The America Invents Act and Innovation by Small Entities

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Abstract

This paper studies patenting activity by small U.S. entities before and after the passage of the Leahy-Smith America Invents Act (AIA) of 2011 which changed the patenting rule in the United States from a first-to-invent to a first-inventor-to-file. The AIA's goals were to encourage patenting and provide certainty by curbing litigation. Contrary to the AIA's intentions, the results indicate a decline in patenting activity post-AIA for all entities, and a widened gap between the small and large entities when compared to the pre-AIA period. Moreover, entities with a greater exposure to litigation drop their patenting activity as compared to the entities with a lower exposure, and among the exposed, the small entities report a further drop in their activity. Prior to the AIA, entities had the benefit of flexibility on when to file for patents but this benefit came at a cost; it created uncertainty in an atmosphere of litigative behavior about the date of the invention. To check litigation, the AIA encouraged early disclosure of inventions, but this added to the already constrained budget of the small entities. This paper contributes in the following way: first, studies the effects of the AIA on small entities and empirically tests its predictions laid out prior to the legislation's enactment, and second, adds clarity to the understanding of the costs and benefits that the smaller entities face while innovating and their differences with the larger entities.

JEL codes: O31, O34, L25

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1 Introduction

The Leahy-Smith America Invents Act (AIA) of 2011 substantially changed the patenting rules in the United States by adopting a first-inventor-to-file (FITF) rule. The goals of the AIA were to reduce uncertainty in patenting and thereby encourage disclosure of inventions through patents.[1] A FITF rule recognizes the *first filer* of an invention as the sole inventor, as opposed to a first-to-invent (FTI) rule, which recognizes the *first inventor*, regardless of the filing date. Through the new rule, FITF, the AIA aims to curb a portion of lawsuits by taking away the flexibility in the date of filing. The previous rule, FTI, provided an inventor the flexibility of inventing first without the thought of filing. While this rule is beneficial to inventors, because they can focus solely on the invention, it also generates uncertainty on when a patent is actually filed. This uncertainty attracts lawsuits, which are not conducive to innovation and this motivated the AIA. Unfortunately, the solution provided through the AIA — recognizing the first filer — implicitly asks an inventor to rush to the patent office immediately after invention, and entities with constrained budgets, such as the small entities, may not have the luxury of doing so.[2] Small entities behave differently, have markedly different patenting strategies than large entities, introduce disruptive inventions, drive innovation in new directions, and are litigated at a higher rate (Aghion et al., 2021; Abrams et al., 2019). It is unknown how they modified their portfolio of patenting activity i.e. their quantity and quality post-AIA. Patents' quality can be heterogenous, and have changed in past as strategic response to change in incentives to patenting (Mezzanotti, 2021). This paper studies the quantity and quality of patents applied at the U.S. Patent and Trademark Office (USPTO) by the small entities relative to the large entities before and after the passage of this legislation.

[1] An invention can be kept secret, or can be disclosed to the public, either freely or through patents. Disclosure proliferates follow-on invention. But, the definition of disclosure of an invention can vary with contexts, and so does its intensity. From only declaring the name of a new invention, to a few mentions on certain websites without its specifics to laying down the exact steps to recreate it, everything can be counted as its disclosure. See De Rassenfosse et al. (2020) and Rantanen (2012) for a discussion on disclosure, patents and its relation to follow-on invention.

[2] A small entity can be a person, a small business concern, or a nonprofit organization. If the entity is a small business, it is defined to have less than 500 employees. Universities and institutes of higher education are categorized under nonprofit organizations. See: https://mpep.uspto.gov/RDMS/MPEP/e8r9#/e8r9/d0e30961.html

The United States followed a different set of patenting rules in comparison with the rest of the major patenting countries for centuries because both the set of rules have their benefits and costs, and the understanding and beliefs of these measures can vary by country because a substantial part of these benefits and costs are immeasurable. As a result, the theoretical comparisons between FITF and FTI rules do not yield a clear winner in terms of proliferation of innovation; rather both can be conducive to innovation under given conditions (Miyagiwa, 2015; Scotchmer and Green, 1990). In practice, however, litigation is uncertain and can seriously undermine the validity of patents and therefore discourage patenting. This also has a cascading effect on follow-on inventions (Mezzanotti, 2021; Kiebzak et al., 2016; Tucker, 2013; Lanjouw and Schankerman, 2001). On the flip side, a FITF rule limits a part of these litigations but comes at a cost of quickly filing for patents as soon as an invention is completed. Anecdotes from the U.S. small entities suggest that these entities often invent first and then search to secure resources to file the invention as a patent, which is not only limited to funds, but also assistance from attorneys and agents.[3,4] Needless to say that these entities have to also worry about their idea being stolen, now more than before. The U.S. Congress members therefore were divided when the AIA was discussed. [5] The AIA aimed to curb the increase in litigation, and also included provisions to limit the increase in costs of filing patents for smaller entities and in particular the individual inventors.[6] Further, to study the effects of the AIA on small entities, a study was comissioned (Lerner et al., 2015). Due to a large number of pending patent applications which resulted in severe lack of data at the time when the study started, the authors could not provide a definite answer as to whether the AIA

[3]https://www.nytimes.com/2012/02/09/business/smallbusiness/business-owners-adjusting-to-patent-system-overhaul.html

[4]In 2015, the cost of filing a patent in the United States ranged from $6000 for an "extremely simple" patent application, to more than $19,000, for a "highly complex" patent application. https://www.ipwatchdog.com/2015/04/04/the-cost-of-obtaining-a-patent-in-the-us/id=56485/

[5]Senator Feinstein's argument on the AIA being detrimental to the small entities: "[t]his presents a particular hardship for independent inventors, for startups, and for small businesses, which do not have the resources and volume to employ in-house counsel but must instead rely on more-costly outside counsel to file their patents. This added cost and time directed to filing for ideas that are not productive will drain resources away from the viable ideas that can build a patent portfolio–and a business."

[6]The AIA created a new category of inventors, called "micro entity", who can avail 75 percent discount in all fees. This is discussed in detail in Section 2.1

was beneficial or harmed the small entities' patenting activity.[7] Therefore, we still do not know if these provisions were enough to offset the increase in costs of patenting for the small entities and provide a net benefit. Thus, this paper studies and provides evidence of changes in patenting activity before and after the AIA in the United States with a focus on small entities. In particular, this paper asks the following question: Did small entities patent more than before and relative to the large entities post-AIA? Patent counts do not indicate if an invention is truly new, or if it is written clearly enough to be replicated by experts — all of which if true, can indicate a patent is of high-quality (Hall et al., 2004). Therefore, I also ask another question for a comprehensive understanding of the total effect of the AIA on the patenting activity of small entities: Were the patents filed by small entities of higher quality than before and relative to the large entities post-AIA?

Though early evidence indicates a reduction in disclosure of inventions by larger entities post-AIA; for the smaller entities, the evidence remains inconclusive partly due to limitations in the data and partly due to unexplored and thus undefined scope of innovative activity in small entities (Lerner et al., 2015; Huang et al., 2020). On top of the different incentives experienced and innovative behavior exhibited by the small entities, which the corporates do not adequately represent; evidence from an AIA-like reform from Canada reports adverse effects on small firms and individual inventors upon its implementation (Abrams and Wagner, 2013; Lo and Sutthiphisal, 2009). This further warrants identification of small entities and studying the AIA's effect on their patents.

To address these questions, I connect various datasets from the USPTO and add entity-level disambiguated identifiers from the Patentsview database to construct an entity-quarter level dataset. I use the number of patent applications applied by different entities as an indicator of invention disclosure, which is the broadest indicator of innovative activity at the entity level. The number of patent applications captures the resulting effect of all the policy changes the AIA introduced, and this approach to the

[7] Two major limitations, as the authors note: "Only a small amount of data exists for patent activity under the FITF rules since (a) the FITF provision became effective on March 16, 2013 and (b) there was still, at that point, a major backlog of patents under the old system because the patenting process — from application to issue/abandonment — took close to 2.5 years for fiscal year 2013. The complexity of the law has led to varying interpretations from small businesses and small business investors, which has likely been reflected in varying responses."

data is in line with the literature. To measure the change in the quality of patents, I use the number of citations a patent received in its first two years of issue per patent. These two measures used for the main set of analyses are not the only measures of quantity and quality of innovation. In recent years, the value of innovation captured through changes in stock value for public entities as well as measures of quality developed from patent texts have been widely used as a proxy for patent value (Kogan et al., 2017; Kelly et al., 2018). These different measures highlight a particular dimension of innovation and none are adequate on their own. Therefore, I will show in this paper a range of alternative specifications and alternative measures in an effort to highlight the nuances of patent analysis and corroborate my findings.

Using a difference-in-differences approach, this paper reports a relative decline in the number of patent applications and an increase in citation per patent for the small entities after the AIA as compared to the large entities. Among the small entities exposed to litigation, I observe a drop in their number of patents and citations per patent on top of the total drop experienced by the small entities post-AIA. The publicly listed small firms report no change in patenting activity compared to the large entities post-AIA, confirming that small entities listed publicly do not sufficiently represent the 30 percent of small unlisted firms and independent inventors.

Answering these questions contributes to the following: First, it estimates the change in patenting activity by small entities post-AIA compared to them pre-AIA and relative to the large entities, which was a longstanding concern among the U.S. Congress members wary of the detrimental effects of AIA on small inventors; and second, it contributes to the understanding of the benefits and costs of the public sector induced incentives to stimulate innovation disclosures among different types of entities.

The remainder of the paper is organized as follows: in Section 2 I detail the provisions of the AIA and compare it with other countries. In Section 3, I list the data sources, the sample selection, and the definition of the variables. Next, in Section 4, I explain the empirical strategy, and lastly, in Section 5, I discuss the inferences derived from the estimates. Finally, I conclude by summarizing my findings in Section 6.

2 The America Invents Act (AIA) of 2011

2.1 Provisions of the AIA

The U.S. patent regime underwent significant changes since World War II and the most recent amendment to the 35 U.S. Code—the America Invents Act of 2011 is regarded as the most substantial one since the Patent Act of 1952, changing the regime from First-to-Invent (FTI) to First-Inventor-to-file (FITF) (Lerner, 2000).[8] Under an FTI rule, an inventor had the option to claim that they are the original inventor even if another inventor had filed a patent application for a similar invention before theirs. Under a FITF rule, the inventor who files for patent rights first is the rightful owner of the patent. Pre-AIA, the invention date could be used to claim rights that do not matter post-AIA, and instead the date of filing matters (Masur and Ouellette, 2020). While the former rule provided flexibility to an inventor as to when to file for patent rights, entities could abuse this flexibility for strategic advantages. A group of entities, commonly known as "patent trolls" or Non-Performing Entities (NPEs) is those who do not invent; but rather acquire patents and assert their rights to invalidate other patents. Such entities wait for other inventors to file for a similar patent application as theirs or start producing a product that uses an invention similar to theirs. When the producing entities apply for patent rights or start production, the NPEs file for injunctive relief and ask for hefty royalty for infringement. This action is known as a hold-up. Due to the fear of hold-ups or infringing upon other patents, inventors restrict the disclosure of their inventions. As a result, the innovation of an economy does not reach its optimum level (Tucker, 2013).

The AIA's FITF rule tries to address the problem of unnecessary lawsuits partially. While not all kinds of patent lawsuits will be taken care of by the implementation of the AIA, at least for the cases related to the invention date, the AIA tries to establish a more certain regime by not providing the opportunity to contest conflicts on the date of invention. Pre-AIA, conflicts on the date of the invention were litigated under interference proceedings. An interference proceeding would be conducted when one patent application

[8] https://www.nytimes.com/2011/09/09/business/senate-approves-overhaul-of-patent-system.html

interferes with another in the process of its filing.[9] Post-AIA, this has been changed to derivation proceedings. Now, an entity cannot claim rights if they were late to the patent office. But, if they can show that an invention already in patent office was derived from their invention, they can file for a derivation proceeding.

To cushion small entities from bearing the extra cost of quick filing, the AIA implemented certain provisions. The AIA sets up two programs to assist small entities to file their patent applications, called the Pro Bono Program and the Patent Ombudsman for Small Businesses. The Pro Bono Program provides the qualifiers with free legal assistance in preparing and filing patent applications. [10] The Patent Ombudsman program assists applicants when a normal application stalls. [11] The AIA defines a new category of entities, called "micro-entity" for whom the USPTO levies a discount of 75 percent on all patent filing fees. [12]

The AIA not only changed the patent rules, but introduces post grant review (PGR) and inter partes review (IPR), replacing the ex parte reexamination. Any third-party can challenge the validity of a patent, using PGR in the first nine months, and then using IPR. As opposed to an ex parte reexamination, where a third party could apply for reexamination of a granted patent but not have active participation in the proceedings, PGR and IPR allows the third party to actively take part in the challenge process. Introduction of new and cheaper ways to oppose a patent's validity can caution entities who operate in areas predominantly exposed to litigation. To put numbers, a court

[9] To understand interference proceedings and its relation to the AIA, I present an example. In a pre-AIA period, an invention i_1 came into existence at t_1 but was not filed at the patent office and an independent invention i_2, also in the pre-AIA period, was invented at t_2 ($t_2 > t_1$) and was filed as a patent application immediately. Here, invention i_2 interferes with invention i_1. Invention i_1 can still claim its patent rights or at the least negate i_2's patentability by conducting an interference proceeding, which will be conducted as a lawsuit. In the post-AIA period, in a similar situation, i_2's patent application will be upheld as the only patent application and i_1 can contest if it files for a derivation proceeding. Derivation proceeding replaced interference proceeding post-AIA and in the example, i_1 will claim that i_2 has been derived from i_1. But in the post-AIA period, invention i_2 will have stronger protection and i_1 will face higher costs because i_1 will have to show that i_2 has been derived from i_1 and not independently invented. A low count of interference proceedings does not mean that they are seldom used. Rather, it indicates that the patent applications prone to such opposition are deterred from filing.

[10] https://www.uspto.gov/patents/basics/using-legal-services/pro-bono/patent-pro-bono-program

[11] https://www.uspto.gov/patents/ombudsman-program

[12] A micro-entity is a small entity with additional thresholds. A micro-entity has to qualify for an income threshold, which is three times the median income household. Note that institutes of higher education are considered micro-entities. The detailed definition can be found here: https://www.uspto.gov/patents/laws/micro-entity-status

litigation can run to millions of dollars while PGR/IPR can be estimated to be at around $500,00 (Masur and Ouellette, 2020).

Lastly, the AIA also sets up Post Grant Review of patents. Any third party can file a petition to challenge the validity of one or all of the claims of a granted patent.[13]

2.2 Comparison with other countries and the unintended effects of the AIA

Most countries have always followed a FITF rule. To date, three countries have made a move from FTI to FITF. Since 2007, different patent reform bills have been highlighting the need of harmonizing the patent system in the US with the rest of the world, and by the advent of AIA, the US is the third and last country to make such a change (Matal, 2011a; Matal, 2011b). In 1989 and 1998 Canada and the Philippines made a similar move respectively.[14,15] Only a few studies exist on the evaluation of patenting activity by entity types around the AIA and the Canadian reform and no study evaluates the Philippines reform. A common theme from all the studies points toward no significant benefit to smaller entities after such a change.

In Canada, patenting activity skewed towards large firms compared to small and independent inventors after their reform (Lo and Sutthiphisal, 2009). Additionally, a drop in the number of patents is reported among independent inventors with no change in their patent quality (Abrams and Wagner, 2013). In the US, studies find a decline in innovative activity, especially among publicly traded firms, after the AIA. Huang et al. (2020) use narrative R&D disclosure of publicly traded firms to measure innovative activity and find a decline, especially for the innovative firms among all publicly traded post-AIA. A narrative R&D is different from the R&D expenditure reported by firms in their annual reports. The authors use the number of R&D-related sentences counted from the firms' 10-K filings. Measures developed from the 10-K filings are considered to be more revealing in terms of firms' innovation strategies and activities as compared to

[13] https://www.uspto.gov/patents/ptab/trials/post-grant-review

[14] Canada's reform: https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/wr04732.html

[15] Phillipines' reform: https://wipolex.wipo.int/en/text/488675

their annual reports (Merkley, 2014). But, a decline in R&D-related sentences does not necessarily mean a decrease in the number of patents. Also, Huang et al. (2020) study a specific group of innovative entities, the publicly traded firms. 10-K is not applicable for individuals and small entities but these entities participate significantly in innovative activity.

Though compared to pre-AIA, Huang et al. (2020) find a decline in R&D-related sentences for publicly traded firms post-AIA, their market returns did not significantly change (Lerner et al., 2015). Among the venture capital-backed firms (VC), Lerner et al. (2015) do not find any significant difference in their formative stage funding post-AIA. It is unknown how the other small entities, such as individual inventors, small firms not backed by VCs, and universities filed their patents before and after the AIA. In fact, the quantity and quality of patents for all entities before and after the AIA remain understudied. Neither 10-K filings nor information on VC fund disbursement completely capture the patenting activity of entities, but they do provide a direction to this paper. The mixed evidence of a decline or insignificant change in the innovative activity while the AIA encourages disclosure seems counter-intuitive. However, economics suggests that given different conditions we can observe either an increase or a decrease in the disclosure of inventions. AIA rewards early filers, which may result in a direct increase in patent applications. But, if an entity discloses one of its inventions, its competitors can preempt any pipeline of inventions that they may have had, which may be connected to a focal invention. Because FITF rewards the first filer as opposed to the previous rule of FTI where an inventor could furnish proof of invention date if another inventor filed for a similar invention, an entity may become secretive and only file patent applications when they are sure that their patent application will not be invalidated or their future work cannot be preempted.

In the case of the AIA, Huang et al. (2020) discuss a similar mechanism of holding back on patenting because of competitors' preemptive activity and therefore we observe a decline in narrative R&D disclosure post-AIA. Abrams and Wagner (2013) also discuss similar explanations for the decline in patents by individuals post-Canadian reform. Some of the possible explanations they discuss are fewer resources for individual inventors which makes it difficult to file quickly for multiple patents, a shift in the use of different intellectual property protection mechanisms such as trade secrets, or a shift to patenting in the US. The authors find significant evidence of an increase in Canadian inventors patenting in the US after the Canadian reform. This is one of the reasons why inferences from the Canadian case cannot readily predict the effects of the AIA. In Canada, inventors still had an option of enjoying First-to-Invent if they filed their application in the US. Therefore, it is possible that the Canadian entities shift their activity toward the US, especially because of their geographical proximity, as well as the US, being a hub for innovative activities. However, in the case of AIA, entities do not have an option to move their activity to another country where they could still enjoy the FITF rule. Therefore, concluding that reforms similar to the AIA always reduce innovative activity, especially by small entities may be misleading.

The other strategies as described in Abrams and Wagner (2013) may play out in the US, especially for small entities. Rather than shifting the patenting activity to another country, entities in the US could choose higher secrecy and file patent applications only for those inventions which they expect to prevail in the market. Economic theory suggests mixed effects of the AIA on invention disclosure (Scotchmer and Green, 1990). Empirically, it is unknown if its intended effects of achieving certainty were indeed achieved or not (Lerner, 2000; Vandenburg, 2013; Cerro, 2014).

2.3 Conceptual framework

The various components of the AIA inevitably overlap with one another. Because of this, even if AIA's FITF rule targets a specific group of lawsuits, the other policy changes provide greater certainty in securing patent rights in the post-AIA period compared to the previous regime. Therefore, the AIA affects all patent applications and not only those which were prone to litigation on the invention date. It may be impossible to decompose the overall effect of the AIA into the effects of the individual components of the policy. But, we know that the AIA's primary goal which encompasses all its components is to improve the innovative environment in the US. The way chosen by the AIA to improve is by favoring certainty over flexibility. Greater certainty should result in timely disclosure of inventions, which also translates to an increase in the number of disclosures. The rationale behind this change in policy is that the increase in welfare from increased disclosure surpasses the welfare from a flexible date of invention. The broadest and most direct measure of innovation that stems from this reasoning is the count of patent applications. Since the AIA encourages disclosure of inventions, I expect an increase in the number of patent applications post-AIA as an indicator of increased disclosure of inventions. This increase is not only expected from the existing entities but should also encourage new entities to disclose their invention. This is the first question this paper explores, for the small entities, did the number of patents increase after the AIA as compared to the large entities and themselves before the AIA? A higher number of patent applications without an increase in their quality of would not mean much. In fact, the AIA specifically mentions that enhancing patent quality is one of its goals. However, the AIA's goal of encouraging quality disclosure can be met with the opposite effect because entities may respond strategically, and like every policy, the AIA is also laced with unintended consequences. It is possible that even though the AIA encourages invention disclosure, it increases the cost of disclosure of follow-on inventions. It is therefore unknown if the quality and quantity of patent applications indeed increase as a result of the AIA. This is the second question this paper explores, did the quality of patents by the small entities increase after the AIA as compared to the large entities and themselves before the AIA?

3 Data

3.1 Data sources

The main results of this paper are estimated using all the patents applied for at the USPTO between and including the years 2008 and 2016. Since not all entities release their balance sheet information, such as their R&D expenditure, assets, number of employees, etc., but such characteristics are determinants of patenting behavior, I use a subset of all patents that are applied for by the publicly traded firms in a separate analysis. For this subset of patent applications, I can control for certain entity-level characteristics (also called firm-level, since they are publicly traded firms). The data sources of patent-level and firm-level characteristics are given below:

Patents: Patent Examination Research Dataset (PatEx) is the dataset compiled by the Office of the Chief Economist (OCE) at USPTO that contains patent-level characteristics for the patents applied in the US from the 1900s to 2020. [16] In this dataset each row is a patent application which contains all the relevant information the patent application's prosecution generated till date; for example, the application number, filing date, issue date (if granted), number of claims, etc. Entity names in the patent database are not standardized and Patentsview bridges this gap using disambiguation algorithms to standardize patent assignee names. I sum the relevant statistics for each quarter for each assignee using the Patentsview standardized assignee names. [17]

Firms: Compustat's North America data provides quarterly financial information from the quarterly balance sheets of the publicly listed firms.[18] The Center for Research in Security Prices (CRSP) provides daily stock prices of these firms.[19] I average the daily stock prices to a quarterly-level.

While Patentsview standardizes patent assignee names, they still have to be connected to the Compustat database to get their financial information. Also, firms merge or hold subsidiaries that may individually file for patents. They may be listed as a different firm in the patent database but the patent belongs to the parent firm. Kogan et al. (2017) (henceforth referred to as KPSS) and Arora et al. (2021)(henceforth referred to as ABS) bridge this gap by standardizing the firm names, connecting them to the patent database,

[16]Patent Examination Research Dataset: https://www.uspto.gov/ip-policy/economic-research/research-datasets/patent-examination-research-dataset-public-pair

[17]Patentsview is a collaborative project developed by the USPTO, American Institutes for Research (AIR), University of Massachusetts Amherst, New York University, University of California, Berkeley, Twin Arch Technologies, and Periscopic. See: https://patentsview.org/what-is-patentsview

[18]Compustat is accessed through Wharton Research Data Services (WRDS). https://wrds-www.wharton.upenn.edu/pages/about/data-vendors/sp-global-market-intelligence/

[19]Center for Research in Security Prices (CRSP) is accessed through Wharton Research Data Services (WRDS): https://wrds-www.wharton.upenn.edu/pages/about/data-vendors/center-for-research-in-security-prices-crsp/

and connecting the Compustat firms and their subsidiaries to one standardized name. I use their databases to obtain a sub-sample of publicly listed firms' patents.

Litigation: The Office of the Chief Economist (OCE) at USPTO recently compiled a dataset on cases involving patents filed at district courts in the United States from 1963 to 2016. This dataset is called the Patent Litigation Docket Reports (PLDR). From the PLDR, I create a measure of exposure to litigation.

3.2 Sample selection

There are three types of patents in the US: utility, design, and plant. Inventions relating to new products or processes, or their improvement are utility patents. The AIA's objectives are best represented by these inventions and therefore, in this paper, I only study the utility patents. Plant or design patents are granted to inventions that relate to the development of new plants and new designs, which may be unaffected by the aspects of the AIA this paper focuses. [20] Each row of the PatEx database is a patent application. The 2020 release of PatEx contains 16,514,638 patent application numbers. After removing design, plant, and blank patent applications, I have 15,811,897 patent applications. A patent application can appear multiple times in the dataset through continuations but will culminate in *one* granted patent.[21] A patent application appearing for the first time in the patent database is called a "parent" application, and all the connected applications, appearing later, are called its "children" applications. Multiple

[20]See USPTO patent process for details on the definitions of utility, plant, and design patents here: https://www.uspto.gov/patents/basics/patent-process-overview#step3

[21]At the USPTO, a patent application can be initially filed as a provisional or a non-provisional application. A provisional application may not contain claims or the specifics of the invention. Its primary use is to establish an effective filing date and should be followed by a non-provisional application, applied within 12 months of the provisional application's filing date. A non-provisional application is prosecuted by an examiner to determine its patentability. This type of application can further be continued as a continuation application, in-part continuation application, or divisional application can If an entity wishes to apply to more than one country, they may opt for a Patent Cooperation Treaty (PCT) application. If applied as a PCT application, the applicant has to choose the countries they wish to apply for patent rights. If an applicant wishes to file for patent protection in multiple countries, rather than applying to every country separately, the entity may choose to file the application as an international patent. This type of patent is also called a Patent Cooperation Treaty (PCT) application. The decision on grants is still given by the countries separately. For details refer here: https://www.wipo.int/pct/en/faqs/faqs.html Later, this enters the conventional application procedure, during which a new application number is assigned to the provisional or PCT application. Counting a PCT or a provisional and its conventional application counterpart as two different patent applications will result in double counting.

parent applications can be connected to multiple children applications. Using the parent and children continuation data from PatEx, I connect all the parents and their children to find the earliest application date. 13,537,926 patent applications contain a filing date.[22] I also restrict the dataset to patent applications that were applied between and including the years 2008 and 2016. I take patent applications post-2008 to avoid distortions from the financial crisis and till 2016 for comprehensive coverage of patent applications. The average grant lag of a patent is about four years and two standard deviations above the grant lag are about eight and half years at the USPTO.[23] Therefore, as years go by, the proportion of pending patent applications post-2016 would increase. For pending patent applications, information on citation is unavailable or scarce. The verdict for these applications, whether they will be granted or abandoned, is also unknown. To avoid these, I consider the patent applications that are applied on or before the end of 2016.

Restricting patent applications by year leaves me with 5,087,133 patent applications. Among these, 3,255,080 patent applications have a standardized assignee ID or an inventor ID in the Patentsview Database. The rest, 1,832,053 patent applications, do not have any ID. While these patent application numbers are unique in terms of their numbers or labels, they still can be a derivative of another application, as discussed earlier. In Appendix A.1, I provide a detailed discussion of the patent application numbers that do not have any ID and provide reasons as to why these applications are either insignificant or are repeats of the patent applications already in the main sample of patent applications that can be identified with a standardized ID.

There are 582,293 unique entity IDs that have applied for patent applications between and including the years 2008 and 2016. I use the standardized Patentsview assignee IDs, wherever they are available, and the standardized inventor IDs where the assignee IDs are unavailable. For the rest of the paper, I refer to the entity identifiers as entity IDs. An entity can be identified as either a company, or an individual, or a Government

[22] The patent application that does not contain a filing date usually are filed as a PCT application. In place of the filing date, such applications receive a World Intellectual Property Organization (WIPO) publication date. The USPTO records these patent applications as National Stage Entry (NST) when they are examined at the USPTO, they receive an application number, and they do contain a filing date at this point.

[23] Grant lag winsorized at the 5 and 95 percentile cutoffs post-2000.

entity. Assignee IDs are unavailable when an applicant is an individual. Each ID on average has 5.59 patent applications. Using the quarter of the earliest application date of each patent and the entity IDs, I sum or average all the variables at the entity-quarter level. I detail all the variables in the next section. 3,255,080 patents by 582,293 IDs are reduced to an unbalanced panel of 1,783,604 entity-quarter rows. Among these, 730,343 entities appeared only once in the sample, and therefore cannot be compared within entity. These observations are singletons. Singletons in models with entity fixed effects where the standard errors are clustered may overstate the number of clusters and hence the statistical significance (Correia, 2015). I, therefore, report the main results without the singletons. The results of this paper however remain unchanged even with the inclusion of the singletons, as we will observe while discussing the results in Section 5. The final sample for the main set of analyses, therefore, is 1,053,261 entity-quarter observations. The concern is evident about entities self-selecting themselves into pre and post-AIA depending on their objectives. The unbalanced panel used in estimating the main results does not have zeroes when an entity does not file for any patent application for a given quarter. I address this issue by adding zeroes for the quarters where an entity does not patent, thereby balancing the entity-quarter panel and replicating the main analyses in Appendix A.2.

Next, I use patent number-*PERMNO* match from Kogan et al. (2017) to identify patents by publicly traded firms.[24] *PERMNO* is the permanent issue identifier as provided by CRSP data. There are 2,075 unique *PERMNO*s in Kogan et al. (2017) who had applied for patent applications between 2008 and 2016. I also use Arora et al. (2021) to match the *PERMNO*s with the Compustat identifier, *GVKEY*. There are 1,374 unique *GVKEY*s who had applied for patent applications between 2008 and 2016. For the firm-level analyses, I have 1,374 publicly traded firms' characteristics and their patent applications. Different studies employ their own assignee standardization method but Arora et al. (2021) corrects for mergers, acquisitions, and patent reassignment. From the 3,255,080 patent applications, 1,309,860 patents can be identified as having a *PERMNO*

[24]The authors have released data updated till 2020. See: https://github.com/KPSS2017

and a *GVKEY*. These observations constitute the sample for the second set of analyses in Table 5.

3.3 Variables

3.3.1 Outcomes

I use two patent outcome measures as dependent variables to study the disclosure and the value of invention; log(1+number of patents) and log(1+number of citations per patent) within two years of issue of a patent. They are calculated at the assignee-quarter level. Older patents may have a higher number of citations and may be incomparable to the newer ones and therefore are capped at two-year after their issue.

Using the parent application number's date of filing, I create an indicator called *Post*. This variable takes a value of 1 if the patent application was applied for after March 16, 2013, and 0 otherwise. Note that I use the "parent" application number as opposed to the "patent" application number. This is because a patent application can claim priority to an earlier provisional or non-provisional application. Through this, an application filed later claims continuation from a previously filed application. If this happens, then the earliest application date is considered the application date for the patent application. In such cases, the patent applications filed post-AIA can still be under the purview of pre-AIA rules.

PatEx provides an indicator *Small Entity*, which takes a value of 1 if the patent application was filed by a small entity and 0 otherwise. A small entity is defined as a person, a small business concern, or a nonprofit organization, which includes universities and educational institutes. An entity is considered to be a small business concern if it meets the size standards, i.e. the total number of employees and affiliates should not exceed 500 persons at the time of application. The size is self-declared at the time of patent application and is not formally verified by the USPTO. A small entity receives a 50 percent discount on all patenting fees. An entity can file its patent as a small or a large entity, and the reasons for choosing either are unknown. [25] To keep the main

[25]If an entity that qualifies as a small entity transfers the rights of its patent to an undiscounted entity

results simple, I assume that within a quarter, if an entity files as a small entity once, the entity is a small entity for that quarter. In Appendix A.3, I relax this assumption to consider the proportion of patents filed as small among all patents an entity had filed for that quarter and replicate the main results.

3.3.2 Controls

A patent application is categorized in the United States Patent Classification (USPC) System. Each patent application is assigned a USPC class and subclass. Since there are numerous USPC classes, I aggregate them into six NBER categories and 36 NBER subcategories. The broad six categories are chemical, computer and communications, drugs and medical, electrical and electronic, mechanical, and others.[26] Since I am collapsing the patent-level statistics into the assignee-quarter level and an assignee can have patents in various categories in each quarter, I take the mode category. If there are multiple modes of categories, I randomly choose one category for that assignee-quarter.

Among the patent level controls, I sum the number of claims for each assignee-quarter. Claims are specific statements that define the uses of a patent. Claims are of two types, independent and dependent claims. The independent claims are the standalone statements defining the invention while the dependent claims define its boundaries and limitations. Until recently, claims were thought to be a mix of complexity and quality of patents, but Marco and Miller (2019) dispel a few confusions around the significance of claims. They find that the narrow claims have a greater probability of being granted. Along with this, claims' length and breadth are strategically written and fought with the examiner. Next, I use the log of experience of an applicant in USPTO. Finally, I also control for the number of patents that are maintained at the 4^{th} year post-grant. Maintenance or renewal of patents is a predictor of the quality of patents. The higher the quality, the greater the chance that the patent would be renewed (Bessen, 2008). These controls act to provide a stricter restriction to the estimates.

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partly or fully, then the patent will cease to be from a small entity. But, licensing to a federal agency or using the patent as a security interest does not preclude the entity's patent to be considered as one from a small entity.

[26] A concordance between NBER categories and USPC classes are provided in Hall et al. (2005)

From Kogan et al. (2017) and Arora et al. (2021), I obtain a patent-*PERMNO-GVKEY* match. I use this information to create a subset of patents summed at the firm-quarter level. For these firms, I observe different firm characteristics which come from their quarterly balance sheets. Following the literature, I control for their quarterly log number of employees, log number of assets, log R&D expenditure, and log of firm age since establishment (Hegde and Sampat, 2009).

3.3.3 Litigation exposure

Following Mezzanotti (2021), I define exposure to litigation as a weighted average of litigation in all NBER subcategories, where the weights are the shares of patents by an entity in a subcategory at a given time.

I calculate the proportion of litigation in each subcategory till time T, where $T = 1 + 2 + ... + t$ as the number of litigated patents in subcategory c till time T (L_{ct}) over the number of patents in subcategory c till time T (P_{ct}). Formally:

$$l_{cT} = \frac{L_{cT}}{P_{cT}}$$

Next, I calculate the proportion of patents in each subcategory c by entity i at time t as the number of patents by entity i in subcategory c at time t over the number of patents by entity i at time t. Formally:

$$p_{ict} = \frac{P_{ict}}{P_{it}}$$

To obtain entity level measure of exposure to litigation (e_{ict}), I calculate the average litigation till time T for all subcategories i.e. average of l_{cT} for all the 36 NBER subcategories and weigh each of the subcategories with the proportion of patents by an entity i in those subcategories at time t (p_{ict}).[27] Formally:

$$e_{ict} = \sum_{c=1}^{36} p_{ict} \times l_{cT}$$

[27]The NBER categories and subcategories are explained in Subsection 3.3

Table 1: Definition of the variables

Panel A: Quarterly patent data

Variable	Definition	Source
Log (1+no. patents)	Log(1+number of patents at entity-quarter)	PatEx
Log (1+2 yr citations/pat.)	Log(1+no. of citations within two years of issue per patent)	Patentsview
Post	1 if the patent was filed on or after March 16, 2013	
Small entity (SE)	1 if the patent was filed by a small entity; 0 otherwise	
Log experience	Log experience of assignee at the USPTO	
First patent	1 if the patent was the first patent for the assignee; 0 otherwise	PatEx
NBER category	Patent classified into one of the six NBER categories: chemical, computer and communications, drugs and medical, electrical and electronic, mechanical, and others	
Log number of claims	Log number of claims per patent	Patentsview
Renewal proportion	Proportion of patents renewed (maintained) at 4^{th} year	
Pending proportion	Proportion of patents pending as of Dec 2020	
Abandoned proportion	Proportion of patents abandoned	
Joint patent	Proportion of patents jointly applied	
Entity type	0 if company, 1 if individual, and 2 if Government	
Revealed tech advantage	Revealed technological advantage is a ratio of ratios the proportion of patents in category c (P_{ict}) out of all patents by entity i at time t (P_{it}) over the proportion of patents in category c (P_{ct}) out of all patents by all entities at time t (P_t) Formally: $\frac{\frac{\sum P_{ict}}{\sum P_{it}}}{\frac{\sum P_{ct}}{\sum P_t}}$	PatEx
Litigation exposure	Weighted average of shares of litigation litigation till time T in category c (L_{cT}) out of all patents till time T in category c (P_{cT}) weighted by patents by entity i in category c at time t (P_{ict}) out of all patents by entity i at time t (P_{it}) Formally: $\sum \frac{P_{ict}}{P_{it}} \times \frac{L_{cT}}{P_{cT}}$ where the time till date (T) is defined as $T = 1 + 2 + ... + t$	PLDR

Panel B: Quarterly firm data

Variable	Definition	Source
Log emp	Log number of employees	
(Log assets)/emp	Log assets per employee	Compustat
(Log R&D)/emp	Log R&D expenditure per employee	
Log age	Log age since establishment	
Log Market cap	Log(stock price $\times$ shares outstanding)	CRSP
KPSS value	Log real-KPSS value of patents	KPSS
PERMNO	CRSP firm identifier; identifies firms in KPSS	
GVKEY	Compustat firm identifier, identifies firms in Compustat; ABS provides GVKEY-PERMNO match	ABS

Panel A lists the variables used for the assignee level analyses. Panel B lists the variables used for the firm level analyses. Kogan et al. (2017) is abbreviated as KPSS, and Arora et al. (2021) is abbreviated as ABS. The variables *PERMNO* and *GVKEY* are not variables. From the assignee-quarter level patent data, the firm identifiers PERMNO and GVKEY are used to create a sub-sample of only-firm assignees.

3.4 Descriptive evidence

Figure 1 shows the number of applications filed each month at the USPTO since 1975. It also marks the months when the said amendments to the Patent Act were enforced. We observe spikes in patent applications during or after each amendment. After each spike, we also observe either a change in growth rate or a parallel shift in monthly patents or both. Along with the amendments to the Patent Act, certain patent lawsuits also delineate boundaries of patent rules by establishing case laws, which may affect patenting activity but such cases are not marked in the figure. The AIA came into effect as a law on September 16, 2011, which is the second red dotted line from the right. The FITF rule came into effect on March 16, 2013, shown by the rightmost red dotted line. A large spike in patenting can be observed in the month when the AIA's FITF rule was enforced. From the Great Recession to AIA, the growth in the number of patents was positive which dampened after the AIA spike. But, we can observe an increase in noise post-AIA. I investigate this further in Figure 2.

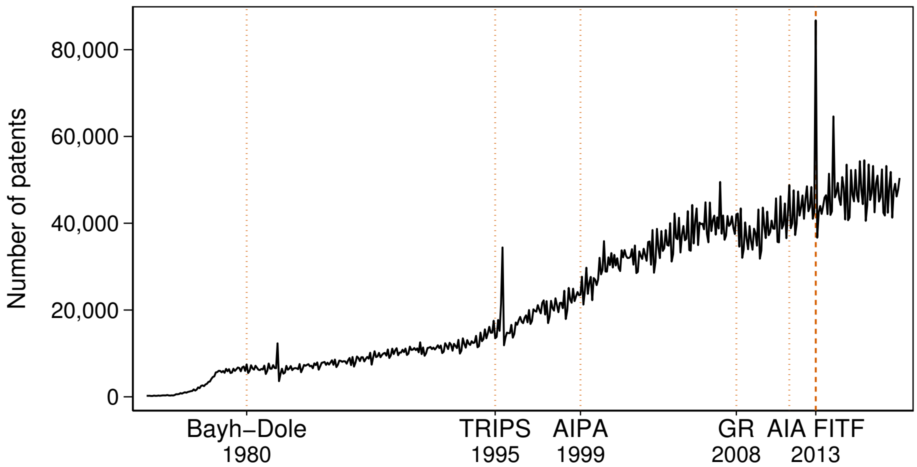

Figure 1: Patent applications filed each month
This figure plots total patents for each month from 1975 through 2018. The months of enforcement for the policies are Bayh-Dole Act (Dec 1980), Trade Related Intellectual Property Rights (Jan 1995), American Inventors Protection Act (AIPA; Nov 1999), Great Recession (Sept 2008), and America Invents Act (Sept 2011 and Mar 2013). Coverage of patents before 1981 is poor and only granted patents are observed till 1999. Post-1999, due to the introduction of pre-grant publication of patent applications, we see all barring the classified patents.

Figure 2 furthers the investigation of the patenting activity around the AIA by separating the patents into small and large entities. After a preliminary cleaning of raw patent application statistics, such as removing plant and design patents and restricting the dataset to observe patent applications only applied between 2008 and 2016, I plot Figure 2. It zooms in on the portion of Figure 1 after the Great Recession and plots the change in quarterly patents for the small and large entities. I move from the monthly number of patent applications to quarterly because of two reasons. First, it irons out the large monthly variations, making it easier to observe the pattern, and, second, in the latter part of the paper, I conduct a separate set of analyses for publicly traded firms for which quarterly financial statistics are available. In the estimations I also switch from the absolute number of patents to $log(1 + number\ of\ patents)$ because regressing large absolute values on small $X's$ or vice-versa makes the estimates unreadable, but in the figures I plot changes quarter-on-quarter for the absolute number of patents.

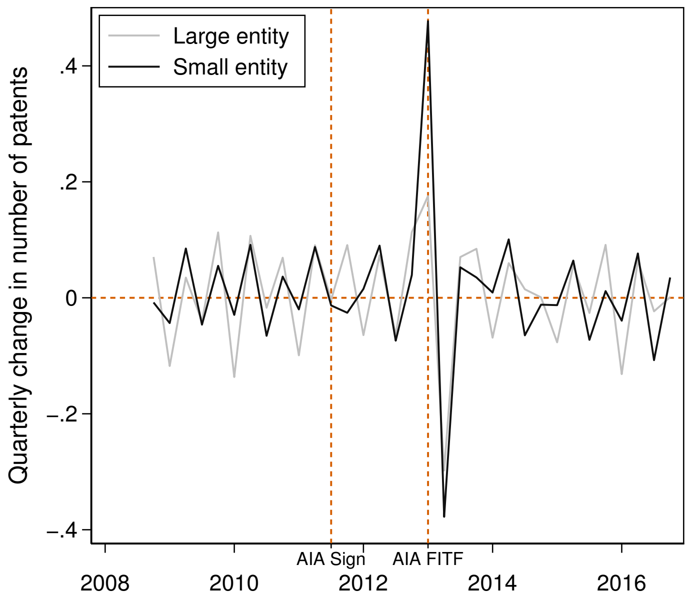

Figure 2: Patent applications by small and large entities
This figure plots quarter-on-quarter change in the absolute number of patents for small and large entities from 2008 to 2016.

We can observe similar trends for both small and large entities in Figure 2. In the USPTO database, entities are recorded as small entities or undiscounted entities. Undiscounted entities do not receive discounts in patenting fees and therefore are assumed to proxy large entities. The number of patents filed by large entities is always higher than the number of small entities, but the change quarter-on-quarter remains similar. Similar to Figure 1, quarterly patent applications grow quarter-on-quarter till the AIA's enforcement, and then the growth rate nears zero.

Not all patent applications are drafted equally. Some are of greater quality than others. The literature on innovation uses citations as a proxy to measure the quality of a patent. Citations can be added to a patent by the examiner and the applicant. Figure 3 plots the change in the number of citations per patent in the first two years after the issue of a patent quarter-on-quarter. Older patents will have an advantage here, and to limit that, I restrict the citations for the first two years after a patent's issue. The quarter in the x-axis is the patent application quarter, rather than the issue quarter since a patent issued post-AIA can still be applied for before the AIA. Small entities on average have a lower number of citations, similar to a lower number of patents. One of the key differences we observe here is that the change in citations start responding immediately after the AIA's sign, while the number of patents change only at the FITF's implementation. Variation in citation is also more than the variation in the number of patents.

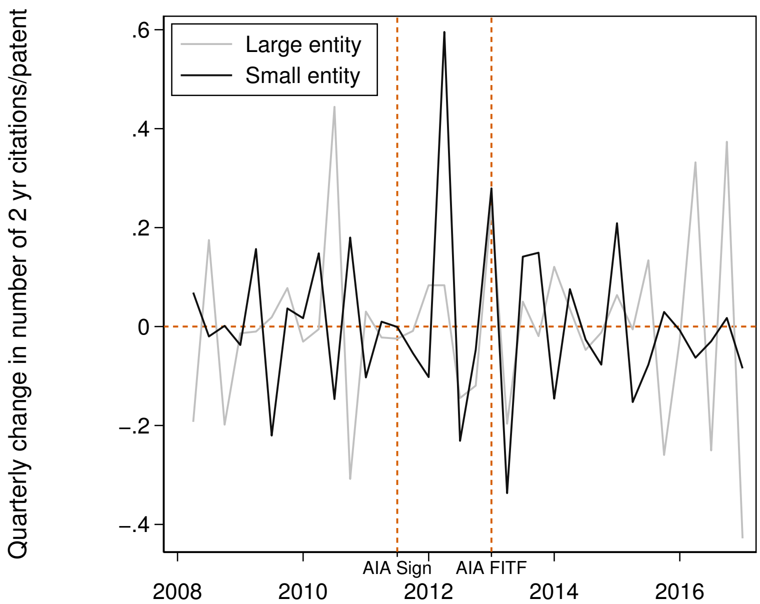

Figure 3: Citations/patent within two years
This figure plots quarter-on-quarter change in the absolute number of citations per patent within two years of issue for small and large entities from 2008 to 2016.

4 Empirical strategy

I estimate the change in the log(1+number of patent applications) and the log(1+number of 2-year citations per patent) at the assignee-quarter level using a difference-in-differences method. The number of patent applications and the number of citations proxy quantity and quality of inventions respectively. I compare the change in quantity and quality of inventions by small entities post-AIA with the inventions by the small and large entities pre-AIA.

The main set of results, as presented in Tables 2 and 5 use two different samples: all patenting entities and a subset of them — the publicly traded firms involved in patenting, respectively. Next, I develop a measure of exposure to litigation, following Mezzanotti (2021) and estimate the changes in the two outcomes for only the small entities. I use the measure of exposure to litigation as a continuous treatment, and the results are reported in Figures 6 and 7.

A crucial assumption of this paper hinges on is the comparison of small and large entities pre and post-AIA. I assume that if the AIA was not enacted, there would be no change in the rate of change of the number of patents and citations between small and large entities quarter-on-quarter. Also, by comparing discrete entity sizes i.e. small and large entities, I implicitly assume that size is an adequate measure to capture the resources the entities have in their disposal. This measure because of being discrete dampens the variation that I could have exploited in the estimation if I had a continuous measure of resources available to entities. One reason to use publicly listed firms is to allow for varying entity sizes.

The main set of results i.e. the entity level and the firm level analyses, are estimated using Equation 1, and the full specification is as follows:

$$Y_{it} = \beta_0 + \delta(Post \times SE_i) + X_{it}^{'}\beta + \lambda_i + \lambda_t + \varepsilon_{it} \tag{1}$$

Here Y_{it} denotes two outcome variables, the log(1+number of patents) for an assignee at each quarter and the log(1+number of citations per patent) received by an assignee at each quarter within two years of the patents' issue. The coefficient δ captures the change in the difference in Ys between the small and the large entities after the implementation of the AIA. I control for the assignee i and the quarter t's baseline using assignee and quarter fixed effects, given by a range of indicator variables and their coefficients in the matrices λ_i and λ_t respectively. I also control for a range of patent quality and complexity correlates denoted by the vector X_{it}. A discussion on these measures follows after the models used in this paper are explained.

I estimate this equation for the full sample, i.e. all the patenting entities, and for only the publicly listed firms. For the firm-level analyses, I employ additional firm-level controls, which control the firm's resources with greater precision than only using the information derived from their patenting behavior and entity size.

While δ reports the average of Ys for the small entities over all the quarters post-AIA, I also separate the effects by each quarter. This enables us to understand and verify if any pre-trend influences δ. The estimating equation is given by Equation 2. The full specification is:

$$Y_{it} = \beta_0 + \sum_{s \neq 0} (\beta_s \times 1[s = t] \times SE_i) + X'_{it}\beta + \lambda_i + \lambda_t + \varepsilon_{it} \tag{2}$$

In this Equation, β_s ranges from the first quarter of 2008 to the last quarter of 2016, barring the first quarter of 2013 i.e. when the AIA was implemented, which acts as the base quarter. The other coefficients have the same interpretation as in Equation 1.

The crucial assumption, as described previously, is the use of the large entities as a comparison group for the small entities. Therefore, I try to report the results from different perspectives, and argue that given the controls variables, the large entities can act as a comparison group for the small ones.

5 Results

5.1 Evidence from all small entities

In this section, I examine and report the change in two outcome variables: quantity of inventions — log(1+number of patent applications) and the quality of inventions — log(1+number of citations per patent) after the enactment of the AIA for all the small entities in the sample. The results are reported in Table 2. For this and all subsequent tables, I present four columns for each Y variable, where the first column is with and the second is without controls.

The estimate δ from Equation 1 reports how the gap between the small and large entities changes after the AIA's enactment. In Table 2, this is reported in the first row $SE \times Post$. The difference between the number of patents filed by the large and small entities is 2.8 percentage points, after the AIA's implementation. This indicates a relative drop in the filing of patents by an average small entity as compared to an average large entity post-AIA.

Table 2: Main results: log(1+patents) and log(1+citations/pat.)

	Patents		Citations	
	(1)	(2)	(3)	(4)
SE x Post	-0.0374***	-0.0254***	-0.0067***	-0.0081***
	(0.0030)	(0.0025)	(0.0017)	(0.0016)
Controls	No	Yes	No	Yes
Qtr F.E.	Yes	Yes	Yes	Yes
ID F.E.	Yes	Yes	Yes	Yes
Subcat F.E.	Yes	Yes	Yes	Yes
N	1053263	1052165	1053263	1052165

This table reports the gap in the number of patents, proxied by log(1+number of patents) and the number of citations, proxied by the log(1+number of 2yr citations/patent) between small and large entities post-AIA. The estimates are derived from the model $Y_{it} = \delta(Post \times SE_i) + X_{it}^{'}\beta + \lambda_i + \lambda_t + \varepsilon_{it}$, where i and t denote entity and quarter respectively, X_{it} denotes a range of patent and entity level controls as defined in Table 1, and λ_i, λ_t control for entity and quarter fixed-effects respectively. The entity-quarter level dataset consists of all patents applied between 2008 and 2016. The indicator variable SE takes value 1 if more than 50 percent of the patents for an entity was applied as a small entity, and 0 otherwise. *Post* takes value 1 if the patents were applied on or after the first quarter of 2013 i.e. the implementation of first-inventor-to-file rule in the United States.

Columns (1) and (3) report results without and (2) and (4) report with controls. P-values at 1, 5, and 10 percent are denoted by *, **, and ***. Standard errors are clustered at entity-level.

The time trends are controlled using quarter fixed effects. To minimize clutter, I plot the fixed-effects in a separate graph and is shown in Appendix A.4's Figure A8 and Figure A9. The trends exhibit a pattern similar to Figures 1 and 2, i.e. for the quarters after the AIA, we observe a decline in the growth rate quarter-on-quarter and a plateauing of the number of patents for all the entities. Note that in Equation 1, SE and ID fixed-effects capture the overall effects for small entities and each entity's mean number of patents. The quarter fixed-effects report a trend over and above the individual baselines of each entity as compared to the quarter when the AIA was enacted. In Figure 1, we observed that the filing of patents was increasing at a fairly constant rate over the years, especially after the Great Recession. This is followed by a spike in the number of patents, on the date of enactment of the AIA and finally is followed by a plateauing of the number of patents, or a near-zero growth rate.

The gap between small and large entities post-AIA, as measured by δ exhibit similarities with the results from Abrams and Wagner (2013), Lerner et al. (2015), and Lo and Sutthiphisal (2009). The results from the Canadian reform act as a reference for this study. Abrams and Wagner (2013) predicted a decline in the number of patents for small entities, especially among them the individual inventors. By and large, we do observe a similar effect. However, there are a number of nuances and divergences from the predictions as well which are discussed in the subsequent paragraphs.

The controls in the matrix X being measures of patents' quality and complexity are also laced with patenting strategies of entities. These patenting strategies are not impervious to the AIA. A change in incentives due to the AIA's introduction may induce a strategic response. Particularly, among the variables described in Table 1, the claims listed in a patent document are shown to be a strategic tool (Marco and Miller, 2019). An example of a strategic response could be an entity separating its claims into multiple patents or combining all into one, which may widen or narrow the purpose of its patent. The AIA can induce a strategic change, and the variation in the number of claims is likely to be non-random. The number of claims may change post-AIA and thus can absorb some of the treatment effects which could be attributable to the Y. The inclusion of claims, therefore, imposes a stricter restriction on the estimate. In other words, it helps us understand if the change in the number of patents is entirely driven by the various measures of quality and complexity, or do the number of patents change as a response to the AIA.

Now, if we move to the second outcome, the log(1+number of citations per patent) within two years of issue of the patent; we observe results similar to that of the log(1+number of patents). Specifically, the estimate of δ reported in columns (3) and (4) of Table 2 indicates a drop in the number of citations within two years of the issue of a patent per patent of about 1.2 percentage points for the small entities post-AIA relative to all entities pre-AIA. A decline in the number of patents is followed by a decline in their citations. While Abrams and Wagner (2013) and Lerner et al. (2015) report a reduction in the number of patents, they do not find any appreciable difference in the quality, as also measured by citation, for the small entities during the Canadian reform in Canada. For the U.S. small entities, we do note a drop in the quality of patents filed post-AIA.

Figures 4 and 5 report the main results in an event study form, as given by Equation 2. I also split the coefficient of $SE \times Post$ by year. Quarterly coefficients of $SE \times Post$ do show similar results as in Table 2. But, averaging by year averages the variation within the year, which enables us to see a broad trend over time. The event study setup serves two purposes. Firstly, it tests the identifying assumption, i.e. whether the small entities patent differently than the large entities pre-AIA — the parallel trends assumption; and secondly, it separates the effect by quarter and year, enabling us to see if a particular time drives the result.

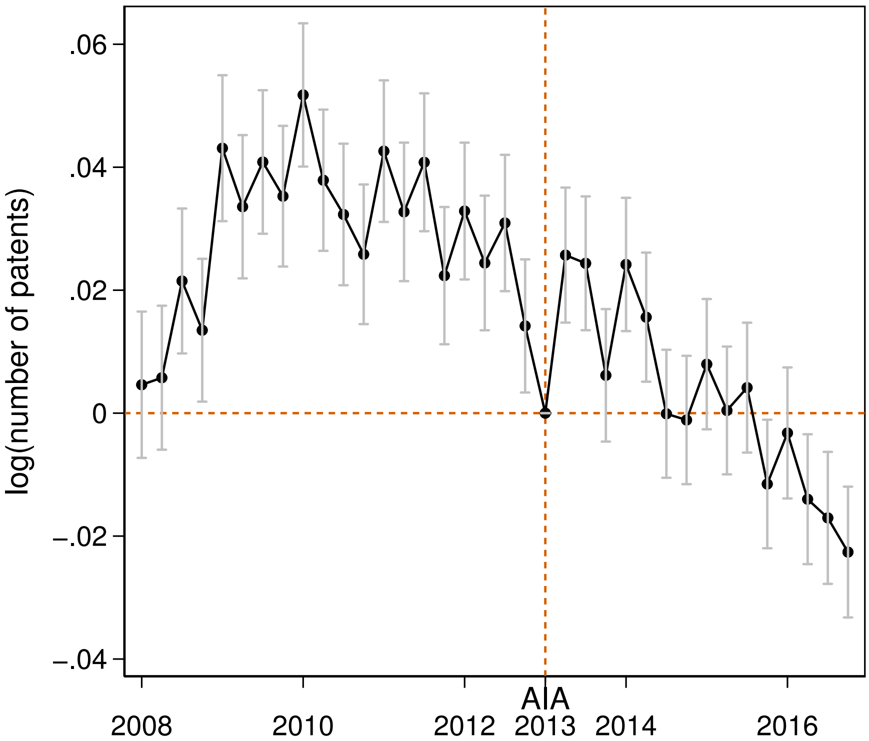

Figure 4: Change in small entities' patents over time
This figure plots the change in log(1+number of patents) by small entities for every quarter. The event study specification is reported in Equation 2, and the figure plots the β_s's estimated from $\sum_{s\neq 0}\beta_s \times 1[s=t] \times SE_i$ part of the equation, with the base quarter being the first quarter of 2013, when the AIA's FITF came in force.

For the number of patents, compared to the AIA's implementation quarter, i.e. the first quarter of the year 2013, the pre-trends have on average coefficients of magnitudes greater than 0. While, post-AIA, the percentage drop is negative. The number of citations within two years of issue per patent does show a similar trend as the number of patents, but with wider confidence intervals. I also provide results using the number of citations within one year of issue per patent in Appendix Figure A14 to show that the two citation figures do move in a similar fashion. Table 3 compares the coefficient of $SE \times Post$ keeping the year 2013 as base. Compared to the base year, we observe a drop in patenting, which increases over years. The number of citations per patent, on the other hand, starts declining in 2015.

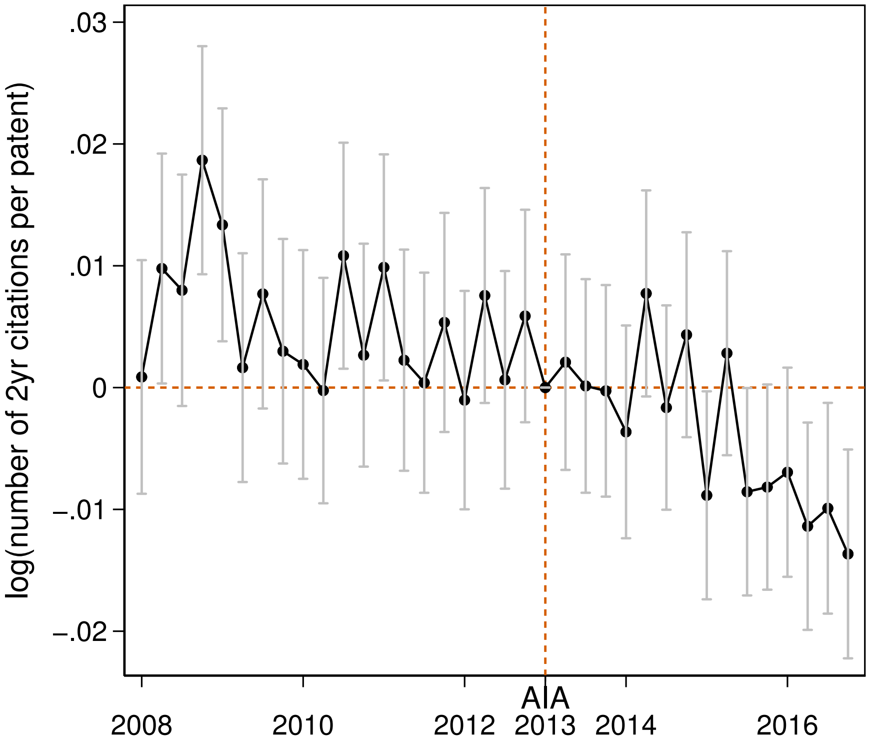

Figure 5: Change in small entities' citations over time

This figure plots the change in log(1+number of 2 yr citations/patent) by small entities for every quarter. The event study specification is reported in Equation 2, and the figure plots the β_s's estimated from $\sum_{s\neq 0} \beta_s \times 1[s = t] \times SE_i$ part of the equation, with the base quarter being the first quarter of 2013, when the AIA's FITF came in force.

Table 3: Event study: Log number of patents and citations

	Patents		Citations	
	(1)	(2)	(3)	(4)
SE x 2008	0.0149***	-0.0041	0.0072**	0.0090***
	(0.0049)	(0.0040)	(0.0033)	(0.0031)
SE x 2009	0.0314***	0.0217***	0.0047	0.0057*
	(0.0046)	(0.0039)	(0.0031)	(0.0030)
SE x 2010	0.0222***	0.0203***	0.0028	0.0033
	(0.0043)	(0.0037)	(0.0031)	(0.0030)
SE x 2011	0.0168***	0.0182***	0.0040	0.0039
	(0.0039)	(0.0034)	(0.0029)	(0.0028)
SE x 2012	0.0065*	0.0096***	0.0023	0.0029
	(0.0033)	(0.0029)	(0.0027)	(0.0026)
SE x 2014	-0.0129***	-0.0062**	0.0022	0.0013
	(0.0031)	(0.0027)	(0.0025)	(0.0025)
SE x 2015	-0.0263***	-0.0159***	-0.0035	-0.0061**
	(0.0034)	(0.0030)	(0.0026)	(0.0025)
SE x 2016	-0.0454***	-0.0301***	-0.0114***	-0.0111***
	(0.0037)	(0.0032)	(0.0026)	(0.0026)
Controls	No	Yes	No	Yes
ID F.E.	Yes	Yes	Yes	Yes
Subcat F.E.	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes
N	1053263	1052165	1053263	1052165

This table reports event study results. The gap in the number of patents, proxied by log(1+number of patents) and the number of citations, proxied by the log(1+number of 2yr citations/patent) between small and large entities for each year before and after the AIA are presented. The estimates are derived from the model $Y_{it} = \beta_0 + \sum_{s \neq 0}(\beta_s \times 1[s = t] \times SE_i) + X_{it}^{'}\beta + \lambda_i + \lambda_t + \varepsilon_{it}$, where i and t denote entity and quarter respectively, X_{it} denotes a range of patent and entity level controls as defined in Table 1, and λ_i, λ_t control for entity and quarter fixed-effects respectively. The entity-quarter level dataset consists of all patents applied between 2008 and 2016. The indicator variable SE takes value 1 if more than 50 percent of the patents for an entity was applied as a small entity, and 0 otherwise. The year 2013 acts as the base year, when the AIA's FITF came into effect.

Columns (1) and (3) report results without and (2) and (4) report with controls. P-values at 1, 5, and 10 percent are denoted by *, **, and ***. Standard errors are clustered at entity-level.

5.2 Evidence from the litigation exposure

In this section, I focus only on the small entities' exposure to litigation, though I refer to results for all the entities which are provided in Appendix A.7.

We observe that in addition to the gap in the number of patents between small and large entities widening post-AIA; within the small entities, those operating in patent categories with heavier exposure to litigation do decrease their patenting even more compared to all small entities post-AIA. Specifically, one-standard deviation increase in exposure to litigation results in about 21 percent reduction in the number of patents, given by the coefficient of $Exposure \times Post$.

Post-AIA, we can infer that the entities experiencing heavy exposure to litigation are in a way more "comfortable" in patenting in those areas. This is because the threat of litigation relatively lowered with the enactment of AIA. Since Table 4 report the average for all the quarters pre and post-AIA, I also separate the pre and post averages by each quarter and report the changes over time and compare it with the quarter when the AIA's FITF was enacted. We note that the exposed entities were anticipating the change and were building up to the AIA's passage, and this buildup sustains post-AIA. However, we also observe that the average fluctuates compared to the pre-AIA period. But, on average, the number of patents are higher for the exposed entities post-AIA. This result is clearer when I consider all the entities, and estimate the change in the number of patents and citations with exposure as a dosage post-AIA. The results are provided in A15 for the number of patents and A16 for the number of 2 year citations per patent. Formally, a unit increase in exposure is related to a 6 percent increase in the log(1+number of patents).

Coming to the quality of patents within the small entities exposed to litigation, for one standard deviation increase in exposure, we observe a drop of about 1.3 percent in the two-year citation per patent for the exposed relative to the unexposed small entities post-AIA. Figure 7 separates the coefficient by quarters and shows that the coefficient for each quarter hovers around 0 pre-AIA and on average falls below zero post-AIA. We do observe that the variation for each quarter for citations is not as precise and the number of patents.

I also report the results using For all the entities, as reported in Appendix A16, we do observe that a unit standard deviation increase in exposure leads to a drop of about 0.63 percentage in the average 2 year citations per patent post-AIA, but this does not change within the small entities.

Table 4: Exposure to litigation within the small entities

	Patents		Citations	
	(1)	(2)	(3)	(4)
Exposure x Post	-0.1323***	-0.2115***	-0.0174***	-0.0130***
	(0.0168)	(0.0290)	(0.0037)	(0.0033)
Exposure	0.2166***	0.3606***	0.0299***	0.0255***
	(0.0141)	(0.0299)	(0.0034)	(0.0034)
Controls	No	Yes	No	Yes
Qtr F.E.	Yes	Yes	Yes	Yes
ID F.E.	Yes	Yes	Yes	Yes
Subcat F.E.	Yes	Yes	Yes	Yes
N	356224	355410	356224	355410

This table reports difference-in-differences estimates within the small entities exposed and unexposed to litigation pre and post-AIA, given by $Exposure \times Post$. The gap in the number of patents is measured by log(1+number of patents) and the number of citations is measured by the log(1+number of 2yr citations/patent). The estimates are derived from the model $Y_{it} = \delta(Exposure \times Post) + X_{it}^{'}\beta + \lambda_i + \lambda_t + \varepsilon_{it}$, where i and t denote entity and quarter respectively, X_{it} denotes a range of patent and entity level controls as defined in Table 1, and λ_i, λ_t control for entity and quarter fixed-effects respectively. The entity-quarter level dataset consists of all patents applied between 2008 and 2016. The indicator variable SE takes value 1 if more than 50 percent of the patents for an entity was applied as a small entity, and 0 otherwise. $Post$ takes value 1 if the patents were applied on or after the first quarter of 2013 i.e. the implementation of first-inventor-to-file rule in the United States.

Exposure is standardized and is defined in Subsection 3.3.3.

Columns (1) and (3) report results without and (2) and (4) report with controls. P-values at 1, 5, and 10 percent are denoted by *, **, and ***. Standard errors are clustered at entity-level.

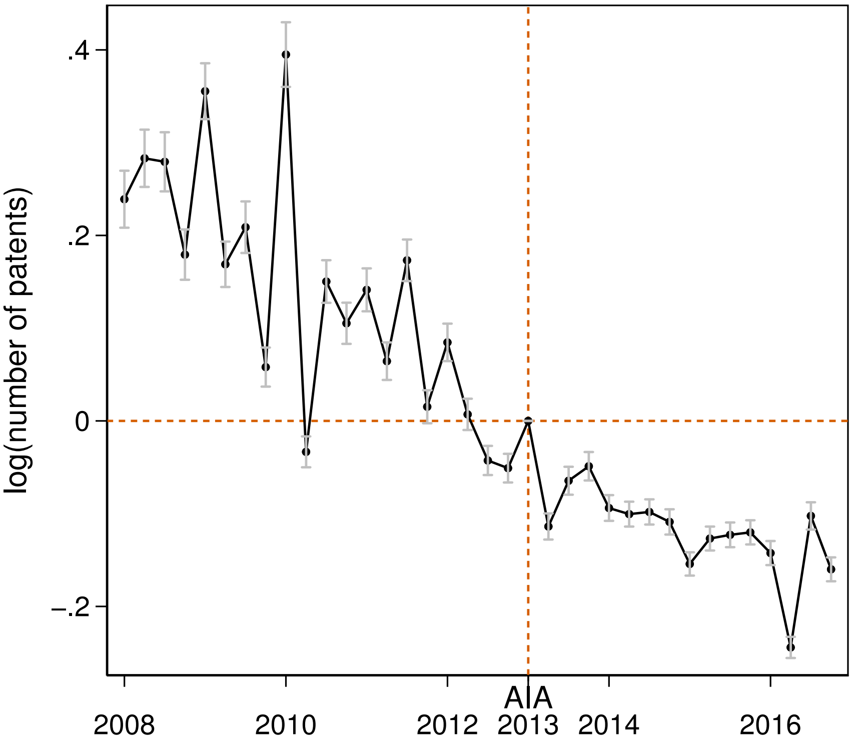

Figure 6: Exposure to litigation: Patents

This figure plots the change in log(1+number of patents) for an exposed vs. an under-exposed to litigation only for the small entity by quarter. The estimates are derived from the model $Y_{it} = \beta_0 + \sum_{s\neq 0}(\beta_s \times 1[s=t] \times Exposed) + X_{it}^{'}\beta + \lambda_i + \lambda_t + \varepsilon_{it}$, where i and t denote entity and quarter respectively, X_{it} denotes a range of patent and entity level controls as defined in Table 1, and λ_i, λ_t control for entity and quarter fixed-effects respectively. The Appendix Table A4, Figures A15 report these results for all entities.

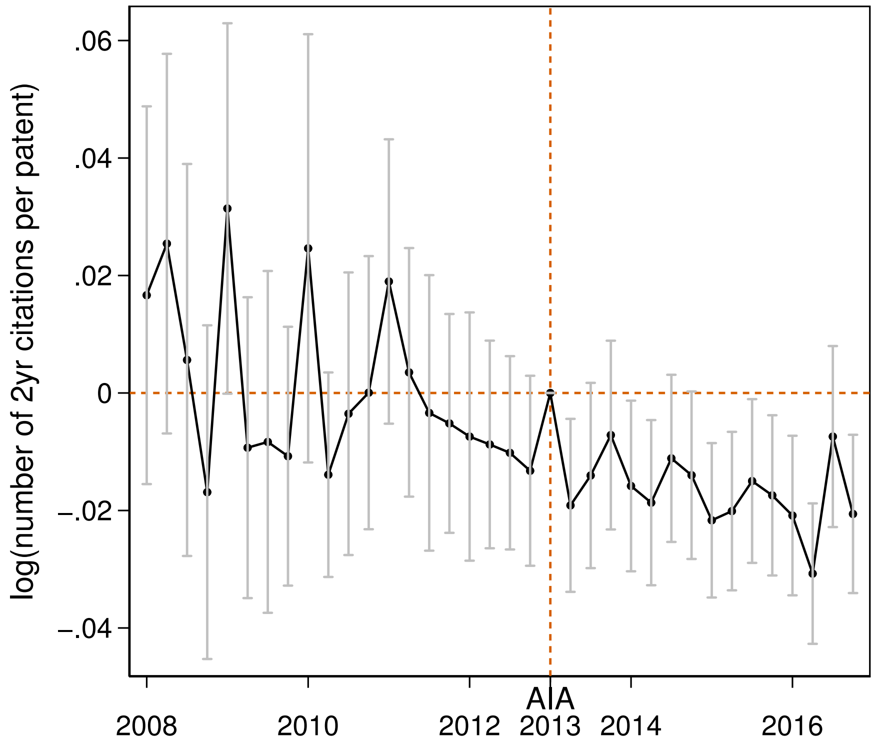

Figure 7: Exposure to litigation: Citations

This figure plots the change in log(1+number of cit./patent) for an exposed vs. an under-exposed to litigation only for the small entity by quarter. The estimates are derived from the model $Y_{it} = \beta_0 + \sum_{s \neq 0}(\beta_s \times 1[s = t] \times Exposed) + X'_{it}\beta + \lambda_i + \lambda_t + \varepsilon_{it}$, where i and t denote entity and quarter respectively, X_{it} denotes a range of patent and entity level controls as defined in Table 1, and λ_i, λ_t control for entity and quarter fixed-effects respectively. The Appendix Table A4, Figures A16 report these results for all entities.

5.3 Evidence from the Compustat firms

Small entities cover about 30 percent of the patents in the main sample. But, among the publicly traded firms, only about one percent of the patents are from small entities. While this sample enables me to control for a greater number of entities' characteristics, such as assets, R&D expenditure, and the number of employees; I inevitably lose all the individual patentees and a large proportion of unlisted firms. Patents by individuals and the small firms are important for this paper because of the results from the Canadian reform, as documented by Lerner et al. (2015), Abrams and Wagner (2013), and Lo and Sutthiphisal (2009). The overarching conclusion all the authors report is that small entities, and particularly the individual patentees decrease their patenting activity in Canada, and the authors observe an increased gap between the large and small entities after an AIA-like reform in Canada. Publicly traded firms do not adequately represent the small entities. The lack of small entities is evident in the results reported in Table 5. We observe that the number of patents and their citations for the publicly listed small entities are not different from the publicly listed large entities.

It should be noted that the publicly listed small entities are still sufficiently large to be listed as compared to the unlisted firms and individuals. They also are significantly less budget constrained than the other small entities. This can be one explanation as to why this sample of small entities do not exhibit a different behavior as compared to the larger ones.

Table 5: Compustat firms results: log(1+patents) and log(1+citations/pat.)

	Patents		Citations	
	(1)	(2)	(3)	(4)
SE x Post	-0.0536	-0.0100	0.0120	0.0075
	(0.0452)	(0.0411)	(0.0297)	(0.0296)
Controls	No	Yes	No	Yes
Qtr F.E.	Yes	Yes	Yes	Yes
ID F.E.	Yes	Yes	Yes	Yes
Subcat F.E.	Yes	Yes	Yes	Yes
N	18289	18289	18289	18289

6 Concluding remarks

This paper studies the quantity and quality of inventions by the small entities relative to the large entities around a recent and substantial change in the patenting rule of the United States, the Leahy-Smith America Invents Act (AIA) of 2011. The AIA brought forth a range of changes in the patenting rules in the United States to put a check on litigation and provide ease in the filing of patents, especially for the smaller entities. But, the AIA's Congressional hearings highlighted that the small entities' could be disproportionately impacted through the AIA's first-inventor-to-file rule, as they were required to file as quickly as possible upon invention, which adds additional costs to their already constrained resources. Therefore, the AIA's passage required a mandated study to assess the impact of implementing FITF on the small entities. Unfortunately, the authors note that the study was premature and warranted further exploration into the questions. Through this paper, I contribute the following: one, I shed light on the innovative activities of a relatively understudied group of entities, the small entities before and after the AIA's enactment, acting as an update to Lerner et al. (2015); two, I add clarity to the understanding of the costs and benefits the small entities engaged in innovation face and perceive, and its differences with respect to the larger entities; and three, I highlight the changes in the trade-offs to patent as brought-forth by the AIA in the United States.

I study the impact of the AIA in two parts: first, estimate the total change in patenting activity by small entities before and after the AIA, as measured by the number of patents and their citations; and second, estimate the change in patenting activity for entities exposed to litigation. I find that on average, the gap in patents' quantity and quality between small and large entities has widened after the enactment of AIA. Entities with a greater exposure to litigation reduce their patenting activity significantly, and among this group, the small entities report an even more pronounced gap in patenting. This hints that resource constrained entities are exercising more caution than the larger ones. And among them, especially the entities that operate in areas previously plagued by litigation. If certain entities are more cautious to disclose their invention than before, we might expect a drop in follow-on inventions in the years to come. This highlights an unintended consequence of the AIA's enactment. The reasons for a cautious move can be many, and a part of the reasons were discussed by Huang et al. (2020) and Abrams and Wagner (2013). Because an FITF rule recognizes the first filer of an invention as the sole inventor, an entity has to file quickly after invention, but also has to ensure that the patent document is as complete as possible. An incomplete document can cause more harm than good. Second, this might also signal an entity's competitors about the portfolio of inventions that they are developing. Hence, an entity is more likely to ensure greater secrecy as long as they are not fully ready to disclose their invention. This behavior is accentuated by the addition of the post-grant review. A post-grant review can question the validity of any granted patent, and therefore, an entity needs to ensure that questions on validity of their inventions do not arise, or at least are minimized.

This paper acts as a first step in analyzing a few broad aspects of the AIA, and focuses on the small entities. But, a range of questions remain unanswered. We do not know if the AIA indeed resulted in eliminating litigation and "bad patents". While this paper suggests that the additional support small and micro entities received was insufficient to counter the increase in resource requirements the AIA invoked, how was the support used by these entities? Also, if the entities patent at a lower rate than before post-AIA, are they also inventing at a lower rate or are they inventing at the same rate but keeping those secret, and later secretly engaging in licensing deals with large manufacturers? In the years to come, an examination of the follow-on patents are required to assess if the AIA's blanket changes in the patenting rules were too harsh and excessively dampened disclosure of invention or if it hit the sweet spot in dampening the costs to patenting arising from litigation and "bad patents" and simultaneously proliferating invention disclosure through patents.

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A Appendix

A.1 Patent applications without assignee IDs

The Subsection 3.2 describes the sample selection this paper. In the second paragraph, I end up with 5,087,133 patent applications, with or without entity identifiers. Among these, 1,832,053 did not have either assignee ID or inventor ID from the Patentsview database. In this section of the Appendix, I argue that the patent application without the IDs is not a systematic error of the disambiguation algorithm. Rather, most of these patent applications are a derivative of another patent application already considered in the main sample. 87 percent of the patent applications which do not have an ID are either connected to the patent applications in the main sample through a parent or a child application. Among the 87 percent, 99.2 percent are either PCT or provisional applications. These applications are not examined if they are not converted into a non-provisional application within a given time. They either end up being abandoned or are marked as "pending" throughout their life in the USPTO patent database. A summary of the types of patent applications among those who do not have an ID is provided in Table A1. Each row reports an application type, and if they are connected to the main sample through parent or child applications. The main concern here is the utility patents, which amount to 13,203 patent applications. Utility patents may end up being examined, but the other patents will not, and therefore do not pose a threat to the main results of the paper. The proportion of utility patents out of the total missing is minuscule and will not disturb the estimates even if they were in the main sample.

Table A1: Patent applications with missing IDs

Patent application type	Connected	Not-connected	Total
Utility	9,080	4,123	13,203
PCT	901,286	209,622	1,110,908
Provisional	679,304	25,644	704,948
Re-issue	2,146	24	2,170
Re-examination	815	7	822
Missing	1	1	2
Total	1,592,632	239,421	1,832,053

A.2 Results from a balanced panel

In Subsection 3.2, I briefly mention a concern regarding selection that may arise from the use of an unbalanced panel. While the sample is intrinsically not unbalanced, because I do observe all the patents each entity files for each quarter and there are no missing observations for any particular quarter for a given entity; in a definitional sense of an unbalanced panel, the main sample *is* unbalanced.

Different entities may find it favorable to choose between the pre and post-AIA periods to file their patent application which may relate to their objectives and characteristics. If the entities in the groups small and large for the before and after periods are vastly different, estimates showing the change in their patenting activity before and after the AIA may also contain bias. One way to tackle the issue would be to control for enough of the varying entity characteristics which explain their choice between the two periods if any. If we assume that the control variables adequately capture their strategies, the estimates would be consistent. This is one reason why I estimate the model with different samples and variables.

Another way to tackle this is to force the unbalanced panel to be balanced. In the quarters when an entity did not file for patent applications, I put zeroes in the number of patents and citations column. The problem with arranging the data in this way is that it adds zeroes to the time period when an entity was not established. This changes the effect size, and because the small entities on average appear at significantly lower rates than the larger ones, their representation is negatively skewed.

Table A2 reports results when a balanced panel is forced. We observe that small entities still file for patents at a lower rate than the larger ones. Their citations per patent though reported to be significantly higher, is still near zero and not economically significant.

Table A2: Balanced panel results

	Patents		Citations	
	(1)	(2)	(3)	(4)
SE x Post	-0.0032***	-0.0031***	0.0007***	0.0007***
	(0.0001)	(0.0001)	(0.0000)	(0.0000)
Individual		-0.6208***		-0.0807***
		(0.0181)		(0.0076)
Government		-0.4147***		0.0325***
		(0.0099)		(0.0041)
Constant	0.0300***	0.5417***	0.0034***	0.0699***
	(0.0000)	(0.0149)	(0.0000)	(0.0062)
Qtr F.E.	Yes	Yes	Yes	Yes
ID F.E.	Yes	Yes	Yes	Yes
N	36441360	36346644	36441360	36346644

A.3 Alternate definition of small entities

An entity can file as a small or undiscounted entity. The reason for this choice is unclear. The main set of results assumes an entity to be small if it is ever claimed to be small. But, it is possible that an entity grew over time to be large and be misrepresented as a small entity because of the assumption. Therefore, Table A3 reports results when the variable small entity is not an indicator variable. Rather, it is the proportion of times an entity claimed to be small out of total patents filed for that quarter. This value ranges between 0 and 1 and is a continuous measure of an entity being small and large in each quarter.

I re-estimate Equation 1 considering the proportion of small entity for each quarter in place of the indicator variable small entity. The coefficients of SE $\times$ Post do not qualitatively change compared to Table 2.

Table A3: Proportion of patents as small entity

	Patents		Citations	
	(1)	(2)	(3)	(4)
SE x Post	-0.0461***	-0.0277***	-0.0077***	-0.0088***
	(0.0020)	(0.0018)	(0.0015)	(0.0014)
Controls	No	Yes	No	Yes
Qtr F.E.	Yes	Yes	Yes	Yes
ID F.E.	Yes	Yes	Yes	Yes
Subcat F.E.	Yes	Yes	Yes	Yes
N	1053263	1052172	1053263	1052172

A.4 Quarter fixed-effects from the main table

Figures A8 and A9 plot the quarter fixed-effects from Table 2.

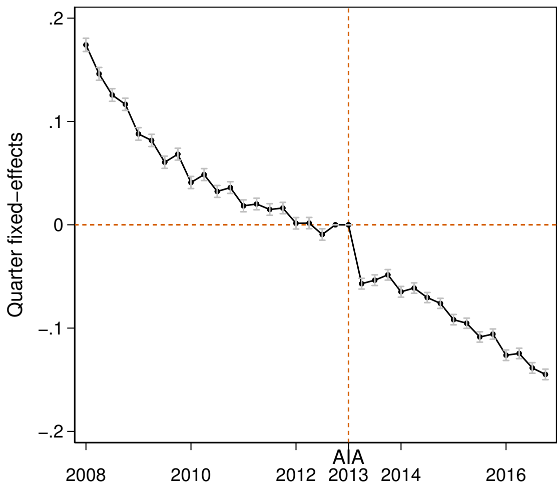

Figure A8: Number of patents' quarter fixed-effects

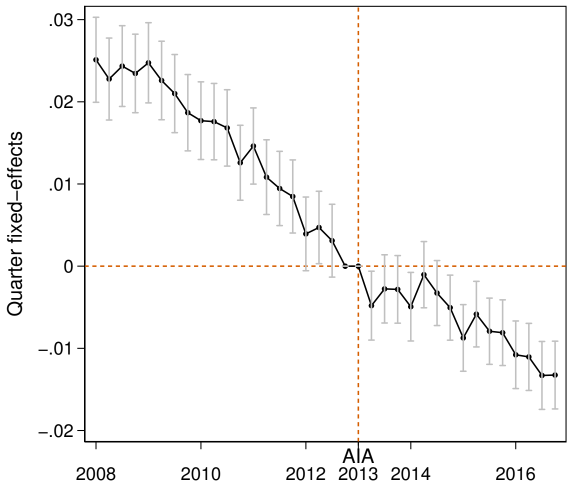

Figure A9: Number of citations' quarter fixed-effects

A.5 Number of citations within one year of issue

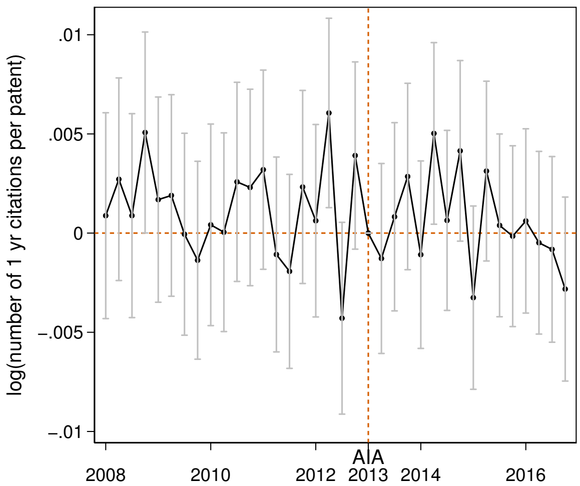

Figure A10: Change in small entities' number of citations over time (within 1 year of issue)

A.6 Results from average scaled citations

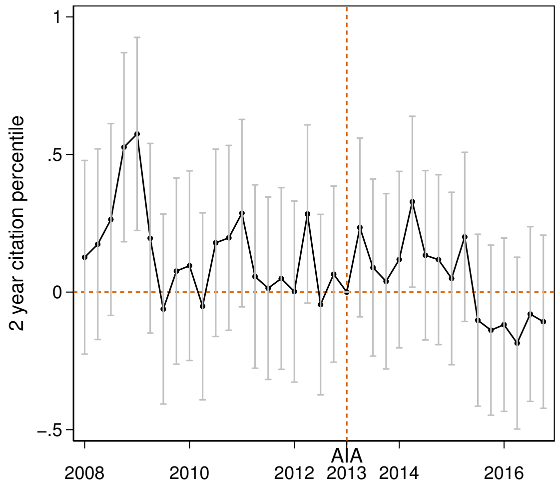

Figure A11: Change in small entities' scaled citations (total)

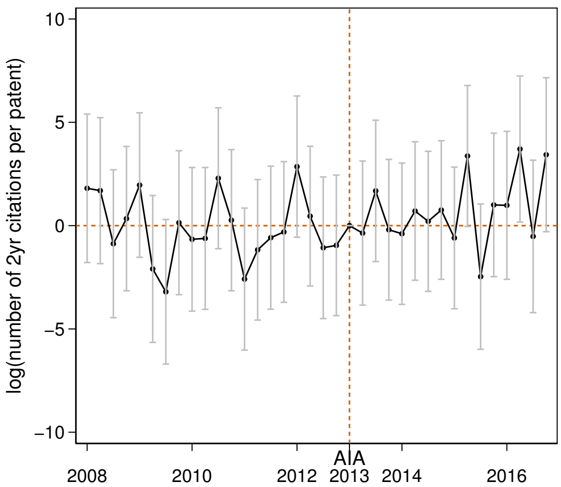

Figure A12: Change in small entities' scaled citations (examiner added)

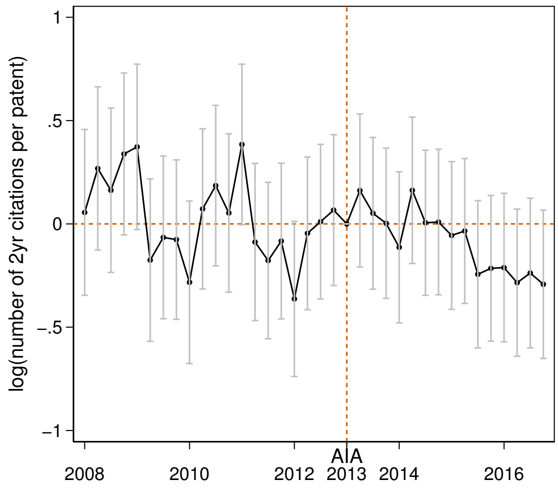

Figure A13: Change in small entities' scaled citations (applicant added)

A.7 Litigation exposure for all entities

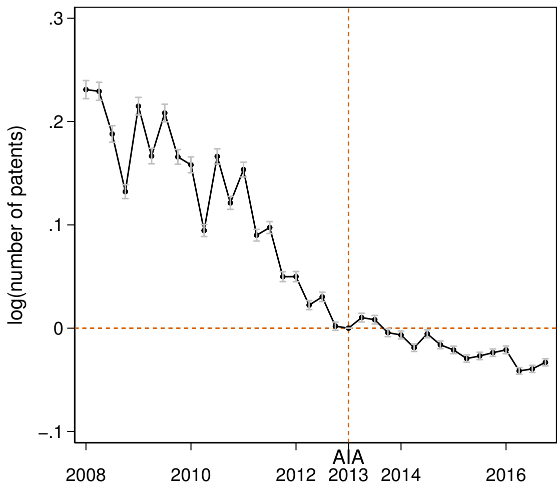

Figure A14: Exposure to litigation: Patents

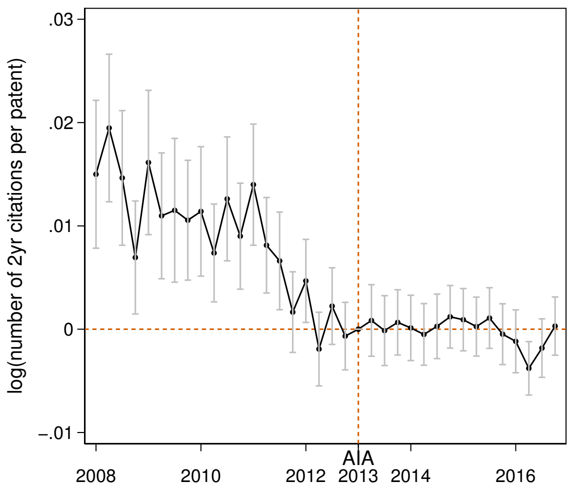

Figure A15: Exposure to litigation: Citations

Table A4: Exposure to litigation: small entities relative to the large entities

	Patents		Citations	
	(1)	(2)	(3)	(4)
SE x Exposure x Post	-0.0724***	-0.1117***	-0.0139***	-0.0085***
	(0.0031)	(0.0026)	(0.0023)	(0.0022)
SE x Exposure	0.0997***	0.1475***	0.0219***	0.0155***
	(0.0030)	(0.0026)	(0.0022)	(0.0022)
Exposure x Post	-0.0590***	-0.0879***	-0.0036***	-0.0040***
	(0.0009)	(0.0008)	(0.0007)	(0.0006)
SE x Post	-0.0559***	-0.0537***	-0.0105***	-0.0107***
	(0.0019)	(0.0016)	(0.0014)	(0.0014)
Exposure	0.1153***	0.1904***	0.0081***	0.0093***
	(0.0010)	(0.0009)	(0.0007)	(0.0008)
Controls	No	Yes	No	Yes
Qtr F.E.	Yes	Yes	Yes	Yes
ID F.E.	Yes	Yes	Yes	Yes
Subcat F.E.	Yes	Yes	Yes	Yes
N	1053263	1052165	1053263	1052165

This table reports triple difference estimates for the small entities exposed to litigation post-AIA, given by $SE \times Exposure \times Post$. The gap in the number of patents is measured by log(1+number of patents) and the number of citations is measured by the log(1+number of 2yr citations/patent). The estimates are derived from the model $Y_{it} = \delta_1(SE_i \times Exposure \times Post) + \delta_2(SE_i \times Exposure) + \delta_3(Exposure \times Post) + \delta_1(SE_i \times Post) + X_{it}^{'}\beta + \lambda_i + \lambda_t + \varepsilon_{it}$, where i and t denote entity and quarter respectively, X_{it} denotes a range of patent and entity level controls as defined in Table 1, and λ_i, λ_t control for entity and quarter fixed-effects respectively. The entity-quarter level dataset consists of all patents applied between 2008 and 2016. The indicator variable *SE* takes value 1 if more than 50 percent of the patents for an entity was applied as a small entity, and 0 otherwise. *Post* takes value 1 if the patents were applied on or after the first quarter of 2013 i.e. the implementation of first-inventor-to-file rule in the United States.

Exposure is standardized and is defined in Subsection 3.3.3.

Columns (1) and (3) report results without and (2) and (4) report with controls. P-values at 1, 5, and 10 percent are denoted by *, **, and ***. Standard errors are clustered at entity-level.