partner (Indicator)	0.53	1.00	11,194	0.51	1.00	979	0.02
Log(1+Number of Projects)	3.30	3.37	11,194	1.20	1.10	979	2.10***
Project Diversification	0.55	0.67	11,194	0.19	0.00	979	0.36***
Percent of Matured Projects	0.25	0.26	11,194	0.38	0.14	979	-0.13***
Percent of Projects with Partner	0.49	0.50	11,194	0.51	0.50	979	-0.02
Log(1+Number of Competitors)	3.12	3.26	11,194	2.88	3.09	979	0.23***
Industry Failure Rate	0.08	0.08	11,194	0.07	0.07	979	0.01***
Percent of Industry Matured Projects	0.10	0.05	11,194	0.17	0.10	979	-0.07***

Panel B. Difference-in-Differences Regression Analysis

	(1)	(2)	(3)	(4)	(5)
Post X Industry-Sponsored Project (Indicator)	0.185***	0.150***	0.146***		
	(0.019)	(0.017)	(0.014)		
Industry-Sponsored Project (Indicator)	-0.038**	-0.050***			
	(0.019)	(0.019)			
Year t-1 X Industry-Sponsored Project (Indicator)				0.035	0.032
				(0.046)	(0.045)
Year t X Industry-Sponsored Project (Indicator)				0.080**	0.062
				(0.039)	(0.039)
Year t+1 X Industry-Sponsored Project (Indicator)				0.183***	0.151***
				(0.047)	(0.044)
Year t+2 X Industry-Sponsored Project (Indicator)				0.241***	0.200***
				(0.048)	(0.045)
Year t+3 X Industry-Sponsored Project (Indicator)				0.274***	0.240***
				(0.047)	(0.045)
Control Variables	No	Yes	Yes	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Entity Fixed Effects	No	No	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	12,171	12,171	12,134	12,134	12,134
R-squared	0.067	0.124	0.193	0.146	0.194
Adjusted *R*-squared	0.043	0.101	0.120	0.069	0.121

Table 4. Effects of the FDAAA on Suspension Rate: Financial Crisis

This table presents results from the OLS regressions (Columns 1 and 2) using clinical trials data from the BioMedTracker database for our sample period from 2002 to 2012 and the difference-in-differences test (Column 3) combining clinical trials data from the ClinicalTrial.gov database for the sample period from 2004 to 2010. We consider the effects of the financial crisis neighboring the enactment of the FDAAA in 2007. We use a refined sample that excludes observations in the two-year event window, [-2, +2] (i.e., five year observations in 2005, 2006, 2007, 2008, and 2009) in Column 1 or observations in 2008 and 2009 in Columns 2 and 3. The dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. Industry-Sponsored Project (Indicator) is one if the project is funded by industry sponsor and zero if the project is funded by non-industry sponsors (i.e., university, NIH, government agency). The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Suspension (Indicator)		
	(1) Excluding Financial Crisis Window [-2, +2]	(2) Excluding Financial Crisis Period 2008-2009	(3) Excluding Financial Crisis Period 2008-2009
Post (Indicator)	0.050**	0.109***	
	(0.023)	(0.009)	
Post (Indicator) X Industry-Sponsored Project (Indicator)			0.154***
			(0.018)
Project with Partner (Indicator)	-0.056***	-0.036***	-0.028**
	(0.013)	(0.008)	(0.012)
Log(1+Number of Projects)	-0.029	-0.050***	-0.013
	(0.020)	(0.015)	(0.026)
Project Diversification	0.047	0.059	0.033
	(0.048)	(0.037)	(0.056)
Percent of Matured Projects	0.053	0.003	-0.055
	(0.050)	(0.035)	(0.049)
Percent of Projects with Partner	0.022	-0.011	-0.052
	(0.048)	(0.036)	(0.053)
Log(1+Number of Competitors)	0.069***	0.047***	0.013
	(0.014)	(0.010)	(0.023)
Industry Failure Rate	1.347***	1.221***	1.042***
	(0.055)	(0.041)	(0.072)
Percent of Industry Matured Projects	0.127***	0.101***	0.047
	(0.025)	(0.018)	(0.032)
Year Fixed Effects	No	No	Yes
Firm and Institution Fixed Effects	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes
Observations	7,526	12,109	7,392
R-squared	0.295	0.258	0.217
Adjusted *R*-squared	0.191	0.189	0.101

Table 5. Peer Learning and Effects of FDAAA on Suspension

This table presents results from the test that examines the effects of peer learning on suspension decisions after the FDAAA using clinical trials data from the BioMedTracker database for our sample period from 2002 to 2012. The dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. High Quality (Indicator) is an indicator variable that takes the value of one for a firm whose overall success rate is positive and zero otherwise. Success rate is the total number of advance events minus the total number of suspension events up to the prior year. Partner (Indicator) is an indicator variable that is one if the project has a partner company and zero otherwise. Peer Advance Rate (Lagged*)* is the average phase advance rate, the number of phase advances divided by the total number of projects, of projects in the same indication as a given project in the prior year excluding the firm's own projects. Peer Suspension Rate (Lagged*)* is the average phase suspension rate, the number of disclosed suspensions divided by the total number of projects, of projects in the same indication as a given project in the prior year excluding the firm's own projects. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Suspension (Indicator)				
	(1) Full Sample	(2) Low Quality	(3) High Quality	(4) Without Partner	(5) With Partner
Peer Suspension Rate (Lagged) X Post	0.222***	0.235***	-0.043	0.360***	0.160**
	(0.057)	(0.078)	(0.057)	(0.104)	(0.066)
Peer Advance Rate (Lagged) X Post	-0.069*	-0.083	0.012	-0.091	-0.077*
	(0.036)	(0.064)	(0.031)	(0.061)	(0.043)
Peer Suspension Rate (Lagged)	-0.032	-0.078	0.059	-0.085	0.044
	(0.043)	(0.060)	(0.077)	(0.077)	(0.049)
Peer Advance Rate (Lagged)	0.034	0.046	-0.000	0.076*	0.018
	(0.021)	(0.050)	(0.017)	(0.040)	(0.025)
Project with Partner (Indicator)	-0.045***	-0.066***	-0.018*		
	(0.008)	(0.016)	(0.009)		
Log(1+Number of Projects)	-0.007	-0.001	0.043	0.009	-0.014
	(0.020)	(0.027)	(0.028)	(0.033)	(0.027)
Project Diversification	0.111**	0.105*	0.058	0.132*	0.100
	(0.046)	(0.058)	(0.083)	(0.072)	(0.070)
Percent of Matured Projects	0.122***	0.186**	0.151***	0.089	0.186***
	(0.044)	(0.075)	(0.051)	(0.081)	(0.056)
Percent of Projects with Partner	-0.025	-0.011	-0.001	-0.087	-0.058
	(0.049)	(0.061)	(0.096)	(0.088)	(0.064)
Log(1+Number of Competitors)	0.081***	0.107***	0.010	0.099***	0.097***
	(0.014)	(0.018)	(0.016)	(0.022)	(0.017)
Industry Failure Rate	1.390***	1.580***	0.875***	1.547***	1.249***
	(0.050)	(0.060)	(0.124)	(0.073)	(0.068)
Percent of Industry Matured Projects	0.174***	0.214***	0.035	0.260***	0.150***
	(0.030)	(0.048)	(0.032)	(0.050)	(0.037)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	13,394	8,253	4,941	6,234	7,131
R-squared	0.195	0.227	0.174	0.234	0.200
Adjusted *R*-squared	0.134	0.134	0.069	0.145	0.119

Table 6. Competition and Effects of FDAAA on Suspension

This table presents results from the test that examines the effect of competition on suspension decisions after the FDAAA using clinical trials data from the BioMedTracker database for our sample period from 2002 to 2012. The dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. High Competition (Indicator) is one if the total number of drug projects in the same indication as a given project in a given year is greater than the sample median and zero otherwise. Non-Expedited Drugs (Indicator) is one if the drug project is not designated as an FDA-expedited program, including fast track, breakthrough therapy, and orphan drug and zero otherwise. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Suspension (Indicator)			
	(1) High Competition	(2) Low Competition	(3) Non-Expedited Drug	(4) Expedited Drug
Post (Indicator)	0.041***	0.031***	0.056***	0.026*
	(0.011)	(0.009)	(0.009)	(0.013)
Project with Partner (Indicator)	-0.042***	-0.022**	-0.036***	-0.069***
	(0.010)	(0.010)	(0.008)	(0.018)
Log(1+Number of Projects)	-0.009	-0.031*	-0.019	-0.045*
	(0.021)	(0.017)	(0.016)	(0.027)
Project Diversification	0.117**	0.092**	0.107***	0.107*
	(0.051)	(0.044)	(0.038)	(0.057)
Percent of Matured Projects	0.119***	-0.004	0.087**	0.027
	(0.044)	(0.041)	(0.037)	(0.053)
Percent of Projects with Partner	0.045	-0.040	-0.022	-0.007
	(0.052)	(0.044)	(0.040)	(0.069)
Log(1+Number of Competitors)	0.091***	0.086***	0.073***	0.086***
	(0.014)	(0.014)	(0.012)	(0.018)
Industry Failure Rate	1.309***	1.200***	1.266***	1.050***
	(0.077)	(0.035)	(0.040)	(0.066)
Percent of Industry Matured Projects	0.352***	0.080***	0.144***	0.098***
	(0.061)	(0.017)	(0.019)	(0.032)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes
Observations	9,997	6,868	13,808	3,081
R-squared	0.154	0.350	0.215	0.277
Adjusted *R*-squared	0.108	0.267	0.159	0.154

Table 7. Financial Constraints and Effects of FDAAA on Suspension

This table presents results from the test that examines the effect of financial constraints on suspension decisions after the FDAAA using clinical trials data from the BioMedTracker database for our sample period from 2002 to 2012. The dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. We divide the sample into two subsamples of firms with high and low financial constraints (Altman Z-score for public sample and VC-backed for private sample) in the pre-FDAAA period. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Suspension (Indicator)			
	(1) Public Sample with High Financial Constraint (Z-Score)	(2) Public Sample with Low Financial Constraint (Z-Score)	(3) Private Sample without VC-Backed	(4) Private Sample with VC-Backed
Post (Indicator)	0.100***	0.041*	0.080***	0.026
	(0.021)	(0.020)	(0.019)	(0.023)
Project with Partner (Indicator)	0.012	-0.052***	-0.025	-0.002
	(0.025)	(0.009)	(0.021)	(0.045)
Log(1+Number of Projects)	0.028	0.126	-0.040	-0.044
	(0.026)	(0.104)	(0.044)	(0.040)
Project Diversification	0.079	-0.335	0.090	0.150
	(0.083)	(0.210)	(0.098)	(0.092)
Percent of Matured Projects	-0.023	0.254	-0.020	0.012
	(0.066)	(0.178)	(0.086)	(0.082)
Percent of Projects with Partner	0.094	-0.085	-0.090	-0.141
	(0.088)	(0.309)	(0.110)	(0.099)
Log(1+Number of Competitors)	0.060***	0.058	0.074***	0.098***
	(0.022)	(0.046)	(0.027)	(0.028)
Industry Failure Rate	1.061***	1.304***	1.114***	1.269***
	(0.089)	(0.124)	(0.101)	(0.114)
Percent of Industry Matured Projects	0.065	0.038	0.064	0.100
	(0.052)	(0.039)	(0.042)	(0.064)
Size	-0.022	0.016		
	(0.013)	(0.060)		
R&D Expense/Assets	-0.015	-0.396		
	(0.009)	(0.382)		
Firm Fixed Effects	Yes	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes
Observations	2,664	2,588	2,134	2,122
R-squared	0.264	0.255	0.276	0.301
Adjusted *R*-squared	0.172	0.191	0.128	0.149

Table 8. Public Status and Effects of FDAAA on Suspension

This table presents results from the test that compares the effects of public status on suspension decisions after the FDAAA using clinical trials data from the BioMedTracker database for our sample period from 2002 to 2012. The dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. We consider a sample that is sponsored by publicly listed companies (Columns 1 and 2), and is sponsored by private companies (Columns 3 to 4). The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Suspension (Indicator)			
	(1)	(2)	(3)	(4)
	Public Sample	Public Sample	Private Sample	Private Sample
Post (Indicator)	0.043***	0.039***	0.046***	0.063*
	(0.009)	(0.012)	(0.016)	(0.037)
Project with Partner (Indicator)	-0.042***	-0.043***	-0.020	0.054
	(0.007)	(0.008)	(0.019)	(0.046)
Log(1+Number of Projects)	-0.010	0.015	-0.050*	0.053
	(0.018)	(0.027)	(0.027)	(0.084)
Project Diversification	0.051	-0.039	0.126*	-0.003
	(0.043)	(0.063)	(0.067)	(0.120)
Percent of Matured Projects	0.073*	0.056	-0.033	-0.074
	(0.041)	(0.051)	(0.058)	(0.129)
Percent of Projects with Partner	0.013	-0.025	-0.094	-0.252
	(0.046)	(0.073)	(0.067)	(0.217)
Log(1+Number of Competitors)	0.072***	0.056***	0.083***	0.167***
	(0.013)	(0.017)	(0.018)	(0.057)
Industry Failure Rate	1.223***	1.219***	1.186***	1.137***
	(0.040)	(0.060)	(0.075)	(0.165)
Percent of Industry Matured Projects	0.146***	0.114***	0.100***	0.247
	(0.022)	(0.022)	(0.033)	(0.175)
Size		-0.012		
		(0.014)		
R&D Expense/Assets		-0.007		
		(0.009)		
Log(1+Total VC Funding)				-0.023
				(0.025)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes
Observations	12,572	7,565	4,270	748
R-squared	0.207	0.202	0.270	0.358
Adjusted *R*-squared	0.158	0.149	0.149	0.098

Table 9. Effects of FDAAA on Drug Quality: Adverse Event Reports (AER)

This table presents results from the test that examines the effects of the FDAAA on drug quality using adverse event reports from the FDA Adverse Event Reporting System (AERS) data for the drugs in our sample for the period from 2004 to 2012. The AERS data start in 2004. We restrict our sample to FDA-approved drugs that are approved in and after 1990. In Columns 1 and 2, Log(1+Number of AER Primary Suspect) is the log of one plus the total number of adverse event reports (AER) for the drug in a given year in which the drug is reported as primary suspect. In Columns 3 and 4, Log(1+Number of Serious AER Primary Suspect) is the log of one plus the total number of AER in which the patient outcome is one of the following serious conditions: death, life-threatening, hospitalization, disability, congenital anomaly, or required intervention to prevent permanent impairment and damage, and the drug is reported as a primary suspect. Project Initiation After FDAAA (Indicator) is an indicator variable that takes the value of one if the drug project is initiated after the passage of FDAAA in 2007 and zero otherwise. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Log(1+Number of AER Primary Suspect)		Log(1+Number of Serious AER Primary Suspect)	
	(1)	(2)	(3)	(4)
Project Initiation After FDAAA	-0.678*	-0.623*	-0.658*	-0.610*
	(0.352)	(0.359)	(0.344)	(0.348)
Years from Approval	-0.064***	-0.132***	-0.058***	-0.124***
	(0.011)	(0.027)	(0.011)	(0.027)
Project with Partner (Indicator)		0.678***		0.679***
		(0.169)		(0.158)
Project Diversification		0.716		0.726
		(0.709)		(0.706)
Log(1+Number of Projects)		-0.683**		-0.635**
		(0.313)		(0.306)
Percent of Matured Projects		-0.201		-0.132
		(0.720)		(0.704)
Percent of Projects with Partner		-0.504		-0.690
		(0.547)		(0.534)
Log(1+Number of Competitors)		0.055		0.050
		(0.145)		(0.139)
Industry Failure Rate		2.119**		1.821*
		(1.030)		(0.994)
Percent of Industry Matured Projects		0.216		0.180
		(0.318)		(0.322)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	6,891	6,891	6,891	6,891
R-squared	0.574	0.556	0.567	0.559
Adjusted *R*-squared	0.547	0.528	0.539	0.532

Table 10. Likelihood of Delivering AER

This table presents results from the linear probability model regressions that examine the likelihood of receiving an adverse event reports using the FDA Adverse Event Reporting System (AERS) data for the drugs in our sample for the period from 2004 to 2012. The AERS data start in 2004. We restrict our sample to FDA-approved drugs that are approved in and after 1990. In Columns 1 to 2, the dependent variable is Primary Suspect in AER (Indicator) that is one if the drug is one of the primary suspects in an AER and zero otherwise. In Columns 3 to 4, the dependent variable is Primary Suspect in AER Serious Reports (Indicator) that is one if the drug is the primary suspect in an AER with serious patient outcome and zero otherwise. Project Initiation After FDAAA (Indicator) is an indicator variable that takes the value of one if the drug project is initiated after the passage of FDAAA in 2007 and zero otherwise. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Primary Suspect in AER Reports		Primary Suspect in AER Serious Reports	
	(1)	(2)	(3)	(4)
Project Initiation After FDAAA	-0.057**	-0.053**	-0.098***	-0.093***
	(0.024)	(0.022)	(0.024)	(0.023)
Years from Approval	-0.008***	-0.016***	-0.009***	-0.019***
	(0.002)	(0.005)	(0.002)	(0.005)
Project with Partner (Indicator)		0.020		0.034**
		(0.014)		(0.017)
Project Diversification		0.058		0.151
		(0.071)		(0.098)
Log(1+Number of Projects)		-0.076**		-0.093**
		(0.034)		(0.040)
Percent of Matured Projects		-0.024		-0.051
		(0.086)		(0.098)
Percent of Projects with Partner		-0.034		-0.082
		(0.063)		(0.064)
Log(1+Number of Competitors)		0.010		0.021
		(0.016)		(0.018)
Industry Failure Rate		-0.008		-0.103
		(0.127)		(0.216)
Percent of Industry Matured Projects		0.018		0.054
		(0.035)		(0.037)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	6,886	6,886	6,886	6,886
R-squared	0.359	0.362	0.379	0.384
Adjusted *R*-squared	0.319	0.322	0.340	0.345

Table 11: Disability-Adjusted-Life-Years (DALY) by Active Project Growth

This table examines how the changes in active project growth rates and in suspension rates between the pre- and post-FDAAA periods are associated with changes in DALY at the indication level. We use the two points DALY data from the WHO for 2000 and 2016. We divide indications into the two groups of high and low active project growth rates between pre- and post-FDAAA periods in (a) and (b), respectively. The significance in the column, Difference (a)-(b), is based on *t*-statistics for the t-tests for the equality of means in the two groups. In Panel A, we compare the differences between pre- and post-FDAAA active project growth rates and suspension rates for the two indication groups, (a) and (b). In Panel B, we quantify the changes in the Burden of Disease based on DALY for each indication group and compare the differences for the two indication groups, (a) and (b). DALY (million years) are the years lived with disability and the years of life lost due to that disease in millions. DALY (%) represents the fraction of DALY attributable to a given disease in DALY for any disease. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A. Changes in Active Project Growth Rates and Suspension Rates

	(a) Indications with low active project growth	(b) Indications with high active project growth	Difference (a)–(b)	*t*-stat
Difference, Post – Pre:				
(1) Active projects growth rates	-0.462	0.049	-0.511***	-11.74
(2) Suspension rates	0.070	0.031	0.038**	2.39
Observations	69	66	135	

Panel B. Changes in the Burden of Disease Based on DALY

	(a) Indications with low active project growth	(b) Indications with high active project growth	Difference (a)–(b)	*t*-stat
Pre-FDAAA period, 2000:				
(1) DALY (million years)	91.900	100.542	-8.643	-0.76
(2) DALY (%)	3.26%	3.57%	-0.31%	-0.76
Difference, 2016 – 2000:				
(3) DALY (million years)	-2.800	-21.483	18.683**	2.60
(4) DALY (%)	0.08%	-0.59%	0.67%***	2.63
Percentage Change:				
(5) (2016 DALY – 2000 DALY) / 2000 DALY	4.21%	-8.27%	12.48%**	2.08
Observations	69	66	135	

Appendix Table A.1 Effects of the FDAAA on Disclosed Project Suspension

This table presents results from the OLS regressions (Columns 1 and 2) and the Probit regressions (Columns 3 and 4) using clinical trials data from the BioMedTracker database for our sample period from 2002 to 2012. In Columns 1 to 2, the sample consists of 16,897 new drug project-year observations. The dependent variable is Disclosed Suspension (Indicator) that takes the value of one if a suspension announcement is made for the project in a given year and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Disclosed Suspension (Indicator)			
	Linear Probability Model		Probit Model	
	(1)	(2)	(3)	(4)
Post (Indicator)	0.127***	0.041***	0.910***	0.120*
	(0.007)	(0.008)	(0.046)	(0.069)
Project with Partner (Indicator)		-0.045***		-0.295***
		(0.007)		(0.046)
Log(1+Number of Projects)		-0.003		0.229
		(0.013)		(0.141)
Project Diversification		0.061**		1.061***
		(0.030)		(0.317)
Percent of Matured Projects		-0.022		0.099
		(0.027)		(0.380)
Percent of Projects with Partner		0.049		0.380
		(0.030)		(0.301)
Log(1+Number of Competitors)		0.027***		0.397***
		(0.009)		(0.090)
Industry Failure Rate		0.907***		7.410***
		(0.044)		(0.261)
Percent of Industry Matured Projects		0.091***		0.386
		(0.015)		(0.286)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes
Indication Fixed Effects	Yes	Yes	Yes	Yes
Observations	16,897	16,897	13,273	13,273
R-squared	0.120	0.185		
Adjusted *R*-squared	0.063	0.131		
Pseudo *R*-squared			0.144	0.262

Appendix Table A.2. Difference-in-Differences with Indication and Year Fixed Effects

This table presents results from the difference-in-differences tests using clinical trials data from the BioMedTracker database and the ClinicalTrial.gov database for the sample period from 2004 to 2010. The sample consists of 16,734 new drug project-year observations that include both industry-sponsored projects and academic-sponsored (non-industry-sponsored) projects. We exclude industry-sponsored projects that have no matched-indication in academic projects. Industry-Sponsored Project (Indicator) is one if the project is funded by industry sponsors and zero if the project is funded by non-industry sponsors (e.g., university, public hospital, NIH). The dependent variable is Suspension (Indicator) that takes the value of one if the project is suspended in a given year or has no progress update for the duration longer than the 90th percentile of the sample duration with the same phase and zero otherwise. Post (Indicator) is an indicator variable that takes the value of one for project-years in the post-FDAAA period and zero for the pre-FDAAA period. Indication X Year Fixed Effects are included instead of indication fixed effects and year fixed effects separately. The detailed descriptions of other variables are available in Appendix B. Standard errors reported in parentheses are robust clustered by firm. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Suspension (Indicator)				
	(1)	(2)	(3)	(4)	(5)
Post (Indicator) X Industry-Sponsored Project (Indicator)	0.180***	0.181***	0.176***		
	(0.022)	(0.021)	(0.019)		
Industry-Sponsored Project (Indicator)	-0.036*	-0.069***			
	(0.020)	(0.021)			
Year t-1 X Industry-Sponsored Project (Indicator)				0.066	0.062
				(0.065)	(0.064)
Year t X Industry-Sponsored Project (Indicator)				0.119**	0.115**
				(0.056)	(0.055)
Year t+1 X Industry-Sponsored Project (Indicator)				0.214***	0.215***
				(0.062)	(0.061)
Year t+2 X Industry-Sponsored Project (Indicator)				0.270***	0.278***
				(0.060)	(0.059)
Year t+3 X Industry-Sponsored Project (Indicator)				0.317***	0.328***
				(0.064)	(0.062)
Control Variables	No	Yes	Yes	No	Yes
Indication X Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Entity Fixed Effects	No	No	Yes	Yes	Yes
Phase Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	11,758	11,758	11,720	11,720	11,720
R-squared	0.129	0.134	0.207	0.205	0.208
Adjusted *R*-squared	0.030	0.035	0.055	0.053	0.055