Empirical Essays in Innovation Economics

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I, Charles A. Wilson-deGrazia, declare that Chapters 1 and 4 are my own work and Chapters 2 and 3 are comprised of collaborative work. Where information has been derived from other sources, I confirm that these references have been duly indicated in the thesis. Chapter 2 was co-authored with Professors Alan C. Marco and Joshua Sarnoff. For this chapter, I (1) created the underlying datasets using USPTO patent application and claim data (created by the USPTO's Office of the Chief Economist); (2) wrote the first draft of this chapter; (3) edited/added to each subsequent iteration (as did my co-authors); (4) ran 95% of the regressions and created each table used in this chapter; (5) discussed research ideas with each co-author. Chapter 3 was co-authored with Dr. Nicholas Pairolero and Professor Mike Teodorescu. For this chapter, I (1) worked collaboratively with my co-authors to write the first draft and subsequent drafts; (2) generated each of the tables and figures except the "First Round of Patent Examination Outcomes" figure and examiner's amendment examples; (3) ran each of the regressions; (4) created each of the datasets from numerous USPTO data inputs except for the TF-IDF cosine similarities (specialization and examiner's amendments) and the initial identification of the examiner's amendments; (5) discussed research ideas with each co-author. Please note that many of the Chapter 2 & 3 tasks, even if executed independently, were performed collaboratively, with input from co-authors. Each co-author has given written permission that each respective collaboratively-written chapter may be included in this thesis. Finally, much of the work on this thesis was undertaken while working at the U.S. Patent and Trademark Office (USPTO), allowing me access to internal data, which was used in this thesis, and a collaborative environment, leading to co-authored work included in this thesis.

Signed..(Charles A. Wilson-deGrazia)

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Abstract

This thesis contains three papers that contribute to the measurement and understanding of patent quality at the United States Patent and Trademark Office (USPTO), its determinants, and its effects on innovation.

Chapter 2 introduces and develops two measures of patent scope, an important aspect of patent quality, which allows for the first large-scale analysis of patent scope changes during the examination process. Results from this chapter show that applications with narrower incoming scope are associated with a higher probability of grant and a shorter and less intense examination period in comparison to applications with broader incoming scope. Further, the results demonstrate that the examination process itself tends to narrow the scope of patents and that changes in scope are more significant when the duration and intensity of examination is increased.

Chapter 3 reexamines prior research on USPTO examiner incentives, and concludes that increasing first-action allowance rates with seniority and experience results in lower examination quality, and thus, patent quality. This chapter identifies an examiner learning mechanism that mostly accounts for the increasing first-action allowance rate, without sacrificing examination quality. However, the results show that examination quality differs between junior and senior examiners (GS-14). This learning mechanism also reduces patent grant delay, likely benefiting innovators and firms.

Chapter 4 examines how patent validity, an aspect of patent quality, may affect follow-on patenting decisions by both assignees and technology rivals. The results indicate that validation increases for both overall and external follow-on patenting but the results are mixed for internal follow-on patenting. The increase in follow-on patenting by rivals can be attributed to an increase in defensive patenting based on the positioning of follow-on patents in technology space after validation. The positioning of external follow-on patenting is unaffected by validation. Finally, the evidence shows that the validation effect is more prominent in complex technologies relative to discrete technologies.

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

This thesis advances the economics of innovation and intellectual property literature by specifically analyzing the relationship between patent office processes at the United States Patent and Trademark Office (USPTO) and patenting outcomes in the United States. Patents, which are used as an incentive mechanism to promote innovative activities, confer the right to attempt to exclude other entities from the claimed technology space detailed in the granted patent. In recent years, academics within the field of innovation economics have studied the issue of "low quality" patents granted by the USPTO, finding that the existence and proliferation of such patents lead to diminished innovative activity (UKIPO 2013). Much of the literature on patent quality determinants focuses on the relationship between patent examination and granted patent quality at the USPTO.[1] A different but related strand of the literature studies the social welfare trade-offs between *ex ante* (patent examination) and *ex post* (post-issuance procedures) screening of patent quality and their effects on the innovation ecosystem. Finally, some studies have examined the effects of intellectual property rights on follow-on innovation (Murray and Stern 2007; Moser and Voena 2012; Moser 2013; Galasso and Schankerman, 2015a, 2015b; Gaessler et al. 2017; Sampat and Williams 2019;), many using outcomes at *ex post* screening venues across multiple patent offices (USPTO and European Patent Office).

[1]See Alcacer *et al.* 2009; Cockburn *et al.* 2002; Cotropia *et al.* 2013; Frakes and Wasserman 2016a, 2016b, 2017, 2019; Kovacs 2017; Langinier and Marcoul 2012, 2016; Lei and Wright 2017; Lemley 2001; Lemley and Sampat 2012; Mann and Underweiser 2012; Tabakovic and Wollmann 2017; and Whalen 2018.

This chapter serves as (1) an introduction to the literature and debates surrounding the issues described above; and (2) an analysis on how my work advances the literature and contributes to these debates. Chapters 2 and 3 of this thesis focus on the relationship between patent examination quality, patent office outcomes, and innovative activity. Chapter 2 delves into a particular component of patent quality, patent scope, and its evolution over the course of examination at the USPTO. Chapter 3 reevaluates the recent literature on patent examination quality, allowance rates, and patent quality at the USPTO (Lemley and Sampat 2012; Frakes and Wasserman 2017, 2019). It concludes that, contrary to the prior literature, the increased allowance rate in grade and experience is due not to diminished examination quality but to improved examination efficiency through learning. These chapters connect to a main area of research in innovation economics, specifically the study of patent quality determinants at the USPTO and their effects on the innovation ecosystem. Chapter 4 deviates from analysis of examination quality to the effects of *ex post* determinations of patent validity on follow-on patenting. This chapter, along with Chapters 2 and 3, contributes to a current debate on the merits of *ex ante* versus *ex post* screening of patent quality in the United States. Broadly, the work of this thesis contributes to the literature on the study and analysis of the U.S. patent system and the optimality of such a system in encouraging innovation. The rest of this chapter is structured as follows: First, I provide a literature review of each interconnected subtheme of my thesis (patent quality, patent examination, innovation outcomes, patent quality screening). Then I provide a summary of each subsequent chapter in this thesis and discuss the implications of each chapter in relation to the broad questions in innovation economics discussed above.

1.1 Patent Quality

Patent quality refers to several legal features of a granted patent application, including patentability of the subject matter (35 U.S.C. 101), utility (35 U.S.C. 101), novelty (35 U.S.C. 102), nonobviousness (35 U.S.C. 103), and an adequate written description (35 U.S.C. 112). These characteristics ensure that a covered invention is new and not a trivial advancement of existing inventions, that the patent right covers an area over which intellectual property rights can be granted, and that the language in the patent itself is clear enough to "enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same," (35 U.S.C. 112(a)). Patents granted without meeting these criteria violate the fundamental trade-off between the disclosure of a technological innovation and the granting of monopoly rights over the claimed invention space. For example, a patent that covers a non-novel or obvious invention is granted monopoly rights to specific technology space, leading to deadweight loss without the compensating technological innovation. Patents, although covering a new invention, may not properly convey the components of the innovation. The disclosure requirement remedies this potential issue and helps to facilitate knowledge spillovers for those who will utilize or improve the invention (Hall and Harhoff 2004).

Researchers have also identified other dimensions of patent quality, namely scope and the clarity of patent claim language, as significant concerns for the innovation ecosystem (Rai 2013; Churnet 2013; Petherbridge 2009; Zimmer 2008; Wagner 2009). This issue arises, in part, because overly broad or vague claims can be exploited for the purposed of rent seeking, particularly by nonpracticing entities, or NPEs (Schwartz and Kesan 2014; Allison and Mann 2007). Abramowicz and Duffy (2011) argues that legally invalid, overly broad, or vague claims also impose deadweight losses, as well as to reduce sequential innovation. Finally, Hall and Harhoff (2004) and Lemley and Shapiro (2005) argue that the certainty surrounding a granted patent is an important aspect of patent quality. Uncertainty surrounding patent rights can occur along two dimensions: likelihood of validity and the scope of the patent. Vague patents or patents with ambiguous scope may cause uncertainty as to the validity of the patent and how far the legal metes and bounds of the patents extend, leading to uncertainty for both the patent holder and technological rivals in the same technology area. Also, patent assignees face uncertainty regarding the validity of a patent right, where existing art could lead to an invalidation of the patent right. Lemley and Shapiro (2005) argues that to some degree, all granted patents are to some extent "probabilistic".

1.2 Patent Quality and Patent Examination

As the arbiters of granted patents, examiners at patent offices across the world make the final determinations as to whether a patent application is ultimately granted (Marco *et al.* 2017). It is the responsibility of each examiner to ensure that each granted application meets the legal standards of patentability, including the aspects of patent quality discussed in the previous section. This responsibility leads to a natural research focus on examiner behavior and patent office policy as determinants of patent quality. Once an applicant submits a patent application to the USPTO, the USPTO provides a technology classification which reflects the technological nature of the invention and routes the application to an examiner concentrated in that art. The prior literature on patent examination has concentrated on the several areas of the examination process that are problematic for accurate examination and subsequent granting of high-quality patents. These areas include production incentives at the USPTO, patent office policies, vast increases in the number of patents that examiners must evaluate as prior art, complex nature of certain technologies, and feedback effects from existing low-quality examination (UKIPO 2013; Lemley and Sampat 2012; Schuett 2013; Frakes and Wasserman 2017, 2019).

As these frictions may lead to examiners granting patents that do not satisfy all requirements of patentability, researchers have focused on the high allowance rates at the USPTO as an indication of low-quality examination. For example, during patent prosecution at the USPTO, an examiner searches existing patents, publicly-available patent applications, and non-patent literature to determine if the examined patent applications is indeed novel and non-obvious, two requirements for a patent application to be granted. *Ceteris paribus*, as an examiners searches the prior art, higher scrutiny will lead to the discovery of prior art that demonstrates the claimed invention is non-novel or obvious. An applicant, in response to these objections, can either modify the claims of the patent in light of the prior art or abandon the application.[2] Therefore, as the higher level of scrutiny increases, examiners are

[2]This example represents the simple case. The applicant may challenge the rejection, file a

less likely to issue "invalid" patents, or patents that do not meet the requirements for allowance. In the face of complex technologies with myriad potential relevant prior art patents or non-patent literature, the task of evaluating the art within the allotted time becomes more difficult, leading to a higher probability of granting "low-quality" patents. There are many issues related to innovation outcomes and "low-quality" patents, which I explore further in the next subsection.

1.3 Patent Quality and Innovation Outcomes

Recent academic and governmental studies have found that low-quality patents cause reduced innovative activity by firms, market failures, and sub-optimal economic outcomes, including limited competition and increased costs (FTC 2003; Hall *et al.* 2004; Galasso and Schankerman, 2015a, 2015b). These studies highlight many of the ways that low-quality patents lead to economic inefficiencies, including:[3] first, patents with uncertain validity or scope lead directly to an increased risk of *ex post* hold up and to higher costs of licensing relevant intellectual property. These issues then cause an underinvestment in new technologies and a diminished rate of innovation, especially in cumulative technologies. Second, the increase of the low-quality patents is associated with fragmentation of ownership and the creation of patent thickets. Increased fragmentation can also lead to *ex ante* contracting failures through an increase in transaction costs for licensing agreements (Ziedonis 2004), resulting in lower innovative activity (Cockburn *et al.* 2010). Finally, within patent thickets, firms with weaker patent portfolios face increased costs of production because they cannot adequately insulate themselves from potential infringement lawsuits from competitors. These higher expected litigation costs can cause firms with weaker patent portfolios to exit the market, effectively erecting barriers to entry. The exit of these firms is coupled with decreased entry from increased barriers to entry (UKIPO 2013). The rest of this subsection expands on the consequences of granting "low-quality" patents dicsussed above.

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continuation, etc.

[3]This is not an exhaustive list. For more information, see FTC (2003) and UKIPO (2013), among other studies related to patent quality.

For low-quality patents, vague claims or unclear scope may lead to disadvantageous outcomes for firms in regards to either patent hold-up or patent invalidation. Hold-up refers to the ability of one firm to expropriate rents from another firm. In the context of technology and innovation, hold-up occurs when a competitor undertakes investment in innovative activity without a license for the relevant intellectual property (bargaining failure or lack of awareness), or the terms of the licensing agreement are unclear and the patent owner asserts the patent *ex post* (Shapiro 2001). In the context of vague patents, firms may be unaware that they are infringing on a patent due to lack of clarity in the claims, leaving them susceptible to hold-up (Ziedonis 2004). This risk of hold-up increases the expected litigation costs, decreasing investment in new technologies and innovative activities. The risk of hold-up could induce risk-averse firms to obtain licenses for potentially relevant vague patents, driving up innovation costs, leading to lower investment in new technologies and innovative activities.

Second, the increase of the low-quality patents in complex technologies is associated with fragmentation of ownership and the creation of patent thickets.[4] Patent thickets are defined as "an overlapping set of patent rights requiring that those seeking to commercialize new technology obtain licenses from multiple patentees," (Shapiro 2001). The UKIPO report on patent thicket notes that one cause of patent thickets is the average drop in patent quality associated with the considerable increase in patent filings in the last thirty years (Jaffe and Lerner 2004; Bessen and Meurer 2008). In addition to overlapping patents, another byproduct of low quality patenting within patent thickets is increased fragmentation within a particular technology. When, in complex technology areas with overlapping patents, the number of potential licensors from which a firm needs to obtain a license is increasing in the number of patents, patent ownership becomes fragmented. Increased fragmentation can lead to *ex ante* contracting failures through an increase in transaction costs for licensing agreements (Ziedonis 2004), resulting in lower innovative activity (Cockburn *et al.* 2010).

[4]UKIPO(2013) provides a discussion of the literature related to the creation of patent thickets, including the increase in "low quality" patents.

Finally, within patent thickets, firms adopt a defensive patent strategy to mitigate the risk of *ex post* hold-up (Hall and Ziedonis 2001; Ziedonis 2004; Noel and Schankerman 2013). A defensive patenting strategy is defined as, the accumulation of patents to use as bargaining chits to preserve the freedom to operate and to improve the bargaining position of the firm in resolving patent disputes when they arise, (Noel and Schankerman 2013). Firms with weaker patent portfolios face increased costs of production because they cannot adequately insulate themselves from potential infringement lawsuits from competitors. These higher expected litigation costs can cause firms with weaker patent portfolios to exit the market, effectively erecting barriers to entry. The exit of these firms is coupled with decreased entry from increased barriers to entry (UKIPO 2013).

1.4 *Ex Ante* v. *Ex Post* Patent Quality Screening

A current academic debate centers on the social optimality of *ex ante* (patent examination) versus *ex post* (post-issuance review procedures) screening of patent quality. Lemley (2001) argues with a cost-benefit analysis that since such a small percentage of patents is ever asserted, society is better off spending additional resources screening valuable patents *ex post*, allowing for the "rational ignorance" of examiners to balance production efficiency with examination quality (Lemley 2001). The study finds that the costs to improve examination quality exceed the social costs of allowing some "bad" patents. Using a similar method and estimates from Frakes and Wasserman (2017), Frakes and Wasserman (2019) comes to the opposite conclusion. The authors argue that some of the main assumptions used in the cost-benefit analysis from Lemley (2001) were not accurate, including the degree to which doubling examination time would reduce the allowance rate at the USPTO. Frakes and Wasserman (2019) then estimates, with updated assumptions derived from empirical evidence, that benefits of additional examiner time per application exceed the cost of such a policy reform. In particular, doubling the amount of time provided to examiners would cost $660 million annually but save over $904 million from decreased litigation, PTAB, and prosecution costs (Frakes and Wasserman 2019).

1.5 Patent Quality Screening and Innovative Outcomes

Several recent studies have leveraged *ex post* patent screening outcomes (U.S. litigation, oppositions at the European Patent Office, etc.) as a way to estimate the effects of intellectual property rights on innovative outcomes, especially follow-on innovation. Galasso and Schankerman (2015a) analyzes a set of nearly 1,400 patent validity decisions at the U.S. Court of Appeals for the Federal Circuit (CAFC) and estimates the effect of invalidation on the number of forward citations within five years of the validity decision for each relevant patent. To address the endogeneity of the ordinary least squares (OLS) estimator for the invalidation dummy variable, the authors construct a propensity to invalidate index for the set of CAFC judges randomly assigned to each case. The index, the paper argues, is correlated with the validity decision, but uncorrelated with unobserved characteristics affecting the dependent variable. The main result of Galasso and Schankerman (2015a) suggests that patent invalidation leads to a fifty percent increase in forward citations to the invalidated patent, but the effect is heterogeneous and depends on the bargaining environment. Gaessler *et al.* (2017) utilizes a large dataset of opposed European Patent Office (EPO) patents granted between 1993 and 2011. The authors construct an instrument from the participation of the opposed patents examiner at grant in the post-grant opposition proceedings. The main results in Gaessler *et al.* (2017) are consistent with the main findings of Galasso and Schankerman (2015a): patent invalidation leads to more total and external citations. However, the Gaessler *et al.* (2017) results differ from Galasso and Schankerman (2015a) in invalidation effects in discrete versus complex technologies, in the presence of patent thickets, and in other environments. Finally, Galasso and Schankerman (2015b) builds on their previous work (Galasso and Schankerman 2015a) and finds that the invalidation effect is driven by smaller firms in specific technologies but the patenting rate for larger firms is mostly unaffected.

1.6 Chapter Summaries

Chapter 2 provides an in-depth analysis of patent scope, one of the important aspects in the debates over “patent quality”. This purported decrease in patent quality over the last decade or two has supposedly led to granting patents of increased breadth, decreased clarity, and questionable validity (in part due to over-breadth). Such patents allegedly diminish the incentives for innovation due to increased transaction costs in the market for technology, more frequent disputes and litigation, trolling behavior, and breakdowns in bargaining. This chapter focuses on the patent examination process at the PTO, highlighting the relationship between patent scope and the patent examination process. My coauthors (Professors Alan Marco and Joshua Sarnoff) and I develop and validate two measurements of patent scope: independent claim length and independent claim count. These metrics —in contrast to other measurements of patent scope— can be calculated before and after examination and enable us to provide the first large-scale analysis of patent scope changes during the examination process. Our results show that applications with narrower scope are associated with a higher probability of grant and a shorter and less intense examination period in comparison to applications with broader scope. Further, we find that the examination process itself tends to narrow the scope of patents relative to the scope at filing, and that the changes are more significant when the duration and intensity of examination is increased. We explain our metrics and make our data available in a public use dataset, which we hope will encourage more research in the evaluation of patent scope, patent examination, and patent quality more broadly. This chapter has been accepted and published at *Research Policy*.

Chapter 3 reevaluates prior research on USPTO examiner incentives, which suggests that first-action allowance rates increase with seniority and experience, resulting in lower patent quality. However, my coauthors on this chapter (Dr. Nicholas Pairolero and Professor Mike Teodorescu) and I identify an examiner learning mechanism that accounts for this empirical fact. Furthermore, we find that patent examination quality does not diminish with the use of this learning mechanism, leading to implications for patent quality. Our analysis suggests that the policy prescriptions in the literature regarding modifying time allocations should be reconsidered. In particular, rather than re-configuring time allocations for every examination promotion level, researchers and stakeholders should focus on the variation in outcomes between junior and senior examiners. Further, we find that the identified examiner learning mechanism also reduces patent grant delay, and therefore likely benefits innovators and firms.

The final chapter analyzes the effects of *ex post* declarations of patent validity, a component of patent quality, on follow-on patenting decisions by both assignees and rivals to a given patent. Using a DiD-matching estimator, this chapter estimates the effects of validation, or an increase in the probability of validity through *ex parte* reexamination on follow-on patenting. I find that validation increases for overall and external follow-on patenting but the results are mixed for internal follow-on patenting. The increase in follow-on patenting by rivals can be attributed to an increase in defensive patenting based on the positioning of follow-on patents in technology space after validation. The positioning of external follow-on patenting is unaffected by validation. Finally, I find that the validation effect is more prominent in complex relative to discrete technologies.

1.7 Contributions to the Literature

Research on patent quality, though a well-studied topic, remains highly relevant given the general persistence of low-quality patents granted by the USPTO and the lack of consensus regarding solutions to the issue. The body of work in this thesis provides an in-depth analysis of patent quality and its implications at various points of the patenting experience, including at filing (Chapter 2), during prosecution (Chapters 2 and 3), and post-grant (Chapter 4). The goals of this thesis, which addresses current holes in the literature, include providing a framework for analyzing changes to patent quality over prosecution, understanding how patent office processes affect patent quality, and analyzing and evaluating policy solutions related to patent quality. This section articulates how my work advances the current understanding of overarching questions in innovation economics, how the chapters relate to each other, and the implications of each chapter for the field and future research. The second and third chapters of this thesis add to the innovation economics literature by addressing a major question currently debated in the literature, namely, how do patent office processes affect patent quality? Or more narrowly, what role do patent office processes play in the determination of patent quality? Chapters 3 and 4 contribute to addressing an overarching policy question in innovation economics: Are current policy recommendations from academic sources appropriate or optimal?

In regards to the first question, several previous studies have investigated features of patent quality at either filing or at grant but have not analyzed how aspects of quality evolve over prosecution process. Chapter 2 provides a framework for studying a particular aspect of patent quality, patent scope, and its evolution over the patent prosecution process. The chapter analyzes patent scope at the USPTO, first studying the characteristics of scope at various points of the examination process, including at filing, allowing for a better appraisal of incoming application quality. We next examine how incoming scope influences examiner effort to reach the patentability threshold, finding that broader applications at filing require more actions and longer pendency before disposal. Then my coauthors and I estimate the degree to which the prosecution process narrows patent scope, conditional on incoming patent characteristics and office action counts. These results show that, generally, patent prosecution improves at least one aspect of patent quality. However, the relationships estimated in this chapter are correlational and not causal. The measures and analytical framework developed in Chapter 2, above and beyond the results, will allow future researchers to further analyze the evolution of patent quality at the USPTO and advance research related to patent examination and patent quality.

Chapter 3 contributes to the literature on patent office processes and patent quality by reevaluating prior conclusions regarding examiner incentives and patent examination quality at the USPTO, finding that binding time constraints (Frakes and Wasserman 2017) may not fully explain why examiners grant "low-quality" patents. In fact, seniority nor experience do not seem to play a role in low-quality examination, with the exception of the highest seniority level (GS-14). These results further the understanding of how (or not) certain aspects of prosecution (specifically, the influence of examiner characteristics) affect examination quality. Finally, the implications of these contributions are twofold: First, the analysis in this chapter demonstrates that the current understanding of patent prosecution by academics may lack institutional knowledge and that academics should carefully consider the complexity of the patenting process when conducting research in this area. Second, more research is needed to isolate the increase in production requirements from a lack of prosecutorial oversight (signatory authority) to determine the cause of relative low-quality examination at GS-14.

The third chapter also evaluates the optimality of policy recommendations from Frakes and Wasserman (2017, 2019) regarding increased time allocation per application, suggesting that the policy proposal may be inappropriate or even counterproductive. By providing counter-evidence to the binding time constraints hypothesis, results from Chapter 3 demonstrate that proposed policies may reduce incentives to conduct compact prosecution, increasing pendency with no improvement to examination quality. There are several implications of this research: First, the policy prescriptions advocated in the literature should be reconsidered. Second, while this chapter provides counter-evidence to the existing literature, it does not provide sufficient policy recommendations related to patent examination and patent quality. In that vein, more research needs to be conducted to isolate the increase in production requirements from a lack of prosecutorial oversight (signatory authority), as stated above.

Though Chapter 4 focuses on firm patenting responses to validity shocks, this research provides additional considerations to the debate surrounding *ex ante* and *ex post* patent quality screening. Chapter 4 finds that rival firms may patent strategically (defensively) in response to increases in the probability of a focal patent's validity, leading to unintended consequences of *ex post* patent screening. The empirical evidence from Chapters 3 and 4 demonstrates that, given the complexity of the secondary effects, a simple cost-benefit analysis of *ex ante* and *ex post* patent quality screening may be an inappropriate strategy to evaluate the optimality of the recommended policies.

The chapters of this thesis are interrelated and together represent a broader analysis of patent quality at multiple points of the patenting experience. Chapters 2 through 4 are linked by the analysis of patent processes and their effects on patent quality, including *ex parte* reexamination, which is an auxiliary of patent prosecution occurring *ex post* (Chapter 4). Chapters 3 and 4, as discussed above, provide additional analysis and a differing perspective on the *ex ante* and *ex post* patent quality screening debate. Finally, each chapter separately establishes that institutional knowledge is key in conducting accurate analysis on patent quality.

Chapter 2

Patent Claims and Patent Scope

2.1 Introduction

For decades patent breadth—or scope—has been recognized by economists as one of the primary levers in patent policy. By altering the length versus breadth of patent rights, policy makers can influence patent value, the incentives for innovation, and the welfare consequences from the resulting deadweight losses (Gilbert and Shapiro 1990; Klemperer 1990; Merges & Nelson 1990). In practice, the statutory patent length is difficult to change, although it can be effectually shortened by charging renewal fees for in-force patents (see Pakes 1986 and subsequent "renewal studies" of patent value). Patent scope—on the other hand—is amorphous, and it is difficult to know how to apply economic concepts of patent scope to policy-making. Consequently, no international agreements seek to define or harmonize patent scope. Nonetheless, all patent systems employ legal doctrines to regulate patent scope, such as adequacy of the written description relative to patent scope, and scope of embodiments of claim language for infringement. Exactly how, in practice, could patent scope be widened or narrowed by statute *across a patent system*? Would one increase the inventive step—and thus the scope of the average patent—by requiring that the claimed invention be *really, really* non-obvious? So, despite the economic importance of patent scope, the discussion of patent scope as a policy "lever" (Lemley & Burk 2003) has remained largely theoretical and historical (Merges & Nelson 1990; Scotchmer 1991; Moser 2013). At the same time, patent scope is at the front and center of debates surrounding patent quality in legal and public policy communities. "Low quality" patents are often thought to be *either* overly broad relative to the inventive contribution *or* to be unduly vague or ambiguous, irrespective of whether they pass legal tests of validity. So, "low quality" may reflect either decisional errors in granting patents or systemic errors in legally authorizing such patents in the first instance. The economic effects of either kind of error may be significant.

Further, recent debates over the effectiveness of the patent system have focused on the central issue of "patent quality." In 2002, then-former Assistant Secretary of Commerce and Commissioner of the U.S. Patent and Trademark Office (PTO) Gerald Mossinghoff noted a "real concern that with the dramatic increase in the number of patent applications filed and patents granted—and with the influx of new and unavoidably inexperienced examiners hired to handle the workload—compromises to patent quality may be inevitable." (Mossinghoff and Kuo 2002).

In turn, the purported decrease in patent quality supposedly led to diminished innovation due to increased licensing and litigation costs as well as to reduced sequential innovation in various industries, particularly with regard to software patents (Rai 2013; Choi and Gerlach 2015).

The scope and the clarity of patent claim language have been identified by researchers as significant concerns for patent quality (Rai 2013; Churnet 2013; Petherbridge 2009; Zimmer 2008; Wagner 2009). This is, in part, because overly broad or vague claims can be exploited for the purposed of rent seeking, particularly by non-practicing entities, or NPEs (Schwartz and Kesan 2014; Allison and Mann 2007). Legally invalid, overly broad, or vague claims are thought to impose deadweight losses (Abramowicz & Duffy 2011), as well as to reduce sequential innovation in various industries, particularly with regard to software (Rai 2013; Choi and Gerlach 2015). Given these concerns, the PTO has adopted many initiatives over the last decade to address patent quality concerns, including the now-completed "Enhanced Patent Quality Initiative."[1] As noted by the PTO in the 2011 "Adoption of Metrics

[1] See https://www.uspto.gov/patent/EPQI-complete.

for the Enhancement of Patent Quality" report, its "previous focus on the correctness of actions taken by an examiner in an individual application has been widened to better encompass the entirety of the patent application and examination process." The agency has particularly focused on assuring the clarity of patent claims and of other aspects of the examination record, even when less clarity would still be legally valid. However, the PTO can only apply the law as enacted by the Congress and as interpreted by the courts, and has limited authority to alter scope and validity doctrines (see Cuozzo Speed Technologies v. Lee, 136 S.Ct. 2131, 2143 (2016) (citing Cooper Technologies Co. v. Dudas, 536 F.3d 1330, 1335 (Fed. Cir. 2008)) and has no jurisdiction over infringement determinations.

The explicit focus on the patent examination process, or *patent prosecution*, by the PTO highlights the relationship between patent quality, the quality of the examination to which the patent application was subject, and patent scope. Recent scholarship exploits new data sources to evaluate the quality of the patent examination processes more directly. For example, Frakes and Wasserman (2013) have used information on application outcomes to test their hypothesis that under conditions of resource constraints the PTO is more likely to grant applications in technology areas of higher continuation application filings. Others have focused on theoretical modeling of the examination process or on application filing behaviors (Comino and Graziano 2015, Schuett 2013, Caillaud and Duchene 2011).[2] Researchers have investigated how purportedly "low quality" patents (variously defined) are treated in litigation (Petherbridge 2009; Marco *et al.* 2015b; Koenen and Peitz 2015; Yelderman 2014). Additional work has focused on the patent allowance rate (grant rate) as an indicator of leniency, either across technological fields (Carley *et al.* 2015), examiners (Frakes and Wasserman 2013), or international offices examining the same inventions (de Rassenfosse *et al.* 2016). The allowance rate alone is an imprecise measure of examination quality if one ignores *what* is being allowed. That is, if applications are sufficiently narrowed prior to grant, a grant rate close to 1.0 would not necessarily have negative implications for patent quality. And none of these studies

[2] Comino and Graziano (2015) posit that "true innovators" are forced to patent more intensively in the presence of "bad patents".

measures patent scope directly, as to do so would require evaluation of every claim of each patent to determine the meaning of each claim and then to measure the full set of existing and potential future embodiments relative to some specific reference time frame (Sarnoff 2004a, 2004b).

Further, there has been little empirical analysis of initial application claiming practices and of changes to patent claims and claim language (and thus changes to patent scope, or "breadth") during the examination process. Other legal analyses (e.g., Merges and Nelson 1990; Sarnoff 2005; Collins 2008; Chiang and Solum 2013) note the substantial discretion that exists in interpreting (or construing) the meaning and scope of patent claims for both claim validity and infringement determinations, and note additional doctrinal and conceptual concerns in regard to determining particular patent claim scope from claim language.

Comparatively little attention has been paid to developing and assessing direct measures of patent scope, particularly in light of the difficulties of interpreting the language of patent claims and the variety of technologies to which the language of patent claims may apply. Further, many proposed measures of patent scope can only be observed for the patent grant. Thus, they provide no way to estimate scope changes during patent prosecution.

This chapter presents the first large-scale analysis of patent application and granted patent scope changes during the examination process, using measures of patent scope that are observable at filing and at grant. We define and validate two claim-related metrics for patent scope based on independent claims. Specifically, for each published application and patent in our dataset we calculate:

1. the number of words used in the *shortest* independent claim (which we call independent claim length, or "ICL");[3] and,

2. the count of the number of independent claims (which we call "ICC").

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[3] We also considered alternative measures for ICL including the average independent claim length and the length of the first independent claim. The shortest, first, and average independent claim length are all highly correlated (see Table 2.2). We re-ran each validation regression performed in Section 2.4 for both first and average independent claim length. The results are insensitive to the definition of ICL.

As discussed in more detail below, we expect that measures directly related to claim language provide improved indicators of patent scope relative to other proxies. Further, analyzing changes in claim language can be measured between publication and grant to provide insights into the examination process which can serve as the basis for further research on patent quality.

We discuss in more detail in Section 2.2 our reasons for focusing on patent scope measured by the word length of the shortest independent claim. In principle, the shortest claim should provide the broadest scope, because each extra word should impose some additional restriction on the *intensional* set of embodiments that limits its *extensional* application from the broader set of embodiments encompassed by the claim meaning without that word (Sheff 2017). This is based on the assumption that all words have *some* meaning, as well as by applying the legal interpretive principle that all words are to be given effect, rather than be treated as mere surplusage (Llewllyn 1950).[4] Because our scope metrics can be observed separately for published patent applications and for patent grants, they provide an advantage over other scope measures in evaluating the patent examination process. Our scope metrics can be used to evaluate the behavior of applicants and of examiners during the application process, and provide new means for assessing the quality of issued patents and the effectiveness of patent examination.

Our results reveal several interesting features about the patent examination process. First, we find that applications with narrower claims are more likely to be granted than those with broader claims. Second, the examination process itself tends to narrow the scope of patents by adding 45 words, on average, to the shortest independent claim and by reducing the number of independent claims by 0.4 claims. Third, we find that broader applications tend to have longer pendency times, both for abandoned applications and granted patents. Further, longer pendency periods

[4]Of course, the scope of meaning of any particular word may not be directly comparable to the scope of meaning of any other particular word, without first engaging in linguistic interpretation or considering its extensional applications within the universe of possible embodiments. Accordingly, direct comparisons of the scope of unrelated technological claims in different fields based on word counts are likely to be problematic. Instead, claim counts provide more useful information in regard to changes to the claim scope in particular applications, and through large-scale observations across and within technology domains.

tend to generate more significant narrowing of the patent between application and grant. We also find significant variation over time in the breadth of patent applications and patent grants, contrary to conclusions drawn from some earlier analyses that suggested a high level of stability in claim lengths of issued patents over longer periods of time (Osenga 2012).

In the next section, we provide a background on patent scope. Section 2.3 discusses the patent examination process and discuss ICL and ICC as proxies for the scope of patent applications and granted patents. Section 2.4 describes the claims data, our parsing process, and the resulting public-use data set. We also describe the econometric validation for using ICL and ICC as measures of patent scope. In Section 2.5 we use ICL and ICC to analyze patent examination at the USPTO. We examine differences in the statistical distributions of ICL and ICC between abandoned applications and applications that are later granted, and we quantify the evolution of claims during examination for granted patents. We present trends in ICL and ICC over time, and consider the relationship between patent breadth and pendency using an econometric framework. Lastly, we examine cross-sectional differences for many types of application characteristics, including technology and origin. Section 2.6 concludes with recommendations for the research community to evaluate, improve, and expand on the data and algorithms provided here, and to incorporate patent scope metrics into their work.

2.2 Background on Patent Scope

2.2.1 Measuring Scope

Economists and other researchers have long used measurements of patent scope in performing empirical work on patents. Often the purpose is simply to control for scope in explaining patent value, patent litigation, investment, or patent strategy. Indeed, because scope is an important component of patent value, these measures are often swept up in the discussion of patent valuation (see van Zeebroeck 2011 for a survey). Less work has been done exploring the endogeneity of patent scope that arises within the patent examination process.

Measuring patent scope typically involves one of two approaches: (1) counting the number of claims in the patent (e.g., Lanjouw and Schankerman 1997, 2004; Frakes and Wasserman 2014); or (2) counting the number of technological classifications assigned to the patent by the examination authority (class counts) (e.g., Lerner 1994). Claim counts historically rely on the total claim count (TCC) rather than a count of independent claims, primarily as an artifact of the available data. Total claim counts have been widely available to researchers for many years. However, the USPTO does not officially publish separate counts for independent and dependent claims. Distinguishing dependent claims from independent claims requires parsing the claim text itself or relying on proprietary datasets. In earlier studies, independent claim counts are used for smaller datasets where hand collection and human evaluation and coding is not cost prohibitive. In recent years, the greater availability of natural language processing software has made the parsing problem less costly, though not without its problems, as we discuss in the working paper (Marco *et al.* 2016). To our knowledge, independent and dependent claim identification is not available in a bulk public-use datafile-a problem that we address by making our data and algorithms available freely available.

Mann and Underweiser (2012) focus on patent quality (understood as validity) for patents involved in Court of Appeals for the Federal Circuit (CAFC) decisions. They use both TCC and the number of independent claims (independent claim count, or ICC), as well as the number of words in the patent abstract (which has no legal significance) and the closeness of the alignment between words in the patent specification and in the patent claims, as explanatory variables for patent validity as determined by appellate court cases. As they note, "[b]y allowing us to quantify the extent to which the prosecution process reduces the number of claims in the patent, these data should provide a measure of the rigor of the prosecution process. Similarly, by allowing us to examine data about independent claims in addition to total claims, we have a second and arguably more precise method for measuring the aggressiveness of drafting reflected in the application."

From a theoretical point of view, independent claims should represent a better measure of patent scope than total claims. By law and practice all dependent claims necessarily should be subsets of the technologies that are already within the scope of the independent claims from which they depend, particularly given the legal interpretive principle of claim differentiation, i.e., that each claim should be treated as distinct in its scope from other claims (Sarnoff & Manzo 2017). Thus, using the total claim count (TCC) should normally result in over-estimating the measure of a patent's technological scope (because all of the technological embodiments of every dependent claim are embedded in the independent claims, and as there may be some overlap between different dependent claims). In practice, TCC and ICC are correlated, as we show below in Table 2.2, simply because each independent claim typically has one or more dependent claims. However, the correlation is much stronger between total claims and dependent claims, indicating that ICC and TCC are not substitutes. Additionally, our validation exercise below shows that ICC has more predictive value.

Novelli (2015) argues that claim counts and technology class counts represent two different dimensions of patent scope, where the total number of claims per patent corresponds to "the number of variations to the core inventive idea that are identified in the patent,"[5] and the number of technological classes determine the position of the invention variations in the patent space (Novelli 2015). She finds that each dimension of patent scope has varying implications on further inventive activity by the inventing firm.

In practice we expect both claims and technology classes to be useful (correlated) indicators of patent scope; and, in principle multiple measurements are preferred where possible. However, claim-based measures have the advantage of being able to measure scope consistently throughout the examination process. In addition to ICC, other claim-based measures have also been proposed. Lichtman (2004) analyzed the total changes to *unique words* used in patent claims between application

[5]However, as patents may claim the same invention as either structures or methods, and may use different terms having similar meanings in different claims, additional claims will not *always* indicate meaningfully different *technological* applications of the same inventive concept. For instance, it is difficult to compare technological differences between a method claim for merely using a system and the system itself.

and issuance for a small sample of application-patent pairs. We adopt a similar approach by measuring the length of independent claims in terms of the number of words (independent claim length, or ICL), which we discuss in more detail below in Section 2.3. Both ICC and ICL are easy to measure and can be observed at the beginning and the end of prosecution for patented applications.

In contrast, in an effort to assess changes to claiming practices over decades, Osenga (2012) looked at *average* independent and dependent claim length, and *at grant alone*, using small samples of randomly selected patents. She found that claim length practices had remained surprisingly stable over five decades, notwithstanding significant doctrinal and technological changes. In contrast, we find significant variations in claim length from 1976 to 2014 for granted patents and from 2001 to 2014 for published applications.

As noted above, many scholars have used a count of *total* claims as a measure of patent scope. For example, Allison and Lemley (2000) performed analyses on the total number of claims at grant, based on the assumption that comparative increases across unrelated patents in the total number of claims should reflect either increased complexity or increased value of the technology sought to be protected, given that additional claims will normally cost patent applicants additional filing fees and drafting and prosecution costs. However, this approach treats the number of claims as an indirect signal of the willingness of the applicant to invest in the technology, which *may* be correlated with breadth or more generally with value. We believe that the number of independent claims is a better direct measure of patent scope.

To understand the value of claims-related measurements of patent scope, it is important to understand some details of the US patent examination process and to provide a description of potential outcomes from examination. Even for experienced patent researchers, understanding the institutions behind the creation of patent data is crucial for proper research design and proper interpretation of the data.

2.2.2 Patent Prosecution

The laws and procedures governing the patent examination process involve many options and strategies that applicants and examiners employ to influence patent scope.[6] These behaviors lead to a natural relationship between the text of patent claims and patent scope, and the way in which patent prosecution influences both. We detail some of these institutional relationships below, and we validate them econometrically in Section 2.4.

A complete patent application-in terms of substantive content-to the PTO contains:

1. a *title* and *abstract*;

2. a *written description* of the nature of the invention made (which may demonstrate that it is eligible subject matter), sufficient to inform those with ordinary skill in the relevant technology how to make and use the invention;

3. optionally, the application may contain one or more *drawings*;

4. one or more *claims*, i.e., a formal "peripheral" description of the invention that defines the legal scope of the invention (by specifying the necessary elements or steps that intensionally define the invention) for which exclusive rights are sought;

5. and a *list of prior art* references (documents describing the relevant technology known to the inventor, relative to which the claimed invention should represent a new and non-obvious advance).

Together, the written description and the drawings are commonly referred to as the *specification* or "*spec*."[7] In addition to being fully enabled, the patent claims must find adequate written description support in the spec (demonstrating objectively that

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[6]For more detailed information about patent examination and examiner incentives, see Marco *et al.* (2017) and Graham *et al.* (2018). A detailed description of the patent examination process can be found in the Manual of Patent Examining Procedure (MPEP) at https://www.uspto.gov/web/offices/pac/mpep/.

[7]Technically the specification as defined by 35 U.S.C. §112 also includes the claims. However, in workaday parlance the "spec" is distinct from the claims.

the applicant mentally "possessed" or "recognized" the full scope of the claimed invention, as its meaning is legally construed at the time of filing) in order to be allowable (see Ariad Pharmaceuticals, Inc. v. Eli Lilly and Co., 598 F.3d 1336 (Fed. Cir. 2010) (en banc)). The negotiation over what has been disclosed and has "written description support" is part of the evolution of claim language during prosecution.

Patent claims are classified as either independent claims or dependent claims.[8] From a legal standpoint, independent claims must be drafted to be complete sentences that stand alone, without reference to any other claim. Many independent claims may exist in the same patent, describing different embodiments or aspects, uses, or methods of producing the invention.[9] For each independent claim, applicants may add dependent claims, which incorporate the independent claim by reference, but also add limitations. Applicants may wish to add dependent claims for several reasons, including as a "fallback" position in case the independent claim is rejected (during prosecution) or invalidated (post-grant). As noted earlier, adding dependent claims should never increase patent scope, as each dependent claim should already cover only a subset of the scope of embodiments of the independent claim. In contrast, even with the potential for substantial overlap in the embodiments of independent claims, adding an independent claim should tend to increase a particular patent's scope (because of the legal doctrine of claim differentiation), and should never decrease the patent's scope (as claim scope coverage should be additive). In contrast, dependent claims can never be technologically broader than the claims upon which they depend.

The submitted application will be assigned a set of initial technological classifications by the PTO, and then will be routed to the most appropriate general art unit

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[8] 35 U.S.C. §112(d). For example patent 8,000,000 has 12 claims. Of those four are independent claims: two visual prosthesis apparatuses, and two methods for limiting power consumption to such apparatuses. One dependent claim, dependent on the first apparatus reads "The visual prosthesis apparatus of claim 1, wherein In this way the dependent claim can be seen to be a narrower (limited) version of the independent claim."

[9] What constitutes a single "invention" poses difficult level of generality considerations, which are the subject of different legal approaches, including so-called "restriction" practice in the United States which is discussed below in regard to divisional applications and "unity of invention" practice in other jurisdictions.

(GAU, or "art unit") for examination. Once in the respective GAU, a Supervisory Patent Examiner (SPE) will assign the application to a patent examiner, by placing the application on an examiner's docket.

Institutional incentives encourage the examiner to work on the applications in filing date order; however, the patent examiner has some discretion. When considering an application, an examiner may issue a restriction requirement indicating that the application contains claims to more than one invention and thus should be separated into separate applications (with the payment of additional filing fees). In response the applicant may restrict the claims of the application to limit it to a single invention. The applicant may further choose to file a *divisional* (DIV) application seeking examination on the claims that were removed from the original application following the restriction requirement. The Patent Act also provides for continuation or continuation-in-part applications, which claim the benefit of an earlier application's filing date for the purposes of determining its "priority date" with respect to prior art.[10] The claims made by the child application must be supported by the parent application's written description. Continuations enable the applicant to pursue broader (or more questionable) claims without holding up the allowance of other claims. In fact, often the continuation is filed immediately following the allowance of some of the parent application's claims. Indeed, we find below that continuation applications are among the broadest applications receiving patent protection. Continuations themselves may have child applications, and this repeated process can lead to long and complicated family trees. In fact, over a third of non-provisional U.S. applications filed between 2001 and 2014 were child applications.[11]

The application will be examined by an examiner in the GAU to which it was assigned. Of course, in response to any action by the office an applicant may abandon the application and end prosecution. Abandonment most frequently occurs by failing to respond to an office action, intentionally or by missing deadlines (which may not always be curable). Applicants may expressly abandon the application at

[10] If the continuation application contains additional written descriptive disclosure ("new matter") that is being claimed, the application is a continuation-in-part (CIP) application. The prior art is evaluated based on whether the relevant claim is supported by the original spec or the new matter.

[11] Both PCT filings and filings with a foreign priority were excluded from this calculation.

any time.

If the application is ready for substantive examination, the examiner will determine if the claimed invention described in the patent application meets the requirements of the patent statute (35 U.S.C.). These requirements include patent eligibility, utility, novelty, and non-obviousness. Additionally, the claims must be clear, and there must be adequate support for them in the specification to enable a hypothetical person having ordinary skill in the relevant art (technology), or PHOSITA, to make and use the invention without undue experimentation. A patent examiner will assess novelty and non-obviousness based on a search of prior art available before the priority date. If the prior art indicates that the claimed invention is not new or suggests that it is obvious, or if the examiner otherwise determines that the invention does not meet statutory requirements, the examiner will issue a *non-final rejection*. However, if the examiner finds that all statutory requirements have been met for some or all claims, the examiner may allow the relevant claims. The applicant may then seek to have the patent issued, and if only some of the claims were allowed the applicant may seek to continue prosecution of the rejected claims in a child application.

Following a non-final rejection, the applicant may proceed by: (1) abandoning the application, (2) amending the claims (typically by narrowing them to avoid lack of novelty or obviousness in light of the prior art), or (3) filing arguments about why the unamended claims should not have been rejected. After the applicant's response, the examiner will re-examine the application and either allow the remaining claims or issue a *final rejection*.

Following a final rejection, an applicant has several alternatives to continue prosecution in the same application for a fee, usually involving a Request for Continued Examination (RCE) or, less commonly, by filing an appeal to the Patent Trial and Appeals Board (PTAB) at the PTO. An RCE has the effect of enabling the applicant to obtain a further round of examination before the same examiner. Typically, the applicant will amend the claims in order to continue prosecution. If the applicant appeals, the case is heard by the PTAB, with further appeals available in U.S.

District Court or before the CAFC (35 U.S.C. §141 or §145). The RCE process ensures that the PTO cannot issue a terminal rejection; prosecution ends only with a granted patent or an abandoned application. That is, “final” rejections are by no means final.

It is important to note that the specification in an application may *not* be substantively amended during patent prosecution to add new (inventive) matter (35 U.S.C. 132(a)). Further, continuation applications must share the same spec as their parent application. In contrast, a CIP may contain new matter that will provide a new priority date for any claims incorporating the new matter. While the background, detailed description of the invention, and figures in the specification do not constitute the claimed invention, the claims are supposed to be interpreted by reference to the specification’s description. Thus, the spec will have relevance to claim interpretation and patent scope. In contrast, the multiple options available to continue prosecution ensure that claims may be amended throughout the examination process. Depending on the costs of RCEs and other continuation options, applicants may have little incentive to unnecessarily or pre-emptively narrow the claims of patent applications. However, applicants have a greater incentive to invest in drafting the rest of the specification to obtain priority.

The next section explores these incentives in greater detail. We describe typical strategies used by applicants to amend claims, and how these strategies relate to patent scope. Because of institutional features of patent prosecution, we argue that patent scope is positively correlated with independent claim count and negatively correlated with independent claim length.

2.3 The Relationship Between Patent Scope and Patent Prosecution

As described above, the specification and the claims are two parts of a patent application. The specification encompasses a background of the invention and a more detailed written description of it, along with drawings or figures, whereas claims represent the legal metes and bounds of the exclusive rights sought by the applicant. Applicants have incentives to file an application with the broadest claims to which they think they are legally entitled (or to which they think they may be able to obtain rights even if it is not clear that they are legally entitled to claims that broad).[12]

Because patent prosecution generally involves several rounds of rejection and amendment,[13] there is little incentive for the applicant to voluntarily narrow the claims before its examination; that would be the legal equivalent of leaving money on the table. Broader claims on the patent grant translate to a larger set of technologies from which the owner can exclude others. Thus, amendments in the face of an examiner's rejection will typically be to narrow the scope of the claims. On the other hand, when the cost of amendments is relatively high to particular applicants, we should expect narrower applications, and fewer amendments.[14]

In order to circumvent the rejection applicants must argue that the rejection was improper or must narrow or cancel claims. Infrequently, amendments may result in *broader* claims when an applicant realizes during prosecution that it can claim additional scope that was disclosed in the specification. Strategically, the applicant may be able broaden claims through amendments rather than through the initial filing: once an examiner indicates that the filed claims will be allowed, the applicant may then negotiate to ask what (if any) additional, broader claims may be allowed.

There are two primary ways in which applicants will narrow the scope of the claims in an amendment: by canceling independent claims outright, or by adding further limitations to existing claims. These strategies help us to define the two scope measures that we rely on in this chapter.

[12]In fact, it has been suggested that applicants and their attorneys sometimes improperly seek to claim broader scope than what they believe is legally justifiable (Liivak 2017).

[13]The correlation coefficient between the number of office actions and the number of claim amendments in our sample is 0.82.

[14]The costs may be in the form of administrative fees or in the cost of delay. For instance, start-ups seeking financing may value speed, which may induce applicants to claim less than they are entitled and to file CONs to seek broader protection at a later date, so as to have prosecution proceed more quickly to an issued patent.

2.3.1 Independent Claim Count (ICC)

The principles of claim construction suggest that more independent claims broaden a patent's scope. The independent claims within a patent-while potentially overlapping-are not generally construed to be identical. Additionally, the fee structure of the USPTO incentivizes fewer claims.[15] Thus, as mentioned in Section 2.2, any additional independent claim will represent a broader scope for the patent; conversely, additional independent claims cannot reduce the patent scope.

2.3.2 Independent Claim Length (ICL)

The process of claim narrowing almost always involves adding words to the claim, such as modifiers, qualifiers, or other details, although applicants may also narrow the scope of their application through argumentation regarding the meaning of the claim words, generating so-called prosecution disclaimers and estoppels (Sarnoff 2005). Aside from responding to examiners' rejections, applicants have little incentive to narrow claims. Accordingly, as we show below, the vast majority of independent claims grow longer during prosecution, in response to examiner rejections. Thus, on an institutional basis we should expect a correlation between the narrowness of claims and the length of claims, *ceteris paribus*.

A common practice is for applicants to include a broad independent claim, along with narrower dependent claims. The examiner may reject the independent claim while indicating approval for a dependent claim, which in theory must have narrower scope because a dependent claim incorporates by reference the independent claim language and adds a limitation to it (e.g., "The device as described in claim 1, further comprising"). In that instance, the applicant may "roll up" at least one dependent claim limitation into the original independent claim to form a new, longer and narrower independent claim. For example, claim 1 of U.S. patent 7,769,690 incorporates the language from claim 1 in its original application, as well

[15] Excess claims fees apply after three independent claims (currently $460 per excess claim for large entities) and 20 total claims (currently $100 per excess claim for large entities). See USPTO Fee Schedule at https://www.uspto.gov/learning-and-resources/fees-and-payment/uspto-fee-schedulePatent%20Misc%20Fee, accessed October 12, 2018. Excess claims fees are charged at filing, but are also assessed if claims are added during prosecution. They are not refunded if claims are canceled during prosecution. The office also charges excess page fees.

as the limitations of dependent claims 5 and 6.[16] This additional language narrowed the scope of the independent claim such that, as modified, the claim was allowable over the prior art. Rolling up the dependent claims necessarily requires adding words to the independent claim, and unambiguously narrows the claim (as compared to the original independent claim). According to interviews with examiners and practitioners, dependent claim roll-ups are the most frequent form of claim amendments.

Where claim language is unduly ambiguous or vague (as well as when it is overbroad in regard to written description or enablement), the examiner may reject the claim under section 112.[17] Clarification by adding words normally narrows the claim scope because it excludes a set of potential embodiments, whether by restricting the meaning of the ambiguous or vague language or by specifying a narrower conception of the things (or relevant properties of things) that the meaning denotes.

There is one particular practice that provides an exception to our interpretation of additional words in the claim text. This is the case when the claim contains a list of possible embodiments, each separated by the word "or." Adding another possible embodiment to the list would add words and potentially add scope.[18] We consider these exceptions in our validation in Section 4.3 below. However, if the list is contained within a limitation, then adding the limitation to an independent claim should still make the claim narrower. As an example, consider three possible claims: (a) a bicycle frame, (b) a bicycle frame made of steel, and (c) a bicycle frame made of steel or aluminum. It is easy to see that (a) is broader than either (b) or (c). However, (c) is broader than (b) even though (b) contains more words.

Altering the independent claim from (b) to (c) by adding "or aluminum" would both lengthen and broaden the independent claim. However, in the case of a depen-

[16]See the full text claim language of application 10/495,059 as reflected in U.S. pre-grant publication 20050065799 (published March 24, 2005), available on Google Patents.) and U.S. patent 7,769,690 (issued August 3, 2010).

[17]35 U.S.C. §112.

[18]Similarly, a so-called Markush claim provides alternatives as being "selected from the group consisting of A, B, and C" (MPEP 803.02). Adding more elements to the group would add words and increase the scope.

dent claim roll-up, the process invariably leads to a narrower independent claim for the reasons explained above. A roll-up could yield change (a) into (b) or (a) into (c); but, it could not change (b) into (c) because "aluminum" is not a limitation of "steel." Examiner interviews confirm that the most frequent use of the "selected from" and "or" language in a independent claim is when that language is contained within a further limitation. While we did not do an exhaustive search, we were unable to find a single example of a case where the language was not embedded in a limitation.

2.3.3 Technological Complexity

The institutional features of patent prosecution indicate that adding words to the independent claims or reducing the number of independent claims in a particular application tends to reduce or otherwise restrict patent scope. However, those institutional features do not necessarily imply that it is appropriate to use the independent claim count or independent claim length to make inferences about the relative scope between two unrelated inventions, that is, the institutional features support "within-application" comparisons more than "between-application" comparisons. For instance, claim counts and word length may be correlated with technological complexity, so that observing more claims and more words in a particular patent may simply indicate that the invention is in a complex technology. Technological complexity of inventions is not, of course, identical to patent scope (i.e., the range of technological embodiments to which construed claim language applies). However, if more words are required to describe complex technologies, we should expect that relationship to hold especially for the specification, including the background and written description. We might also expect more drawings to be used. Indeed, the correlations presented in Table 2.2 show that the page length of the spec and page length of drawings are highly correlated.[19] Yet, page length and the number of drawings are not highly correlated with our measures of patent scope. If technological complexity is well reflected in the specification, then the claim-based measures

[19] The correlation coefficient is 0.53. Note that the page length of the spec does not include drawings.

are virtually independent from complexity.[20]

Our validation exercise in Section 2.4 also supports the interpretation of ICL and ICC as measures of patent scope. Thus, we feel comfortable making some comparisons across patents, especially with respect to time trends. Nonetheless, comparing the claim text within narrow technology groups may be more appropriate than across arbitrarily chosen technology classes.

Based on the discussion above and the validation exercise below, we proceed under the propositions that *ceteris paribus*, a patent's scope is correlated with (1) fewer words in its shortest independent claim, and (2) a greater number of independent claims. Therefore, as the length of the shortest independent claim increases, and as the number of independent claims decreases, the scope of patent should narrow.

The analysis in Section 2.5 shows that narrower applications (as measured by ICL and ICC at publication) have a shorter prosecution time and a higher probability of grant on average. In the next section we describe the way in which we construct our claims data and validate our scope measures.

2.4 Data and Validation

We build our claims data sets from publicly available full-text information on pre-grant publications and patent grants.[21] Machine-readable claims information is readily available on published patent documents, including patent grants themselves (since 1976), as well as pre-grant publications (since 2001).[22] Both patent grants and pre-grant publications are technically "publications" in the generic sense; thus, we adopt the agency's convention of calling pre-grant publications *PGPubs*.[23] The

[20]The correlations between spec page length or drawings page length and various measures of claim length and claim count are positive but very low: around 0.05-0.10, with the highest correlation of 0.11 between the number of pages and the total claim count.

[21]The USPTO's Patent Claims Research Dataset is available at www.uspto.gov/economics.

[22]The USPTO publishes a pre-grant publication eighteen months after filing, unless the applicant files a non-publication request. See 35 U.S.C. §122. Each pre-grant publication contains an application's specification, claims, prior art references (both patent and non-patent literature), classifications, abstract, drawings, and other application data.

[23]The agency itself uses the term *publications* to include all published documents. However, some writers and commentators use the term to mean pre-grant publications only.

term can lead to some confusion because not all PGPubs are "pre-grant" in the sense that PGPubs exist for non-granted (abandoned) applications.

Machine readable claims information is available only from official publications of the USPTO. However, the *file wrapper* (alternatively, *image file wrapper* or *IFW*) of a published application comprises the full documentation of each individual application, including the initial filing, office actions by examiners, claim amendments, disclosures, etc. Published applications are those that have been made available to the public, typically coinciding with either the publication of the PGPub or the patent grant. The individual claim amendments during prosecution are only available as image files in the file wrapper. Incorporating the information from the file wrapper would involve identifying each amendment, performing optical character recognition on each related document, and correcting for any errors. This is perhaps fruitful work for future research; however, we also encourage the agency to consider altering their document ingestion and distribution protocols to enable the provision of full-text machine-readable versions of the file wrapper.[24]

The scope of the data work described in this chapter includes parsing the published applications and patent documents themselves. The bulk data files incorporate the entire text of the PGPub or patent, not just the claims, and the claims themselves are not individually parsed. Consequently, the claims are not individually identified or tagged as being independent or dependent claims. Our parsing algorithm identifies each claim and its dependencies; the dependencies are included in the public use datafile.

2.4.1 Claims Text

To develop the datasets, we first clean and identify the claims section of each bulk file for published applications and patents. Second, we apply an algorithm to the parsed files to identify individual claims, as well as the dependency relationships between claims.

From the parsed claims text, we measure the length of each claim based on

[24] This has the further benefit of making the file wrapper searchable, which is of considerable import given that those published documents constitute prior art.

word count. We create data sets at the claim level and summary statistics at the document level.[25] Claim-level and document-level data are available for each PGPub (available for applications filed between November 29, 2000 and December 31, 2014) and for each patent granted from January 1, 1976 to December 31, 2014. For each PGPub, we distinguish between those that are later granted (*PGPub-grants*) and those that are later abandoned (*PGPub-abandonments*), as well as those that were pending (*PGPub-pending*) as of December 31, 2016.

We use the claims from the PGPub as a proxy for the claims at filing. The two may not be identical because applicants may proactively file claim amendments prior to the time of publication. And, in some instances patent prosecution may begin prior to 18 months after filing. Two things mitigate any problems that might arise from mis-measuring the claims at filing. First, the 18-month time frame applies to the filing date of the earliest *parent* application. So, in practice many CONs, DIVs, and CIPs are published shortly after filing. Second, we find that only 8.1 percent of applications in the dataset have a preliminary claim amendment filed before the publication date. Normal office practice is to incorporate preliminary amendments into the claims when they are published, and thus these claim amendments (except for the possible few that are filed too close to publication to be incorporated) are reflected in the publication data. We thus use the terms *claims at publication* or *the claims at filing*, alternatively, to refer to the claims as published in the PGPub.

To analyze patent prosecution, we create *publication-patent* pairs.[26] The publication-patent pairs allow us to observe within-application changes in scope due to patent prosecution. The available sources do not contain machine-readable text for each amendment that is filed, nor do they contain the claims of abandoned applications at the time of abandonment. Thus, we cannot create corresponding matched pairs for pending or abandoned applications. Consequently, we only observe changes to patent scope during prosecution for published applications that were later granted.

[25] More information about the methodology and the structure of the data sets can be found in the Appendix.

[26] We define a publication-patent pair to be a pairing of the earliest PGPub (PGPub-grant) and the corresponding patent grant for a given application number.

	Frequency	ICL				ICC			
		Mean	P25	P50	P75	Mean	P25	P50	P75
Publications (2001-2014)									
Later Abandoned (PGPub-abandonments)	1,089,427	94.2	46	75	115	3.03	1	2	3
Later Granted (PGPub-grants)	2,113,273	111.4	58	90	137	3.08	2	3	4
Pending*	790,019	107.1	59	90	133	2.73	2	3	3
All (PGPubs)	3,992,719	105.8	54	86	130	2.99	2	3	3
Grants									
At Publication (PGPub-grants)	2,113,273	111.4	58	90	137	3.08	2	3	4
At Grant (previously published)	2,113,273	155.9	93	136	195	2.70	1	2	3
At Grant (not previously published)	634,235	141.0	82	121	176	3.12	2	3	4
At Grant (1976-2000)	2,203,409	155.6	92	137	198	2.43	1	2	3

** As of December 31, 2016*

Table 2.1: Sample summary for PGPubs (2001-2014) and patent grants (1976-2014)

For the publication-patent pairs we define ΔICL and ΔICC, which represent changes in the values of ICL and ICC, respectively, between publication and grant. Note that the shortest independent claim at grant may be a different claim number than the shortest independent claim at publication. First, claims may be renumbered at various times during prosecution. Second, amendments may cause the shortest independent claim on the PGPub to grow longer than another independent claim.

2.4.2 Sample Summary

Table 2.1 summarizes our final sample, which represents 3.9 million PGPubs, 4.9 million granted patents (including those granted after 2000 and previously published, those not previously published, and those granted prior to 2001), and 2.1 million publication-patent pairs. For PGPubs, the table shows that PGPub-abandonments tend to have broader claims relative to PGPub-grants with respect to ICL (75 words versus 90 words, respectively, at the median). Further, granted patents are narrower at grant (136 words at the median) than at publication (90 words at the median). Granted patents also have one fewer independent claim at grant than at publication. We discuss these differences in greater detail in Section 2.5, below.

Table 2.2 shows the correlation matrix for various measures of claim length, claim count, and other relevant patent-level statistics. In practice the number of independent, dependent, and total claims are highly correlated. However, because dependent claims are usually more numerous than independent claims, the correlation between total claims and dependent claims is highest among the claim counts (0.99). The correlation between independent claims and dependent claims is only 0.33. Further, the correlation between independent claims and the number of *dependent claims per independent claim* is -0.33. Thus, a patent with more independent claims, will have more dependent claims. But, the ratio of independent claims to dependent claims will be higher. Independent claim length as measured by the shortest, average, or first independent claim are also highly correlated, with shortest and average being most highly correlated (0.93), and shortest and first being least correlated (0.81). This suggests that one should not necessarily assume that the first claim is the broadest.

Table 2.2 also presents the correlations between claim length and claim count both at PGPub and at grant, which are negative in all pairwise cases. The negative correlations reflect the expectation that claim length is negatively correlated with patent scope and claim count is positively correlated. Table 2.2 shows that the strongest negative correlation (-0.20) is between the length of the shortest independent claim (ICL) and the independent claim count (ICC) at PGPub, which are the measurements on which we focus our analysis.

Lastly, as discussed in Section 2.3, Table 2.2 also includes the page length of the specification and the number of drawings. Because those variables reflect technological complexity, they are highly correlated. But, they are not highly correlated with our scope measures, especially for patent grants.

2.4.3 Validation

While the primary purpose of this chapter is to examine the trends in patent scope and patent examination, it is also important to validate our ICL and ICC as measures of patent scope. We employ several statistical tests to compare these measures with post-grant outcomes and other variables traditionally correlated with patent scope, as shown in Tables A.1 and A.2 in the Appendix. The tests extend validation methods used in the previous literature (Lerner 1994) by examining the associations between ICL/ICC and (1) patent maintenance; (2) forward citations; and (3) the num-

	Correlation Coefficients																
	ICL at PGPub	ICL at Grant	Avg. ICL at PGPub	Avg. ICL at Grant	First IC at PGPub	First IC at Grant	TCC at PGPub	TCC at Grant	ICC at PGPub	ICC at Grant	DCC at PGPub	DCC at Grant	DCC/ICC at PGPub	DCC/ICC at Grant	Drawing Page Ct.	Spec. Page Ct.	CPC Count
ICL at PGPub	1.00																
ICL at Grant	0.66	1.00															
Avg. ICL at PGPub	0.94	0.66	1.00														
Avg. ICL at Grant	0.65	0.96	0.70	1.00													
First IC at PGPub	0.85	0.61	0.91	0.64	1.00												
First IC at Grant	0.63	0.92	0.68	0.96	0.67	1.00											
TCC at PGPub	-0.16	-0.10	-0.09	-0.06	-0.09	-0.06	1.00										
TCC at Grant	-0.10	-0.15	-0.05	-0.08	-0.05	-0.09	0.62	1.00									
ICC at PGPub	-0.20	-0.11	-0.08	-0.05	-0.08	-0.05	0.51	0.26	1.00								
ICC at Grant	-0.13	-0.17	-0.05	-0.05	-0.07	-0.06	0.28	0.47	0.47	1.00							
DCC at PGPub	-0.14	-0.09	-0.08	-0.05	-0.08	-0.05	0.99	0.62	0.38	0.22	1.00						
DCC at Grant	-0.08	-0.13	-0.05	-0.08	-0.05	-0.08	0.61	0.99	0.19	0.33	0.63	1.00					
DCC/ICC at PGPub	0.06	0.03	-0.01	0.00	0.00	0.00	0.37	0.37	-0.29	-0.18	0.45	0.43	1.00				
DCC/ICC at Grant	0.03	0.02	0.00	-0.04	0.02	-0.03	0.33	0.47	-0.14	-0.33	0.38	0.57	0.68	1.00			
Drawing Page Ct.	0.04	0.06	0.06	0.07	0.06	0.06	0.11	0.09	0.12	0.06	0.10	0.08	0.04	0.06	1.00		
Spec. Page Ct.	0.08	0.07	0.12	0.08	0.12	0.09	0.15	0.11	0.15	0.07	0.14	0.10	0.06	0.07	0.53	1.00	
CPC Count	-0.03	-0.05	-0.03	-0.06	-0.02	-0.05	0.05	0.03	0.01	-0.03	0.05	0.04	0.06	0.08	0.06	0.09	1.00

Note: In this table, we calculate correlation coefficients for measures recorded at different points in time (e.g., at PGPub and at Grant), limited to those applications for which we observe both measures. For example, we cannot observe the ICL at Grant for an abandoned application, so abandoned applications are dropped from the sample for this particular estimate but are included in the measure at PGPub. Additionally, we observe the number of pages containing drawings, page length for the specification, and the count of CPCs at PGPub, not at Grant.

Table 2.2: Correlation Matrix for Measures of Independent Claim Length (in words)

ber of Cooperative Patent Classification subclasses (CPCs)[27] to which the patent was assigned.

We use a variant of the validation method introduced by Lerner (1994), which analyzes the relationship between the number of 4-digit International Patent Classifications (IPCs - for which we substitute CPCs) to which a patent was assigned and (1) the number of forward citations assigned to a given patent, and (2) the incidence of litigation. In the Appendix, we present evidence that our measures of patent scope explain traditional scope proxies in a way consistent with Lerner. We also discuss how our measures relate to the results from the USPTO's *Patent Litigation and USPTO Trials: Implications for Patent Examination Quality*, which examined the relationship between the incidence of litigation and ICL and ICC at grant. Our results show that the relationship between our measures of patent scope and the outcome variables above is consistent with other validation tests of patent scope in the literature. Validation regression results and further discussion are provided in the Appendix.

Finally, we validate our our scope measure against two particular claim formats for which the addition of words may be more likely to expand than to narrow claim scope: claims using the connecting word "or"; and claims using so-called Markush format that use the words "selected from." Using the validation methods described above and further discussed in the Appendix, we empirically tested the relationship between our measures of scope and existing measures of scope and value from the literature. For each claim format type, we separated our sample into two groups by identifying patents with and without the specified claim language ("or" or "selected from") in any of the patent's independent claims. We then re-ran the validation regressions on each of the four subsets and found that the results were generally consistent across subsets for each claim format type.[28]

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[27]The CPC classification system was jointly developed by the USPTO and European Patent Office (EPO) and is similar to the IPC classification. For more information on the CPC classification system, please visit http://www.cooperativepatentclassification.org/. The USPC classification system is the USPTO's classification system, where each classification is comprised of a class and subclass. The USPTO provides a statistical mapping between USPC and CPC via web interface at https://www.uspto.gov/web/patents/classification/index.htm.

[28]Results are not included in this thesis but are available on request.

2.5 Patent Scope and the Examination Process

Our analysis starts with two basic stylized facts, as discussed in detail in Section 2.2 and validated in Section 2.4. First, inventors (or their attorneys) seek to claim what they think will be the broadest scope for their inventions that they may legally obtain in light of their disclosures. Broader scope can be observed, on average, in more independent claims and shorter independent claims. Second, on the basis of broad incoming applications, the examination process will normally (and on balance) result in a reduction of patent scope. This will result in a reduction in independent claims and longer independent claims, where additional words impose additional limitations (such as when a dependent claim is rolled up into the independent claim).

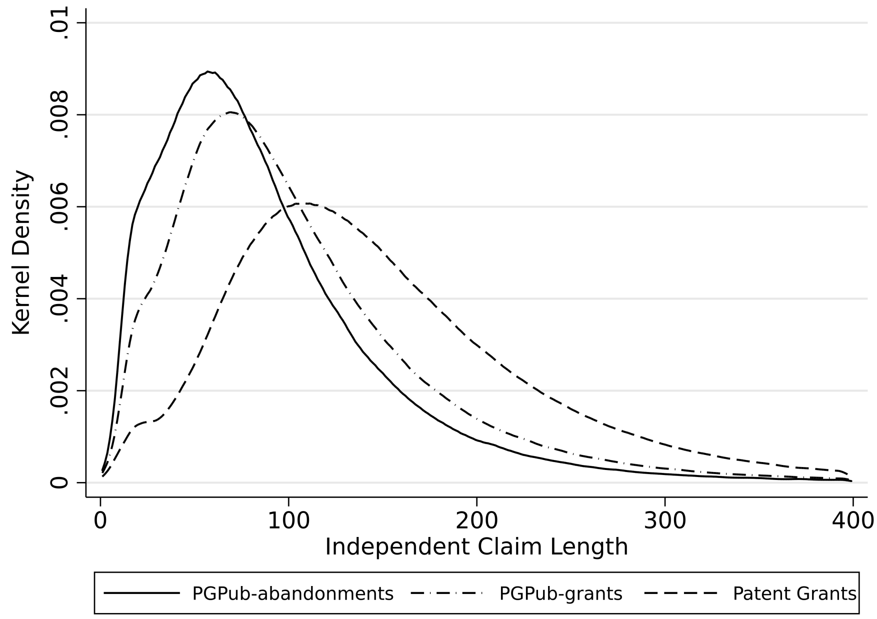
The analysis in this section explores the relationships between patent examination and patent (or patent application) scope. We focus on two basic comparisons: (1) for applications we compare applications that are later abandoned to those that are later granted (PGPub-abandonments versus PGPub-grants), and (2) for publication-patent pairs, we compare the change in scope between filing and issuance (PGPub-grants versus patent grants).

In Section 2.5.1 we examine the overall distributions of ICL and ICC. In Section 2.5.2 we describe the time trends in ICL and ICC. Section 2.5.3 explores the relationship between examination intensity and patent scope. Lastly in Section 2.5.4, we explore differences in patent scope based on observable application characteristics.

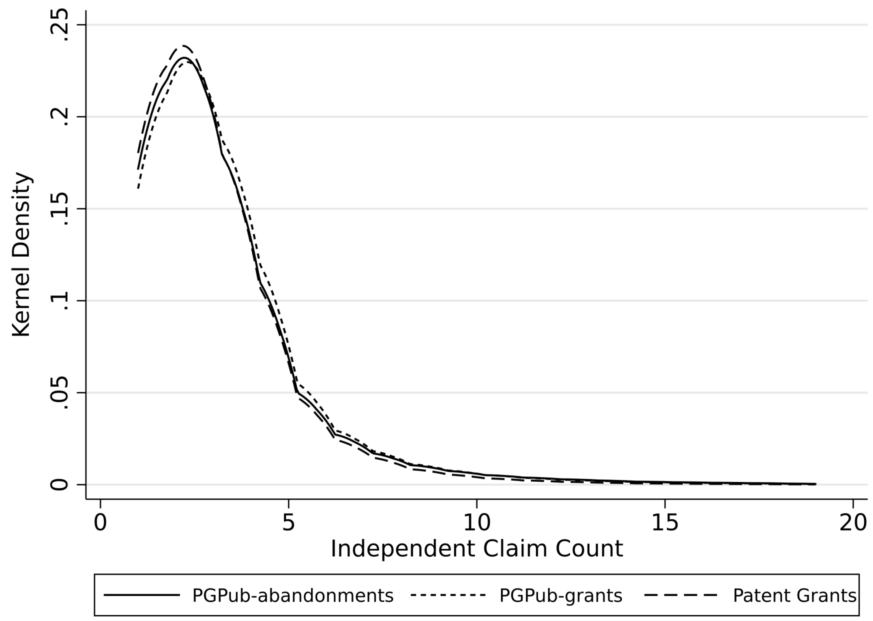
2.5.1 Abandonments and Grants

Figure 2.1 shows the kernel densities for the distributions of ICL and ICC for all pre-grant publications and patent grants for application years 2001-2014. PGPubs are separated based on whether they resulted in abandonments or grants (pending applications are not shown).

From the ICL distributions in panel (a), it is notable that: (1) applications with narrower claims at the time of publication are more likely to be granted, and (2) granted patents are narrower in scope at the time of grant than at the time of



(a) Independent Claim Length



(b) Independent Claim Count

Figure 2.1: Distribution of (a) ICL and (b) ICC

publication.[29] These results imply that the prosecution process leads to narrower claims. This is also consistent with the common practice of applicants to roll up allowed dependent claims into rejected independent claims. Further, it shows that applicants who file broad claims are more likely to abandon those applications. Or, put another way, applicants with narrower applications are more likely to survive the examination process with a granted patent.

The distributional characteristics of the ICL for PGPub-grants and for patent grants indicate that examination significantly narrows patent scope between publication and issuance. The examination process increases the mean ICL from 106 words at publication to 156 words at issuance for application years 2001-2014. Unfortunately, we cannot observe the distribution of ICL for abandoned applications at the time of disposal, which would provide more insight into the effects of examination relative to the initial filing choices by applicants. Nevertheless, the overall distribution of ICL for PGPub-abandonments has the same general shape as that for PGPub-grants, except that abandonments have a larger mass of shorter claims. This confirms that allowances are less frequent for applications that have broader scope, on average.

Figure 2.1(b) shows the kernel density for ICC distributions, separated by document type. In contrast to the ICL distributions, the ICC distributions are much more similar to one another (although they are still significantly different from a statistical standpoint).[30] Even so, the modal ICC for PGPub-grants is three independent claims, compared to two independent claim for PGPub-abandonments.[31] The difference in means is small: the mean ICC at PGPub-abandonment (2.99 claims) is slightly lower than the mean ICC at PGPub-grant (3.07 claims).

The distributions for ICC suggest (contrary to what might be expected based

[29] A t-test confirms a difference in the means for all distributions represented in Figure 2.1(a). Further, the Kolmogorov-Smirnov non-parametric test for the equality of distributions confirms that all ICL distributions are different from one another at the 1% significance level. With our sample sizes, even very small quantitative differences will be statistically significant.

[30] A t-test reveals that the means are statistically different from one another at the 1% level. Similarly, the Kolmogorov-Smirnov non-parametric test for the equality of distributions reveals that the ICC distributions differ significantly at the 1% significance level.

[31] The kernel density generation obscures the modes to an extent.

on the ICL results) that abandoned applications have slightly *narrower* scope compared to allowed applications. However, two potential explanations are possible. First, applications that have more than one independent claim are more likely to be able to continue prosecution if one independent claim is rejected. As a consequence, relative to an application with more independent claims, an applicant with a single independent claim may be less willing or able to continue prosecution of the application. Second, it is possible that applications that include only one claim may be of lower quality, in a drafting sense. For instance, *pro se* applicants, who prosecute applications without an attorney or agent, may not explore all possible ways of formulating a claim (i.e. method format, apparatus format, etc.). Regardless of disposal type, however, the mean number of independent claims for PGPubs is consistent with the maximum number of allowable independent claims per patent application (three) before incurring additional fees. In comparing granted patents between filing and issuance, the ICC distributions again show little difference, although the difference is statistically significant. Even with the small difference, the distributions show a shift towards narrower claims at grant. Patent grants have fewer independent claims at issuance than at publication (2.70 at the mean for patent grants and 3.08 for PGPub-grants according to Table 2.1). This is consistent with the results for the ICL distributions: patent applications become narrower between filing and grant.

2.5.2 Trends in Patent Scope

The majority of patent applications are filed by experienced patent attorneys or agents, whose ability to practice is regulated by the PTO through an admissions examination.[32] Further, market pressures incentivize these attorneys and agents to closely follow legal developments and PTO practices. Accordingly, we expect that applicant behaviors will be sensitive to changes in legal doctrines and examination practices. Changes in patent scope over time also may be attributed to changes in office initiatives and examiner behavior (e.g. increased examiner effort, incentivization schemes, examiner training and turnover, etc.). We would therefore expect that

[32] 37 C.F.R. §11.7.

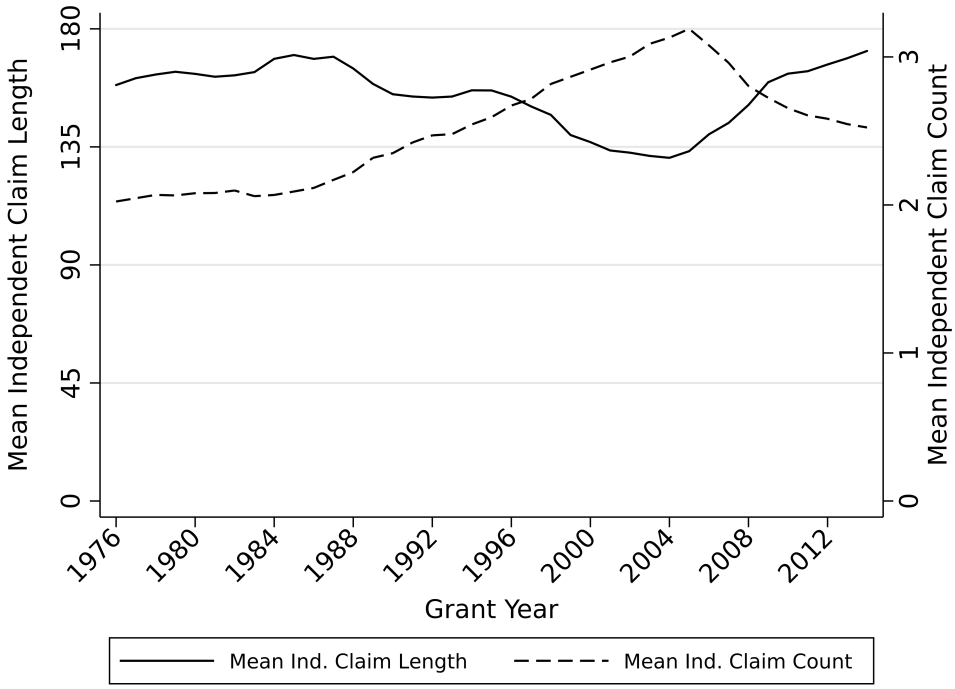


Figure 2.2: Mean Independent Claim Length and Independent Claim Count at Grant (1976-2014)

increased examiner effort or an emphasis on patent quality would generally decrease the average patent scope over time. In contrast, an elevated threshold for the required "inventive step" may lead to patents of greater scope, and may dissuade the filing of applications with narrow scope.

Figure 2.2 shows the trends over time in the mean ICL and ICC for patent grants. As expected, these trends move inversely to each other, given the negative correlation of ICL and ICC. The trends also provide some insights into applicant filing behavior as well as potential changes in examination practice over the past 40 years. For patent grants, we observe claims information since 1976. Published applications can only be observed since November 2000, with the implementation of the AIPA.[33]

Figures 2.3 and 2.4 compare time trends between patent applications and issued patents. We compute the annual arithmetic means for three different types of documents, similar to those of the previous section: (1) PGPubs for applications

[33]The American Inventor's Protection Act of 1999, implemented November 29, 2000.

that are later abandoned (PGPub-abandoned), (2) PGPubs for applications that are later granted (PGP-grants), and (3) patent grants. To identify the dates across which we compare the means, we define two comparison groups.

First, we define *disposition cohorts* based on the year of an application's final disposition, whether the disposition was by abandonment or grant. That is, we compare abandoned PGPubs, granted PGPubs, and patent grants based on the year of their final disposition. This grouping (by time of disposition) is natural for granted PGPubs and patent grants, because the set grants will necessarily contain the set of PGPub-grants (in addition to grants that derive from unpublished applications). For PGPub-abandonments, we use the disposal date in order to be sure the timing of the comparison is approximately equivalent to that of patent grants.[34] The disposition cohort analysis is presented in Figure 2.3.[35]

Second, we examine publication-patent pairs, which we refer to as "paired comparisons." This permits us to measure trends over time in the *change* in claim language during prosecution, by computing annual means of ΔICL and ΔICC within applications that are granted in a given year.[36] Because paired comparisons provide an indication only of the changes to ICL or ICC of a given application, we believe that this measure is the least likely to suffer from problems of comparing technologies from different fields or with for which different linguistic descriptors are used. The paired comparisons are presented in Figure 2.4.

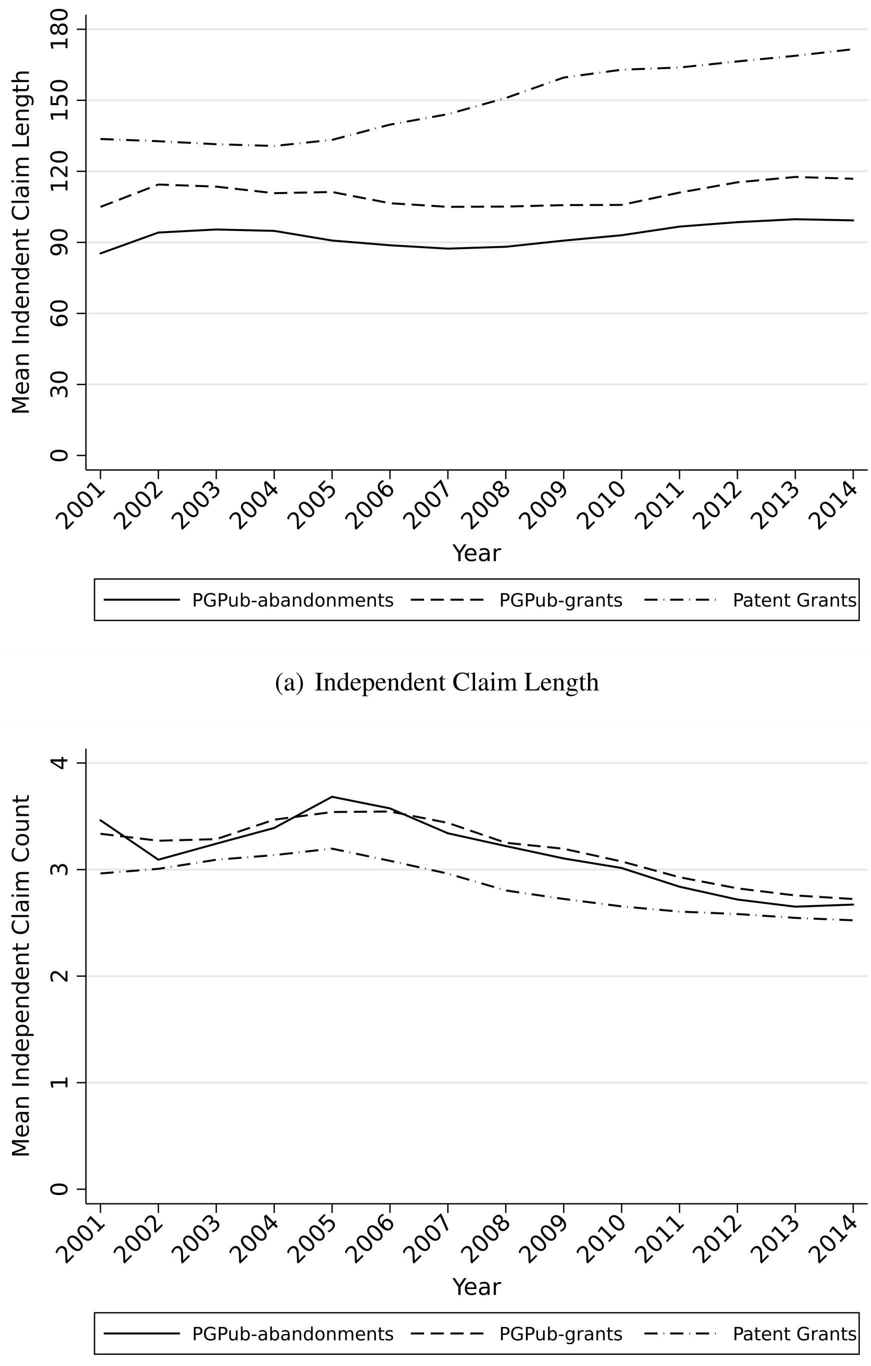
A few stylized facts emerge from examining the trends in Figures 2.2 to 2.4:

1. There have been significant long-term trends in ICL and ICC over time. Figure 2.2 shows the trend in ICL and ICC, respectively, for granted patents. There is a notable shift towards broader patents from 1984-2004, after which there is a shift towards narrower patents (2004-2014). The trend holds for both ICL and ICC.

[34] Note that abandonments generally take less time than grants, so the comparison is not perfect. Additionally, the disposition cohorts exclude pending applications, by definition.

[35] It is feasible to aggregate by the application date or initial publication, rather than by date of disposition, which may better highlight applicant filing behaviors rather than examination behaviors. Those comparisons are not presented here for the sake of parsimony but are available on request.

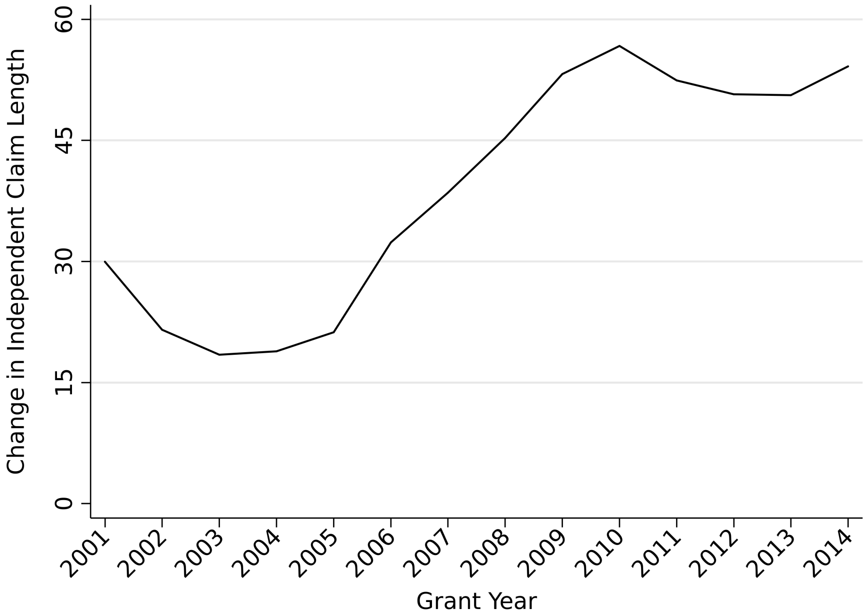
[36] The paired comparisons are aggregated based on the date of disposal (issuance). As with cohort comparisons, it would be feasible to aggregate by date of application or initial publication.



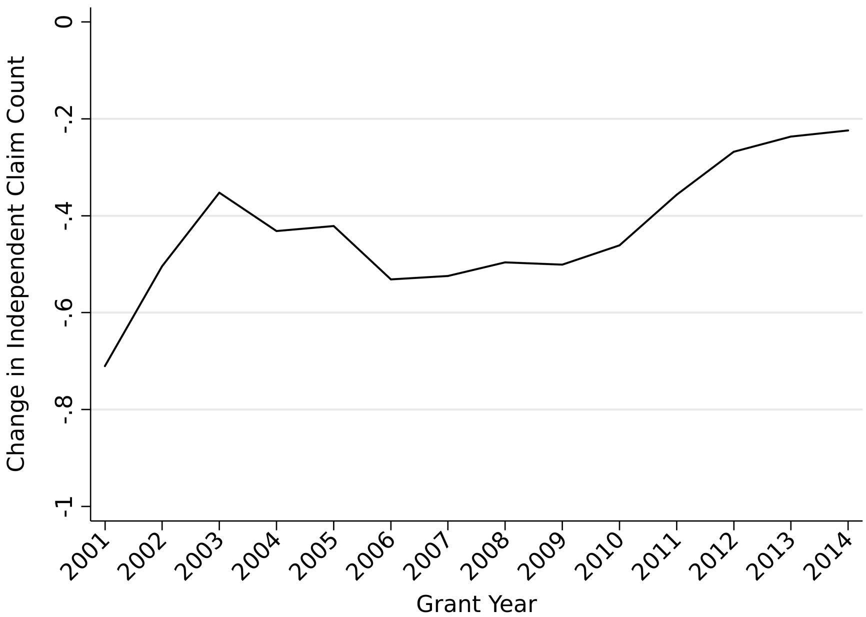
(a) Independent Claim Length

(b) Independent Claim Count

Figure 2.3: Disposition Comparison - Mean (a) Independent Claim Length and (b) Independent Claim Count by Application Status (2001-2014)



(a) Independent Claim Length



(b) Independent Claim Count

Figure 2.4: Mean Change in (a) Independent Claim Length and (b) Independent Claim Count From Publication to Grant (2001-2014)

2. Granted patents are narrower in scope than PGPubs. Granted patents have a higher ICL as measured by the disposition cohorts (Figure 2.3(a)). Figure 2.3(b) also shows that patents have a smaller ICC than PGPubs; however, that difference has been getting smaller over the last decade as measured by the disposition cohorts. The publication-patent pairs confirm that the scope is narrower across both ICL and ICC for patent grants relative to their scope at publication (Figure 2.4). However, the paired comparison shows that the difference is increasing in ICL and is decreasing in ICC over time.

3. The scope of applications is narrower for those that are granted relative to those that are abandoned. This observation is based primarily on ICL, which is higher at the mean for PGPub-grants than PGPub-abandonments (Figure 2.3(a)). It confirms what we observed for the full distribution in Figure 2.1(a). The mean ICC of PGPub-grants is very similar to that of PGPub-abandonments (Figure 2.3(b)). Thus, PGPub-grants are narrower than PGPub-abandonments at the mean based on differences in ICL, with roughly equal ICC.

Overall, the trends reinforce the thesis that the examination process reduces the scope of granted patents and that patent application scope affects the likelihood of grant. On average, examination adds words to the shortest independent claim and reduces the number of independent claims. Further, the trend over the last decade has been towards narrower patents. In particular the mean ICL for granted patents has increased significantly since 2004. This potentially indicates that the examination process may have become more stringent, and that applicants may have responded in turn. In particular, the change in the observed trends beginning around 2004 may correspond to various PTO examination quality initiatives adopted following the PTO's 2003 21st Century Strategic Plan and July 2003 legislative hearings on patent quality, including expanded reviews of primary examiners' work, "second-pair-of-eyes" reviews, and quality assurance reviews.[37] We expect that more recent initiatives, including the Enhanced Patent Quality Initiative

[37] See 21st Century Strategic Plan (2005).

implemented in 2015, will continue the trend. In the next section, we explore the relationship between pendency and scope in greater detail.

2.5.3 Patent Scope and Examination Intensity

In this section we investigate the relationship between patent scope and examination intensity, by which we mean examination pendency and the number of examiner actions to which an application is subject. For a given invention, one might expect examination intensity to be *reduced* for applications containing claims with broader scope. Such claims are more likely to be rejected without extensive examiner search and analysis based on claim definiteness and claim breadth doctrines,[38] such as enablement and written description. And, such claims will apply to a broader range of prior art embodiments and be more readily found unpatentable as anticipated or as obvious with less search effort by examiners.[39]

On the other hand, broader claims may require additional evaluations that could take examiners more time, such as when having to determine whether broader independent claims constitute patent eligible subject matter,[40] particularly given that the PTO requires that all grounds for rejection be addressed in initial office actions (so-called "compact prosecution").[41] Further, applicants who desire to continue prosecution in order to secure a patent may require more rounds of examination in order to whittle down the scope of initially broad claims. The impact will be exacerbated if the applicant is willing to accept multiple rounds of examination in order to ensure that it receives the broadest possible allowable scope. Such an applicant will make only incremental changes in scope with each amendment. Thus, whether by adding additional issues to address, or by triggering more rounds of amendments, applications containing claims with broader scope may increase the initial and total time in examination. On balance, we would expect the latter effect to dominate any initial reductions in examination time, *particularly for applications*

[38] See 35 U.S.C. §112(a)&(b).

[39] See 35 U.S.C. §102, 103.

[40] See 35 U.S.C. §101.

[41] See, e.g., PTO, Manual of Patent Examining Procedure, §2103(I), 9th ed. rev 07-2015 ("Under the principles of compact prosecution, each claim should be reviewed for compliance with every statutory requirement for patentability in the initial review of the application, even if one or more claims are found to be deficient with respect to some statutory requirement.").

resulting in grants.

The differences in scope as measured by ICL and ICC between patented and abandoned applications suggest that there may be differences in patent prosecution and examination outcomes based on the scope of the incoming applications. To investigate this we consider examination pendency, which is an issue central to applicants, to the PTO, and to Congress (Mitra-Kahn *et al.* 2013). For the reasons just discussed, we would expect that pendency, or the length of patent prosecution, would increase with an application's scope. *Ceteris paribus*, a broader application will be more likely to require more rounds of prosecution and examination before fulfilling the requirements for allowance, leading to a longer examination process. These differences should manifest themselves in changes to the claim language between publication and grant. We complement the pendency analysis by analyzing the number of examination actions actually performed on the application, in order to ensure that observed examination pendency is not simply the result of administrative or applicant delays.[42] In particular, we estimate the following equation:

$$ln(Intensity) = \beta_0 + \beta_1 ln(ICL_{PGPub}) + \beta_2 ln(ICC_{PGPub}) + \beta_3 FE + \varepsilon \qquad (2.1)$$

where *Intensity* is measured, alternately, by months of total pendency or the number of examiner actions. The explanatory variables ICL and ICC are for PG-Pubs, so that they represent the incoming claim scope of the patent application. The specification also includes fixed effects for filing year, technology class, application type, and examiner fixed effects.[43] We also segment the sample by abandonments and patent grants.

[42] The results are robust to other measures of pendency, including post-first-action pendency, which removes the queuing time before the first action by the examiner. We define examiner actions as all examiner allowances or rejections observed in the file wrapper of an application, including non-final rejections, final rejections, and allowances. The correlation coefficient between total pendency and the number of actions is 0.82.

[43] See Section 2.5.4 for application characteristics. Technology class is defined by NBER technology classification. Application type includes indicators for new applications, those with foreign or PCT parent applications, and those with US parent applications (provisional, CONs, CIPs, and DIVs).

	Log Pendency			Log Office Actions (Counts)		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	All	Later Abandoned	Lated Issued	All	Later Abandoned	Lated Issued
Log ICL - at PGPub	-0.0326***	-0.00237**	-0.0663***	-0.0757***	-0.0286***	-0.148***
	(0.00106)	(0.000811)	(0.00154)	(0.00170)	(0.00116)	(0.00260)
Log ICC - at PGPub	0.0664***	0.0747***	0.0481***	0.0484***	0.0602***	-0.00164
	(0.000667)	(0.000948)	(0.000775)	(0.000886)	(0.00123)	(0.000881)
Constant	3.553***	3.421***	3.740***	1.100***	0.781***	1.568***
	(0.0176)	(0.0227)	(0.0188)	(0.0163)	(0.0210)	(0.0205)
Observations	3,136,935	1,065,677	2,071,258	3,066,896	995,638	2,071,258
R-squared	0.273	0.217	0.332	0.056	0.047	0.116
Number of worker	12,155	11,669	11,421	12,125	11,620	11,421

Robust standard errors in parentheses. The OLS models above include filing year, examiner, parent type, and technology USPC fixed effects. *** p<0.001, ** p<0.01, * p<0.05

Table 2.3: Examination intensity on the basis of incoming claim scope - Regression Results

Table 2.3 presents the results of regressing examination intensity on incoming patent scope. As one might expect from the earlier discussion, we find a positive and significant correlation between application scope and examination intensity, for both patented applications (PGPub-grants) and abandoned applications (PGPub-abandonments). That is, applications with shorter independent claims and more independent claims tend to have longer pendency and more examiner actions. The coefficients on the logged values of ICL and ICC can be interpreted as elasticities. For PGPub-grants, a one percent *decrease* in ICL is associated with a 0.066 percent *increase* in total pendency, and a one percent increase in ICC is associated with a 0.048 percent increase in total pendency. With respect to the number of actions, the elasticities are similarly small: -0.148 for ICL and close to zero (and insignificant) for ICC (broader applications are associated with more examination actions). More reasonable changes in ICL and ICC show larger, but still modest, effects on examination intensity. Because the distributions of ICL and ICC are skewed, we consider interquartile increases (from the 25th to the 75th percentile) or decreases (from the 75th to the 25th percentile) rather than a one-standard deviation change. An interquartile decrease in ICL (-87% at the median) is associated with a 5.8% increase in pendency and a 12.9% increase in actions. For ICC, an interquartile increase (67% at the median) corresponds to a 3.2% increase in pendency, and no substantial change in actions.

The results are similar for abandonments, with a few quantitative differences. In particular, the examination intensity for abandonments tends to be more responsive to ICC and less responsive to ICL, relative to grants.

If broad patents have more intense examinations, a natural question is the extent to which the additional intensity has any mitigating effect on the resulting scope at the time of disposal. With our data, we cannot observe claim language at the time of abandonment. However, we can investigate the relationship between intensity and the claims at disposal for granted patents. More precisely, we are interested in the relationship between examination intensity and the *change* in scope for granted patents. For a given invention, broader patent applications have longer pendency and more rounds of rejections and amendments between the examiner and the applicant. We should expect those rounds of examination to lead to more significant changes in the claims, all other things being equal.

For our publication-patent pairs, we estimate the change in patent scope as a function of examination intensity and other control variables. More precisely, we estimate

$$\Delta S = \beta_0 + \beta_1 ln(Intensity) + \beta_3 FE + \varepsilon \tag{2.2}$$

where the change in scope, ΔS, is measured, alternately, by the change in ICL or ICC between publication and issuance. About 25% of applications do not have a change in ICL between publication and grant, and over 50% do not have a change in the number of independent claims. Nonetheless, we expect examination intensity to affect the change in scope, and thus, the ultimate scope of the granted patent. In the regressions *Intensity* is measured, alternately, by examination pendency or the number of examination actions. The specification includes a similar set of fixed effects that we used in the previous estimation: technology class, application type, and examiner fixed effects, but we replace filing year fixed effects with disposal year fixed effects to control for trends in issuance Table 2.4 shows the results of the estimation; the four columns show all combinations of scope and intensity variables.

VARIABLES	(1) ΔICL	(2) ΔICL	(3) ΔICC	(4) ΔICC
Log Total Pendency	25.88***		-0.486***	
	(0.292)		(0.0223)	
Log Office Actions		30.54***		-0.0166
		(0.261)		(0.0127)
Constant	-30.34***	22.25***	0.239	-0.914***
	(5.662)	(5.656)	(0.159)	(0.149)
Observations	2,071,258	2,071,258	2,071,258	2,071,258
R-squared	0.018	0.028	0.008	0.004
Number of examiners	11,421	11,421	11,421	11,421

Robust standard errors in parentheses. The OLS models above include disposal year, examiner, parent type, and technology USPC fixed effects. *** p<0.001, ** p<0.01, * p<0.05

Table 2.4: Change in Claim Scope on the Basis of Examination Intensity - Regression Results

In all specifications we find that greater examination intensity is associated with more extensive narrowing of scope during prosecution. Both pendency and the number of actions have a positive and significant correlation with ΔICL at grant. Pendency and the number of actions have a negative effect on ΔICC, but only the pendency coefficient is statistically significant. Additionally, the magnitudes of the effects are not unsubstantial. The coefficients in Table 2.4 can be interpreted as semi-elasticities: a 1% increase in pendency adds 0.26 words to ΔICL and subtracts a small fraction of a claim from ΔICC. However, an interquartile increase in pendency (63% at the median) adds 16 words to ICL and subtracts a third of a claim from ICC during prosecution. The number of examiner actions is statistically and economically significant for ΔICL: an interquartile increase in actions (100% at the median-from 1 action to 3 actions) adds 30 words to ICL during prosecution. The number of actions is not statistically or economically significant for ΔICC. The marginal effects in ICL (16 and 30 words, respectively) are quantitatively important considering that the median ΔICL is 27 for PGPub-grants (mean 44). Similarly, the marginal effects in ΔICC (-0.3 and zero claims, respectively) are almost identical to the mean and median of ΔICC (-0.37 and zero) for PGPub-grants.

In short, we find that broader applications are subject to greater examination intensity, and more intense examinations are associated with more significant narrowing of patent scope during prosecution, both in the length of claims and the number of claims. We can expect this relationship to hold for any given invention, *ceteris paribus*. That is, for a particular invention, broader claims on an application should extend prosecution, and longer prosecution should narrow the claims.

Our data include all published applications, and thus surely contain heterogeneity in the many characteristics of the underlying inventions and applicants. Thus, it is instructive to consider how application and patent scope vary with respect to application; we do this in the next section. In general, we find the same pattern within application characteristics as we do across the population: (1) at publication, granted applications are narrower than abandoned applications, and (2) granted patents are narrower than published applications. However, the effects are more significant for particular technological fields and for particular application types.

2.5.4 Application Characteristics

We find that different characteristics of applications can lead to statistically significant differences in measures of scope. However, the general patterns about scope discussed above hold for all groupings: narrower applications tend to be granted, and the prosecution process tends to narrow applications.

Table 2.5 shows the ICL and ICC for PGPub-grants and PGPub-abandonments grouped by various characteristics, including: entity size,[44] examination unit (technology center),[45] NBER technology category,[46] and parent application type.[47] The

[44]Entity status is based on fee payments at the time of filing. Small and micro entities are combined as a single category relative to large entities.

[45]There are eight technology centers (TCs) used during our period of study, including Biotechnology and Organic Chemistry (1600), Chemical and Materials Engineering (1700), Computer Architecture, Software, and Information Security (2100), Computer Networks, Multiplex Communication, Video Distribution, and the Security (2400), Communications (2600), Semiconductors, Electrical, and Optical Systems and Components (2800), Transportation, Construction, Electronic Commerce, Agriculture, National Security and License & Review (3600), and Mechanical Engineering, Manufacturing and Medical Devices/Processes (3700).

[46]NBER technology categories, as defined by Hall, Jaffe, and Trajtenberg (2001) and Marco *et al.* (2015a) are: Chemical (1), Computers and Communications (2), Drugs and Medical (3), Electrical and Electronics (4), Mechanical (5), and Other (6).

[47]Parent application type or application status relative to the parent. If there was no parent (a first time filing), we identified the application as having "no parent" (not applicable, or USNA). For applications having a parent application, we identified the type of such application. These were

technology center analysis was generally similar to that for the NBER technology categories; thus, we restrict our discussion to the technology centers. For each characteristic, the ICL is higher for PGPub-grants relative to PGPub-abandonments. The number of claims is not substantially different between PGPub-grants and PGPub-abandonments across application characteristics, which is consistent with the aggregate results in Figure 2.1(b).

Of notable interest, there are some characteristics that differ substantially from the general means. With regard to technology, applications in *biotechnology and organic chemistry* (TC 1600) have the largest difference in ICL between granted applications and abandoned applications: approximately 28 words. This is driven by the very low values for PGPub-abandonments, which are about 12-15 words below the overall PGPub-abandonment mean of 94 (from Table 2.1). However, these applications tend to have the most independent claims at filing. Further, *biotechnology and organic chemistry* is the only technology center for which PGPub-abandonments have more claims, on average, than PGPub-grants. TC 3600 (including transportation, construction, e-commerce, and agriculture) tends to have the longest claims (125 words for PGPub-grants and 107 words for PGPub-abandonments, relative to the means of 111 and 94, respectively). These applications also tend to have the fewest independent claims.

Surprisingly, small and large entities look almost identical at the mean for ICL and ICC at publication, which may suggest that differences in funding and experience may not have dramatic effects on drafted claims (although they may have some effect on the degree of narrowing, as discussed below). Applications with foreign parents tend to be narrower than the average at filing, having higher ICL and lower ICC. This may reflect differences in foreign claiming and examination practices, as well as differences in fee structures (assuming that relatively little change is made to

divided into applications having a parent that was: a foreign application (Foreign, or FOR); a Patent Cooperation Treaty (PCT) application (which was further subdivided by the designated office of the parent either PCT-foreign or PCT-US); a prior US non-provisional application (and if so, the relationship to that parent application as discussed below), or a US provisional application (US-provisional, or US-PRO). If the application had a prior US non-provisional application as its parent, we denoted the application's relationship to the parent as a continuation (CON), a divisional (DIV), or a continuation-in-part (CIP) application to a US application.

	IC Length			IC Count		
	Later Granted	Later Abandoned	Difference	Later Granted	Later Abandoned	Difference
Small entity status						
Large	111.0	94.1	16.96	3.1	3.1	0.02
Small or Micro	112.2	94.0	18.21	3.0	2.9	0.08
Technology Center						
1600 Biotech, Organic Chem	110.2	81.8	28.44	3.7	4.0	-0.23
1700 Chem & Mat Engineering	97.8	84.4	13.38	2.7	2.7	0.08
2100 Comp Architecture	107.8	95.7	12.11	3.6	3.5	0.10
2400 Comp Networks	107.7	95.6	12.13	3.6	3.5	0.10
2600 Communications	109.2	95.7	13.53	3.5	3.2	0.27
2800 Semiconductors, Electrical	111.0	95.6	15.35	2.9	2.6	0.27
3600 Trans, Constr, E-Comm, Ag	125.5	106.9	18.60	2.8	2.8	0.02
3700 Mech, Mfg, Products	117.0	99.9	17.11	2.8	2.7	0.17
NBER category						
1 - Chemicals	102.1	95.2	6.87	2.9	2.8	0.07
2 - Comp & Comm	109.7	97.4	12.28	3.4	3.4	0.07
3 - Drugs & Medical	107.3	78.8	28.47	3.5	3.7	-0.18
4 - Electrical	110.8	95.4	15.41	2.9	2.6	0.23
5 - Mechanical	123.4	105.3	18.18	2.7	2.5	0.17
6 - Others	114.2	95.7	18.45	2.8	2.6	0.25
Parent application type						
Foreign	122.9	101.8	21.10	2.7	2.7	0.03
PCT - foreign	119.9	97.1	22.81	2.7	2.8	-0.15
PCT - US	109.4	87.9	21.46	3.4	3.6	-0.21
CIP of US app	107.1	95.8	11.37	3.6	3.5	0.07
CON of US app	112.1	94.8	17.24	3.3	3.4	-0.17
DIV of US app	109.0	94.3	14.74	3.2	3.1	0.04
No parent	98.7	91.9	6.82	3.3	3.0	0.36
US provisional	98.8	83.2	15.64	3.7	3.4	0.23

IC Length is defined as the length of an application's shortest Independent Claim. IC Count is defined as the number of independent claims in an application.

Table 2.5: Applications at publication by application characteristics (2001-2014)

claims when such foreign applications are "nationalized" by filing a US application claiming foreign filing priority).[48] The broadest patents at filing tend to be those with US provisional parents, which may reflect differential attention to claiming.

Table 2.6 provides the ICL and ICC by application characteristics for publication-patent pairs.[49] By comparing claims at publication to claims at grant, we can identify the average change in claims during patent prosecution for granted patents. There are several interesting facts that emerge from Table 2.6. Most notably, for each group claims are narrower at grant than they are at publication, in terms of the means of ICL and ICC. We also see interesting differences between application types.

Small and large entity applications tend to be similar at filing, but small entities experience greater narrowing of patent scope during prosecution, leading to 5 more words and 0.25 fewer claims at issue relative to large entities. Some of this difference could be a function of relative funding or legal expertise, particularly in knowing how to draft claims that are more likely to be accepted or less in need of narrowing amendment. Biotech applications again stand out relative to other technology centers: they are not significantly narrowed with respect to ICL (only 11 words), but they lose an average of 1.5 independent claims during prosecution. On the other hand, computer-related patents are more subject to increases in ICL than to decreases in ICC.

Parent types reveal some interesting facets about application sources. Applications that claim priority to a foreign parent or PCT-foreign parent are filed with the longest independent claims (ICL of 123 and 120 words, respectively), yet they are among the highest with respect to changes in ICL during prosecution (an additional 44 and 48 words, respectively). This means that the mean ICL of the resulting patents is over 165 words-more than 15 words higher than the next highest parent type. This is perhaps surprising, because foreign applications may already have been through an examination process in the home jurisdiction, and thus may have been "pre-narrowed" prior to filing in the U.S. The other application types

[48] 35 U.S.C. §119.

[49] The publication values in Table 2.6 match those found in Table 2.5 for granted applications.

	IC Length			IC Count		
	At publication	At issuance	Difference	At publication	At issuance	Difference
Small entity status						
Large	111.0	155.0	43.94	3.1	2.7	-0.34
Small or Micro	112.2	160.0	47.79	3.0	2.5	-0.53
Technology Center						
1600 Biotech, Organic Chem	110.2	121.4	11.16	3.7	2.3	-1.48
1700 Chem & Mat Engineering	97.8	138.6	40.88	2.7	2.2	-0.54
2100 Comp Architecture	107.8	175.5	67.73	3.6	3.3	-0.28
2400 Comp Networks	107.7	183.7	75.99	3.6	3.3	-0.25
2600 Communications	109.2	159.7	50.53	3.5	3.3	-0.21
2800 Semiconductors, Electrical	111.0	145.4	34.36	2.9	2.7	-0.23
3600 Trans, Constr, E-Comm, Ag	125.5	179.4	53.90	2.8	2.6	-0.22
3700 Mech, Mfg, Products	117.0	168.2	51.18	2.8	2.5	-0.31
NBER category						
1 - Chemicals	102.1	135.3	33.25	2.9	2.2	-0.71
2 - Comp & Comm	109.7	165.6	55.88	3.4	3.2	-0.24
3 - Drugs & Medical	107.3	138.3	31.04	3.5	2.5	-1.07
4 - Electrical	110.8	148.2	37.37	2.9	2.6	-0.25
5 - Mechanical	123.4	167.6	44.16	2.7	2.4	-0.22
6 - Others	114.2	165.7	51.54	2.8	2.5	-0.30
Parent application type						
Foreign	122.9	166.8	43.88	2.7	2.5	-0.20
PCT - foreign	119.9	168.1	48.14	2.7	2.2	-0.44
PCT - US	109.4	150.8	41.38	3.4	2.6	-0.81
CIP of US app	107.1	149.3	42.15	3.6	3.0	-0.56
CON of US app	112.1	141.7	29.59	3.3	2.9	-0.38
DIV of US app	109.0	140.5	31.49	3.2	2.4	-0.79
No parent	98.7	150.0	51.30	3.3	3.0	-0.29
US provisional	98.8	146.7	47.85	3.7	3.0	-0.63

Note: 10,311 of 2,113,273 publication-patent pairs were lost due to data availability issues for application characteristics. IC Length is defined as the length of an application's shortest independent claim. IC Count is defined as the number of independent claims in an application.

Table 2.6: Publication-Patent Pairs (2001-2014)

with significant narrowing during prosecution are those with no parent ("progenitor" applications) and those with provisional parents, adding 51 and 48 words to ICL at the mean, respectively). Those applications tend to be filed with the broadest claims (99 words at the mean); so, it is not surprising that they are significantly narrowed during prosecution. However, it is surprising that foreign applications and new applications are narrowed by similar amounts.

Continuations and divisionals of regular US applications had the largest ICL at publication of all domestic parent applications (112 and 109 words, respectively) and had the smallest increase (29.6 and 31.5 words, respectively), suggesting that they have the narrowest incoming scope and thus need the least amount of change in scope to achieve patentability. It is intuitive that continuations tend to be narrower when filed and require fewer changes from application to grant than other applications, because continuations tend to have gone through at least one round of US prosecution before the continuation was filed.[50]

2.6 Conclusion

This chapter presents the first large-scale analysis of patent claim characteristics and patent prosecution as they relate to patent scope. The results provide ample evidence that simple measurements of patent scope can be usefully exploited by researchers.

We define two document-level measurements of scope that should be useful to researchers interested in patent value and patent quality: independent claim length (ICL) and independent claim count (ICC). Our hypotheses that ICL is negatively correlated with patent scope and ICC is positively correlated with patent scope are born out in our validation exercise in Section 2.4. The validation shows that ICL and ICC independently explain other measures of patent scope that have been used in the literature: patent maintenance, forward citations, and the breadth of patent classes.

Simple measurements of word counts or claim counts do not capture the many

[50] Technically, continuations can be filed before any substantive examination on the parent has occurred. However, it is common practice to file them after the first action.

complex relationships between patent claim language and the technology space that the language circumscribes. In fact, we expect that the use of natural language processing (NLP) techniques is likely to produce more sophisticated measurements of patent scope, particularly for comparisons between different technology sectors. We release the parsed claims data to enable researchers to use ICL and ICC in their research as well as to encourage the development of new text-based measures.

In Section 2.4, we discuss technological complexity. Scholars have argued that measures of scope may be correlated with technological complexity. In fact, linguists and computer scientists argue that word length should be correlated with syntactical complexity (Szmrecsányi, 2004). Interestingly, we find that the length of the specification (in terms of page length and the number of drawings) to be uncorrelated with independent claim length and the number of independent claims. Our contention is that the length of the specification is a better measure of complexity, which indicates that patent scope as measured by ICL and ICC is independent from complexity.

One of the primary benefits in using claim text to measure patent scope is the fact that it can be separately measured for patent applications and patent grants. As a result, ICL and ICC are particularly useful in investigating the patent examination process because they measure claim scope at the beginning and at the end of prosecution. Our results show that the examination process (as would be expected) tends to add words to the shortest independent claim and to reduce the number of independent claims, leading to narrower overall patent scope. This result holds across time and across a variety of application characteristics including technology, entity size, and the type of parent application.

Further, our results show that application scope and examination intensity-in terms of duration and the number of examiner actions-are related. First, narrower applications tend to have shorter examination times with fewer examination actions. Second, longer examination times and more examiner actions tend to correspond to more significant narrowing of application claims during prosecution. Further, quantitatively the effects are important. These two relationships imply an endogenous relationship between application scope, the intensity of the examination process, and the final patent scope. This relationship is further complicated if applicants are strategic with respect to the breadth of incoming applications. Our regressions do not account for this endogeneity, and we see it as an important avenue for future research.

Strategic applicants may fight for broad claims on an otherwise incremental invention if they perceive that they may be able to successfully engage in rent-seeking on such broad claims. This behavior will depend on applicants' perceptions about examination quality, the costs associated with a lengthy prosecution, and the ability to enforce broad claims in the marketplace (and the courts). In fact, strategic behavior on the part of applicants should lower the correlation between the inventive step of the invention and the incoming claim scope. In this case our measured relationship between scope and examination intensity may well be *understated*. To understand this, consider a pioneering invention that is due broader claims. If the application is so-written, then we should not necessarily expect the prosecution to take longer than normal. However, in our simple correlations, we have not attempted to distinguish between pioneering and incremental inventions, focusing solely on claim word length and claim counts. This heterogeneity in invention quality will show up as noise in the resulting pendency and number of actions, lowering the observed correlation between incoming claim scope and examination intensity. This argument suggests avenues for future research, especially with respect to how patent applicants respond to changes in PTO rules, as well as changes in patent fees regarding excess claims, extra time, and Requests for Continued Examination. The passage of the America Invents Act (AIA) in 2011 gave the PTO fee setting authority effective in March 2013. We hypothesize that higher RCE fees incentivize not only fewer actions and shorter pendency, but also narrower applications at the time of filing, as applicants "pre-narrow" their claims prior to filing. Indeed, preliminary results show this to be the case. We expect that applicants are sensitive to patenting fees in ways that can impact overall patent examination and potentially patent quality.

Applicant behavior is only the demand side of the examination "market." The PTO should also continue to study examiner incentives, and to make available prosecution-related data. The *count system* and examiner performance appraisal (Marco *et al.* 2017 and Simmons 2017) largely govern examiner incentives. We hope that our analysis will provide some guidance for future studies on patent scope and the examination process, including both applicant and examiner behaviors.

Understanding these complex relationships requires institutional knowledge as well as an understanding of how to model endogeneity within the patent examination process. To this end, we encourage the USPTO to continue to improve data transparency, to improve digital data ingestion (and to use more routine data coding during examination, including of any claim amendments and claim constructions) in order to provide machine-readable text of the documents involved in patent prosecution, and to make confidential data available through the already established Federal Statistical Research Data Centers. These efforts will ensure that external researchers can both expand the research frontier and validate the agency's internal estimates.

Our continuing research agenda includes more in-depth analysis into the examination process, as well as exploring how natural language processing techniques can be applied to claim text. By making our data on claims widely available we hope to stimulate more research into the usefulness of analyzing claim text in order to understand patent scope and its relationship to examination quality and patent quality, and the incentives that influence those relationships.

2.7 Chapter Acknowledgements

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Chapter 3

Debunking the Myth of the Rubber Stamp Patent: Impact of Examiner's Amendment on Patent Office Outcomes and the Innovation Ecosystem

3.1 Introduction

"Low quality" patents may reduce innovation and produce other adverse economic outcomes.[1] A large portion of the patent quality literature is centered on patent examination quality and patent office outcomes.[2] Since Jaffe and Lerner (2004), this literature has focused on high patent allowance rates at the United States Patent and Trademark Office (USPTO) as an indication of low quality patent examination (Lemley and Sampat 2008; Frakes and Wasserman 2013, 2017; Schuett 2013). Frakes and Wasserman (2013) explain high grant rates from the perspective of USPTO financial incentives ("higher granting propensities" and "shorter wait

[1] See Scotchmer, 1991; Bessen and Meurer 2009; Choi 2010; Galasso and Schankerman 2015; Sampat and Williams 2019; Choi and Gerlach 2015.

[2] See Alcácer *et al.* 2009; Cockburn *et al.* 2002; Cotropia *et al.* 2013; Frakes and Wasserman 2016a, 2016b; Kovács 2017; Langinier and Marcoul 2012, 2016; Lei and Wright 2017; Lemley 2001; Mann and Underweiser 2012; Tabakovic and Wollmann 2018; and Whalen 2018.

times" increase user fees for the patent office), whereas Schuett (2013) sees a "bias toward granting patents" since USPTO examiner incentives may appear to reward production over quality.

The USPTO varies examiner incentives across seniority levels and technologies to account for the impact of experience and technological complexity on the expected time required to examine an application. Researchers have analyzed these differential incentives, and the resulting impact on patent examination quality (Lemley and Sampat 2012; Frakes and Wasserman 2017). The patent examination process typically allows for two rounds of review before the applicant needs to pay additional fees to reopen prosecution but Lemley and Sampat (2012) finds that more experienced examiners cite fewer patents as prior art and are more likely to allow a patent application after just one round of review. The authors interpret these "first-action allowances" as lower quality examination, arguing that if examiners of varying experience receive applications from the same distribution of incoming quality, less resistance could lead to lower quality patents. With an application-level analysis, Frakes and Wasserman (2017) finds that with the increasing production requirements imposed by the USPTO with seniority, the quality of examination decreases, as measured through citations from the examiner and rejection rates. In particular, examiners face "binding time constraints" and are unable to adjust to the increased production requirements with increased examination efficiency. Finally, this literature discusses policy implications. Lemley and Sampat (2012) suggests that since "human resource policies have important effects on PTO outcomes ... the tenure system, the count system and examiner recruitment and retention policies should be a more prominent part of current patent reform deliberations." Frakes and Wasserman (2017) goes further, suggesting that if "all examiners were allocated as many hours as are extended to GS-7 examiners, the Patent Office's overall grant rate would fall by roughly 14 percentage points, amounting to roughly 40,000 fewer patents issued per year."

We find that this prior literature fails to account for an examiner learning mechanism, and therefore draws inappropriate operational and policy conclusions related to USPTO examination and patent quality. In particular, we find that with experience and seniority, examiners increasingly and successfully negotiate with the applicant before the first round of official review (the first-action).

The procedure is called an examiner's amendment and is designed to expedite the patent prosecution process. Its use is consistent with USPTO policy, as one of the stated goals of the USPTO is to decrease patent pendency (the amount of time between filing an application and decision) and "enhance compact patent prosecution initiatives".[3] After accounting for this examiner learning mechanism, we find that, counter to prior literature, first-action allowance rates no longer increase with experience, and increase only for the highest seniority level (GS-14). Further, the increase in first-action allowance rates for GS-14 examiners is significantly reduced from the increase in rates observed in previous studies. While our results do explain the increase in first-action allowance rate, we find also that examination quality does not deteriorate with the use of the examiner's amendment. Specifically, we find there is no significant difference in examination quality between a first-action allowance with an examiner's amendment and a single office action rejection that leads to an allowance. Further, the quality of examination when using an examiner's amendment does not deteriorate with grade and experience.

Despite the benefits of patent protection to innovators and firms, patent grant delay remains a significant source of uncertainty (Gans, *et al.* 2008). Uncertainty reduces both investment (Dixit *et al.* 1994) and revenue opportunities through licensing (Gans *et al.* 2008; Hegde and Luo 2018). As literature on markets for technology has shown, transaction costs are high in markets where property rights are uncertain. This is particularly acute for small businesses and individual entrepreneurs, as "without the prospect of being able to capitalize on their innovations by trading the property rights protecting the innovation, many small technology-based firms would not invest in creating new and useful technologies" (Arora *et al.* 2004). Often higher transaction costs are due to the need to validate claimed IP rights, which is necessary in the absence of a granted patent.

[3]USPTO Strategic Plan 2014-2018, https://www.uspto.gov/sites/default/files/documents/USPTO_2014-2018_Strategic_Plan.pdf

Examiner's amendments are a means to alleviate intellectual property uncertainty for patent applications by providing a path to allowance without requiring multiple rounds of examination and by expediting communication with the applicant. Reducing uncertainty in the patent examination process through the use of pendency-shortening examination mechanisms (such as the examiner's amendment) is likely beneficial to innovators and firms by reducing frictions in the markets for technology. We find that the examiner's amendment, compared to a single office action rejection, reduces post-first-action pendency by over 50 percent.

Our results suggest refocused policy conclusions on the relationship between USPTO examiner incentives, patent quality, and economic outcomes. In particular, researchers and policy makers should reconsider the re-configuration of time allocations for every examination seniority level (initially proposed after prior research found evidence of increasingly "binding time constraints" with seniority and experience) for two reasons: First, the studies on which these prescriptions are based ignore an important examiner learning mechanism, and therefore their policy prescriptions are not supportable by empirical evidence. Second, increasing the amount of time allocated to examiners may actually reduce the incentive to use examiner's amendments, and therefore reduce the benefits firms and innovators receive from this pendency-reducing mechanism.[4] Instead, researchers and stakeholders should focus on the variation in outcomes between junior (GS-13 and below) and senior examiners (GS-14), including the USPTO's signatory program.

Our findings in part overturn prior literature, and in part open up new opportunities for study. Since examiner's amendments explain away the effects of prior studies, we find that the examiner's amendment is a little studied, yet impactful mechanism of patent prosecution. The paper is structured as follows: Section 3.2 provides an overview of first office actions at the USPTO and examiner's amendments, specifically detailing the institutional background, the content of examiner's

[4] It should be noted that some applicants may prefer to extend pendency to allow the modifications of claims in light of updated information on technological direction and value. Therefore, the benefit of pendency does not necessarily extent to all innovators. Assuming pseudo-random allocation of applications, however, an applicant's willingness to delay related to a particular application should be uncorrelated with examiner characteristics. Thank you to my Ph.D. Viva examiners for identifying this issue.

amendments, and the proposed examiner learning mechanisms. Section 3.3 describes the data construction process and our sample. Section 3.4 explains our identification strategy and empirical methodology and Section 3.5 describes the results. Section 3.6 details our robustness checks and Section 3.7 describes the policy implications of our analysis. Finally, Section 3.8 concludes.

3.2 The First Action and Examiner's Amendments

This section provides a description of the USPTO examination process, discusses and provides examples of examiner's amendments, and describes and the underlying examiner learning mechanism of the paper.

3.2.1 Institutional Background

The USPTO employs patent examiners who are assigned patent examination responsibilities. The role of the patent examiner is to assess the patentability of patent application claims as well as conform each examined application to existing rules and regulations. The first round of the patent examination process (see Figure 1) may result in either an allowance ("first-action allowance"), where the application claims are deemed patentable without further revision, or in a denial of the claims as filed.

A denial of the claims can take the form of a *non-final* rejection, where an examiner may reject one or several claims, or a *restriction*, which identifies multiple claimed inventions within a single patent application. If the application meets the statutory requirements, the examiner may allow the application without a rejection. This type of response, also referred to as a "rubber stamp" allowance, has been studied extensively in the prior literature and constitutes the first-action allowance utilized in Lemley and Sampat (2012).

However, there is another category of patent examination response that has not been explored in the literature: examiner's amendments. Examiners may identify patentable subject matter in the patent application and discuss potential changes to the claims with the applicant in order to render the application allowable. *Any aspect* of the claims may be changed in an examiner's amendment. From the Manual of

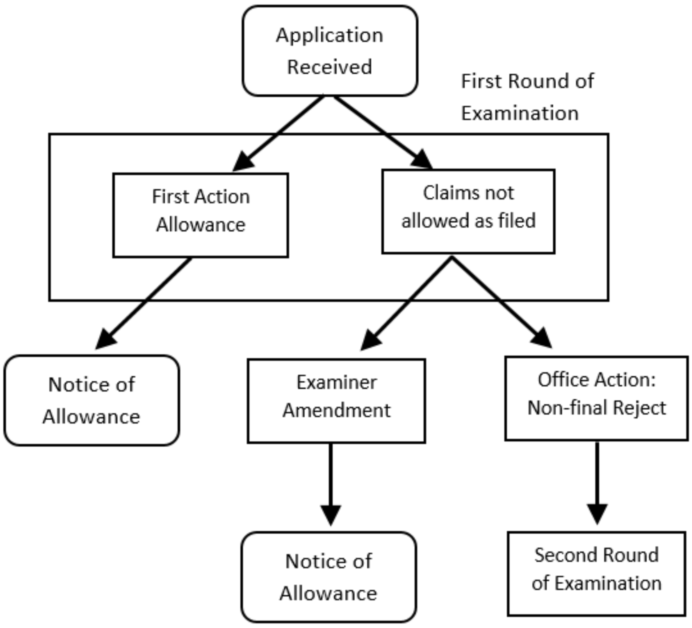


Figure 3.1: First Round of Patent Examination Outcomes

Patent Examining Procedure (MPEP), "An examiner's amendment may be used to correct informalities in the body of the written portions of the specification as well as all errors and omissions in the claims," (MPEP section 1302.04). If the applicant agrees to such changes, the examiner will draft an examiner's amendment detailing changes made, which is included in the notice of allowance. Examiners utilize examiner's amendments to effectively perform the same operations as the first office action rejection, without requiring another round of review, and thus expediting the process. The examiner's amendment process is detailed in the Manual of Patent Examining Procedure (MPEP) section 1302.04.

A review of the incentive system for USPTO examiners is essential for understanding the underlying examiner learning mechanism of this paper. Examiner seniority levels are determined by the federal grade scale,[5] and a few other relatively rare categories of examination (for example, senior and expert examiners). These seniority levels are assigned "position factors", which determine how much time an examiner is given to complete activities relative to a GS-12 in the same technology.

[5]Typically, the GS-levels for a patent examiner include 5, 7, 9, 11, 12, 13, 14, and 15. Depending on prior experience, an examiner may start at a higher GS-level.

Specifically, the amount of time an examiner is given to examine an application decreases with seniority level. For example, GS-12 examiners in the bridge technology area (USPC 14) are given 17.5 hours per balanced disposal (Marco, Toole, Miller, and Frumkin 2017). Using the examiner's expectancy formula, GS-7 and GS-14 examiners have 27.5 and 15.46 hours, respectively, to complete a single balance disposal, a difference of over twelve hours. Examination activities are assigned "counts", and, currently, an examiner will receive 1.25 counts for a non-final rejection, 0.75 counts for an allowance or final rejection after the initial non-final rejection, 0.75 counts if the applicant abandons the application after the first action, or the full 2 counts for a first-action allowance (Marco, Toole, *et al.* 2017). After the first two rounds of prosecution, the application may result in an allowance, an abandonment by the applicant, or filing of a Request for Continued Examination (RCE). The completed round of examination (ending in either a disposal or an RCE filing) is called a balanced disposal (BD).

Finally, we briefly describe the USPTO's "compact prosecution" policy, described in Section 2173 of the MPEP. According to the policy, "The goal of examination is to clearly articulate any rejection early in the prosecution process so that the applicant has the chance to provide evidence of patentability and otherwise reply completely at the earliest opportunity."[6] In other words, the examiner is encouraged to provide all the grounds for rejection at the earliest opportunity. In an examiner's amendment, the examiner provides the grounds for rejection to the applicant before the first action, and both parties successfully agree to modifications of the claims to immediately bring the application to allowance on the first action. The use of an examiner's amendment reduces pendency by eliminating further rounds of formal prosecution, and therefore satisfies the Office's policy of "compact prosecution".

3.2.2 The Content of Examiner's Amendments

Before turning to the underlying examiner learning mechanisms of this paper, we provide several examples of examiner's amendments. By analyzing these examiner's amendments, we provide a deeper understanding of this understudied as-

[6] https://www.uspto.gov/web/offices/pac/mpep/s2173.html#d0e219183

Variables	(1) N	(2) Mean	(3) St. Dev.	(4) p5	(5) p10	(6) p25	(7) p50	(8) p75	(9) p90	(10) p95
ΔICC	75,098	-0.207	1.635	-1	-1	0	0	0	0	0
ΔICL	75,079	21.95	59.86	-2	0	0	0	20	20	124
Cos. Sim.	75,020	0.964	0.0957	0.789	0.898	0.981	0.998	1	1	1

Table 3.1: Examiner's Amendment Summary Statistics

pect of examination, specifically examining how examiners have used examiner's amendment to modify claims. We argue that the use of this examination technique is consistent with substantive examination and should be differentiated from a "Rubber Stamp" allowance. In this section, we use Term Frequency-Inverse Document Frequency (TF-IDF) cosine similarity, a natural language processing technique, to identify the degree of change within a patent application that is due explicitly to the use of an examiner's amendment. After calculating the statistics, we analyze a sample of documents at various percentiles of the TF-IDF cosine similarity distribution to contextualize the types of semantic changes that were made through this patent examination tool. Our qualitative analysis using this method is expositional because the degree of change within a patent document does not *precisely* correlate to examination quality. However, sampling this distribution allows us to analyze the types of changes one might see with an examiner's amendment and the degree to which this changes relate to patent examination quality.[7]

The TF-IDF cosine similarity method is becoming increasingly popular in the innovation economics literature. The use of similarity measures in the analysis of patent text was introduced by Kuhn and Younge (2016), and validated further in Arts, Cassiman and Gomez (2018). Term frequency was first used in information retrieval (Sparck 1972) as a means to compare texts; inverse document frequency re-weights down the terms that are common across documents. Specifically, Cosine Similarity is defined as:

[7] Summary statistics are provided in Table 3.1. In addition to the TF-IDF cosine similarity, we provide additional patent examination quality measures that have been used in the literature, ΔICC and ΔICL. These variables measure changes in scope that occur during patent prosecution. In this section, we use TF-IDF cosine similarity to identify claims modifications due to an examiner's amendment over the scope measures because we would like to identify the changes to the all claims and not changes to scope.

$$cos\_sim(X,Y) = \frac{XY}{|X||Y|} \tag{3.1}$$

where X,Y are two vectors of the same dimension n and n is equal to the number of words in the patent corpus. The vectors X and Y comprise the TF-IDF-weighted counts of words appearing in the claims of a particular application, A, at filing (X) and after the text has been modified through an examiner's amendment (Y). The elements of each vector correspond to a weighted word count from the set of all words that appear in the patent corpus. If a word appears in document i's claims ($i \in \{A,B\}$), the word count is weighted by the term-frequency-inverse-document-frequency of the particular word. If the word does not appear in the document's claims, the value for the corresponding element is equal to zero. The combination of term frequency and inverse document frequency is the standard method of processing the similarity between texts (Wu et al. 2008), and is appropriate for our purposes since we use it to identify documents with varying degrees of changes to the application on the examiner's amendment.

To understand how examiner's amendments modify the claims of a patent application, we first compute the TF-IDF between the pre-examiner amendment claims and the allowed claims.[8] We then sample the amendments from the distribution of actual differences between pre-examiner amendment claims and granted claims, or the claims that incorporate the changes from the examiner's amendment (TF-IDF statistic). Table 3.1 contains summary statistics for the examiner's amendment similarities. Cosine similarity, represented by *TF-IDF Cos. Sim.*, varies between 0 and 1, where a similarity of 1 represents identical texts, and a similarity of 0 represents no overlap. The similarity values identify the degree of change negotiated on the examiner's amendments, and, after manual inspection, are therefore useful in obtaining a qualitative understanding of their use. Despite this, examiner amendment similarity values do not provide any information about the change in

[8] The full sample for our paper is described in the data section. Also described in the data section, for this exercise, we identify applications with pre-grant publication before the examiners amendment, and where a new claim submission was not submitted before the examiner's amendment. This restriction ensures that the pre-grant publication is the set of claims available to the examiner when negotiating the examiner's amendment.

patent quality with the examiner's amendment, so we chose not to use the similarity measures for any further analysis. To understand examiner's amendments further, we supplement the summary statistics Table 3.1 with manual inspection of example amendments from our sample. These examples show that examiner's amendments can lead to important changes in the claims, including creating new claims and dropping other claims, removing and adding several terms which modify the scope of the invention, and, in some cases, subtle changes such as modifying a single word, but which greatly changes the scope of the claimed invention. We present four examples of examiner's amendment selected from various segments of the TF-IDF statistic distribution and discuss how the examiner's amendment modified the claims and to what degree. Two examples are provided in the text, and two more examples are in the Appendix.

The first example, application 13/077,181, has a similarity value of 0.79 taken from the 5th percentile. The examiner's amendment for the first independent claim is shown in appendix figures B.3, B.4 and B.5. From the examiner's amendment in the notice of allowance, the examiner states the amendment was to "clarify features and bring out additional features and distinctions of the invention in the independent claims, to overcome prior art discovered by the Examiner in the course of examination." For example, elements of claims 2, 3 and 15 are added to the first independent claim, narrowing its scope. For brevity, all additional figures of examiner amendments are in the appendix.

Next, the examiner's amendment from application 13/085,015 has a similarity value at the mean, of roughly 0.96. The examiner's amendment is contained in appendix figures B.6, B.7, B.8 and B.9. In the Examiner-Initiated Interview Summary[9] published on the same day as the Notice of Allowance for this application, the examiner states "It was agreed to alter the language of claim 1 as a formality to further clarify the constituents required by the instant claims. It was further agreed to allow the addition of claims to further elaborate on these particular features." Here, instant claims refer to the claims of application 13/085,015, rather than any other

[9]This document summarizes what was discussed during the telephone interview for the examiner's amendment.

claims in prior art. For example, in claim 1, "which may include" is removed and "selected from" is added. Even though this appears to be a simple change, and minimally affects the similarity value, it actually greatly narrows the scope of the claim since before the change neither amphoteric or zwitterionic surfactants are required to be in the invention, but afterwards one or the other must be. Additionally, the applicant agreed to move several "preferably" limitations to new dependent claims 9 and 10, further limiting scope, as in dependent form, the "preferably" conditions become requirements. This was done to clarify the invention in the first independent claim,[10] and all these substantive changes were made through an examiner's amendment rather than a lengthier rejection-response cycle.

Two additional examples are provided in the appendix. In the first appendix example of an examiner's amendment, all of the claims are cancelled and one new claim is added. In the second appendix example, a single yet important term is modified to clarify the scope of the claims.

This section used the similarity between the pre-examiner's amendment claims and the granted claims to discuss the use of examiner's amendments at the USPTO. Critically, substantive changes in the claims may come from examiner's amendments that have numerous edits, or modifications that change a single, key, word. For this reason, the similarity measure will not be used to measure the quality of an examiner's amendment. The similarity values are however very useful to gain insight into the nature of the examiner's amendment. In the next section, we discuss why an examiner might issue a first-action allowance with an examiner's amendment over a rejection and how this decision may be related to both grade and experience.

3.2.3 Mechanisms

This section identifies two main behavioral mechanisms that could lead to variation in patent examination outcomes on the first action. The first mechanism is examiner learning. As an examiner becomes more experienced, the examiner might be more

[10] Recall the examiner stated above, "to further clarify the constituents required in the instant claims."

likely to issue an examiner's amendment on the first action for a variety of reasons. First, after gaining experience in both prosecuting patents and acquiring significant knowledge of her technical domain, the examiner might be able to quickly identify eligible subject matter in the patent claims, or the specification more broadly. Second, through repeated interaction with applicants, a more experienced examiner may have higher negotiating ability. Third, a more experienced examiner may be more likely to have the confidence necessary to avoid the full patent prosecution process and negotiate an examiner's amendment on the first action to expedite prosecution. These explanations lead to the first hypothesis.

Hypothesis 1. *Examiners are increasingly likely to issue examiner's amendments on the first office action with experience.*

The second mechanism through which examiners might issue more examiner's amendments on the first office action relates to examiner incentives. Recall from the institutional background section that examiners are given less time to prosecute patent applications at higher seniority levels. Successfully negotiating an examiner's amendment before the first action significantly reduces the amount of time to prosecute an application. This leads to the second hypothesis.

Hypothesis 2. *Examiners with higher seniority levels are more likely to issue an examiner's amendment on the first office action.*

If you recall, the previous literature uses allowance rates, and in particular, first-action allowance rates to examine the impact of examiner incentives on patent quality. For example, Lemley and Sampat (2012) find that first-action allowance rates increase with experience, and suggest this relationship is consistent with lower quality examination. The prior literature misclassified first-action allowances with an examiner's amendment as "rubber stamp" allowances without substantive examination. However, the use of an examiner's amendment demonstrates *both* substantive examination and learning. Because of this, we define a *true* rubber stamp allowance to be a first action allowance without an examiner's amendment. If learning rates are properly aligned (i.e. learning increases are commensurate with increased production requirements), then we should not see an increase in the *true* "rubber stamp" allowance rate with either grade or experience. If this is true, then increased first-action allowance rates are indicative of examiner learning, rather than low quality examination. This leads to the next hypothesis.

Hypothesis 3. *If examiner learning rates are properly aligned, then the "true rubber stamp" first-action allowance rates should increase neither with experience nor seniority.*

The final hypotheses relates to pendency, and describes the channel through which innovators and firms benefit through the use of examiner's amendments at the USPTO. At the first-action decision, an examiner can choose to issue a non-final rejection or attempt to negotiate with the applicant. *Ceteris paribus*, the use of an examiner's amendment at this juncture should lead to shorter pendency, benefiting the applicant.

Hypothesis 4. *Patent applicants achieve lower pendency through the use of examiner's amendments relative to an office-action rejection.*

The remainder of this paper attempts to empirically identify these mechanisms in USPTO patent examination data. Additionally, we explore the implication of examiner's amendments for the literature that assumes increasing first-action allowance rates in grade and experience results in a reduction of patent quality. Finally, we examine the impact of examiner's amendments on pendency.

3.3 Data

The sample, summary statistics for which are shown in Table 3.2, is comprised of 4.64 million public patent applications filed at the USPTO with a first action completed between 2001 and 2017. These data were made publicly available in a bulk downloadable format by the USPTO's Office of Chief Economist (OCE) in the Patent Examination dataset, called PatEx (Graham, Marco, and Miller 2018). The application data includes overall prosecution outcome, filing and disposal dates, anonymized USPTO examiner identification numbers, U.S. patent classification (USPC), technology center (TC), and other patent application characteristics. In addition to the application data, PatEx includes a history of all patent office events (both by the applicant and the USPTO) for each application from filing to disposal, disposal type, and expiration date (if expired). The transaction history includes a list of all USPTO office actions, including rejections, notice of allowances, restrictions, and Quayle actions.[11] We assume that the examiner's first action is the first instance of a non-final rejection, final rejection, notice of allowance, restriction or Quayle action in the PatEx transaction history. Additionally, occurrence and date of examiner's amendments are obtained from the PatEx transactions data, identified using the transaction code "Ex.a".

Variables	N	Mean	St. Dev.	p25	p50	p75
FA_allow	4.642e+06	0.0883	0.284	0	0	0
RS_allow	4.642e+06	0.0649	0.246	0	0	0
Bal. Sample Ind.	4.642e+06	0.282	0.450	0	0	1
Exam_Amend	4.642e+06	0.0234	0.151	0	0	0
Exper	4.642e+06	97.51	71.72	39	83	143
ICC	4.642e+06	2.876	3.221	2	3	3
ICL	4.641e+06	108.6	104.2	58	90	135
3-year	4.642e+06	0.600	0.490	0	1	1
USPC Special.	4.612e+06	73.78	60.57	34	62	97
Avg. Cos. Sim.	4.276e+06	0.0713	0.0386	0.0471	0.0619	0.0865
Var. Cos. Sim.	4.276e+06	0.00838	0.00881	0.00431	0.00665	0.00982

Table 3.2: Summary Statistics

Examiner promotion and grade data at first action were taken from internal USPTO databases, and observations with examiner GS-levels 5 and 15 were dropped from the sample (due to infrequency).[12] Examiner experience was calculated using the examiner promotion data by measuring the length of time, in months, between the first action and the examiner's start date. Additionally, we only kept applications where the examiner was assigned to a technology center at the time

[11]The MPEP states that, "Under the decision in Ex parte Quayle, 25 USPQ 74, 1935 C.D. 11; 453 O.G. 213 (Commr Pat. 1935), after all claims in an application have been allowed the prosecution of the application on the merits is closed even though there may be outstanding formal objections which preclude fully closing the prosecution," (MPEP 714.14).

[12]In a small number of cases, two examiners were assigned to a particular application at the data of first action, where application was transferred and re-docketed to another examiner on the first-action date. In these cases, we assume that the examiner to whom the application had been assigned completed the first action. Please see Figure 3.2 for the GS-level distribution at first action.

of first action, excluding the Patent Training Academy (TC 4100). This restriction drops applications where examiners are on a detail (on loan to a unit where they perform non-examiner duties), and those examiners prosecuting applications on a part-time basis since they have different incentives.

To control for additional application-level heterogeneity, we include scope and parent type variables in our sample. According to Marco *et al.* (2016),[13] patent scope can be measured simultaneously by the length of the shortest independent claim (ICL) and the independent claim count (ICC). These scope measures can be calculated both at publication and at grant[14] and are computed from the text of the pre-grant publication (PGPub) and issued patents provided by USPTO.[15] To determine the type of parent application, we combine two variables (foreign priority and parent type) from the PatEx data to create a modified parent type variable (see Figure 3.2). From this variable, we can differentiate by type of parent application (Patent Cooperation Treaty, continuation, continuation-in-part, or divisional) and whether an application had been filed previously within another jurisdiction.

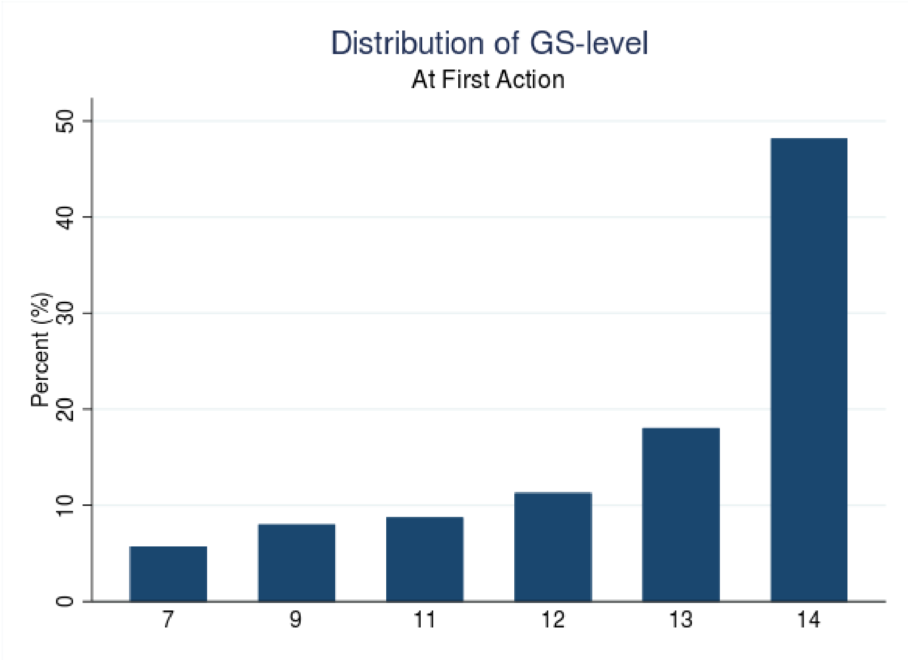
We construct two sets of examiner specialization measures used in robustness checks, both of which are computed at the examiner and year level. The first is the number of technology (USPC) subclasses on first actions submitted by an examiner in the previous year. The second set includes the average and variance of TF-IDF cosine similarity between pairs of claims from first actions submitted by the examiner in the previous year. When using the similarity measure of specialization, we also control for the standard error of the mean similarity.

In our robustness checks, we use two text-based variables to assess changes

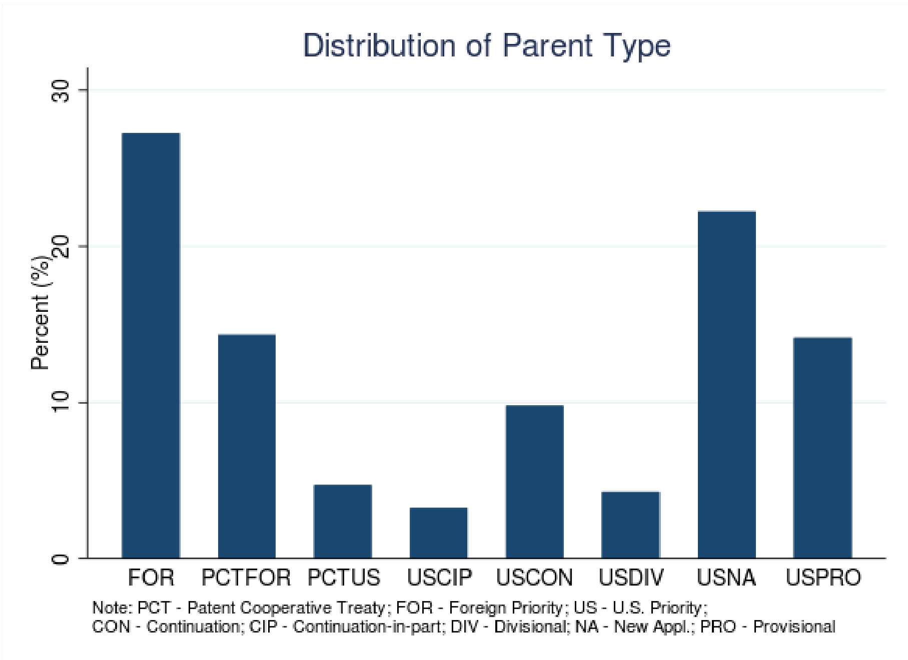
[13]Kuhn and Thompson (2017), forthcoming in the International Journal of Business and Economics, measures patent scope by the length of the first independent claim instead of the shortest. Although both methods capture patent scope, we prefer the Marco *et al.* (2017) measures because they are already computed and available both publicly (through 2014) and internally (through the present) at the USPTO.

[14]The USPTO's Office of Chief Economist parsed the PGPub and patent text and calculated the measures. Data through 2014 are available publicly on the USPTO's Office of the Chief Economist website. We also utilized a yet-to-be-released USPTO data product that contains the updated measures through the end of 2017 because the publicly-available patent scope data only contains the measures through 2014.

[15]The USPTO's Bulk Data Products can be found at `https://www.uspto.gov/learning-and-resources/bulk-data-products`.



(a) GS-Level



(b) Parent Type

Figure 3.2: Distribution of (a) GS-Level and (b) Parent Type at First Action

in patent claim scope. Specifically, we use the change in independent claim count, and the change in shortest independent claim length between the PGPub claims and the granted patent claims. Marco *et al.* (2016) show that these variables capture patent scope, and that patent claims narrow during the course of patent prosecution. Because of this direct link between patent scope and patent quality, we use the change in scope variables to proxy for the quality of examination, conditional on incoming scope.

3.4 Empirical Methodology

We first run the following patent application-level empirical specification:

$$FA\_Allow_{eit} = \beta_0 + \beta_1 Exper_i + \beta_2 ICL_i + \beta_3 ICC_i + \beta_4 Parent_i + \gamma_t + \gamma_e + \gamma_g + \varepsilon_{eit} \tag{3.2}$$

where $FA\_Allow_{eit} = 1$ if the application was allowed on the first action (with or without an examiner's amendment), and $FA\_Allow_i = 0$ if the application was rejected on the first action.[16] γ_t are first-action year fixed effects, γ_e are examiner fixed effects, and γ_g are examiner grade at first-action fixed effects, relative to GS-9. We include claim scope measures at PGPub (ICL_i and ICC_i), application parent type ($Parent_i$), and examiner experience ($Exper_i$) in months at the application first-action date. Additionally, when noted we include a technology fixed effect γ_u. The first set of regressions aim to demonstrate consistency between our approach and prior research on patent examination, GS-level, and experience. Specifically, we verify the positive relationship between the first-action allowance rate and both examiner grade and experience (Lemley and Sampat 2012; Frakes and Wasserman 2017). Our models closely resemble those used in the literature, but deviate from Frakes and Wasserman (2017) in the choice of dependent variable (overall allowance ver-

[16] The FA_allow variable is equivalent to the "Rubber Stamp" allowance from Lemley and Sampat (2012). The "True Rubber Stamp" allowance, defined in this paper, incorporates the spirit of the original "Rubber Stamp" allowance definition, *i.e.*, a first-action allowance without substantive examination. The updated allowance variable groups first-action allowances with an examiner's amendment with first-action rejections as both outcomes represent substantive examination. An alternative approach would implement a multinomial logit framework where we could separate the three outcomes and estimate a single model. That framework could distinguish between the grade/experience effects associated with each outcome type. Thank you to my Ph.D. Viva examiners for this suggestion.

sus first-action allowance). The reasoning behind this change is discussed in detail during the identification section below.

$$Exam\_Amend_{eit} = \beta_0 + \beta_1 Exper_i + \beta_2 ICL_i + \beta_3 ICC_i + \beta_4 Parent_i + \gamma_t + \gamma_e + \gamma_g + \varepsilon_{eit} \tag{3.3}$$

The second set of regressions explores the relationship between examiner grade and experience, and the likelihood of an examiner's amendment. In equation (3.3), the dependent variable, $Exam\_Amend_i$, is equal to one if the examiner issued an examiner's amendment on the first action (only available for allowances), $Exam\_Amend_i = 0$ otherwise. The independent variables are the same as in equation (3.2) above. The purpose is to assess the degree to which the likelihood of an examiner's amendment at first-action varies with grade and experience. An increasing rate of examiner's amendment on the first action with experience would validate hypothesis 1, while an increasing rate of examiner's amendment on the first action with grade would validate hypothesis 2.

We run an additional specification, replacing first-action allowance rate, FA_Allow_i with the "true rubber stamp" allowance rate, RS_Allow_i. For this regression, we define $RS\_Allow_i = 1$ if the application was allowed on the first action without an examiner's amendment, and $RS\_Allow_i = 0$ if the application was either allowed with an examiner's amendment, or rejected. The purpose is to examine how grade and experience impact the probability that an application is a "true rubber stamp" allowance. We are interested in the degree to which examiner's amendments influence the correlation between first-action allowance rate and examiner grade/experience described in the literature. If learning rates are properly aligned with increases in production requirements (*i.e.*, 1 and 2 hold), then the correlation between grade/experience and the "true rubber stamp" allowance rate should be insignificant. The regression is specified in the following specification:

$$RS\_Allow_{eit} = \beta_0 + \beta_1 Exper_i + \beta_2 ICL_i + \beta_3 ICC_i + \beta_4 Parent_i + \gamma_t + \gamma_e + \gamma_g + \varepsilon_{eit} \tag{3.4}$$

For each of the regressions, we subset the data in several ways. First, we run the regression on the entire sample. Second, we limit the applications to only new applications. By new, we only consider new regular utility applications (no continuations or continuations in part) without a foreign priority filed at the USPTO. The purpose of examining this subset is to exclude applications with any prior examination. If an application has a foreign priority or U.S. parent application, it may have been examined in a foreign jurisdiction or through the USPTO. Applicants may modify the set of incoming claims in a subsequent and related patent application after the initial round of prosecution, which can affect the allowance rate. Typically, though not always, a continuation will be assigned to the same examiner that prosecuted the parent application, so it is not surprising that continuations make up a higher percentage of a higher grade examiner's docket relative to the docket of a junior examiner. Without excluding these applications, our regressions could be susceptible to bias if examiners with varying grade and/or experience were deferentially likely to receive these types of applications.

Finally, we restrict our sample to applications with an examiner less than three years removed from her most recent promotion at the time of first action.[17] In some cases, examiners will forego or delay promotion and stay at a lower grade for an extended amount of time. For example, some examiners stay at GS-12 for several years but were eligible for promotion after one year at GS-12. The examination behavior after an examiner delays or foregoes a promotion may be qualitatively different from those on the promotion path. Therefore, subsetting our sample to first-action decisions within three years of the most recent promotion allows us to examine any differences between examiners on and off the standard promotion path.

3.4.1 Identification Strategy

Our identification strategy is based on the pseudo-random assignment of patent applications to examiners within art units at the USPTO. Researchers have used the pseudo-random assignment of patent applications to address research questions related to the patent system (Lemley and Sampat 2012; Frakes and Wasserman 2017;

[17]These restricted samples correspond to columns (3) and (4) of Tables 3.3, 3.4, and 3.5

Williams 2013; Farre-Mensa, Hegde, and Ljungqvist 2017). This research design is validated through discussions with patent examiners (Lemley and Sampat 2012) and empirical research (Righi and Simcoe 2019) suggesting that patent applications are generally pseudo-randomly assigned within USPTO art unit by technology groups. However, Righi and Simcoe (2019) also find evidence that more specialized examiners have lower grant rates. We argue that non-random assignment based on examiner technological specialization could be absorbed by the examiner and technology fixed effects. As a robustness check, we add measures to proxy for examiner specialization directly in Section 3.6.

As noted by Lemley and Sampat (2012), any non-random assignment correlated with grade/experience and patent quality would be problematic for identification, but this is unsupported by both the literature on random assignment and interviews with examiners (Lemley and Sampat 2012). Additionally, office policy effects on grant rates are absorbed in the year fixed effects (Frakes and Wasserman 2013, 2014). Since examiner cohorts (Frakes and Wasserman 2016a) and initial ability might impact prosecution behavior, we note that the examiner fixed effects control for both starting grade and starting cohort since neither vary within examiner. We also note that our micro-level data allows us to identify both the GS-level and experience of the examiner at first action simultaneously. Experience and grade do not increase in lockstep because starting grades and time to promotion for each grade vary across examiners.

Consistent with Lemley and Sampat (2012), we analyze examination behavior at the first-action decision. Our reasoning for this choice is twofold: First, the first-action decision allows us to isolate an examiner's decision from the influence of subsequent applicant behavior. Second, grade estimates in allowance rate regressions may suffer from unobserved variable bias due to the varying timing of application disposals based on application quality in relation to promotion dates.

For the overall allowance rate, the allowance decision depends on both examiner negotiating ability and applicant behavior (the persistence of applicants after rejections, the willingness of applicants to narrow the claims to meet patentability requirements, etc.), which increases the complexity of identifying examiner behavior. The first-action decision does not suffer from this weakness. We demonstrate in Section 3.5 that first-action allowance rates are increasing in grade and experience, which is consistent with the results of Lemley and Sampat (2012). Once the examination process has begun, the examiner conducts the first round of substantive examination and typically does not interact with the applicant prior to the first-action decision.[18] Therefore, the influence of the applicant on the first-action decision, other than through the quality of the incoming patent application, is limited. By isolating examiner behavior at the first action, we allow for the cleanest look at examination behavior.[19]

Even under the pseudo-random assignment assumption, examiner grade and patent quality may be correlated, leading to omitted variable bias. Under the assumptions of random assignment, the quality of an incoming application should not be correlated with grade but the quality of existing applications on an examiners docket may *become* correlated with grade as the examiner climbs the GS scale. For example, take the set of randomly assigned applications docketed to a new examiner. Only a fraction of these applications will be disposed before the examiner's next promotion.[20] Applications that are disposed before the next promotion date

[18] An applicant and examiner may interact in some ways prior to first-action decisions, but these actions are limited. For example, an applicant or examiner may request an interview prior to first action or the examiner may contact the applicant for an examiner's amendment.

[19] Applicants are typically unaware of the identify of the examiner until after the first action, with some exceptions including examiner's amendments. This structure limits the ability of applicants to influence the first-action decision. However, recent work by Tabakovic and Wollmann (2017) suggests that some applicants and examiner's may collude, leading to preferential treatment of certain applicants in exchange for later employment opportunities. This study does not determine the timing of the influence, i.e., at what point of examination does collusion contaminate the process. If applicant influence extends to first-action decisions (i.e., examiner's become more lenient with repeated actions), then this bias might reflect the results. An examiner may identify the law firm/applicant and be predisposed to grant the application after repeated interactions. This omitted variable would be positively correlated with both the allowance decision and grade/experience, leading to an upward bias of our results. This bias would only strengthen the counterevidence to existing results on patent examination and patent quality. Repeated interactions could be the driving force behind the use of examiner's amendments, changing only the mechanism, not the general results. It should be noted, However, that Tabakovic and Wollmann (2017) does not provide any evidence nor indicate that collusion begins before first action. Our methodology only considers first-action decisions, so if collusion occurs after the first action, then the point is moot. Therefore, we assume that collusion would occur after the first action.

[20] Average total pendency for an application in our sample is just under three years for all applications and 3.4 years for a new U.S. application (non-continuation) but an examiner can be promoted

may exist in the extremes of the patent application quality distribution, i.e. very low- and high-quality applications. The quality of these applications (disposed) relative to the remaining docketed applications assigned at the previous GS-level is ambiguous. This ambiguity prevents us from determining the direction of the potential bias. Therefore, we mitigate this endogeneity problem by concentrating on the first-action allowance decision.

Finally, we note that the promotion path for examiners within the USPTO is standardized, based on performance metrics, and, once an examiner is hired, does not depend on the availability of positions at the next GS-level. An examiner may advance from their starting grade to GS-14 based on satisfying production and quality requirements among other training and certifications. To advance to GS-13, an examiner must pass the certification examination and, to advance to GS-14, an examiner must pass the signatory authority program. These promotions are well regimented but production and quality requirements may be correlated with unobserved examiner characteristics. Therefore, we control for examiner-level, first-action year, and TC-by-year fixed effects (the last of which is presented in the Robustness Checks section).

3.5 Results

3.5.1 First-action Allowance Rates

In this section, we first demonstrate that our analysis is consistent with the prior literature on USPTO patent examination quality. Table 3.3 shows that the probability of a first-action allowance is increasing in GS-level and experience (labeled as *Exper*), which is consistent with the literature (Lemley and Sampat 2012; Frakes and Wasserman 2017). This result is robust to a number of different specifications, including sub-setting the sample to include only new applications without a foreign priority or U.S. parent application. Even in the case of new applications, the first-action allowance rate is increasing in the GS-level. Columns (2) and (4) in Tables 3.3 to 3.5 represent our preferred regressions. Column (2) limits the sample to only

from $GS-7$ to $GS-12$ in only a little more than two years.

new applications and column (4) limits the applications to only those within a three-year window of the examiner's most recent promotion. By excluding first-action decisions occurring more than three years after promotion, the column (4) regressions mitigate the issue of behavioral changes by examiners who have plateaued at a certain grade.[21] In column (4), we dropped any application outside of a 3-year window after an examiner's most recent promotion. In this case as well, GS-level exhibits a positive and statistically significant relationship with the probability of first-action allowance.

Notice the coefficients in Table 3.3 that are very low for grades GS-7 to GS-11. Despite this, first-action allowance is a relatively rare event so the effect is much larger as a percentage of overall first-action allowance rates. The experience coefficient is small in magnitude, but recall that experience is measured in months, therefore the variable has a relatively large effect. In particular, with the point estimate in column 4, an additional year of experience leads to a 0.19 percentage point increase in the first-action allowance rate. Broader incoming claims (smaller *ICL* and larger *ICC*) are associated with a lower chance of receiving a first-action allowance. This result is intuitive, because, as the count of independent claims increases, the complexity of the examination and the likelihood that at least one aspect of the patent will overlap with prior art increases.

3.5.2 Examiner's Amendment Rates

We delve further into the usage of examiner's amendments by studying the relationship between the incidence of an examiner's amendment and experience/grade. In Table 3.4, we find that the probability of a first-action examiner's amendment is increasing in both grade and experience. Column (4) demonstrates that the probability of a first-action allowance with an examiner's amendment is increasing from GS-9 through GS-14, providing further evidence that higher grade examiners are more likely to use this tool to prosecute patent applications. From column (4), relative to a GS-9 examiner, the probability of an examiner's amendment associated with a first

[21]Column (3) limits the sample to applications with a first-action decision less than three years after promotion but includes all types of applications and is included only for completeness.

VARIABLES	(1) All	(2) New Apps	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00641***	-0.00183*	-0.00577***	-0.00215**
	(0.000897)	(0.00107)	(0.000945)	(0.00109)
Grade: GS-11	0.00687***	0.00313***	0.00586***	0.00366***
	(0.000789)	(0.00101)	(0.000874)	(0.00105)
Grade: GS-12	0.0129***	0.00277**	0.0103***	0.00406***
	(0.00106)	(0.00137)	(0.00141)	(0.00157)
Grade: GS-13	0.0188***	0.00498***	0.0158***	0.00780***
	(0.00138)	(0.00177)	(0.00197)	(0.00226)
Grade: GS-14	0.0567***	0.0376***	0.0436***	0.0328***
	(0.00208)	(0.00269)	(0.00297)	(0.00326)
Exper	0.000178***	0.000189**	0.000251***	0.000161*
	(4.45e-05)	(7.59e-05)	(5.85e-05)	(8.56e-05)
ICC	-0.00134**	-0.00201***	-0.00139***	-0.00114***
	(0.000613)	(0.000214)	(0.000243)	(0.000145)
ICL	0.000360***	0.000638***	0.000344***	0.000534***
	(3.38e-05)	(1.53e-05)	(3.92e-05)	(1.35e-05)
Constant	0.0508***	-0.0531***	0.0312***	-0.0485***
	(0.00552)	(0.00400)	(0.00673)	(0.00588)
Observations	4,647,312	1,036,155	2,786,385	677,632
R-squared	0.029	0.041	0.032	0.038
Examiners	13,765	13,499	12,989	12,683
Parent Type FE	YES	NO	YES	NO

Significant at *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Columns (1) and (3) include parent type fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to equation 3.2.

Table 3.3: First-action Allowance Regressions (Dependent Variable: FA_Allow_{eit})

action is 0.27, 0.42, 0.7 and 1.4 percentage points higher for GS-11, GS-12, GS-13 and GS-14 examiners, respectively. This confirms hypothesis 2, that because of examiner incentives, examiners increasingly use examiner's amendments with higher seniority levels. Additionally, the coefficient on experience is positive and statistically significant in all regressions. For example, with the point estimate in column (4), each additional year leads to a 0.16 percentage point increase in the probability of using an examiner's amendment on the first action. This verifies hypothesis 1,

VARIABLES	(1) All	(2) New Apps	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00122***	-0.000186	-0.00107**	-0.000105
	(0.000467)	(0.000600)	(0.000492)	(0.000628)
Grade: GS-11	0.00330***	0.00287***	0.00288***	0.00273***
	(0.000427)	(0.000579)	(0.000465)	(0.000622)
Grade: GS-12	0.00600***	0.00428***	0.00494***	0.00419***
	(0.000552)	(0.000734)	(0.000730)	(0.000891)
Grade: GS-13	0.0101***	0.00726***	0.00866***	0.00740***
	(0.000706)	(0.000883)	(0.00100)	(0.00126)
Grade: GS-14	0.0162***	0.0136***	0.0143***	0.0141***
	(0.00106)	(0.00132)	(0.00149)	(0.00185)
Exper	0.000198***	0.000149***	0.000181***	0.000137***
	(2.43e-05)	(4.33e-05)	(3.22e-05)	(4.94e-05)
ICC	-0.000228***	-8.44e-05	-0.000186***	6.98e-05
	(8.00e-05)	(5.63e-05)	(6.39e-05)	(6.46e-05)
ICL	8.74e-05***	0.000161***	9.57e-05***	0.000153***
	(8.28e-06)	(5.01e-06)	(1.10e-05)	(5.38e-06)
Constant	-0.0123***	-0.0169***	-0.00159	-0.00674**
	(0.00153)	(0.00134)	(0.00244)	(0.00271)
Observations	4,640,782	1,031,126	2,783,587	675,470
R-squared	0.008	0.011	0.010	0.011
Examiners	13,764	13,498	12,988	12,682
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Columns (1) and (3) include parent type fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to equation 3.3.

Table 3.4: Examiner Amendment Regressions (Dependent Variable: $Exam\_Amend_{eit}$)

that ceteris paribus, more experienced examiners are more likely to use examiner's amendments. As for the magnitudes of these estimates, as you recall, examiners only use examiner's amendments on first-action allowances, which are a relatively rare event. Because of this, the marginal increase in examiner's amendment rates with grade and experience are a far larger percentage of first-action allowances.

3.5.3 "True Rubber Stamp" Allowances

Recall hypothesis 3 about the relationship between examiner experience and seniority and first-action allowance rates. Since examiners increasingly use examiner's amendments on the first action, we expect the difference in first-action allowance rates across grade and experience to diminish after accounting for the examiner's amendment. To assess this hypothesis, we explore the probability of issuing a "true rubber stamp" allowance (see equation (3.4)). Table 3.5 shows these results. In Columns (2) and (4), the significance of examiner grade disappears for all but GS-7 and GS-14, and completely disappears for experience. From column (4) in Table 3.3, GS-14 examiners are 3.28 percentage points more likely to issue a first-action allowance, but from column (4) in Table 3.5, GS-14 examiners are only 1.95 percentage points more likely to issue the application without any changes. These results demonstrate that even when the outcome variable accurately represents the "True Rubber Stamp" allowance, GS-14 examiners are more likely to allow applications without substantive examination compared to GS-9 examiners. The magnitude of this coefficient, reduced by 40.5 percent compared the results in Table 3.3, can attributed to the use of examiner's amendments. Although the GS-7 first-action allowance rate without an examiner's amendment is negative and significant relative to a GS-9 examiner, we show in the robustness checks section that this result is not robust. Despite this result, it's reasonable that very new examiners are less likely to issue first-action allowances without any change to the claims. For this reason, and the overall lack of robustness, we do not emphasize these GS-7 results.

These results generally verify hypothesis 3 since the "true rubber stamp" allowance rate only increases for GS-14 examiners. Table 3.5 demonstrates that the earlier results from the literature (Lemley and Sampat 2012) are generally overturned, by taking the learning mechanism (examiner's amendment) into account. Additionally, these results show that, at least at the first action, examiners exhibit learning behavior and adjust to the increased production requirements through more efficient prosecution and not "true rubber stamp" allowances.

There are several possible explanations for the increased "true rubber stamp"

VARIABLES	(1) All	(2) New Apps	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00523***	-0.00174**	-0.00475***	-0.00215**
	(0.000721)	(0.000849)	(0.000750)	(0.000856)
Grade: GS-11	0.00358***	0.000479	0.00303***	0.00121
	(0.000619)	(0.000806)	(0.000668)	(0.000830)
Grade: GS-12	0.00693***	-0.00109	0.00545***	0.000395
	(0.000859)	(0.00109)	(0.00108)	(0.00121)
Grade: GS-13	0.00866***	-0.00214	0.00726***	0.000864
	(0.00117)	(0.00150)	(0.00156)	(0.00172)
Grade: GS-14	0.0405***	0.0243***	0.0295***	0.0195***
	(0.00181)	(0.00219)	(0.00235)	(0.00251)
Exper	-2.22e-05	2.68e-05	6.51e-05	6.53e-06
	(3.86e-05)	(6.52e-05)	(4.73e-05)	(7.17e-05)
ICC	-0.00111**	-0.00192***	-0.00120***	-0.00121***
	(0.000541)	(0.000194)	(0.000186)	(0.000120)
ICL	0.000273***	0.000479***	0.000249***	0.000381***
	(2.57e-05)	(1.22e-05)	(2.84e-05)	(1.06e-05)
Constant	0.0633***	-0.0346***	0.0331***	-0.0401***
	(0.00465)	(0.00338)	(0.00532)	(0.00500)
Observations	4,647,312	1,036,155	2,786,385	677,632
R-squared	0.023	0.031	0.023	0.027
Examiners	13,765	13,499	12,989	12,683
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Columns (1) and (3) include parent type fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to equation 3.4.

Table 3.5: "True Rubber Stamp" Allowance (Dependent Variable: RS_Allow_{eit})

grant rate for GS-14 examiners relative to GS-9 (although far less severe than the overall first action allowance rate). The difference could be driven by examination time incentives, as described in earlier literature (Frakes and Wasserman 2017), although this is not the only possibility. In particular, the USPTO signatory program or risk aversion could also drive this result. We discuss this further in the policy discussion section below.

Finally, increased use of examiner's amendments and generally flat "true rubber stamp" allowance rates across grade and experience further suggest that time constraints are not necessarily binding at the first action (Frakes and Wasserman 2017), although our results may not extend to the full examination process. We argue that our models better capture the quality of examination as it relates to allowance. Specifically, we focus solely on the examiner's behavior at the first action and eliminate endogeneity due to unobserved applicant behavior after the first action. As a consequence however, we cannot extend our results directly to the entire examination process.

3.6 Robustness Checks

3.6.1 General Robustness Checks

We include general several robustness checks to the examiner amendment and true rubber stamp allowance regressions, many of which are similar to those run in Frakes and Wasserman (2017). First, to eliminate the possibility that examiner sorting is driving the results, we run specifications that include technology-by-year (technology center), United States Patent Classification (USPC) fixed effects[22] and several proxies for examiner specialization. The technology-by-year fixed effects account for examiners who switch technology centers, and allow also for the technology effect to change over time. The USPC fixed effects regressions account for technology at a more dis-aggregated level. Second, we subset the data to include only first-action decisions for examiners who begin at GS-7, and are GS-14 by the

[22]Frakes and Wasserman (2017) use NBER categories (37 groups) for technology-by-year fixed effects. We use technology center (7 groups) because the NBER concordance relies upon USPC, which is only publicly available through 2014.

end of our sample. Running each regression on this subset accounts for possible selection due to examiners that start at a higher grade, leave the USPTO before becoming GS-14, or decide to not be promoted at some point within the grade scale. Finally, we further explore the contribution of experience by running specifications that include experience fixed effects (at the month level), and 6 month experience bands. The purpose of these regressions is to examine any non-linearity between experience and the probability of issuing an examiners amendment. The regression results are contained in Tables B.1 and B.2, where the dependent variables are the probability of receiving an examiner's amendment and the probability of allowing the application without any changes to the application in Tables B.1 and B.2, respectively.

Table B.1 shows that after accounting for these additional factors, the examiner's amendment rate increases with both grade and experience. For the "balanced sample", we note that there is a loss of statistical significance for the GS-11, GS-12, and experience coefficient. Whereas the experience coefficient is insignificant in this regression at the 5 percent level, it is still significant at the 10 percent level (p-value not shown). A possible explanation for this loss of significance is the large decrease in the number of observations due to enforcing the balanced panel restriction for this table.[23] Columns (3) and (4) from Tables B.1 and B.2 allow for non-linearities in the examiner experience variable. Figure 3.3 shows that the linear and increasing contribution of experience to the probability of issuing an examiner's amendment holds when we allow for more flexibility in the experience variable (in particular, by allowing a different experience effect for each month of experience). Table B.2 further verifies the results on the probability of issuing a "true rubber stamp" allowance. In particular, the results are even stronger since with the additional robustness checks, the only grade that affects the probability of issuing an allowance without any change to the application is GS-14.[24]

Finally, the results from Tables B.3 to B.8 of the appendix further confirm that

[23]By balanced panel, we follow Frakes and Wasserman (2017) to mean that the sample consists only of examiners experiencing all of the grades.

[24]With the earlier specifications, GS-7 was slightly, but significantly, less likely than GS-9 to issue a first-action allowance without any change to the application

our results are robust to quasi-random assignment based on technological specialization. In particular, the results do not change after controlling for both the USPC sub-class and similarity measures of examiner specialization. Interestingly, consistent with Righi and Simcoe (2019) and with additional examiner characteristics not included in that study, we find that more specialized examiners have lower first-action allowance rates. Overall, the robustness checks confirm the results of our analysis.

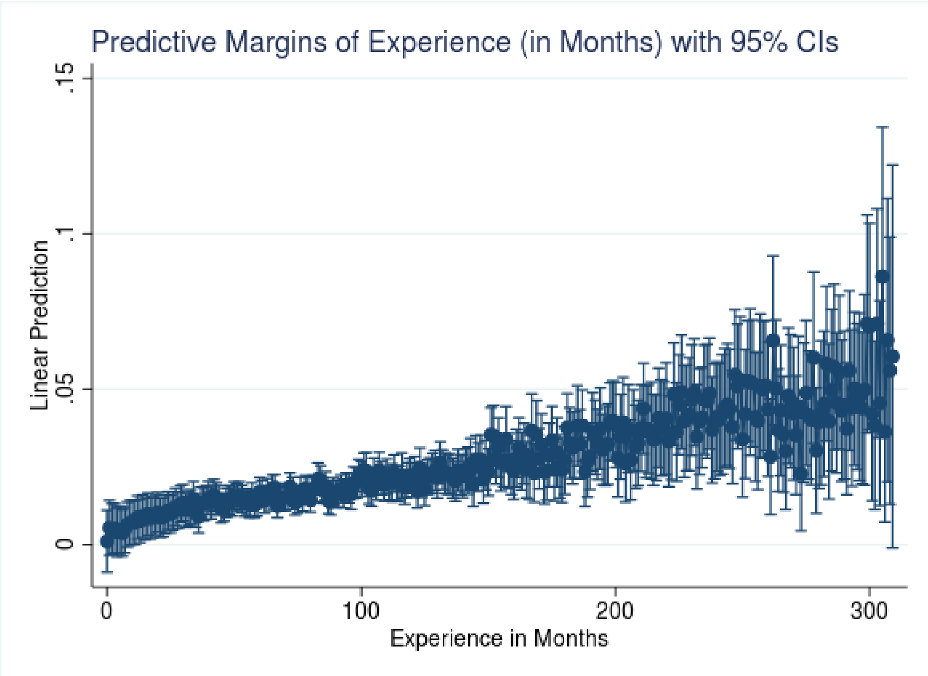


Figure 3.3: Examiner Amendment Experience Fixed Effects

3.6.2 Examiner's Amendment and Examination Quality

In this subsection, we examine the impact of the use of an examiner's amendment on patent examination quality. While we have previously shown that the propensity to use an examiner's amendment generally accounts for the disparity in allowance rates by grade and experience, it is unknown how this learning mechanism affects the quality of examination. For example, suppose an examiner issues a first-action allowance with an examiner's amendment on an application. In the process, the examiner's amendment modifies the quality of the application by some observable and quantifiable amount, Δq.[25] Now suppose that the examiner had issued a non-final rejection on the same application instead of allowing the application with an examiner's amendment. The applicant modifies the claims to be allowable in response to the rejection, increasing the quality of the application to $\Delta q'$. If $\Delta q > \Delta q'$, then the learning mechanism leads to both higher quality examination and shortened pendency. If $\Delta q \approx \Delta q'$, then the examination quality is the same but the applicant enjoys the benefits of shortened pendency and the examiner was able to obtain the full production counts with fewer hours. Finally, If $\Delta q < \Delta q'$ then the examiner is sacrificing examination quality for expediency, potentially leading to lower patent quality. In this section, we explore how the decision to allow a patent with an examiner's amendment affects the relative quality of examination. Specifically, we test for differences in examination quality between those applications allowed after a first-action allowance and those applications that required only one non-final rejection before allowance.

Since patent prosecution generally narrows the claims (Marco *et al.* 2016), we use the change in patent scope during prosecution to analyze one component of patent examination quality. According to Marco *et al.* (2016), changes in patent scope can be measured by the difference between the scope measure (ICL or ICC) at two successive points in time (ΔICL or ΔICC).[26] Using $\Delta Scope$ as a dependent variable allows us to estimate the relative change in scope due explicitly to an examiner's amendment, where $\Delta Scope$ is measured as the simple difference between the patent scope measures (ICL and ICC) at grant and at PGPub. In particular, we estimate the following specification

$$\Delta Scope_{eit} = \beta_0 + \beta_1 Exper_i + \beta_2 ICL_i + \beta_3 ICC_i + \beta_4 Parent_i + \nu Exam\_Amend_i + \gamma_t + \gamma_e + \gamma_g + \varepsilon_{eit} \tag{3.5}$$

where $\Delta Scope_{eit}$ is either ΔICL_{eit} or ΔICC_{eit}, e indicates the examiner, t is the first-

[25] Where Δq is equal to the difference in patent quality over patent prosecution.

[26] In Marco *et al.* (2016), the authors analyzed the change in patent scope over the entirety of patent prosecution, or, in other words, from filing to grant.

action year, g indicates the USPC and the remaining variables are described above. We restrict the underlying sample only to those granted patents with a first-action examiner's amendment and those applications receiving a single non-final rejection followed by an allowance decision. Because of this sample restriction, we are careful to interpret our estimates only for incoming applications similar to those in the selected sample. In particular, our sample does not contain high-quality incoming applications that were allowed on the first action (without an examiner's amendment), nor very low incoming quality applications that required multiple rounds of review before either being granted, or ultimately abandoned. Despite this, the restricted sample is not overly limiting since we are interested in the patent quality trade-off between first-action examiner's amendments, and longer prosecution through the non-final rejection to allowance examination route.

The examiner's decision to use a first-action examiner's amendment rather than more traditional patent prosecution is likely positively correlated with incoming patent quality, leading to omitted variable bias. Therefore, we utilize two additional empirical approaches to overcome this issue. The first is directly controlling for incoming patent scope by including the PGPub ICL and ICC. Despite this, additional components of incoming patent quality may reside in the error term. To account for this, we turn to an instrumental variables framework. In particular, we use the examiners leave-one-out first-action examiner's amendment rate to instrument for the examiner's first-action decision on the current application. In particular, for each application i examined by examiner e, we compute the fraction of examiner e's earlier first-action decisions that resulted in a first-action examiner's amendment relative to the total number of first-action decisions that resulted in a first-action examiner's amendment or non-final rejection to allowance (that is, relative to all examiner $e's$ earlier first-action decisions in the sample). This IV approach is similar to the leave-one-out examiner grant rate utilized in the literature (Farre-Mensa *et al.* 2017, Sampat and Williams 2019). As before, to control for examiner technological specialization (Righi and Simcoe 2019), we use examiner and USPC fixed effects, along with our direct measures of examiner specialization discussed earlier.

Finally, we first consider applications with first-action examiner's amendments where the pre-grant publication (PGPub) directly precedes the examiner's amendment, without a claim amendment submitted between the PGPub and examiner's amendment. This ensures that the examiner used the PGPub text when considering the examiner's amendment. After issuing an examiner's amendment an allowing the application, the claim changes resulting from the examiner's amendment are published in the patent's claims. Therefore, we compute the text measures on the PGPub and grant text for only those applications where the examiner's amendment satisfies this condition. This is also the sample we used earlier to compute the TF-IDF similarity values. As a robustness check, we run additional regressions that include *all* examiner's amendments and the results are consistent between the two samples.

The regression results are shown in Tables B.9 through B.12 in the appendix. To isolate the effect of an examiner's amendment, observations with applicant amendments *after* pre-grant publication were dropped for the set of regression results in Tables B.9 and B.10. Tables B.11 and B.12 include the set of *all* first-action allowances with an examiner's amendment and allowances with a single non-final rejection. In Table B.9, we first regress ΔICL on a binary indicator, where *Exam_Amend* takes value one if the application was allowed on the first action with an examiner's amendment and zero if the application was allowed after a single non-final rejection, and a set of controls. We repeat this regression in column (3) but only include applications without a parent (i.e. U.S. new applications). In columns (1) and (3) we find that the use of an examiner's amendment is associated with 15 fewer words added to the shortest independent claim from filing to grant compared to those applications with a single non-final rejection. However, as noted above, it is likely that the examiner's amendment decision is endogenous. Therefore, we turn to the instrumental variables regressions in columns (2) and (4).

Instrumenting for examiner's amendment using 2SLS, the leave-one-out examiner's amendment rate for each examiner should be correlated with the first-action decision but uncorrelated with the quality of the examined application. The

F-statistic for the first stage (results not shown) is above 45 for column (1) and 13.13 for column (2), satisfying the F-statistic cutoff of 10 for weak instruments suggested in Stock, Wright, and Yogo (2002). The IV estimates are insignificant but much less precise than the OLS estimates. Following the interpretation of insignificant IV estimates in Sampat and Williams (2019), we rule out relative decreases in scope narrowing (scope narrowing is increasing in ΔICL) of greater than 7.45 to 10.4 words compared to a single non-final rejection. The results in Table B.10 are similar. The IV estimates are insignificant, ruling out relative decreases in scope narrowing (scope narrowing is decreasing in ΔICC) greater than .258 to .345 claims. These IV estimates demonstrate that examination quality, to the extent described above, is not significantly different between issuing an examiner's amendment and extending examination to a single non-final rejection. Therefore, to a certain extent, examination quality is unaffected by the decision to issue an examiner's amendment. Finally, these results are robust to the inclusion of applications that had been modified by the applicant after publication.

3.6.3 Examiner's Amendment Quality By Grade and Experience

While our main results demonstrate that the likelihood of an examiner's amendment is increasing, and the previous robustness check shows that patent quality doesn't generally deteriorate with the use of examiner's amendments, we have not directly explored variation in examiner's amendment quality across examiner grade and experience. This distinction is importance since a deterioration in examiner amendment quality across grade and experience (given that examiner's amendment rates increase in these variables) would likely indicate that examiner learning rates are not properly aligned with examiner incentives.

In this section, we investigate whether more experienced examiners or examiners with different seniority incentives show any variation in their tendency to narrow claims with first-action examiner's amendments. To test this relationship, we run the specification in equation (3.2), where we replace the dependent variable with $\Delta Scope$. Decreases in narrowing by grade/experience demonstrates that the quality of examination through the issuance of an examiner's amendment is also decreasing in grade/experience. This deterioration in examiner's amendment quality, along with increased use of examiner's amendments would likely indicate that patent office examiner incentives are not properly aligned with the actual rate of examiner learning. We run the regression on the subset of first action examiner's amendments where the PGPub directly precedes the examiner's amendment. As described earlier, this ensures that the examiner used the PGPub when negotiating the examiner's amendment.

The results are shown in Tables B.13 (ΔICL) and B.14 (ΔICC). First, in both tables, broader patent claims are narrowed by examiner's amendments.[27] Table B.13 shows that neither grade nor experience have a significant effect on the change in the number of independent claims modified by an examiner's amendment, across all specifications. The same holds for ΔICC in Table B.14. Although the results do not prove there is no effect, since an insignificant result does not prove there is no relationship, we find the results are suggestive that the substance of examiner's amendments across both grade and experience is largely the same. These results demonstrate that examiner amendment quality does not deteriorate with experience or seniority. As described in more detail earlier, any deterioration would have suggested that patent office incentives are not properly aligned with the actual rate of examiner learning. Additionally, as expected, larger incoming scope is generally significantly and positively correlated with a larger change in scope on the examiner's amendment.

3.7 Discussion

3.7.1 Pendency Reduction

While our analysis focuses on the relationship between examination quality and the use of examiner's amendments, examiner's amendments provide additional ben-

[27] In particular, more incoming independent claims lead to a greater reduction in independent claims on examiner's amendments, and a shorter minimum independent claim word count leads to a smaller reduction in minimum independent claim word count. These results are always statistically significant.

efits to the applicant in the form of compact prosecution, shorter pendency, and longer effective patent term. To quantify these benefits, we estimate the effect of a first-action examiner's amendment on post-first-action pendency. The empirical specification for this regression is:

$$ln(PEND_{eit}) = \beta_0 + \beta_1 Exper_i + \beta_2 ICL_i + \beta_3 ICC_i + \beta_4 Parent_i + \nu Exam\_Amend + \gamma_t + \gamma_e + \gamma_g + \varepsilon_{eit} \tag{3.6}$$

where $PEND_{eit}$ is defined to be post-first-action pendency (issue month - month of first action) and the covariates are similar to those defined for the previous set of regressions. For these regressions, the sample is the same as the examination quality regressions described in Section 3.6, where we compare first-action allowances with an examiner's amendments to allowances with a single non-final rejection. Similarly to the examination quality regressions in Section 3.6, the unobserved quality of the application will be correlated with both the decision to issue a first-action allowance with an examiner's amendment and the length of prosecution, leading to omitted variable bias. Therefore, we again instrument for the examiner's amendment decision by using the leave-one-out examiner's amendment rate. In addition to the full sample, we also run models on the sub-sample restricted to granted patents with no parent application (*i.e.*, U.S. new applications).

The results are shown in Table B.15. In specifications with a logged dependent variable and a dummy independent variable, one cannot interpret the coefficient on the dummy variable as the percentage change. To obtain the percentage change in pendency from a single rejection to a first-action allowance with an examiner's amendment, one must transform the coefficient using the following formula: $100 * (e^{\beta} - 1)$. We find that relative to those granted patents that received at least one office action rejection, a first-action allowance with an examiner's amendment decreases pendency by more than 50 percent, confirming Hypothesis 4. Interestingly, the results are consistent across method (OLS and IV) and sample (full sample and U.S. new applications).

Our results demonstrate that increased examiner's amendment use, *ceteris paribus*, leads to shorter pendency without sacrificing examination quality. The literature on pendency and firm outcomes provide evidence that the reduction in pendency could benefit both innovators and firms in several ways. For example, decreased patent grant delays will hasten the resolution of (some of the) uncertainty regarding granted patent scope and intellectual property rights conferred to assignees (Gans *et al.* 2008). This reduction of uncertainty should in turn mitigate frictions related to technology transfer.

3.7.2 Patent Office Policy

In recent years, the USPTO has received considerable criticism from academia, journalists, practitioners, and policy-makers over the impact of examiner incentives on patent quality, and related economic outcomes. In 2016, the GAO concluded that the "USPTO has not fully assessed the effects of the time allotted for application examinations or monetary incentives for examiners on patent quality." Further, based upon survey evidence, the GAO estimated that 70 percent of examiners do not have enough time to thoroughly examine patent applications (GAO 2016). Frakes and Wasserman (2017) go further, suggesting that if "all examiners were allocated as many hours as are extended to GS-7 examiners, the Patent Office's overall grant rate would fall by roughly 14 percentage points, amounting to roughly 40,000 fewer patents issued per year." Utilizing estimates in their earlier work, Frakes and Wasserman (2019) perform a cost-benefit analysis, and find that doubling examination time would increase the social welfare of the patent system.

The debate over examiner incentives, patent quality and economic outcomes has several dimensions. First, as discussed in this chapter, patent examiners face different incentives based on seniority and complexity of the technology being examined. If these incentives across examiners are improperly aligned with learning rates and the variance in complexity across technology, then average patent quality will likely vary across examiners. A related, yet different question, is whether society would be better off spending additional resources on patent examination. The fundamental trade-off here is between *ex ante* screening and *ex post* screening

(Lemley 2001). *Ex ante* screening refers to screening patents before grant, while *ex post* screening refers to screening patents for validity after grant in the litigation system. Lemley (2001) argues with a cost-benefit analysis that since patent value is highly skewed (Pakes, 1986), society is better off spending additional resources screening valuable patents *ex post*, rather than screening all patents *ex ante* in the patent examination system. Using a similar method, and estimates from Frakes and Wasserman (2017), Frakes and Wasserman (2019) comes to the opposite conclusion. In particular, doubling the amount of time provided to examiners would increase the welfare of the patent system.

Our results primarily contribute to the first question, although indirectly contribute to answering the second question. First, previous literature suggests that examiner incentives are improperly aligned with learning rates based upon seniority and experience. These authors suggest that improperly aligned examiner incentives contribute to the "crisis in patent quality" (Frakes and Wasserman 2017). Additionally, they suggest that examiner incentives should be re-aligned, and in particular, more senior examiners should be given relatively more time. This solution would be very costly. As Frakes and Wasserman (2019) notes, doubling the amount of examination time provided to examiners would cost 800 million dollars a year.

Our results suggest a different view. After accounting for several features of the data, and misconceptions about patent prosecution, we find that examiner time incentives are generally not misaligned with examiner learning rates. In particular, the variation in examination outcomes disappears for experience and every seniority level except for GS-14. Despite the remaining gap for GS-14 examiners, the difference is significantly less than previous studies. Therefore, any policy response should be restricted to GS-14 examiners. To determine the appropriate response however, more research is needed.

In addition to receiving less time to examine patent applications, GS-14 examiners also receive full signatory authority. This allows them to sign off on their own cases. We can think of three reasons why GS-14 examiners might allow more applications on the first action. First, as studied in previous literature, the time adjustment for GS-14 may be particularly steep. Second, GS-14 examiners may become more lenient with less oversight provided by the full signatory program. Third, without signatory authority, risk averse junior examiners might allow too few applications on the first action. This could be the case since an examiner does not generally get another look at allowed applications, or if the repercussions for allowing an invalid patent are particularly severe. The precise mechanism driving the variation in GS-14 first-action allowance rates will determine the policy response, which we leave for further research. Our results provide counterevidence to studies advocating that examiner incentives should be modified across all seniority levels. Further, if based on prior literature, examiners may have less of an incentive to utilize the pendency-reducing examiner's amendment mechanism. As noted, the use of examiner's amendments may reduce pendency by approximately 50 percent, and therefore innovators and firms may face longer pendency on average through a modification of examiner incentives for all seniority levels.

3.8 Conclusions

We identify a new outcome measure to the patent examination literature, specifically, the use of examiner's amendments. Examiner's amendments are used in lieu of an office action rejecting claims by providing a set of changes to the applicant which will, either by restricting or by clarifying the claims, place the patent application on a path to a notice of allowance. We employ natural language processing techniques as well as an internal USPTO dataset on examiner promotions and experiences to revisit prior literature suggesting that promotion and experience are both associated with lower patent quality. We find that by accounting for examiner's amendments, the results are mostly overturned. Therefore, far from being a rubber stamp, we find that more experienced examiners provide more value to the patent system by more quickly tailoring otherwise un-allowable applications into patented inventions. This behavior is encouraged by the Office's emphasis on compact prosecution, and reduces uncertainty in patent grant delay; the latter of which increases efficiency in the markets for technology (Gans *et al.* 2008; Hegde and Luo 2018).

We find that higher grade examiners, or examiners with more stringent incentives, are more likely to use examiner's amendments. Further, conditional on incentives, examiners with more experience are more likely to use examiner's amendments. These results suggest that examiners both use examiner's amendments through increased learning about patent prosecution, and through USPTO examination incentives. Additionally, we do not find significant differences in the quality of examination between the examiner's amendment, and the use of office action rejections. These results, coupled with the USPTO's emphasis on compact prosecution imply that the examiner's amendment is an effective tool to expedite patent prosecution, increasingly used by the patent examination core with both experience and grade. In particular, we find that use of the examiner's amendment may reduce pendency by over 50 percent.

While this study investigated the effects of examiner's amendments on patent allowability and found that more seasoned examiners and examiners with more stringent incentives utilize examiner's amendments as a tool to enable inventions to more quickly obtain patent rights, the overall impact of USPTO examination on patent quality, and economic outcomes need to be further explored. Our paper provided counter evidence to the previous literature which contends that examination incentives are misaligned across examiners. Our results suggest that the proposed policy advocating for increased time allocations across all grades to align examiner incentives (because of increasingly "binding time constraints") should be reconsidered. Before modifying existing policies, researchers and stakeholders should further explore the variation in outcomes between junior (GS-13 and below) and senior examiners (GS-14) and the impacts of the signatory program, examiner risk aversion, and variation in time allocations. Finally, we note that our research does not disprove the notion that overall changes in examination time across the board may lead to greater efficiency in the patent system, which may be a fruitful avenue for further research.

3.9 Chapter Acknowledgements

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Chapter 4

Patent Validity and Follow-on Patenting: Evidence From *Ex Parte* Reexamination at the USPTO

4.1 Introduction

As the number of patents granted at the U.S. Patent and Trademark Office (USPTO) has skyrocketed over the last three decades, the issuance of low-quality patents has become a growing concern (FTC 2003; Hall and Harhoff 2004, Hall *et al*. 2004). Low-quality patents, typically granted with overly broad scope or questionable validity, cause reduced innovative activity by firms, market failures, and sub-optimal economic outcomes, including limited competition and increased costs (FTC 2003; Hall *et al*. 2004; Galasso and Schankerman, 2015a, 2015b). Low-quality patents lead to economic inefficiencies in the following ways: first, low-quality patents lead directly to greater uncertainty regarding the validity and scope of the property rights, leading to underinvestment in new technologies and a diminished rate of innovation, especially in cumulative technologies. Second, the increase of the low-quality patents is associated with fragmentation of ownership and the creation of patent thickets. Increased fragmentation can also lead to *ex ante* contracting failures through an increase in transaction costs for licensing agreements (Ziedonis 2004), resulting in lower innovative activity (Cockburn *et al*. 2010). Finally, within patent thickets, firms with weaker patent portfolios face increased costs of production because they cannot adequately insulate themselves from potential infringement lawsuits from competitors. These higher expected litigation costs can cause firms with weaker patent portfolios to exit the market, effectively erecting barriers to entry. The exit of these firms is coupled with decreased entry from increased barriers to entry (UKIPO 2013).

The USPTO has adopted a number of initiatives, including the introduction of the "Enhanced Patent Quality Initiative", to address the issue of low-quality patents. These initiatives focus on patent examination (work quality, patent quality measurements, and customer service),[1] increasing the quality at each stage of the patent prosecution process and providing accurate measurements to evaluate the USPTO's progress. While these quality initiatives aim to improve the quality of granted patents going forward, several procedural avenues are also available to invalidate erroneously-granted patents *ex post*, including reexamination (*ex parte* and *inter partes*), post-grant review, *inter partes* review, and the U.S. federal court system. Patent litigation in the U.S. court system is costly; in 2013, the median cost of a "low-stake" case (less than \$1 million at risk) reached \$700,000 and the median cost "high-stakes" case (greater than \$25 million at risk) exceeded \$5.5 million (AIPLA 2013; Vishnubhakat *et, al.* 2016). The other methods to invalidate a patent are housed within the USPTO and are less expensive than invalidation through litigation, but vary procedurally. In this paper, I focus on *ex parte* reexamination, which essentially re-opens prosecution at the USPTO between the assignee and a specialized reexamination unit. Section 4.3.2 provides a thorough discussion of this process.

The discussion on patent quality also extends to the strength of the intellectual property right afforded to each granted patent. Until the last decade or so, there was little empirical research on the effect of intellectual property rights on follow-on innovation and patenting. Several recent papers though have investigated the effects of intellectual property rights on follow-on innovation, including Gaessler *et al.*

[1] https://www.uspto.gov/patent/EPQI-complete

(2017), Galasso and Schankerman (2015a, 2015b, 2018), Moser and Voena (2012), Murray and Stern (2007), Sampat and Williams (2019). These papers explore how the existence or varying degrees of patent protection may affect follow-on innovation, positively or negatively. Notably, three papers (Galasso and Schankerman 2015a, 2015b; Gaessler *et al.* 2017) study how the revocation of patent rights, or patent invalidation, can lead to both increases and decreases to follow-on innovation (measured principally in forward citations to a focal patent) in certain contexts. In each of these papers, the authors compare a set of invalidated patents, from the U.S. Court of Appeals for the Federal Circuit (Galasso and Schankerman 2015a, 2015b) and post-grant oppositions at the European Patent Office (Gaessler *et al.* 2017), to a set of patents that survived each respective process. These papers aim to measure the effects of invalidation but I argue in this paper that the estimated invalidation effect from the aforementioned papers captures both an invalidation effect and a separate *validation* effect, i.e., the effect of validation on follow-on innovation.

This paper aims to disentangle the validation and invalidation effects and directly estimate the effect of validation on follow-on patenting. I concentrate on follow-on patenting rather than follow-on innovation because firms do not always patent to appropriate returns to R&D. In fact, studies have shown that firms also patent for strategic purposes in certain technology areas (Cohen *et al.* 2000; Hall and Ziedonis 2001). Section 4.4 presents mechanisms for changes in follow-on patenting behavior by both the assignee and rivals in response to validation. Following patent validation, the assignee may increase its follow-on patenting due to lower costs of innovative activity or decrease its follow-on patenting because of lower expected competition. The considerations for rivals are similarly ambiguous. The validation effect for them is ambiguous because validation should theoretically raise innovation costs, lowering innovative activity (and thus patenting). However, the validation should also raise the expected litigation costs for the rival, inducing an increase in strategic patenting. A more thorough discussion of the possible mechanisms is provided in Section 4.4.

Utilizing the *ex parte* reexamination process, this paper estimates the effect of validation on follow-on patenting. First I collect a set of patents that were reexamined *and* confirmed through *ex parte* reexamination between 1999 and 2010. I then match 702 validated patents to a corresponding set of non-reexamined patents, where the control group has similar observable patent and technology characteristics, went through the same initial prosecution process, but did not receive the additional scrutiny of the reexamination process. To reduce selection bias, the reexamined patents are matched to the patent corpus on patent value, technology, scope, and other patent characteristics and the average treatment effect on the treated (ATT) is estimated. To calculate the ATT, I control for time-invariant, patent-level, unobserved heterogeneity by implementing a variant of the difference-in-differences matching estimation (DiD-matching) strategy (Heckman *et al.* 1997). While DiD-matching mitigates some portion of the potential selection bias, the identification for the DiD-matching estimator is violated if the pre-treatment conditional parallel trends between the treatment and control groups diverge, among other assumptions. Therefore, prior to estimating the ATT, each relevant assumption is discussed (Chabé-Ferret and Subervie 2013, and Wooldridge 2010) and tested (when applicable). Most notably, I find that the parallel trends assumption is violated when implementing a standard difference-in-differences framework with the entire sample, but is satisfied after the matching procedure (see Appendix).

The DID-matching results show that validation increases overall follow-on patenting and generally increases follow-on patenting for both the patent assignee and rivals, but this result depends on the characteristics of technology (complex versus discrete). This paper, to the best of my knowledge, is the first to empirically indicate the direct effects of validity confirmation through *ex parte* reexamination (or any other post-issue review proceeding) on follow-on patenting. The results further demonstrate that while confirmation of the focal patent may increase follow-on innovative activity by the assignee, it also encourages increased strategic patenting by rivals, which may be sub-optimal. Further research should explore the efficiency and optimality of these proceedings relative to other means of increasing patent quality, including increased fees (de Rassenfosse and Jaffe 2018), higher quality examination (Frakes and Wasserman 2019), among other alternatives.

The rest of the paper is organized as follows: Section 4.2 presents a literature review on patent rights and both follow-on innovation and patenting. Section 4.3 provides a brief description of patent prosecution and the reexamination process at the USPTO. Section 4.4 provides theoretical considerations for how an increase in the probability of patent validity modifies follow-on patenting behavior. Section 4.5 describes the data and presents summary statistics. Section 4.6 describes the estimation strategy and Section 4.7 discusses results and robustness checks. Section 4.8 concludes.

4.2 Literature Review

A number of recent papers have delved into the relationship between follow-on innovation or research and both the existence and strength of intellectual property rights. Murray and Stern (2007) examines how the issuance of patent rights for patents linked to academic papers leads to a modest anti-commons effect, or the reduction in expected journal citations for the related academic research. Sampat and Williams (2019) investigates how patents rights affects follow-on innovation in human genome research, comparing follow-on scientific research and investment activity in genomes with and without patent protection. The paper concludes that, although the patented genomes are more valuable prior to granting decisions, there is no significant patent rights effect on follow-on innovation. Moser (2013) provides an excellent literature review of the effects of patent rights on innovation from a historical context. Zobel *et al.* (2016) analyzes the link between patenting by entrants and subsequent open innovation relationships. The paper argues that an entrant's accumulation of patents both protects its innovative activity and signals innovative capability to potential collaborators, leading to more open innovation relationships. Finally, Moser and Voena (2012) exploits weakened patent laws under the Trading with the Enemy Act of 1917 (40 Stat. 411) which granted compulsory licenses to firms after World War I. The issuance of compulsory licenses led to a twenty percent increase in "domestic innovation", or the number of patents granted by the USPTO within a U.S. Patent Classification subclass in a given year.

Several papers have been written on the relationship between revocation of patent rights, or "invalidation", and follow-on innovation, measured principally by follow-on patenting (Galasso and Schankerman, 2015a, 2015b; Gaessler *et al.* 2017). Galasso and Schankerman (2015a) analyzes a set of nearly 1,400 patent validity decisions at the U.S. Court of Appeals for the Federal Circuit (CAFC) and estimates the effect of invalidation on the number of forward citations within five years of the validity decision for each relevant patent. To address the endogeneity of the ordinary least squares (OLS) estimator for the invalidation dummy variable, the authors construct a "propensity to invalidate" index for the set of CAFC judges randomly assigned to each case. The index, the paper argues, is correlated with the validity decision, but uncorrelated with unobserved characteristics affecting the dependent variable. The main result of Galasso and Schankerman (2015a) suggests that patent invalidation leads to a fifty percent increase in forward citations to the invalidated patent, but the effect is heterogeneous and depends on the bargaining environment. Gaessler *et al.* (2017) utilizes a large dataset of "opposed" European Patent Office (EPO) patents granted between 1993 and 2011. The authors construct an instrument from the participation of the "opposed" patent's examiner at grant in the post-grant opposition proceedings. The main results in Gaessler *et al.* (2017) are consistent with the main findings of Galasso and Schankerman (2015a): patent invalidation leads to more total and external citations. However, the Gaessler *et al.* (2017) results differ from Galasso and Schankerman (2015a) in invalidation effects in discrete versus complex technologies, in the presence of patent thickets, and in other environments. Finally, Galasso and Schankerman (2015b) builds on their previous work (Galasso and Schankerman 2015a) and finds that the invalidation effect is driven by smaller firms in specific technologies but the patenting rate for larger firms is mostly unaffected.

These papers (Galasso and Schankerman, 2015a, 2015b; Gaessler *et al.* 2017) compare the set of invalidated patents to a set of "validated" patents (validated by either the CAFC or in post-grant opposition proceedings). In the ideal economic experiment (which is obviously infeasible), one would study the effects of invalidation on follow-on innovation by first taking a random sample of granted patents from the patent corpus. Then the patent rights would be removed randomly from a subset of the sample, allowing the claimed invention to enter the public domain. One could then compare the forward citation rates between patents with intact intellectual property rights and patents whose rights had been invalidated. The papers discussed above deviate from this setting. In these papers (Galasso and Schankerman, 2015a, 2015b; Gaessler *et al*. 2017), the estimates of the invalidation effect capture two effects: the invalidation effect from the revocation of patents rights, but also the validation effect which affects the comparison group, or "validated" patents. The use of this comparison group prevents proper estimation of the invalidation effect. Lemley and Shapiro (2005) argues that patents are probabilistic in nature and do not necessarily guarantee the right to exclude a potential competitor from using or producing a protected invention; Rather, assignees are granted the right to *try* and exclude potential competitors from the patented technology space. If one accepts the premise of probabilistic patents (Lemley and Shapiro 2005), validation signals to both the patent owner and potential competitors that the patent is enforceable (although it does not guarantee a ruling of infringement if a competitor enters the technology space). This signaling effect would be more pronounced in patents with a lower probability of validity compared to more "certain" patent rights. Further discussion of how this validation effect might affect follow-on patenting decisions by the patent holder and rivals is presented in detail in Section 4.4.

4.3 Institutional Background

4.3.1 Patent Examination and Patent Quality

Once an application is submitted to the USPTO by the applicant, the office will docket the application to an examiner skilled in the relevant art. The examiner then begins to review or *prosecute* the application. The prosecution process is complex but the examiner typically begins the process by determining if the patent contains a single invention, performing a double patenting search, searching and evaluating existing literature or "prior art", and, depending on the outcome of the previously mentioned tasks, drafting either a rejection or allowance.[2] Unless the examiner determines that the patent application does not meet the standards described in 35 USC 101 (patentability), 35 USC 102 (novelty), 35 USC 103 (obviousness), and 35 USC 112, the assignee is entitled to an allowance. However, if the examiner believes that the standards have not been met, she will typically issue a non-final rejection. At this point, the applicant has multiple options to respond. In the simple case, the assignee will modify the metes and bounds of the claimed invention (patent claims) in an attempt to overcome the examiner's non-final rejection. The examiner will then evaluate the new set of claims and determine if the standards have now been met. If allowed and subsequently issued, the patent rights are held by the assignee and are transferable. The typical patent term is 20 years beginning with the priority date[3] but may be adjusted because of office or regulatory delays.[4]

The examiner is time-constrained in prosecuting each patent. Marco *et al.* (2017) provides an example for a GS-12[5] level examiner examining in U.S. Patent Classification class 14, bridges. This type of examiner has just 17.5 hours to reach a balanced disposal of the application (please see Marco *et al.* (2017), for a thorough description of balanced disposals). Within this time, the examiner must perform all initial checks (double patenting search, verification of single invention, etc.), research all relevant prior art, including both patent and non-patent literature (i.e., academic publications, existing products, etc.), and draft up to two office actions[6] before reaching a balanced disposal. Additionally, the examiner may reject the application only if the patentability standards are not met. This requirement

[2] Marco *et al.* (2017) provides an in-depth overview of the patent prosecution process.

[3] MPEP 211

[4] MPEP 211

[5] General Schedule Level, or GS-level, refers to the seniority of a U.S. government employee. Within the U.S. Patent and Trademark Office, patent examiners can obtain the following GS-levels: 5, 7, 9, 11, 12, 13, 14, 15. Examiners typically start at either GS-7 or GS-9 depending on their level of education and experience. Production requirements at the USPTO increase with seniority. Historically, within the production requirement, all seniority factors are normalized to the GS-12 rate. For example, a GS-9 has a seniority factor of 0.8, meaning that a GS-9 examiner must produce 80% of the production counts of a GS-12 examiner in the same art. Examiners receive production counts for allowances, office-action rejections, abandonments, and other examination actions.

[6] There are exceptions. Please see Marco *et al.* (2017) for more detail.

is potentially problematic because time-constrained examiners may not be able to thoroughly evaluate the literature to find the appropriate prior art on which to draft a rejection. Previous research on the patent examination process has found that time-constraints are binding and examiners are therefore likely to perform lower quality examination and to allow low-quality patents (Frakes and Wasserman 2017; Jaffe and Lerner 2004; Lemley 2001; Lemley and Sampat 2012).[7] In performing a lower quality examination, the examiners may allow overly broad or potentially invalid patents. Additionally, examiners may make mistakes and miss relevant prior art that would have led to an office action rejection. Some researchers argue that limiting the amount of time spent prosecuting each application is rational because a relatively small number of patents are litigated and validity decisions may be made more efficiently by the courts (Lemley 2001). Therefore, under this theory, the USPTO at times should be rationally ignorant in allowing some "bad" patents.

4.3.2 Ex Parte Reexamination at the U.S. Patent and Trademark Office

According to the literature on uncertain patent rights, the boundary of a patent's claimed invention is often unclear (Merges and Nelson 1990), and there is some "uncertainty about the validity and scope of the legal right being granted," (Lemley and Shapiro 2005). Although 35 U.S.C. 282 states that all granted patents are presumed to be valid,[8] a patent's validity may be challenged in various venues after it is granted by the USPTO.[9] This section presents an overview of one of those venues, *ex parte* reexamination proceedings at the USPTO, and describes how a successful patent reexamination (for the patent holder) would increase the probability of a

[7]Although, research in this thesis provides counter-evidence to this literature.

[8]35 U.S.C. 282: "A patent shall be presumed valid. Each claim of a patent (whether in independent, dependent, or multiple dependent form) shall be presumed valid independently of the validity of other claims; dependent or multiple dependent claims shall be presumed valid even though dependent upon an invalid claim. The burden of establishing invalidity of a patent or any claim thereof shall rest on the party asserting such invalidity."

[9]At other patent offices, the invalidity rate is non-trivial for challenged patents. For example, the EPO, in its 2017 Annual Report, provided statistics for its opposition process (similar to reexamination), noting that only 3.7 percent of patents were opposed after grant, where 32 percent of the oppositions were rejected outright. Of those patents for which the EPO issued a final decision, 27 percent had their monopoly rights revoked.

patent's validity.[10] According to *Patlex Corp. v. Mossinghoff*, 771 F.2d 480 (Fed. Cir. 1985), the benefits of *ex parte* reexamination include the less expensive and faster resolution of patent validity suits than through the U.S. court system, utilization of the technological expertise of examiners at the patent office to ensure the accuracy of the validity decisions, and the correction of improperly granted patent applications from the USPTO (Vishnubhakat *et al.* 2016). However, the process excludes third parties from participating in the reexamination process (hence, *ex parte*). *Inter partes* reexamination was introduced in 1999 but was never widely adopted as a means of patent validity challenges (Vishnubhakat *et al.* 2016). *Inter partes* review (IPR) was only established by the Leahy-Smith America Invents Act of 2011, precluding its use in this paper because of the limited initial number of IPR filings and limited post-decision time frame.

Once the USPTO issues a patent, various parties (including the patent assignee, third parties, or the Director of the USPTO) may elect to file an *ex parte* reexamination request. *Ex parte* reexamination, introduced by the U.S. Congress via the Bayh-Dole Act of 1980,[11] requires the request for reexamination to contain a substantial new question of patentability to be approved by the USPTO.[12] If USPTO grants the request, the Central Reexamination Unit (CRU) will assign the patent to a primary examiner (other than the original examiner) who is most familiar with the claimed subject matter.[13] The examiner then reopens patent prosecution on the challenged patent claims and "reexamination will be conducted according to the procedures established for initial examination."[14] There are no limitations on who can file a request for reexamination but only the office and the assignee may participate in the reexamination process. During the reexamination process, the examiner may confirm the validity of claims or find that the claims, as stated, are

[10]For a thorough description and history of post-issue proceedings, please read Vishnubhakat *et al.* (2016), from which, among other papers, this description is based.

[11]35 U.S.C. 200

[12]35 USC 302; 35 USC 303(a)

[13]MPEP 2236

[14]35 USC 305; Additional post-grant review proceedings include inter partes review (addressing 35 USC 102 (novelty) and 35 USC 103 (obviousness) concerns), Covered Business Methods (challenging a patent's validity) post-grant reviews, and inter partes reexamination (now defunct).

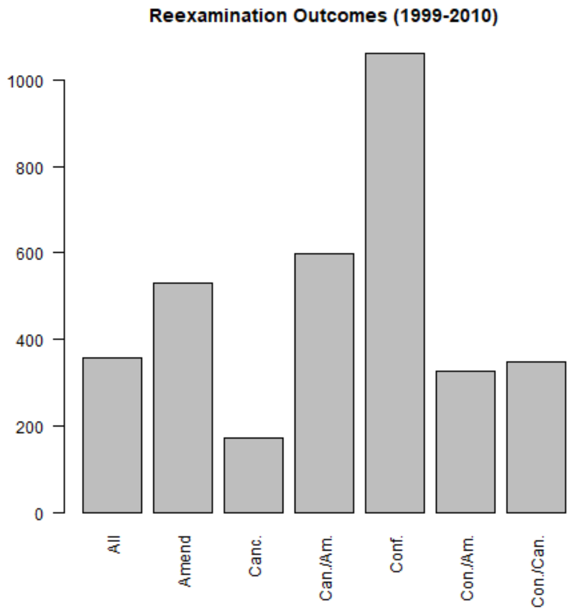


Figure 4.1: Reexamination Outcomes

invalid. However, assignees can amend challenged claims in response to an adverse patentability decision. If the assignee decides to amend its claims, it cannot enlarge the scope of the patent during the reexamination process. At the end of the reexamination process, a reexamination certificate is issued. The reexamination certificate details which challenged claims have been amended, canceled, or confirmed. In this case, the set of "treatment" patents include the case where all challenged claims have been confirmed. The distribution of reexamination outcomes (1999-2010) for which a certificate was issued is presented in Figure 4.1.[15] As can been seen, the most frequent outcome was that all reexamined claims were confirmed.

Ceteris paribus, the additional scrutiny given to a patent during the reexamination process, relative to only participating in the initial patent examination process, should provide a credible signal regarding the patent's validity. In fact, according to Vishnubhakat *et al.* (2016), "[c]ertain Federal Circuit cases have indicated that patents that survive reexamination should be viewed even more deferentially by the courts than ordinary patents," suggesting that the reexamination process provides an expert opinion on the patent in question to the court which must be taken into ac-

[15]This graph shows the proportion of reexamination outcomes by outcome type: amended claims, cancelled claims, confirmed claims, or combinations of these outcomes.

count when ruling on validity. Therefore, if a patent has survived the reexamination process with all of its claims intact (without amendments), the probability of patent validity, all else equal, should be non-decreasing in claim confirmation by *ex parte* reexamination.

There are two obvious selection biases here: (1) an agent (assignee, third party, or the Director of the USPTO) must request patent reexamination; and (2) the patent must survive the reexamination process. In (1), reexamined patents are likely to differ from the rest of the patent corpus because assignees and third parties alike may target these patents based on their characteristics, including quality, value, and strategic importance. Patent owners and third parties have different motivations for filing an *ex parte* reexamination request. Patent owners seek reexamination to validate existing patent claims or modify existing claims to ensure validity (Baughman 2007). Third parties, according to Baughman (2007), use *ex parte* reexamination to challenge the validity of a patent in lieu of challenging the validity of the patent in U.S. Federal Court. The article describes the various trade-offs between using each venue: (1) the burden of proof required to invalidate a patent is lower in *ex parte* reexamination, "in litigation an alleged infringer faces the challenge of proving invalidity by clear and convincing evidence, but a third party does not face this burden in reexamination." Additionally, in *ex parte* reexamination, the examiner interprets the claims using the "broadest reasonable interpretation" standard, which allows for broader interpretation of the claims against prior art than would be allowed in federal court. The article argues that a third party may choose reexamination depending on the strength of the "invalidity arguments". (2) Reexamination is a much cheaper process than invalidation through the court system. (3) Reexamination may lead the patent owner to narrow the claims of the patent to avoid invalidity decisions, providing more space for rivals to operate in the technology space. The author describes several more reasons for why a third party might use *ex parte* reexamination but these additional reasons are far less broadly applicable.

In (2), the likelihood of the surviving reexamination typically depends on time-invariant characteristics of the patents (claim construction, prior art at the time of filing, etc.). These issues are addressed in section 4.6.

4.4 Theoretical Considerations

The decision to follow-on patent in a probabilistic patent setting is influenced by a number of factors. This section presents the theoretical considerations regarding the effects of a patent's validation through reexamination on follow-on patenting. First, I examine follow-on patenting incentives in an environment with uncertain validity and scope for both the patent holder and its rivals. Then, I discuss how an increase in validity modifies the follow-on patenting incentives for both the patent holder and its rivals. I also argue that validation effects should be larger in complex relative to discrete technologies.[16] Finally, I present additional and alternative mechanisms for the modification of follow-on patenting behavior after validation. This section proposes and discusses several potential mechanisms for the observed patenting responses, but the precise mechanism is not directly tested in this paper.

4.4.1 Considerations for Follow-on Patenting

Firms are often sensitive to two technology market inefficiencies when deciding to invest in R&D and innovative activities: *ex post* hold-up and the complements problem (Hall and Ziedonis 2001; Noel and Schankerman 2013; Shapiro 2001; Ziedonis 2004). Hold-up refers to the ability of one firm to expropriate rents from another firm, while the complements problem, first introduced by Cournot, suggests that transaction costs are increasing in the number of licensors (Shapiro 2001). In the context of technology and innovation, hold-up occurs when a competitor undertakes investment in innovative activity without a license for the relevant intellectual property (bargaining failure or lack of awareness), or the terms of the licensing agreement are unclear and the patent owner asserts the patent *ex post* (Shapiro 2001). This bargaining failure typically arises in a cumulative innovation setting where the ownership of the patented technology space is fragmented and the patent boundaries are fuzzy, commonly referred to as a patent thicket (Bessen and Meurer 2008; Far-

[16] The definitions of complex and discrete technologies was first introduced by Cohen *et al.* (2000).

rell and Shapiro 2008; FTC 2003, 2011; Hall *et al.* 2016; Noel and Schankerman 2013; von Graeventiz *et al.* 2013).[17] These fuzzy boundaries within patent thickets are the result of unclear patent claims allowed by patent offices and contribute to overlapping patented inventions (UKIPO 2013), which are often of questionable validity. The complements problem and hold-up are closely intertwined, but the complements problem refers to *ex ante* bargaining failures due to increased ownership fragmentation and thus to increase transaction costs. These increased transaction costs lower returns on R&D, entry, and investment in R&D (Shapiro 2001).

While facing the threat of hold-up, the conditions in a patent thicket lead firms to patent strategically. A large literature exists on strategic patenting (Arundel *et al.* 1995; Arundel and Patel 2003; Blind *et al.* 2006; Blind *et al.* 2009; Cohen *et al.* 2002; Hall and Ziedonis 2001; Noel and Schankerman 2013; among others), which, according to Noel and Scankerman (2013), consists of two distinct aspects: defensive patenting and patenting to combat the complements problem. A defensive patenting strategies is defined as, "the accumulation of patents to use as bargaining chits to preserve the freedom to operate and to improve the bargaining position of the firm in resolving patent disputes when they arise," (Noel and Schankerman 2013). This strategy allows firms to mitigate the risk of *ex post* hold-up (Hall and Ziedonis 2001; Ziedonis 2004; Noel and Schankerman 2013). Hall and Ziedonis (2001) and Ziedonis (2004) also found evidence that the threat of *ex post* hold-up increases with fragmentation, showing an intersection between hold-up and the complements problem in complex technologies with fragmented ownership. Ziedonis (2004) further argues that within the context of fragmented ownership rights, certain *ex ante* bargaining solutions may be unattainable. Before investing in R&D and patenting, firms in fragmented technology space will therefore consider and evaluate the validity of each relevant patent, the likelihood that proposed innovations are covered by existing patents, and the probability that the corresponding assignee will sue for infringement if the firm's invention does infringe on existing patents. These considerations demonstrate the hold-up risk if the firm fails to secure

[17] These conditions are typically found in complex but not discrete technologies (Shapiro 2001).

a licensing agreement.

The firm, after evaluating the relevant set of patents, may attempt to negotiate *ex ante* licensing agreements, proceed without an agreement, or refrain from investing in the innovative activity. If the transaction costs are too high to secure an *ex ante* licensing agreement (complements problem) or the claim boundaries are sufficiently unclear, the firm may invest in innovative activities without an agreement to relevant patents or reduce innovative activities to a sub-optimal level. The sheer number of patents and unclear boundaries can lead to difficulties in identifying the relevant set of patents, especially for certain technologies. The literature on defensive patenting (see set of papers above) suggests that firms continue to invest in innovative activities in the presence of patent thickets, but also amass a patent portfolio to offset the risk of hold-up from fragmentation-induced bargaining failures and lack of awareness of the patent landscape due to the density of the technology space. With defensive patent portfolios, firms are able to bargain, threaten a countersuit, cross-license their patents, etc., to protect the firm from the risk of hold-up (Arundel *et al.* 1995; Cohen *et al.* 2002; Noel and Schankerman 2013).

4.4.2 External (Rival) Follow-on Patenting, Validity, and Reexamination

As discussed in section 4.3.2, the reexamination process reopens patent prosecution by the CRU. If no patentability issues are discovered by the patent examiner, a reexamination certificate will be issued with no amendments or cancelled claims, effectively providing further validation for the reexamined patent. This increase in the probability of a patent's validity should affect the rival's follow-on patenting decisions in a number of ways. First, the higher probability of validity should decrease follow-on innovation and therefore patenting due to increased costs of innovative activity. When the probability of validity increases, the rival modifies its original assessment of hold-up risk for the reexamined patent, increasing the rival's incentive to seek an *ex ante* licensing agreement, if one did not already exist. Licenses, which can incorporate the probability of validity and infringement into the licensing fees, become relatively more expensive as the probability of validity increases (Sherry and Teece 2004). Therefore, when the rival seeks an *ex ante* licensing agreement, the cost of innovative activity increases and the level of innovative activity should decrease because it is now more costly to undertake innovative activity.[18] This reaction is consistent with Cockburn *et al.* (2010), which established the empirical link between reduced innovation performance in fragmented technology and licensing agreements. The authors also find that firms operating without licensing agreements in fragmented technologies achieve relatively higher innovative performance. Finally, in lieu of a licensing agreement, firms may reduce their innovative activity because the risk of hold-up increases expected litigation costs.

Second, if the firm foregoes a licensing agreement or already has invested in the relevant technology space, the firm may seek to increase defensive patenting to mitigate the increased risk of hold-up, which is consistent with the literature on defensive patenting described above. This should increase patenting. **Therefore, the effect of an increase in the probability of validity on external follow-on patenting is ambiguous and the direction of this effect (*i.e.*, which influence dominates) must be determined empirically.**

To summarize, following an increase in the probability of validity for a patent, follow-on patenting by rivals may increase because of increased defensive patenting. However, the increased cost of innovative activity may dampen innovative activity by rival firms, decreasing follow-on patenting related to the innovative activity. Therefore, the direction of the effect is ambiguous.

4.4.3 Internal (Incumbent) Follow-on Patenting, Validity, and Reexamination

Patent assignees face many of the same patenting incentives as the rivals described above. In a patenting environment with fuzzy patent boundaries and fragmented ownership, assignees are at risk for *ex post* patent hold-up (Hall and Harhoff 2004)[19] and will patent strategically to protect their inventions (Hall and Ziedonis 2001; Ziedonis 2004). Patent-holding firms operating within a thicket lack certainty re-

[18] If a licensing agreement already exists, the rival should be unaffected.

[19] The risk of patent predation and *ex post* hold-up are higher for assignees with sunk costs and patents belonging to a technology standard (Hall and Harhoff 2004).

garding the validity of their patent portfolio because the boundaries demarcating these and other patents in the technology area are often unclear. In a similar manner to rivals, assignees, when facing the decision to invest in follow-on innovation, will evaluate patents in nearby technology space for validity, claim overlap, and the probability that the rival patent owners might sue if their patents were infringed. Though the assignees may already have patented defensively to mitigate the risk of *ex post* patent hold-up, rivals may also have undertaken subsequent innovative activity and patented in the related space, potentially hindering future follow-on innovation for the assignee. Rival firms may also have patented in the assignee's technology space to improve their bargaining position with the assignee (Blind *et al.* 2006; Blind *et al.* 2009).[20] The assignee may decide to conduct follow-on patenting to strengthen the defensive barrier around its inventions, patent strategically to improve its bargaining position with rivals, or conduct innovative activities and subsequently patent them.

After an increase in the probability of validity, the assignee's incentives to follow-on patent will differ from those of firm's rivals. First, the increase in the probability of validity will lead to lower expected costs of innovative activity. This cost reduction occurs due to a lower expected probability of infringement suit against the assignee (*i.e.*, reduced risk for *ex post* hold-up). The higher probability of validity strengthens the patent portfolio because the probability of successful enforcement is increasing in the probability of validity, *ceteris paribus*. Strong patent portfolios assist firms in avoiding costly litigation by inducing settlements and licensing agreements and providing possible counterclaims (Parchomovsky and Wagner 2005). Therefore, leveraging a stronger patent portfolio should lead to a lower probability of litigation, reducing the expected costs of innovative activity. Second, the relative value of the validated patent may increase, inducing the assignee to engage in strategic patenting to defend the intellectual property (Blind *et al.* 2009).

From a theoretical perspective, the increase in the probability of validity does not lead to an unambiguous increase in follow-on patenting. Aghion *et al.* (2009)

[20]This type of defensive patenting is also called exchange patenting.

finds a positive relationship between entry and incumbent innovative activity (including patents), especially those firms near the technological frontier. As the probability of validity increases, the assignee may expect a reduction of both entry into the focal patent's technology space and rival innovative activity (discussed above). The results from Aghion *et al.* (2009) suggest that the incumbent, in response to the lower expected competition, may reduce its innovative activity and follow-on patenting. **Therefore, similar to external follow-on patenting, the effect of an increase in the probability of validity on internal follow-on patenting is ambiguous and the direction of this effect (*i.e.*, which influence dominates) must be determined empirically.**

To summarize, following an increase in the probability of validity for a patent, follow-on patenting by the incumbent may increase because of lower expected costs of innovative activity and increased strategic patenting. However, reduced competition may decrease innovative activity by the incumbent, decreasing follow-on patenting related to the innovative activity. Therefore, the direction of the overall effect is ambiguous.

4.4.4 Complete Versus Discrete Technologies

The majority of the discussion within this section has focused on patent validity effects in fragmented technologies with fuzzy patent boundaries, which typically occur in complex technologies (Shapiro 2001; UKIPO 2013) and has not delved into the potential effects within discrete technologies. This discussion is limited to complex technologies because patent characteristics and, as a result, patenting behavior, are heterogeneous across the two technology types. According to Cohen *et al.* (2000), complex technologies are characterized by "numerous separately patentable elements" where inventions within discrete technologies is characterized by "relatively few" separately patentable inventions. Cohen *et al.* (2000) argues that patent protection is sufficient to earn monopoly rents in some, but not all, discrete product industries (*e.g.*, the pharmaceutical industry). In discrete technology industries with "weaker" patent protection, firms may engage in patent blocking or fencing strategies, which prevent entry into the technology space surrounding a firm's invention. These firms, however, do not generally utilize their patent portfolios for negotiations. It should be noted, that the increase in the probability of validity should increase the value of the intellectual property through an increase in the enforceability of the patent or through increased licensing revenue. The increased relative value may prompt the incumbent firm to increase patent fencing activities, which results in higher follow-on patenting by the incumbent.

Issues associated with overlapping claims, fuzzy claim boundaries, and fragmented ownership are not typically present, or are at least less severe, in discrete technologies. As a result, the complements problem and hold-up are not typically associated with discrete technologies. Additionally, discrete product firms "will file stronger individual patents, meaning patents more likely to be held valid if opposed," (Alcácer *et al.* 2009), on average, especially in technologies where a single patent is sufficient protection. These characteristics of discrete technologies (incentives for stronger patents, minimal granted patent overlap, and clear boundaries) minimize the effects of an increase in the probability of patent validity for this grouping of technologies relative to complex technologies. **Therefore, an increase in the probability of validity should result in a weaker effect on follow-on patenting in discrete technologies compared to complex technologies.**

4.4.5 Theoretical Considerations Summary and Other Considerations

This section aims to provide context and theoretical considerations to how and why firms (rivals and assignees) may alter follow-on patenting behavior in response to an increase in the probability of a patent's validity. However, this question is not a simple one and deals with numerous economic considerations. For example, Egan and Teece (2015) and deGrazia *et al.* (forthcoming) demonstrate that economic interactions within complex technologies, specifically patent thickets, are complicated and are not limited to a single economic consideration. Therefore, this section provides plausible mechanisms for how firms *might* react given the existing literature.

4.5 Data

4.5.1 Patent Examination Research Dataset

Information on the entire patent corpus (granted patents since 1976 and patent applications since 2001) was taken from the Patent Examination Research Dataset (PatEx). PatEx, provided by the USPTO's Office of the Chief Economist, contains publicly-available, application-level data, including filing date, issue date, U.S. Patent Classification, and other patent prosecution data for 9.2 million patent applications and granted patents through November 2017.[21] Though the PatEx contains applications filed and patents granted through 2017, the sample was limited to patents granted through 2007 for two reasons: (1) to allow for at least three years pre- and post-reexamination; (2) to avoid issues with the increased use of alternative post-issue review proceedings (*inter partes* review) created by the Leahy-Smith America Invents Act (AIA) of 2011.[22] The AIA introduced the Patent Trials and Appeals Board and with it, additional avenues for the post-issue review of patents. However, the number of new filings for these proceedings were limited in the first few years after enactment.

4.5.2 Patent Reexamination Data

Ex parte reexamination requests, where each request is assigned a new application number beginning with the numbers "90", can be filed only after a patent has been granted by the USPTO. The *ex parte* reexamination applications were retrieved from the PatEx continuity dataset and linked with the corresponding parent patent data. Once the original patent numbers were identified, Google Patents was scraped using R to obtain the "Legal Events" section for each reexamined patent. The "Legal Events" section contains all pre- and post-grant legal events, including maintenance payments, reexamination requests, assignment, etc. From this information, *ex parte* reexamination outcomes can be identified. When a reexamination certificate is issued, Google Patents captures the outcomes in free form text. For example, the

[21] This is the first update to the original PatEx release. Please see https://www.uspto.gov/learning-and-resources/electronic-data-products/patent-examination-research-dataset-public-pair for more information.

[22] 125 STAT. 284

USPTO issued a reexamination certificate on patent 7479949, where the free form text reads: "THE PATENTABILITY OF CLAIM 11 IS CONFIRMED. CLAIMS 1-10 AND 12-20 WERE NOT REEXAMINED."[23] Each reexamination was parsed and categorized based on outcome type, including only confirmed, only cancelled, only amended, and a group for multiple simultaneous outcomes (see Figure 4.1).

The sample of reexamined patents used in this paper contains all reexaminations with populated outcome data[24] between 1999 and 2010. Similar to the set of pre-match patents, the sample is right-truncated at 2010 to provide an appropriate timeframe for the observation of follow-on innovation and to avoid potential issues stemming from the passage of the Leahy-Smith America Invents Acts of 2011 (AIA). The "treatment" set of patents is comprised of patents which were reexamined and confirmed by the CRU at the USPTO (other outcomes are excluded to allow for a clean estimation of the validation effect). However, patents with either a single or multiple consistent reexamination confirmation are kept in the sample (over 900 unique reexamined patents). These restrictions, along with the timing of the treatment described below, assume that only the initial reexamination outcome will provide a reduction of uncertainty. I test the robustness of this assumption in Section 4.7.2.

4.5.3 Citation and Family Size Data

Citation and family size data were taken from the Google Patents Public Data dataset,[25] provided by Google and IFI CLAIMS Patent Services. For this paper, both pre-grant publications and issued patents are included in the backward and forward citation counts. Family size is measured as be the number of jurisdictions associated with each family identification number. Family size is a proxy for patent value (Harhoff *et al.* 2003; Lanjouw *et al.* 1998; Putnam 1996; Sapsalis and van Pottelsberghe 2007; and van Zeebroeck 2011), where the implied value of the intellectual property right is increasing in the number of jurisdictions (countries, or

[23] https://patents.google.com/patent/US7479949

[24] The vast majority of reexamination certificates issued after October 10, 1999 include outcome information.

[25] https://cloud.google.com/blog/big-data/2017/10/google-patents-public-datasets-connecting-public-paid-and-private-patent-data

rather different patent and trademark offices) to which the applicant applies. If an applicant does not believe the value of obtaining intellectual property rights to be high, it will not submit an application to additional jurisdictions due to the increasing costs of doing so. There are different variants of this measure, but family size in this paper is defined to be the number of individual countries to which an applicant applies.

4.5.4 Patent Scope and Technology Classes

Recent work regarding the measurement of patent scope argues that scope at grant can be measured by both the length of the shortest independent claim in words and the count of the independent claims in a granted patent (Marco *et al.* 2016; Kuhn and Thompson, forthcoming).[26] The USPTO's Office of the Chief Economist provides publicly-available patent scope data for all patents granted between 1976 and 2014. PatentsView[27] provides various technology class data including the NBER patent classifications for all patents issued through mid-2015. The NBER classifications,[28] originally introduced in Hall *et al.* (2001) and derived from the internal U.S. Patent Classification system (USPC), provide broader patent technology classes than the original USPCs.

4.5.5 Technological Similarity

Researcher Jeffrey Kuhn has provided technological similarities ($TS \in [0,1]$) between cited and citing patents, described in Kuhn *et al.* (2018). The authors used a vector space model of patent text (full text, including the specification, abstract, claimed invention, etc.) similarity and calculated the "angular distance" between each citing-cited patent pair. The comparison included vectors of more than 700,000 dimensions for patents and publications issued between 1976 and 2017. The technological similarity of a citing-cited pair measures the proximity of the two inventions in technology space. Unfortunately, the authors did not provide technological sim-

[26] Kuhn and Thompson (forthcoming) argue that patent scope can also be measured by the length of the first independent claim instead of the shortest independent claim.

[27] www.patentsview.org

[28] There are six main classifications and numerous hierarchical sub-classifications. The main classifications include chemical, computers and communications, drugs and medical, electrical and electronics, mechanical, and other.

ilarities from pre-grant publications (PGPubs) to their respective backwards citations and only granted citations can be used for the comparison set (i.e., abandoned or pending applications are not included in the sample). To increase the coverage, I replaced cited PGPub numbers with the corresponding patent number if the application was later granted. Therefore, I assumed that each issued patent contains similar technological content to its PGPub.

4.5.6 Data Set Construction

To construct the pre-match sample, I first collected all *ex parte* reexamination proceedings between 1999 and 2010 with at least three years between grant and reexamination to allow for the observance of a pre-trend. These reexamination certificates were subsetted by outcome and only confirmed reexamined patents were kept. These patents, issued between 1990 and 2007, were combined with the set of all non-reexamined patents granted during the same time period. *Ex parte* reexamination outcomes cases with amended or canceled claims[29] were dropped for two reasons: (1) amended claims alter the metes and bounds of the claimed invention. While the USPTO cannot expand the scope of a claim during *ex parte* reexamination, the altered language may have an effect on the underlying value, quality, and strategic importance of the reexamined patent. These changes could alter the follow-on behavior of both the patent holder and third parties. (2) Similarly, the set of partially or fully invalidated patents would potentially contaminate the comparison group because it would be difficult to distinguish between the effect of an increase in the probability of legal enforceability and the invalidation of the property rights on follow-on innovation (the latter of which was studied by Galasso and Schankerman, 2015a, 2015b; and Gaessler *et al.* 2017). Therefore, the pre-match sample is limited to those patents confirmed through reexamination and those patents for which a reexamination request was not filed.

[29]Other types of cases were also dropped, including reexaminations filings that were rejected because the request did not meet the standard of substantial new question of patentability.

Variable	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Small Entity	2,246,485	0.240	0.427	0	0	0	1
Family Count	2,249,891	2.760	2.127	1	1	4	16
ICC	2,249,891	2.828	2.395	0	1	3	130
ICL	2,249,756	144.786	99.372	0	85	182	20,085
Backward Citations	2,249,974	11.418	16.477	0	4	13	777
Log Fwd. Cites (5 yrs - File)	2,249,974	0.248	2.582	−4.605	0.010	1.947	6.628
Log Fwd. Cites (3 yrs - Grant)	2,249,974	−0.881	2.728	−4.605	−4.605	1.102	6.801

Table 4.1: Summary Statistics - Pre-match Sample

Variable	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Small Entity	702	0.308	0.462	0	0	1	1
Family Count	702	3.593	2.854	1	1	6	14
ICC	702	3.392	3.339	1	2	4	35
ICL	702	141.983	90.812	1	82	174.8	965
Backward Citations	702	18.714	30.069	0	5	20	413
Log Fwd. Cites (5 yrs - File)	702	1.385	2.233	−4.605	0.698	2.709	5.361
Log Fwd. Cites (3 yrs - Grant)	702	0.190	2.656	−4.605	0.010	2.081	6.620

Table 4.2: Summary Statistics - Successfully Reexamined Patents

Variable	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Small Entity	702	0.308	0.462	0	0	1	1
Family Count	702	3.452	2.580	1	1	5	12
ICC	702	3.386	2.998	1	1	4	25
ICL	702	144.333	87.616	7	83	187.5	700
Backward Citations	702	16.500	22.863	0	5	19	188
Log Fwd. Cites (5 yrs - File)	702	1.587	1.972	−4.605	0.698	2.773	5.247
Log Fwd. Cites (3 yrs - Grant)	702	0.308	2.416	−4.605	0.010	1.793	4.395

Table 4.3: Summary Statistics - Control Group Patents

4.5.7 Descriptive Statistics

Tables 4.1 and 4.2 display summary statistics for those patents in the "non-reexamined" and "confirmed by reexamined" groups, respectively. There exists a stark difference in the distribution of several variables between the two groups: (1) There is a larger percentage of small entity patents in the "treatment" group than in the patent corpus as a whole (0.308 compared to 0.240); (2) Patents in the "treatment" group tend to be more valuable than those in the set of non-reexamined patents, where both family size (2.76 to 3.59 countries) and three-year forward citations are indicators of underlying value (Harhoff *et al.* 2003, van Zeebroeck 2011);

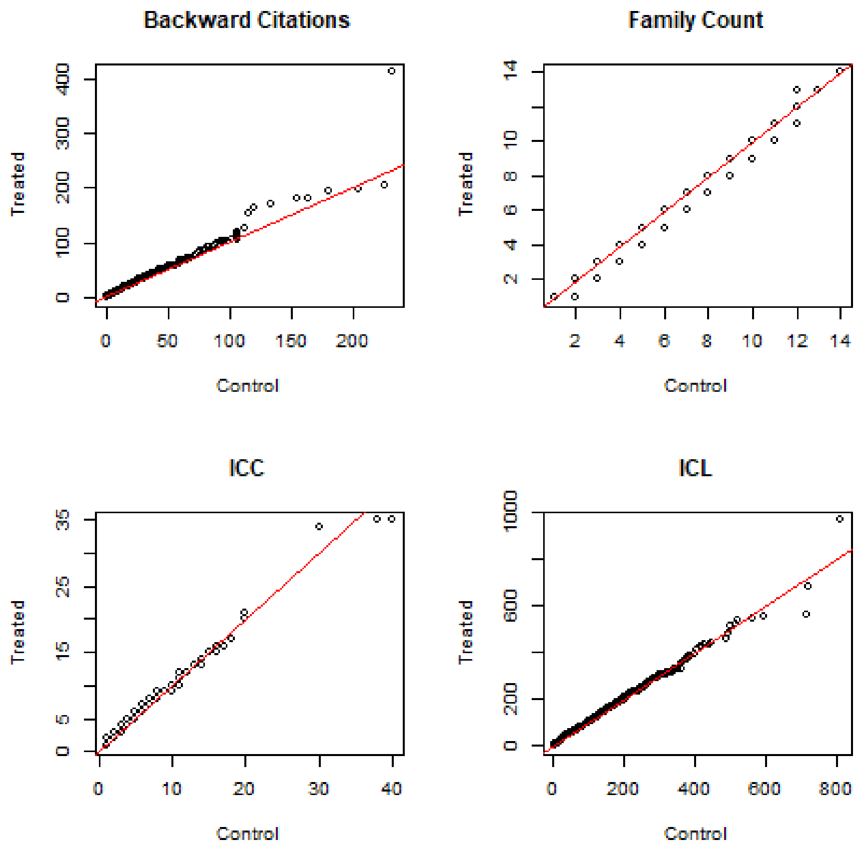


Figure 4.2: Matched Sample Q-Q Plots

(3) Patents in the "treatment" group also tend to be broader than those in the general patent corpus, as measured by ICC and ICL. An increase (decrease) in the number of independent claims (length of the shortest independent claim) is indicative of a broadening of patent scope. Therefore, a higher (lower) value for ICC (ICL) would indicate a broader patent, all else equal (Marco *et al.* 2016; Kuhn and Thompson, forthcoming). Patents confirmed by the CRU are, by both ICL (144.79 words to 141.98 words) and ICC (2.83 claims to 3.39 claims), broader on average than non-reexamined patents. There are also stark differences between the pre-match distribution of technological classes (NBER categories) by group (see Figure 4.3), indicating a possible difference in patenting strategies and uses across technology classes, leading to higher attempted invalidity rates.

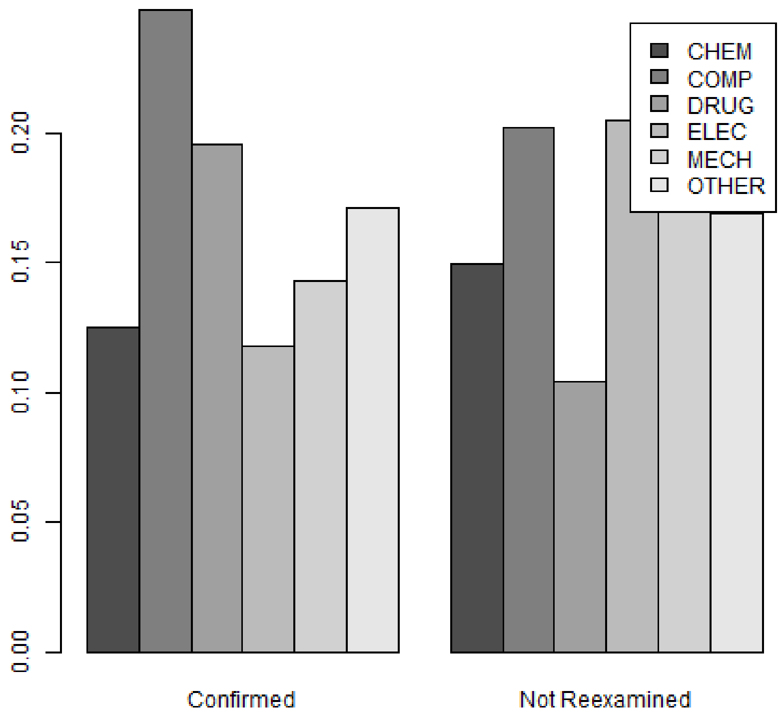


Figure 4.3: NBER Classification - By Group

4.5.8 Selection into Reexamination and Matched Sample Characteristics

The differences in averages and distributional characteristics for the each of the variables mentioned above indicate differences in composition between the two groups. In order to use claim confirmation by the CRU as an appropriate treatment, one must understand how pre-matching differences in these characteristics might affect selection into reexamination. There have been several studies on the determinants of EPO opposition proceedings (including Harhoff and Reitzig 2004; Harhoff *et al.* 2006; Schneider 2011; Gaessler *et al.* 2017), a process similar to *ex parte* reexamination at the USPTO. These studies focus on the firm- and patent-level characteristics that are associated with the incidence of an opposition filing for a given patent at the EPO. Harhoff and Reitzig (2004) found that the number of designated countries, grant lag, number of claims, backward citations, forward citations, "crowded" patenting areas, and technology classes, and nationality of assignee were statistically significant determinants of oppositions at the EPO. They also found that PCT application status, scope variables (Lerner 1994), non-patent literature, and assignee type (individual inventor or firm) did not have a significant effect on incidence of opposition. This strand of research is relevant to this study because it presents a set of variables associated with selection into a procedure that is similar to the *ex parte* reexamination. To mitigate the selection effects, I matched (described in the section 4.6) on characteristics similar to those described in Harhoff and Reitzig (2004), in addition to pre-treatment citations (Biasi and Moser 2018; Calel and Dechezleprêtre 2016).

After completing the matching process, the treatment and control groups show improved balance. Comparing Tables 4.2 and 4.3, the averages for the control group variables (family count, ICC, ICL, and backward citations) are much closer to the corresponding averages of the treatment group variables. This improvement in balance is also shown graphically in Figure 4.2. The q-q plots, which plot the quantiles of the treatment group against the quantiles of the control group for backward citations, family count, ICC, and ICL, show good balance between the two groups in each variable. Balance is improved as the data points approach the 45 degree line. These q-q plots demonstrate that observable value and scope characteristics are similar between the two groups in an effort to mitigate the selection bias. In addition to the q-q plots, Figure 4.3 depicts the distribution of NBER technology classifications by confirmed patents and those patents that were not reexamined (pre-match). In the matching algorithm, the patents were matched directly on the NBER technology category and therefore have the same technological distribution.

4.6 Estimation Strategy

When estimating a treatment effect using a quasi-natural experiment, it is natural to first examine a difference-in-differences framework. However, the conditional parallel trends assumption, the main assumption on which the identification of the DiD estimation relies, requires the pre-reexamination trends in the dependent variable (log forward citations, log self-citations, and log external citations) to be parallel prior to the date of the reexamination certificate. In this case, the conditional parallel pre-trend assumption is violated when the assumption was tested on the entire sample (see Appendix). Therefore, to overcome these econometric issues, I use a variant of the DiD estimator, DiD-matching, which first matches treated patents to a set of control patent candidates. Patents are matched on observable patent-level characteristics to mitigate selection effects and other confounding effects, to control for patent-level heterogeneity, and to satisfy the conditional parallel trends assumption. The DiD-matching estimator has been described and used in various forms in several economics studies (Heckman *et al.* 1997; Heckman *et al.* 1998; Smith and Todd 2005; Abadie 2005; Toole and Czarnitki 2010; Chabé-Ferret and Subervie 2013; Calel and Dechezleprêtre 2016; Biasi and Moser 2018; Teodorescu 2018). This section provides an overview of the DiD-matching method and discusses the specific variant implemented for this paper. Additionally, the matching method used to create the set of "control" patent is described in the Appendix. Finally, this section includes a discussion of the assumptions needed for the identification of the DiD-matching estimator and argues that each assumption is satisfied.

4.6.1 DiD-matching Estimator

The DiD-matching methodology, a method combining difference-in-differences and matching strategy, overcomes some violations of the unconfoundedness assumption (selection bias) by eliminating time-invariant heterogeneity. Using the Chabé-Ferret and Subervie (2013) nomenclature, there are three main assumptions of the DiD-matching estimator which need to be satisfied to ensure identification: (1) the Stable Unit Treatment Value Assumption (SUTVA); (2) the conditional parallel trends assumption; and (3) the common support assumption. This subsection first discusses these identification assumptions in detail, and, where applicable, the results for each robustness check. Then, I present the estimator used for the main empirical analysis.

4.6.1.1 Assumption 1: Stable Unit Treatment Value Assumption (SUTVA)

The Stable Unit Treatment Value Assumption (SUTVA), or the "no interference" assumption (Rubin 1978; Imbens and Wooldridge 2009), requires that the assignment of individual i into the treatment group not affect the potential outcomes for individual j ($Y_j(T_i, T_j) = Y_j(T_j)$). In other words, if a patent is further validated through the reexamination process, the follow-on innovation related to another patent is unaffected. Generally speaking, the area covered by a patent is narrow and limited relative to the entire inventive space. However, in analyzing the applicability of this assumption one should consider two cases, each with a different relationship between an arbitrary pair of patents. First, consider the case in which the patents are in two technology areas distant from each other (e.g. telecommunications versus pharmaceuticals, etc.). It is unlikely that the confirmation of validity would have any bearing on the follow-on innovation of another patent in a different technology. Second, consider the case of two patents that are in close technological proximity. This case could result in a violation of the SUTVA, but Section C.2 in the Appendix provides further discussion of this case and argues that this assumption should generally hold.

4.6.1.2 Assumption 2: Conditional Parallel Trends

The second assumption for DiD-matching requires conditional parallel trends over time (absent treatment), or $\mathbf{E}[Y_{it'}(1) - Y_{it}(1)|X] = \mathbf{E}[Y_{it'}(0) - Y_{it}(0)|X]$, where i refers to an individual patent, t to an arbitrary pre-treatment time period. This expression implies that the pre-treatment differences in follow-on patenting from period-to-period, conditional on X, are equivalent for both groups. In other words, in the absence of treatment, the trends for both groups should be parallel. This assumption is crucial for the application of both difference-in-differences and the DiD-matching estimator and can be shown graphically. Figure 4.4 demonstrates the quality of matched pairs for the overall logged annual forward citations. Trend graphs for external (rival) and internal (assignee) logged annual forward citations are shown in the Appendix. The treated and matched non-reexamined patents display similar reexamination trends for logged forward citations, logged internal citations, and logged external forward citations. I further demonstrate the strength of the matching process by regressing the binary treatment group assignment on pre-reexamination characteristics for the matched sample (Calel and Dechezleprêtre 2016). The coefficients on the pre-treatment characteristics are not statistically significant, indicating that conditional on pre-reexamination characteristics, the assignment seems random (Calel and Dechezleprêtre 2016), as shown in table 4.4.[30] I note that, even if the conditional parallel trends is satisfied, unobserved, time-varying heterogeneity may be a concern. This issue is addressed in Section 4.7.2.

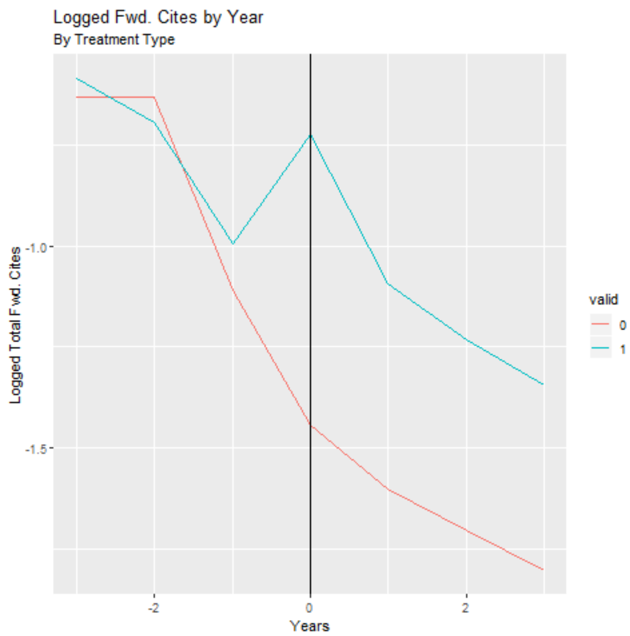


Figure 4.4: Logged Annual Forward Citations - Treatment and Control Groups

4.6.1.3 Assumption 3: Common Support

The final assumption on the DiD-matching estimator is the common support assumption, or $0 < \mathbf{P}[T_i = 1|X_i] < 1$. According to Heckman *et al.* (1997), "A major limitation of nonexperimental methods compared to experimental methods... is that they do not guarantee that the support for the comparison group equals the support

[30]Consistent with Calel and Dechezleprêtre (2016), I ran the Wilcoxon signed-rank test to determine if the distributions for lagged forward citations, pendency, family count, scope, and backwards citations are statistically nonidentical across treatment groups. For each variable, the test failed to reject the null hypothesis of statistically identical distributions.

	Dependent variable:
	Reexamination
Ln Forward Citations (t-1)	0.002
	(0.004)
Pendency	0.00001
	(0.00003)
Small Entity	0.001
	(0.031)
Family Count	−0.00003
	(0.005)
ICC	0.004
	(0.005)
ICL	0.0002
	(0.0001)
Ln Backcites	0.003
	(0.008)
Observations	1,404
R^2	0.002

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regressions include 702 matched patent pairs. The dependent variable is an indicator variable equal to one if the observation was successfully confirmed through reexamination and zero otherwise. Standard errors are presented in parentheses.

Table 4.4: Probability of Treatment

for programme participants." The common support assumption requires that there are no regions in covariate space with only treated or control observations. If such regions exist, the conditional probability of treatment in those regions will equal exactly 1 or 0. This assumption is somewhat trivial for estimating the average treatment effect on the treated (ATT) using patent data and can be satisfied using most matching packages in R.

4.6.1.4 Implementation

The DiD-matching can be implemented in several ways to estimate the average treatment effect on the treated. Early DiD-matching estimators (Heckman, Ichimura, Smith and Todd 1997; Heckman, Ichimura, and Smith 1998) utilized a "regression-adjusted semiparametric difference-in-differences matching estimator" while Abadie (2005) introduced an alternative framework using a two-step procedure, accounting for "dynamics of the outcome variable [that] are unbalanced between the treated and the untreated." A number of estimators use semi-parametric or non-parametric methods to estimate the ATT. Additionally, some studies have implemented the DiD-matching procedure using parametric means, specifically by running ordinary least squares on the matched sample of treatment and control observations (Toole and Czarnitzki 2010; Biasi and Moser 2018).Essentially, the empirical strategy in this paper leverages a matching algorithm to improve the pre-treatment balance between the distribution of covariates for the treatment and control group. According to Ho *et al.* (2007), "The immediate goal of matching is to improve *balance*, the degree to which the treatment and control covariate distributions resemble each other ..., without losing too many observations in the process." The authors argue that, after matching, parametric analysis should proceed using "the same parametric analysis on the preprocessed data as would have been used to analyze the original raw data set without preprocessing." Additionally, Imbens and Wooldridge (2009) states, "Given a more balanced sample, one can use any of the previously discussed methods for estimating the average effect of the treatment, including regression, propensity score methods, or matching. Using those methods on the balanced sample is likely to reduce bias relative to using the simple difference in averages by treatment status."

In this paper, the sample of patents is reduced to only the reexamined and matched patent pairs by the algorithm discussed in the Appendix (without significant loss of observations). The patent-level fixed effects included in the DiD-matching framework controls for time-invariant unobserved heterogeneity including underlying patent quality, firm fixed effects, patent examiner effects, and any other time-invariant characteristic that may be correlated with selection into reexamination. Specifically, the fixed-effects model can be written as:

$$Y_{it} = \lambda_t + \tau w_{it} + c_i + \varepsilon_{it} \tag{4.1}$$

Where Y_{it} is equal to the logged number of forward citations per period (total, internal, and external) from both patent grants and pre-grant publications (PGPubs) to the focal patent, λ_t represents year fixed effects, w_{it} represents the treatment indicator, and c_i is defined to be the patent-level fixed effect. The estimate of the ATT in this model is defined as $\hat{\tau}$. For this equation, I run both panel DiD-matching and two-period DiD-matching regressions. For the panel DiD-matching regressions, I use logged annual forward citations by citation type as the dependent variables. In the 2-period DiD-matching regressions, the dependent variable is modified from logged annual forward citations to logged count forward citations in each period (three years before and after reexamination) by citation type. The DiD-matching estimator can be interpreted as the mean difference between two sub-components: (1) the mean difference in follow-on patenting for the treated group between post-treatment and pre-treatments years; and (2) the mean difference in follow-on patenting for the control group between post-treatment and pre-treatments years. Under assumptions 1-3, the DiD-matching estimator estimates the ATT for reexamination on follow-on patenting.

4.6.2 Similarity Regressions

While the follow-on patenting regressions above show how the patenting rate changes in response to validation, the regression results provide no evidence on what might be driving this change. To investigate this question, I turn to an analysis of the technological similarity between the focal patent and each of its follow-on patents. Kuhn and Younge (2016) provides a methodology on how to calculate the technology similarity of two patent documents by measuring the TF-IDF Cosine Similarity of the patent text for each patent pair. Kuhn, Younge, and Marco (2018) analyzes the degree of technological similarity between patents and their citations. In these papers, the degree of similarity is increasing in the technological similarity measure. Using the data provided by one of the authors,[31] one can test how validation affects the relative positioning in technology space of forward citations to the focal patent:

[31] http://www.jeffreymkuhn.com/index.php/data

$$TS_{ip} = \tau w_{ip} + X_{ip}\gamma + c_i + \varepsilon_{ip} \tag{4.2}$$

Where the unit of observation is each forward citation to the matched set of patents. TS_{ip} is equal to the pairwise similarity between the focal patent and its forward citations, were i denotes the focal patent and p denotes the citing patent. w_{ip} represents the treatment indicator where w_{ip} is equal to one if the citing patent was filed after the reexamination date and zero otherwise; c_i is defined to be the a fixed effect for the focal patent; and X_{ip} are the set of controls, including technology and year fixed effects for the follow-on patents. This regression is not meant to be causal but to provide further evidence of how firms react to changes in validity. If the coefficient on $\hat{\tau}$ is positive, then firms are patenting closer to the focal patent in technology space. For rivals, this may be indicative of strategic patenting by patenting defensively or by generating a set of patents as bargaining chits. If the coefficient on $\hat{\tau}$ is negative, it may be indicative that the rival is attempting to invent around the focal patenting or is shifting their patenting efforts elsewhere. I run this regression for each type of forward citation: total, internal, and external.

4.7 Results

4.7.1 Baseline Results

The baseline DiD-Matching results (described in section 4.6) are shown in Table 4.5.[32] For the panel model, the results show a positive and significant validation

[32] Abadie and Spiess (2019) examines ”valid inference in linear regression after nearest-neighbor matching without replacement” (Abadie and Spiess 2019). Proposition 4 in Abadie and Spiess (2019) states that post-matching OLS standard errors are valid under the assumption that the post-matching regression is correctly specified (which is a fairly strong assumption) and the observations are matched without replacement. Proposition 5 in Abadie and Spiess (2019) shows that if the standard errors are clustered by matches and under assumptions 1-5 in the paper, then the post-matching clustered standard errors are valid. These standard errors are also robust to misspecification. The main results in this paper use standard errors clustered at the patent level in Table 4.5. As a robustness check, the standard errors were clustered at the match level, show in Table C.14 of the Appendix. The results in Table C.14 show that the significant of the treatment effects are similar. Interestingly, the treatment effect in the internal follow-on patenting regression becomes significant, which is consistent with the panel model. However, once litigated patents are removed from the sample, the results are insignificant and robust to the type of standard error (Table C.15).

effect on follow-on patenting, using the log of annual follow-on patents by type.[33] This pattern persists for overall, internal, and external follow-on patenting. The magnitude of the treatment effect is larger for total (0.505) compared to self (0.134) or external citations (0.454). The positive and significant relationship persists in the two-period DiD-matching regressions for total and external citations, but not self-citations. The coefficient on the treatment indicator requires a transformation before interpretation ($\hat{\tau}_{ATT} \approx 100 * [e^{\beta} - 1]$) because the dependent variable is measured in logs and the DiD variable is a dummy variable. Therefore, following reexamination, the confirmation of validity through reexamination increased total follow-on patenting by 65.70 percent. Furthermore, the reexamination process leads to follow-on patenting increases of 14.34 percent for self-citations and 57.46 percent for external citations. In regards to the direction of the overall effect on external follow-on patenting, the increase in external citations post-reexamination indicates that the strategic patenting effect dominates the reduction in innovative activity.

This relationship is tested further in Table 4.6. The coefficient on *Post*Valid* indicates that, post-reexamination, external citations are closer in technology space to the reexamined focal patents relative to the non-reexamined focal patent and their respective external follow-on citations. These results indicate that rivals are patenting closer to the focal patent to pursue a defensive strategy following validation. An alternative explanation is that rival firms could have pursued licensing agreements and the increase in technological similarity stems from freedom to operate in the technological space. However, consistent with Cockburn *et al.* (2010) and the resulting cost increases due to licensing, follow-on patenting should decrease for those firms that have to in-license their products. For incumbents, the results are mixed. The estimated treatment effect on internal patent citations in the panel DiD-matching setting is positive and significant, indicating that the increase in the probability of validity should increase follow-on patenting by the the assignee. However, in the simple 2-period DiD-matching regression, the treatment

[33]The dependent variable in this case is Ln(Cites + 0.01) to allow for instances of zero follow-on citations in a particular period. The results are robust to alternate minimum values (*e.g.*, Ln(Cites + 0.0001).

effect is insignificant, demonstrating that the overall treatment effect for validation on external citations is not robust.

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.505***	0.134**	0.454***	0.397***	0.250	0.416***
	(0.110)	(0.068)	(0.111)	(0.140)	(0.156)	(0.147)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	9,828	9,828	9,828	2,808	2,808	2,808
R^2	0.028	0.018	0.027	0.006	0.025	0.006

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols. 1 through 3 include an annual panel dataset of the 702 matched patent pairs. For cols. 1 through 3, the sample size includes seven years of observations for each patent (1404 focal patents - 702 matched pairs). Regression results shown in cols. 4 through 6 include a 2-period panel dataset of the 702 matched patent pairs (citations three years before and three years after reexamination). For cols. 4 through 6, the sample size includes 2 periods of observation (three years before and after) for each patent (1404 focal patents - 702 matched pairs). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table 4.5: Matching-DiD Results - All Patents

The estimated treatment effects for total and external follow-on citations indicate that the main result in both Galasso and Schankerman (2015a) and Gaessler *et al.* (2017) may have been *underestimated*.[34] If the validation effect is similar between the courts and the reexamination process, "validated" patents may also experience an increase in the number of forward citations post-decision relative to a non-litigated patent. Therefore, the invalidity effect should be larger when comparing the relationship between the follow-on activity of an invalidated patent to a non-litigated patent rather than the relationship between the follow-on activity of an

[34]This assumes that validation effect would be consistent in direction and significance across venues (CAFC, CRU, and EPO oppositions). The current version of this chapter does not re-estimate the invalidation results of Galasso and Schankerman (2015a) and Gaessler *et al.* (2017). Given my data, this approach is feasible and will be undertaken. Without re-estimating the invalidation effect, the results estimated in this chapter cannot be directly compared to the earlier works. Thank you to my Ph.D. Viva examiners for identifying this inconsistency.

invalidated patent and a "validated" patent.

	Dependent variable:		
	Total	Internal	External
	(1)	(2)	(3)
Post*Valid	0.008***	0.005	0.005*
	(0.003)	(0.013)	(0.003)
Post	−0.002	0.018	−0.003
	(0.003)	(0.013)	(0.003)
Observations	72,613	4,922	67,691
R^2	0.026	0.070	0.020
Note:	*p<0.1; **p<0.05; ***p<0.01		

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols. 1 through 3 were run on the set of all (1), internal (2), and external (3) citations to the treated and control group patents. The sample size in this table reflects the total (col. 1), internal (col. 2), and external (col.3) forward citations to each of the focal patents. The unit of observation reflects the pairwise citation relationship between the focal patent and a subsequent forward citation. Regressions include patent, grant year, and technology fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table 4.6: Technology Similarity Regressions

Finally, I examine the potentially different relationships between validation and technology type (complex versus discrete). Tables 4.7 and 4.8 show the regression results from running equation 4.1 on subsets of individual NBER technology classes - Electrical and Electronics (complex) compared to Drugs and Medical (discrete).[35] In table 4.7, the results show that the validation effect in complex technologies is consistent with the overall effect for total and external citations. The magnitude of the overall and rival's response is larger in the Electrical and Electronics technology relative to the full sample regression estimates.

Interestingly, the effect is also significant for internal citations as well across both regression types (panel and 2-period DiD-matching). This result indicates that,

[35] The technology type designations for each NBER class were taken from Galasso and Schankerman (2015a).

within complex technologies, an increase in the probability of validity leads to more follow-on patenting. I cannot determine whether this increase in follow-on patenting is due to an increase in strategic patenting behavior or increased innovative activity resulting from lower expected costs of such activities. However, these results illustrate that the relative increase dominates the potential decrease in follow-on patenting due to lower expected competition. The effect in discrete technologies (Table 4.8 - Drugs and Medical) is statistically insignificant for all types. These results together are consistent with the discussion above, suggesting that the validation effect should be stronger in complex technologies relative to discrete technologies. Similar to the baseline results above, I find that Galasso and Schankerman (2015a) may underestimate the invalidation effect in complex technologies. Both the results in Galasso and Schankerman (2015a) and in this paper find no effect in discrete technologies.

The results in this section are not necessarily generalizable because the matched sample is not representative of the patent corpus as a whole, but they demonstrate the validation effect for patents with similar characteristics as the matched set (*e.g.*, valuable patents). I discuss this limitation further in the conclusion.

4.7.2 Robustness Checks

I perform a number of robustness checks to accompany the main results. As mentioned in Section 4.6.1, the DiD-matching estimator controls for time-invariant unobserved heterogeneity, but assumes the absence of meaningful *time-varying* unobserved heterogeneity. A potential source of time-varying unobserved heterogeneity in this setting is patent litigation. In some instances, reexamined patents may be utilized in patent litigation, either concurrently with the reexamination process or at another period in time. To establish that the results in this paper are not driven by the time-varying effects of litigation, I drop litigated patents from the sample and re-run each regression described in Section 4.7.1 on this subset. The results, shown in the Appendix, are consistent with the main results with some minor exceptions. The treatment effect for the panel DiD-matching regression on internal citations be-

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.976***	0.461**	0.787**	0.889**	0.882*	0.863**
	(0.331)	(0.203)	(0.338)	(0.404)	(0.475)	(0.405)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	1,232	1,232	1,232	352	352	352
R^2	0.065	0.041	0.070	0.034	0.061	0.034

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols. 1 through 3 include a subset of the main sample. Regression results shown in cols. 4 through 6 include a subset of the 2-period sample (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those patents in the NBER Electrical and Electronics classification. The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table 4.7: Matching-DiD Results - NBER: Electrical and Electronics

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.347	−0.196	0.327	0.155	0.117	0.133
	(0.235)	(0.159)	(0.239)	(0.262)	(0.371)	(0.278)
Obs.	2,002	2,002	2,002	572	572	572
R^2	0.021	0.029	0.020	0.001	0.020	0.003

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols. 1 through 3 include a subset of the main sample. Regression results shown in cols. 4 through 6 include a subset of the 2-period sample (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those patents in the NBER Drugs and Medical classification. The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table 4.8: Matching-DiD Results - NBER: Drugs and Medical

comes insignificant, providing further evidence that the estimated validity effects related to internal citations are not robust.[36] However, the treatment effect is still positive and significant for internal citations within complex technologies, as shown in Table C.7.

Second, the set of reexamined patents is restricted to only those with one reexamination proceeding. Nineteen of the original 702 reexamined patents had been reexamined more than once and each reexamination had confirmed the validity of the patents. In the main results, it was assumed that only the original reexamination would have a significant effect on the perception of validity. To check the robustness of the main result, these patents (and their respective matched pair) were dropped from the sample. The DiD-matching coefficients are shown in Table C.1 in the Appendix. The results for the logged total, self, and external forward citations are consistent with the corresponding coefficient in the main results.

Finally, the magnitude and significance of the treatment effect may differ based on the length of time between initial patent issuance and the confirmation decision. In general, unlike at the EPO where patents are eligible for opposition proceedings for nine months post-issuance, reexamined patents in the U.S. are not re-prosecuted at a consistent point in a patent's life-cycle. Therefore, the sample is split into two groups based on the timing of the reexamination in relation to the issuance year - lag ≤ 10 or lag > 10. Table C.4 displays the results for the lag ≤ 10 group. The treatment effect is positive and significant across citation and regression type for those patents that were reexamined up to ten years after grant but is insignificant for those with patents that were reexamined more than ten years after grant (not shown).

4.7.3 Alternative Matching Strategies

As a final robustness check, I re-estimate each model using logged cumulative forward citations instead of annual logged forward citations. First, I re-run the matching algorithm using pre-treatment logged cumulative forward citations as one of the

[36] Though the results using non-litigated patents are robust to the type of standard error, *e.g.*, robust standard errors clustered by patent or the Abadie and Spiess (2019) standard errors.

matching covariates. Trivially, assumptions one and three still hold but the conditional parallel trends assumption was retested for each response type (overall, internal, external), as shown in Figures C.3 to C.5. For each citation type, the conditional pre-trends appear parallel. Additionally, I run a linear probability model, regressing the treatment indicator on the set of covariates used for matching. The results are similar to those in Table 4.4 in that all matching covariates are insignificant, indicating a good match. Overall, the regression results using logged cumulative forward citations are similar in sign but not magnitude to the main results, as shown in Table C.10. I find reexamination increases overall follow-on patenting by 3.35 percent, external follow-on patenting by 3.87 percent, and internal follow-on patenting by 5.76 percent.

4.8 Conclusion

This paper, using a DiD-matching estimator on 702 matched patent pairs, estimates the effects of validation by *ex parte* reexamination on follow-on patenting. I find that confirmation of validity through reexamination increased total follow-on patenting by 65.70 percent and 57.46 percent for external citations. The validation effect differs in magnitude and significance by assignees and rivals but also across technology type. Overall, the validation effect is positive and significant for total and external follow-on patenting both overall and in complex technology areas, but insignificant in discrete technology areas. The results on citations by assignees are mixed. The significance of the overall treatment effect for internal citations is dependent on the type of standard errors used in the regression but consistently insignificant when the sample was limited to non-litigated patents. To better understand these results, I propose and discuss the channels through which validation alters patenting behavior of firms and how the effect depends on the underlying characteristics of the technology area. This analysis is supplemented by technology similarity regressions, which provide further evidence that the validation effect induces increased defensive patenting for rivals.

This work also adds to the literature on the evaluation of post-grant correction procedures at patent offices worldwide. Harhoff *et al.* (2016) argues that the EPO's post-grant review process may be susceptible to the public goods problem and strategic behavior within patent thickets and therefore may not be an effective way to correct or invalidate erroneously-granted patents. In this paper, the increase in defensive patenting by rivals after validation demonstrates the unintended consequences of post-issue review procedures. It is my hope that my work will spur future research into the relative efficiency trade-offs between higher quality initial patent examination and removing "bad" patents *ex post* through post-issue review procedures.

Finally, the two main limitations of this paper are the generalizability of the results to the entire patent corpus and the possibility of unknown time-varying unobserved differences between the treatment and control groups. As shown in Section 4.5, the characteristics of "validated" patents do not reflect those of the patent corpus as a whole (entity size, family size, scope, citations, pendency, etc.). In fact, there is a statistically significant difference in means between validated and non-reexamined patents in regards to each of the variables used in the matching procedure. The sample used in this paper may only capture the validation effect for *certain* patents and not the entire patent corpus. Gaessler *et al.* (2017) discusses this issue with respect to the differences in results between Gaessler *et al.* (2017) and Galasso and Schankerman (2015a). The authors identify the weaknesses of using such a limited sample, indicating the difference in results may stem from the difference in sample composition. In this paper, the matching procedure improved the balance between the two groups, but the underlying characteristics of the matched control group no longer corresponded to those of the non-reexamined patents. Future work could test whether these results apply to the entire patent corpus. Finally, concerning time-varying unobserved differences between the treatment and control groups, I tested the robustness of my results against a main potential source of time-varying unobserved differences, patent litigation. However, as in much of the matching and DiD-matching literature, I cannot rule out the influence of idiosyncratic shocks on my results, which is an issue not only for the DiD-matching regressions but certainly for the technological similarity regressions. Shocks to technological demand of focal patents could bias both sets of results in terms of citations counts but also technological space positioning (technological similarity regressions).

4.9 Chapter Acknowledgements

I would like to thank the USPTO's Office of Chief Economist for parsed patent application text and claim-based measures. I would also like to thank thank Jesse Frumkin, James Forman, Andrew Toole, Richard Miller, Amanda Myers, Juan Pablo Rud, Maris Goldmanis, Mike Teodorescu, Joshua Sarnoff, and Alan Marco for valuable feedback. Charles deGrazia would also like to thank his Ph.D. Viva examiners, Benjamin Balsmeier and Georg von Graevenitz, for their helpful comments.

Appendix A

Patent Claims and Patent Scope

A.1 Validation Results

In this section, we first describe existing measures of patent scope and the corresponding methods used to validate these measures. We then discuss how our measures improve upon the existing scope variables and describe our variant of the validation methodology. Finally, we present our validation results, finding that our measures are consistent with other validation tests of patent scope in the literature. Lerner (1994), one of the first empirical papers to introduce a measure of patent scope, proposed the number of 4-digit IPCs to which a patent was assigned as a measure of patent scope. The study found that an increase in the number of 4-digit

VARIABLES	(1) Maintenance	(2) Maintenance	(3) Maintenance	(4) Maintenance
ICL at Grant	-0.0219***		-0.0162***	-0.0171***
	(0.00263)		(0.00205)	(0.000430)
ICC at Grant		0.0127***	0.0114***	0.0137***
		(0.000569)	(0.000518)	(0.000177)
DCC per ICC at Grant				0.00393***
				(7.70e-05)
Constant	0.518***	0.449***	0.478***	0.453***
	(0.00491)	(0.00392)	(0.00445)	(0.00183)
Observations	1,447,917	1,448,014	1,447,917	1,447,917
R-squared	0.017	0.019	0.020	0.022
Number of uspc_group	425	425	425	425
Years	1994-2004	1994-2004	1994-2004	1994-2004

Robust standard errors in parentheses. The OLS models above include disposal year and USPC fixed effects. *** p<0.001, ** p<0.01, * p<0.05

Table A.1: Validation Results

VARIABLES	(1) Forward Citations	(2) Forward Citations	(3) Forward Citations	(4) Forward Citations	(5) Number of CPCs	(6) Number of CPCs	(7) Number of CPCs	(8) Number of CPCs
ICL at Grant	-0.0736***		-0.0427***	-0.0435***	-0.0214***		-0.0187***	-0.0195***
	(0.0121)		(0.0112)	(0.00125)	(0.00191)		(0.00185)	(0.000348)
ICC at Grant		0.0425***	0.0412***	0.0432***		0.00818***	0.00652***	0.00946***
		(0.00284)	(0.00278)	(0.000232)		(0.000539)	(0.000540)	(0.000160)
DCC per ICC at Grant				0.00707***				0.00438***
				(4.80e-05)				(5.44e-05)
Observations	2,068,087	2,068,177	2,068,087	2,068,087	5,192,070	5,192,238	5,192,070	5,192,070
Number of USPCs	416	416	416	416	494	494	494	494
Model Type	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Years	2000-2011	2000-2011	2000-2011	2000-2011	1976-2014	1976-2014	1976-2014	1976-2014

Robust standard errors in parentheses. The Poisson models above include disposal year and USPC fixed effects. *** p<0.001, ** p<0.01, * p<0.05

Table A.2: Validation Results (continued)

IPCs assigned to a patent reflects an increasing number of distinct technologies incorporated into the invention, which can be interpreted as increasing broadness of a given patent. Lerner (1994) used a Poisson regression to estimate the relationship between the count of forward citations for a given patent and the number of IPCs. He also controlled for the time since grant, to account for varying exposure time among patents in his sample of biotechnology firms. His results show a positive correlation. Recent work by Novelli (2015) examines patent scope as measured by both the number of technological classes and the total number of claims per patent. She argues that these two measures reflect two dimensions of patent scope and that a firm's subsequent inventive activity differs in reaction to movements along each dimension. Novelli (2015) finds that firms are less likely to cite their own patents in future inventive activity as the number of technological classes for the original patents increase. She does, however, confirm Lerner's original finding that the number of technological classes per patent is positively related to the number of total forward citations a patent receives.

Most of the previous scope metrics, including those shown in Tables A.1 and A.2, are observed at or after the time of patent issuance (maintenance and forward citations). The change in the number of technological classes can be observed at PGPub and grant. However, the classification processes are quite different at filing and at grant. As described in Section 2, the initial classification is done primarily for the purpose of routing the application to the correct art unit for examination. In contrast, more care is taken in classifying a granted patent to ensure that classes are included for the purposes of prior art search by other examiners. We do note, however, that our validation results in Tables A.1 and A.2 are generally consistent with Novelli (2015) and prior studies. We prefer to use the number of independent claims, because from a technical point of view, the addition of another dependent claim does not change the scope of the independent claim on which it depends, but rather only adds additional complexity as a subset of the embodiments of the independent claim. That said, Table 2.2 shows that there is a high correlation between the number of independent claims and the number of dependent claims, as well as the number of total claims.

We extend Lerner's analysis to include maintenance rates and forward citations (following van Zeebroeck, 2011). Further, we include the number of CPCs as a substitute for the older IPC classifications. Our dependent variables include two count variables and one binary indicator, which are defined as follows:

- *Fully maintained.* A binary indicator of whether the patent was maintained to its maximum statutory term (paying the requisite fees at 3.5, 7.5, and 11.5 years after grant).

- *Forward citations from U.S. New Applications.* A count of the number of U.S new application (or patent) citations[1] received by the patent within three years of the issue date.

- *Number of subclasses.* A count of the number of unique CPC subclasses (4-digit) assigned to the patent.

We expect each indicator to be positively correlated with patent scope, along the lines of Lerner's argument and the findings in van Zeebroeck (2011). Forward citations have long been used by economists as a correlate of patent value and scope (van Zeebroeck, 2011). Patent maintenance is closely related to patent value, and

[1]We use forward citations from U.S. new applications (i.e. applications without foreign priority nor a parent application) to eliminate noise caused by cross-citations within a patent family (Kuhn 2011; Kuhn, Younge, and Marco 2018).

thus indirectly to patent scope. According to Bessen (2008), "[t]he implicit value of a patent is revealed when its owner pays a renewal fee, implying that the patent is worth more than the fee required to keep it in force." Broader patents, *ceteris paribus*, have wider applicability than a narrower patent representing similar underlying technologies, and should therefore be more valuable.

We expect ICL and ICC to be negatively and positively correlated, respectively, to our patent scope indicators. To confirm this hypothesis, we run Poisson regressions with *forward citations from U.S. new applications* and the *number of subclasses* as dependent variables, and a linear probability model (ordinary least squares) for the *fully maintained* indicator. Tables A.1 and A.2 in the Appendix present the results of the regressions.

For each of the three dependent variables we estimate four models based on the explanatory variables: ICL, ICC, ICL and ICC together, and ICL, ICC, and the number of dependent claims per independent claim. We also include year fixed effects and US Patent Classification fixed effects, to control for differences in claim length and citation behavior by applicants between classes and across years. Our expectation is that ICL will have a negative coefficient and ICC will have a positive coefficient, corresponding to a positive correlation between scope and the dependent variables.

For ICC, all coefficients are positive and statistically significant at the 1 percent significance level for all specifications. For ICL all coefficients are negative and statistically significant at the 0.1 percent significance level. The robustness of the results across specifications implies that ICL and ICC are useful measures of patent scope. Because the models that include both measures tend to have the expected signs suggests that ICC and ICL may represent different aspects of patent scope.[2]

As further evidence that ICL and ICC represent patent scope, we rely on results from Marco et al (2015b). There, the authors find that patent scope—as measured

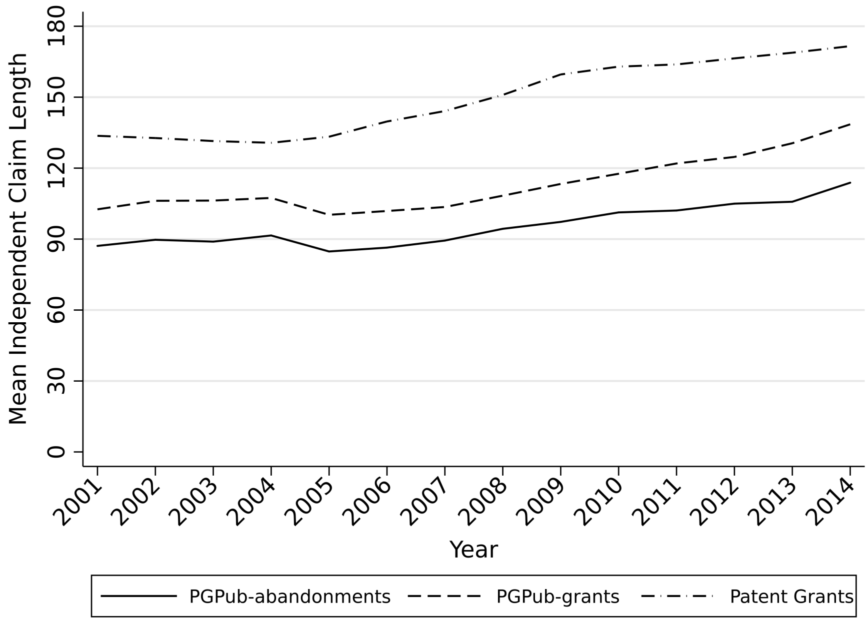
[2]Independent claims may take different forms, such as claiming methods and claiming systems, both directed to the same underlying creative advance. Comparison of scope across such different forms of embodiments may be difficult (and have significant implications for proof of infringement (directly and indirectly, such as with multiple actors). These different forms may therefore reflect one of many of the different aspects of claim scope at issue.

by average independent claim length and independent claim count—is correlated with the incidence of patent litigation. Lanjouw and Schankerman (2001) explain why patent breadth should be positively correlated with litigation. Thus, the result provides more evidence that ICL and ICC are indicators of patent scope.

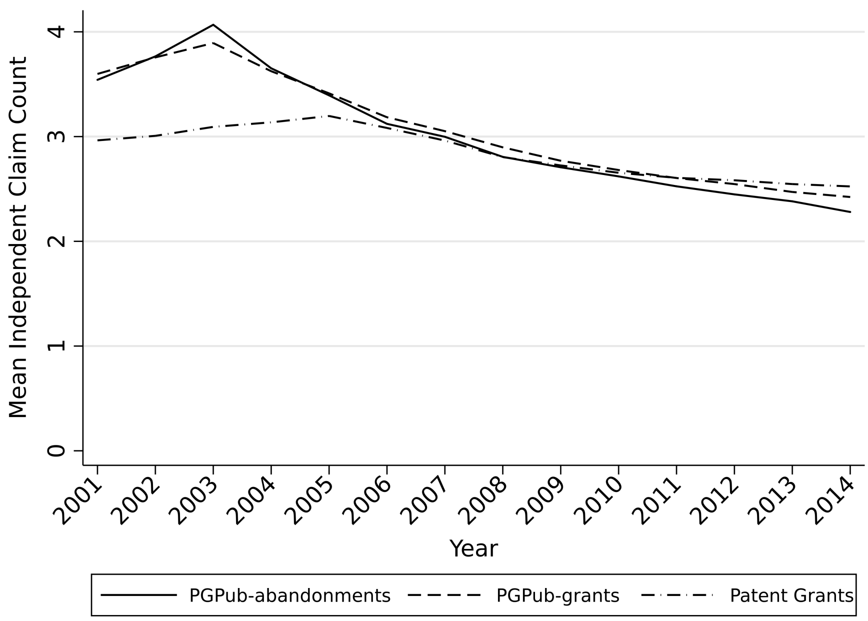
A.2 Additional Trend Analysis

Similar to the *disposition cohorts* described in section 2.5, we created *contemporaneous cohorts*, based on the actual publication date of the document: publication dates for PGPubs and issue dates for patent grants. These "contemporaneous comparisons" provide an indication of how both application and patent claims are changing in a particular year, which may be more helpful in identifying the timing of behavioral changes. The contemporaneous cohort analysis is presented in Figure A.1.

The contemporaneous cohorts in Figure A.1(a) show that ICL for PGPubs is trending upwards since 2005. Thus, it appears that the trend towards higher ICL began with patents, and then began to be reflected in newly arriving applications (as measured by PGPubs in the contemporaneous comparison). Additionally, as shown in Figure 2.4(b) in the main text, there is some convergence in the mean ICC between patent grants and PGPub-grants; the mean change in ICC during prosecution has gone from -0.7 in 2001 to -0.2 in 2014. However, Figure A.1(b) shows that the ICC for PGPubs catches up to the ICC for patents for the contemporaneous comparison. Granted patents have a higher ICL as measured by the disposition cohorts (Figure 2.3(a)) and the contemporaneous cohorts (Figure A.1(a)). Figure 2.3(b) also shows that patents have a smaller ICC than PGPubs; however, that difference has been getting smaller over the last decade as measured by the disposition cohort. The difference virtually disappears at the mean when measured by the contemporaneous comparison in Figure A.1(b), which is driven by a strong decrease in the number of independent claims for new applications.



(a) Independent Claim Length



(b) Independent Claim Count

Figure A.1: Contemporaneous Comparison - Mean (a) Independent Claim Length and (b) Independent Claim Count by Application (2001-2014)

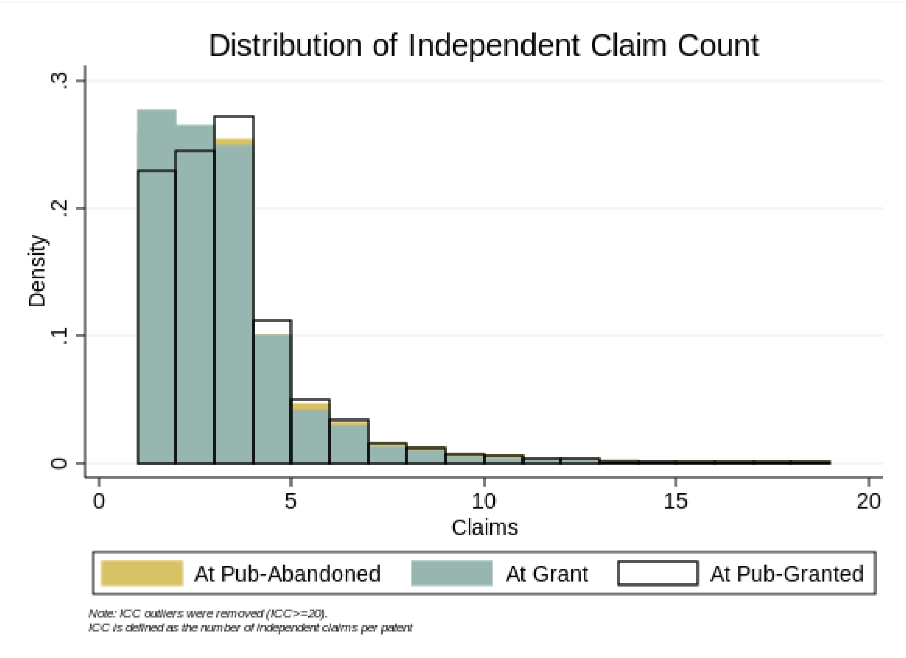


Figure A.2: Distribution of Independent Claim Count (2001-2014)

A.3 Alternative Figures

Finally, Figure A.2 represents the histogram version of Figure 2.1(b). The analysis of this histogram is consistent with the discussion of Figure 2.1(b) in the main text of this thesis.

Appendix B

Debunking the Myth of the Rubber Stamp Patent: Impact of Examiner's Amendment on Patent Office Outcomes and the Innovation Ecosystem

B.1 Additional Examples of Examiner's Amendments

The first example, beyond the examples given in the text, is one of the smallest similarity values, 0.07. Application number 14/120,777 received a first-action allowance on July 14th, 2016, and an examiner's amendment on June 24th, 2016. The section of the notice of allowance document containing the examiner's amendment is shown in figures B.1 and B.2.[1] From the examiner's amendment in the notice of allowance, all claims were cancelled and one new claim was added. Further, this claim adds elements of a dependent claim to the first independent claim. According to Marco *et al.* (2016), the act of "rolling up" elements of a dependent claim into

[1]The examiner's amendment is split into two figures since the amendment occurred on more than one page in the notice of allowance document.

an independent claim during patent prosecution is common practice. Applicants will submit broad independent claims and narrower dependent claims. After an initial rejection by the examiner, applicants "may roll up at least one dependent claim limitation into the original independent claim to form a new, longer and narrower independent claim." For example, in the application in figure 3, to overcome a potential rejection, Hexaflumuron from the fourth claim is added to Gluconacetobacter in the first claim, making the claim significantly narrower.

The next example is application 14/172,071 from the median, with similarity value 0.99. The examiner's amendment is contained in figures B.10 and B.11. The word "type" was removed from the first claim. From the MPEP, "the addition of the word 'type' to an otherwise definite expression extends the scope of the expression so as to render it indefinite[2]." This example illustrates that the failure to change a single word in the claims of a patent application can have an important impact on patent quality. In particular, as described in more detail in the footnote, the word "type" was crucial in Ex parte Attig, 7 USPQ 2d 1092 for understanding the boundary of the claimed invention.

[2] `https://www.uspto.gov/web/offices/pac/mpep/s2173.html`. Specifically, the relevant section reads "The addition of the word type to an otherwise definite expression (e.g., Friedel-Crafts catalyst) extends the scope of the expression so as to render it indefinite. Ex parte-Copenhaver, 109 USPQ 118 (Bd. Pat. App. Inter. 1955). Likewise, the phrase ZSM-5-type aluminosilicate zeolites was held to be indefinite because it was unclear what type was intended to convey. The interpretation was made more difficult by the fact that the zeolites defined in the dependent claims were not within the genus of the type of zeolites defined in the independent claim. Ex parte Attig, 7 USPQ 2d 1092 (Bd. Pat. App. Inter. 1986)."

Application/Control Number: 14/120,777 Page 2
Art Unit: 1655

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

EXAMINER'S AMENDMENT

2. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with John Dodds on 6/24/2016.

The application has been amended as follows:

IN THE CLAIMS:

Figure B.1: Examiner's Amendment for Application Number 14/120,777: Page 1

Application/Control Number: 14/120,777 Page 3
Art Unit: 1655

Cancel all claims and allow:

7. (New) A termite killing composition consisting essentially of termite killing amounts of Gluconacetobacter malus and Hexaflumuron.

The following is an examiner's statement of reasons for allowance: The claimed composition is a termite killing composition consisting essentially of termite killing amounts of Gluconacetobacter malus and Hexaflumuron which impart a markedly different characteristic since the combined effect of the components of the composition kills termites and repairs damage to wood and related cellulosic products caused by termites and other wood damaging insects.

Figure B.2: Examiner's Amendment for Application Number 14/120,777: Page 2

Application/Control Number: 13/077,181 Page 2
Art Unit: 2174

Reasons for Allowance

1. An examiner's amendment to the record appears below. This was made as a result of a series of Interviews initiated by the Examiner and followed through by Applicant's Representative to clarify features and bring out additional features and distinctions of the invention in the independent claims, to overcome prior art discovered by the Examiner in the course of examination. Also accordingly, dependent claims 2-3 and 15 are thereby cancelled. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Mr. Mark Wieczorek on 4/18/14.

Please rewrite the claims as follows:

1. (Currently Amended) A method of arranging a browsing session for content items for playback on a content playback device, comprising:
   i. establishing a user account session between a plurality of secondary mobile displays and a server, the secondary mobile displays further in communication with ~~at least one~~ a plurality of common content playback devices, wherein the establishing a session between ~~a~~ the secondary mobile displays and ~~a~~ the server includes downloading an application from the server to each of the plurality of secondary mobile displays, the application configured to display, for each respective secondary mobile display:

Figure B.3: Examiner's Amendment for Application Number 13/077,181: Page 1

Application/Control Number: 13/077,181 Page 3
Art Unit: 2174

1. a first user interface element pertaining to the style of display, including:
    a. text in a first language and character font set associated with a user profile associated with the respective secondary mobile display ~~or with the content playback device or with a default value~~;
    b. a background image associated with a user profile associated with the respective secondary mobile display ~~or with a default value~~; or
    c. a background layout associated with a user profile associated with the respective secondary mobile display ~~or with a default value~~;
2. a second user interface element pertaining to content items or service providers, the second user interface element based on:
    a. a parental block rating level associated with a user profile associated with the respective secondary mobile display ~~or with a default value~~;
    b. a listing of favorite content items or services associated with a user profile associated with the respective secondary mobile display; or
    c. a listing of content items or services in a browsing history associated with a user profile associated with the respective secondary mobile display;

ii. receiving an input from a user of a respective secondary mobile display, the input indicating a user ~~selection of:~~ alteration of the first user interface element;

~~1. a second language, the second language having a corresponding character font set;~~

~~2. a second background image;~~

~~3. a second background layout; or~~

~~4. a second parental block rating level; and~~

iii. changing the user interface of the respective application of the secondary mobile display, or sending a signal to change the user interface of the respective application of the secondary mobile display, according to the user alteration of the first user interface element ~~selection, or, if the selection is not available, then changing the user interface of the application, or sending a signal to change the user interface of the application, according to a default value of the selection, the default value of the~~

Figure B.4: Examiner's Amendment for Application Number 13/077,181: Page 2

Application/Control Number: 13/077,181 Page 4
Art Unit: 2174

~~selection associated with a service provider, the content playback device, the second display, or the server~~;

iv. receiving input from a user of the respective secondary mobile display, the input indicating a user alteration of the second user interface element;

v. changing the user interface of the respective application of the secondary mobile device, or sending a signal to change the user interface of the respective application of the secondary mobile device, according to the user alteration of the second user interface element;

vi. receiving an input from a user of the respective secondary mobile display of the plurality of secondary mobile displays, the input indicating a user selection of a content playback device from the plurality of common content playback devices;

vii. causing a display of a list of content items on the secondary mobile display, wherein the items on the list are generated based on at least the selection of the second user interface element, and at least in part using a device characteristic of the selected common content playback device;

viii. receiving an input from the user of the secondary mobile display of the plurality of secondary mobile displays, the input indicating a user selection of a content item on the list from a service provider; and

ix. causing the selected content item to play back on the selected common content playback device.

~~2.~~ (Cancelled) ~~The method of claim 1, further comprising:~~

~~i. receiving an input from a user, the input indicating a user selection of a content item from a service provider; and~~

ii. ~~causing the content playback device to request the content item from the service provider, wherein the content playback device requests the content item using an authentication credential~~.

Figure B.5: Examiner's Amendment for Application Number 13/077,181: Page 3

Application/Control Number: 13/085,015 Page 2
Art Unit: 1761

DETAILED ACTION

EXAMINER'S AMENDMENT

1. Claims 1, 3-5, and 7-10 are found to be allowable.

2. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Andrew Parfomak on 11/20/2012.

The application has been amended as follows:

Please replace the current set of claims with the following amended set (noting that claims 1, 3-5, and 7-10 remain):

Figure B.6: Examiner's Amendment for Application Number 13/085,015: Page 1

Application/Control Number: 13/085,015 Page 3
Art Unit: 1761

1.(currently amended) An acidic hard surface cleaning compositions comprising:

about 0.05 – 1 %wt. of one or more anionic surfactants;

about 0.05 – 7.5%wt. of a nonionic surfactant constituent which said constituent preferably ~~comprises~~ both about 0.5 – 2.5 %wt. of a first alcohol ethoxylate nonionic surfactant derived from monobranched alkoxylated C_{10}-fatty alcohols and/or C_{11}-fatty alcohols and about 0.05 – 0.5 %wt. of a second alcohol ethoxylate nonionic surfactant~~, preferably a C_{10}-C_{14} linear alcohol ethoxylated surfactant having at least about 8 mols ethoxylation~~;

about 0 – 5%wt. of one or more further surfactants selected from ~~which may include~~ amphoteric or zwitterionic surfactants, but which expressly exclude cationic surfactants;

about 0.01 - 5%wt. of an organic solvent constituent~~, which preferably comprises or consists of a phenyl containing glycol ether solvent~~;

about 0 - 5%wt. of an alkanolamine;

about 2 - 15 %wt. of an acid constituent which comprises ~~, which most preferably comprises, or consists of~~ a ternary acid system comprising each of: sulfamic acid, formic acid and oxalic acid in a respective weight ratio of sulfamic acid:formic acid:oxalic acid of 1-8:1-5:1-3;

optionally one or more further constituents which are directed to improving one or more aesthetic or functional features of the composition, which may be present in a cumulative amount of not in excess of about 10%wt. of the total of the composition of which they form a part,

at least 85%wt. water~~, preferably at least about 90%wt. water~~;

wherein the compositions have a pH of about 2 or less~~, but especially preferably have a pH not in excess of 1,~~ and

further wherein the compositions exhibit good removal of greasy stains and concurrently also exhibit good soapscum removal from hard surfaces.

Figure B.7: Examiner's Amendment for Application Number 13/085,015: Page 2

Application/Control Number: 13/085,015 Page 4
Art Unit: 1761

2.(cancelled)

3.(original) The acidic hard surface cleaning composition according to claim 1, wherein:

the organic solvent constituent comprises a phenyl containing glycol ether solvent.

4.(original) The acidic hard surface cleaning composition according to claim 1, wherein:

the organic solvent constituent consists of a phenyl containing glycol ether solvent.

5.(original) The acidic hard surface cleaning composition according to claim 1, wherein the composition has a pH not in excess of 1.

6.(cancelled)

7.(original) The acidic hard surface cleaning composition according to claim 1, wherein the acid constituent consists of a ternary acid system comprising each of: sulfamic acid, formic acid and oxalic acid in a respective weight ratio of sulfamic acid:formic acid:oxalic acid of 1-8:1-5:1-3.

8.(original) A method of providing a cleaning treatment of a hard surface which method comprises the step of: applying a cleaning effective amount of a composition according to claim 1, and optionally, thereafter wiping the treated hard surface to remove at least a part of the composition from the hard surface.

9.(new) An acidic hard surface cleaning composition according to claim 1, wherein the second alcohol ethoxylate nonionic surfactant is a C10-C14 linear alcohol ethoxylated surfactant having at least about 8 mols ethoxylation.

Figure B.8: Examiner's Amendment for Application Number 13/085,015: Page 3

Application/Control Number: 13/085,015 Page 5
Art Unit: 1761

10.(new) An acidic hard surface cleaning composition according to claim 1, which comprises at least 90%wt. water.

Figure B.9: Examiner's Amendment for Application Number 13/085,015: Page 4

Application/Control Number: 14/172,071 Page 2
Art Unit: 3655

DETAILED ACTION

The following is a first action on the merits of application serial no. 14/172071 filed on 2/4/2014.

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Information Disclosure Statement

The information disclosure statement filed 2/4/14 has been considered.

Allowable Subject Matter

Claims 1-3 are allowed.

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

-In claim 1, all the characters "KO" have been enclosed in parenthesis objectable via MPEP 608.01(m)

-In claim 1, line 3, the word "type" has been deleted via MPEP 2173.05(b)(E), the addition of the word "type" to an otherwise definite expression extends the scope of the expression so as to render it indefinite.

Figure B.10: Examiner's Amendment for Application Number 14/172,071: Page 1

Application/Control Number: 14/172,071 Page 3
Art Unit: 3655

-In the abstract, line 1, "Embodiments of " has been deleted as pertaining to an implied phrase objectable via MPEP 608.01(b).

The following is an examiner's statement of reasons for allowance: The prior art of record does not disclose or render obvious a motivation to provide for:

- A control apparatus for a hybrid vehicle provided with an engine, an electric motor, a clutch disposed in a power transmitting path between the engine and the electric motor and a step variable transmission disposed in a power transmitting path between the motor and drive wheels, wherein the apparatus has a processor and a memory storing a computer readable and executable instruction set which is executed by the processor to increase an operating speed of the engine in a slipping state of the clutch to complete a start of the engine when an operating state of the clutch is changed from the slipping state into a fully engaged state; when the engine is started while the transmission is selected to perform a shift down action, the apparatus holds a hydraulic pressure of a releasing side clutch of the transmission at a predetermined lowest stand by value to prevent a slipping action of the releasing side clutch while the clutch is in the slipping state when the engine is started while the transmission is selected to perform the shift down action and when the engine is started while the transmission is selected to perform the shift down action, reduce the hydraulic pressure of the releasing side clutch from the predetermined lowest stand by value at which the hydraulic pressure is held in the slipping state of the clutch, after the clutch has been placed in the fully engaged state and in combination with the limitations as written in claim 1.

Figure B.11: Examiner's Amendment for Application Number 14/172,071: Page 2

B.2 Dataset Construction

Variable	Description	Source
FA_allow	Binary indicator for patent allowance. 1 = FAOM grant, 0 otherwise.	PatEx - transactions
RS_allow	Binary indicator for patent allowance without examiner amendment. 1 = FAOM grant without examiner amendment, 0 otherwise.	PatEx - transactions
Appl. ID	Patent Application number	PatEx - application_data
USPC	USPC classification.	PatEx - application_data
Bal. Sample.	Binary indicator for "balanced sample". 1 = Examiner observed from GS	FOIA Request Needed
ΔICC	The change in the number of independent claims from PGPub to grant, calculated by a simple difference.	Patent Claims Research Dataset
ΔICL	The change in the number of words in the shortest independent claim from PGPub to grant, calculated by a simple difference.	Patent Claims Research Dataset
Ex.a	Binary indicator for an examiner's amendment prior to or including the FAOM decision.	PatEx - Transactions
Exper	Examiner experience in months.	FOIA Request Needed
Exper. Bands	Examiner experience, grouped into 6 month bands.	FOIA Request Needed
Grade	Categorical variable for GS-level of the examiner at First-action on the Merit (FAOM) decision.	FOIA Request Needed
ICC	Independent Claim Count or the number of independent claims at PGPub.	Patent Claims Research Dataset
ICL	Independent Claim Length or the number of words in the shortest independent claim at PGPub.	Patent Claims Research Dataset
Parent	Categorical variable listing the parent type of an application.	PatEx - application_data
Tech. Year	Technology Center by year fixed effects.	PatEx - application_data
Three Year	Binary indicator for promotion path. 1 = experience in grade < 3 years at FAOM decision, 0 otherwise.	FOIA Request Needed

Figure B.12: Variables: Description and Sources

In line with open data initiatives, this section describes our data construction process and how to obtain each individual data sources used to build our sample. The sample contains both internal and external USPTO data, including patent application, scope, and examiner data. While we cannot directly release certain variables that contain personal information of USPTO examiners, this section provides an overview on which variables are available from public data sources, which data components to request via a Freedom of Information Act (FOIA) request, and how to reconstruct the sample. We constructed our sample using three publicly-available data sources: Patent Examination Research Dataset - application data, Patent Examination Research Dataset - transactions, and the Patent Claims Research Dataset. Each of these datasets were produced by the USPTO's Office of Chief Economist (OCE) and can be found at https://www.uspto.gov/learning-and-resources/ip-policy/economic-research/research-datasets.

B.2.1 Patent Examination Research Dataset

The Patent Examination Research Dataset - application data file contains patent application data including application number, patent number, file and disposal dates, technology classifications, examiner name etc. The Patent Examination Research Dataset - transactions file contains the transaction history for each publicly-available patent application filed from 2001 onward. From this file, we construct the first-action allowance variables (FA_allow) and RS_Allow), where a first-action allowance (FA_allow) is defined to be an allowance without the observance of a non-final rejection, final rejection, restriction, or Quayle action.[3] We defined a first-action allowance without an examiner's amendment (RS_allow) to be the same as *allow* above, except applications with an examiner's amendment (*Exam_Amend*) issued prior to the first-action allowance are reclassified to the same group as the first-action rejections. Once the FA_allow, RS_allow, and *Exam_Amend* variables have been constructed at the application-level, the data can be linked to the Patent Examination Research Dataset - application data file using the application number, available in both datasets.

B.2.2 Patent Claims Research Dataset

The Patent Claims Research Dataset - PGPub_document_stats and patent_document_stats files contain document-level claims statistics at PGPub and at grant. The independent claim count (*ICC*) is defined as the number of independent claims at PGPub (which is a good proxy for the number of claims at filing) and the independent claim length (*ICL*) is defined as number of words in the shortest independent claim at PGPub. *ICC* and *ICL* are contained in the Patent Claims Research Dataset - PGPub_document_stats file (pub_clm_ct and pub_wrd_min, respectively). The change in independent claim count (ΔICC) and length (ΔICL) were constructed by creating publication-patent pairs, or granted patents for which we observe both the PGPub and granted patent. We linked the two datasets (PGPub_document_stats and patent_document_stats) by application number, contained in both datasets. The

[3]The transaction codes are listed as follows: allowance (*MN/=.*), examiner's amendment (*Exam_Amend*) non-final rejection (*MCTNF*), final rejection (*MCTFR*), restriction (*MCTRS*), or Quayle action(*MCTEQ*).

ΔICC and ΔICL measures are then calculated by taking the simple difference, e.g. $\Delta ICC = ICC_{GRANT} - ICC_{PGPub}$ and $\Delta ICL = ICL_{GRANT} - ICL_{PGPub}$, for each respective variable.[4] This data can then be linked back to the application data using the patent application number, available in both the Patent Claims and Patent Examination Research Datasets.

B.2.3 Examiner Docketing Data (FOIA)

The examiner docketing data contains date ranges during which an application is docketed with a specific USPTO employee, typically an examiner. An application may be transferred between and therefore records may show that the application was docketed to multiple examiners over the course of prosecution. To determine which examiner completed the FAOM decision, one should link the docketing data with the application-level FAOM data described above and find which examiner was docketed the application at the time of the FAOM decision. In some cases, an application was docketed to multiple employees on the FAOM date, therefore we assumed that the employee to which the application was docketed prior to the FAOM date most likely conducted the FAOM decision. Therefore, all other examiners who had the application on their docket on the FAOM date were dropped. This data has been previously disseminated to researchers via FOIA requests made to the USPTO. To obtain this data, request data for all examiners docketed to each publicly-available application and the respective docket date ranges.

B.2.4 Examiner Grade Data (FOIA)

The examiner grade data contains promotion dates for each examiner at the USPTO over the course of their career (including start date), but is not currently publicly available in a downloadable format. However, researchers have previously been granted access to this data via a FOIA request to the USPTO. Specifically, researchers should request the starting and promotion dates for each examiner at the USPTO. In our sample, using the linked application-examiner data described above, we determined the GS-level of each respective examiner at first action. We then

[4] In the patent_document_stats dataset, *ICC* and *ICL* at grant are labelled as pat_clm_ct and pat_wrd_min, respectively.

calculated experience by subtracting the examiner's start date from the FAOM date and divided the experience in days by 30.5 to obtain the experience in months. The month variable was then truncated using the *trunc()* function in STATA. The *trunc()* function rounds to the nearest integer toward zero.

B.2.4.1 Parent Type Variable

In this section, we detail the construction of the "parent type" variable (*parent*), which is in fact a combination of variables contained in three Patent Examination Research Dataset files: application_data, continuity_parent, and foreign_priority. First, we merge the application_data and foreign_priority files based on application number (contained in both files) and create a binary indicator of foreign priority for each application in the application_data file, i.e. the indicator is equal to one if the application had a foreign priority and 0 otherwise. Second, using the continuity_parent file, we subset the data by keeping the following parent-child patent application relationships: continuation-in-part (CIP), continuation (CON), divisional (DIV), and provisional (PRO). We further subset the data by keeping the most recently filed parent application for each child application. Therefore, the remaining observations should contain a unique parent-child relationship. We then merge this data to the application_data file by linking the child application numbers in the continuity_parent file to the corresponding application numbers in the application_data file. Finally, we identify PCT applications by creating a binary indicator where the application is declared to be a PCT application if the first three digits of the application are "PCT" and is zero otherwise.

Therefore, using the variables created above, we construct the categorical variable *parent* as follows:

- Foreign - An application has foreign priority but is not a PCT application.
- PCT Foreign - An application has foreign priority and is a PCT application.
- PCT US Application - An application has no foreign priority but is a PCT application.

- U.S. Continuation - An application has no foreign priority and is a continuation of another U.S. application.

- U.S. Divisional - An application has no foreign priority and is a divisional application.

- U.S. Continuation-in-part (CIP) - An application has no foreign priority and is a CIP application.

- U.S. Provisional - An application has no foreign priority and is a provisional application.

- U.S. New Application - An application has no foreign priority and has no parent application.

B.2.4.2 Examiner Specialization

To control for examiner specialization, we generated two sets of measures: (1) the number of USPCs in which an examiner examined during the previous year, and (2) the average and variance of TF-IDF cosine similarity between pairs of claims from first actions submitted by the examiner during the previous year. To calculate (1), we used summed the number of unique USPCs for each given first-action year and lagged the variable by one year. This variable captures the technological spread of each examiner and allows that expertise to evolve over time. One downsize to this approach is that the USPC specialization variable cannot be calculated for observations in the examiner's first year. To calculate (2), we calculated the pairwise TF-IDF cosine similarity between each application with a first-action decision for a given examiner in the previous year. The similarity measured was calculated using the claims at PGPub. The average and variance of the TF-IDF cosine similarity was then calculated for each examiner-year combination, except each examiner's starting year.

B.3 General Robustness Check Regressions

VARIABLES	(1) TC-Year FE	(2) Bal. Sample	(3) Exp. FE	(4) Exp. Band FE	(5) USPC FE
Grade: GS-7	3.24e-06	-0.00194*	0.000880	0.000756	-0.000196
	(0.000600)	(0.000873)	(0.000726)	(0.000709)	(0.000600)
Grade: GS-11	0.00240***	0.00110	0.00179*	0.00187**	0.00288***
	(0.000583)	(0.00107)	(0.000703)	(0.000693)	(0.000579)
Grade: GS-12	0.00378***	0.000817	0.00310**	0.00323**	0.00428***
	(0.000736)	(0.00147)	(0.00106)	(0.00104)	(0.000730)
Grade: GS-13	0.00639***	0.00601***	0.00651***	0.00667***	0.00731***
	(0.000903)	(0.00174)	(0.00139)	(0.00137)	(0.000880)
Grade: GS-14	0.0123***	0.00991***	0.0139***	0.0141***	0.0136***
	(0.00130)	(0.00271)	(0.00173)	(0.00171)	(0.00131)
Exper	0.000154***	0.000146			0.000148***
	(4.36e-05)	(7.89e-05)			(4.33e-05)
ICC	-7.14e-05	0.000215*	-7.33e-05	-7.61e-05	-8.16e-05
	(5.59e-05)	(0.000105)	(5.58e-05)	(5.59e-05)	(5.65e-05)
ICL	0.000161***	0.000187***	0.000160***	0.000161***	0.000161***
	(5.00e-06)	(9.10e-06)	(5.00e-06)	(5.00e-06)	(5.02e-06)
Constant	-0.00978	-0.000331	-0.0148*	-0.0144**	-0.00899*
	(0.00511)	(0.00718)	(0.00581)	(0.00494)	(0.00411)
Obs.	1,031,106	299,384	1,031,106	1,031,106	1,031,106
R-squared	0.012	0.014	0.012	0.012	0.012
Examiners	13,496	2,520	13,496	13,496	13,496
TC-by-Year FE	YES	YES	YES	YES	NO
Balanced Panel	NO	YES	NO	NO	NO
Exp. FE	NO	NO	YES	NO	NO
Exp. Band FE	NO	NO	NO	YES	NO
USPC FE	NO	NO	NO	NO	YES

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all new applications in Public Pair with an observed first-action decision between 2001 and 2017. TC-by-year fixed effects were added to Column (1). Column (2) includes only new applications for which the examiner started at GS-7 and was promoted through GS-14. Columns (3) and (4) include experience fixed effects (*e.g.*, months and 6-month bands, respectively). Column (5) contains USPC fixed Effects. Regressions in this table correspond to modified versions of equation 3.3.

Table B.1: Robustness Check - Examiner's Amendment (Dependent Variable: $Exam\_Amend_{eit}$)

VARIABLES	(1) TC-Year FE	(2) Bal. Sample	(3) Exp. FE	(4) Exp. Band FE	(5) USPC FE
Grade: GS-7	-0.00145	-0.000219	4.48e-05	-0.000280	-0.00191*
	(0.000845)	(0.00123)	(0.00103)	(0.00101)	(0.000845)
Grade: GS-11	0.000741	0.000833	0.000917	0.000877	0.000795
	(0.000786)	(0.00136)	(0.001000)	(0.000985)	(0.000773)
Grade: GS-12	-0.000212	-0.000638	0.00151	0.00166	-0.000630
	(0.00106)	(0.00186)	(0.00166)	(0.00163)	(0.00103)
Grade: GS-13	-0.000686	-0.00398	0.00378	0.00400	-0.000912
	(0.00139)	(0.00225)	(0.00220)	(0.00216)	(0.00136)
Grade: GS-14	0.0246***	0.0154***	0.0290***	0.0293***	0.0248***
	(0.00216)	(0.00324)	(0.00290)	(0.00286)	(0.00212)
Exper	1.47e-05	0.000196			4.15e-05
	(6.48e-05)	(0.000106)			(6.45e-05)
ICC	-0.00193***	-0.000921***	-0.00193***	-0.00193***	-0.00192***
	(0.000195)	(0.000196)	(0.000194)	(0.000194)	(0.000195)
ICL	0.000480***	0.000455***	0.000479***	0.000480***	0.000480***
	(1.23e-05)	(1.81e-05)	(1.22e-05)	(1.23e-05)	(1.23e-05)
Constant	-0.00269	0.0237	0.0279	-0.00685	-0.0452***
	(0.0137)	(0.0170)	(0.0344)	(0.0136)	(0.00861)
Obs.	1,031,106	299,384	1,031,106	1,031,106	1,031,106
R-squared	0.033	0.037	0.034	0.034	0.033
Examiners	13,496	2,520	13,496	13,496	13,496
TC-by-Year FE	YES	YES	YES	YES	NO
Balanced Panel	NO	YES	NO	NO	NO
Exp. FE	NO	NO	YES	NO	NO
Exp. Band FE	NO	NO	NO	YES	NO
USPC FE	NO	NO	NO	NO	YES

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all new applications in Public Pair with an observed first-action decision between 2001 and 2017. TC-by-year fixed effects were added to Column (1). Column (2) includes only new applications for which the examiner started at GS-7 and was promoted through GS-14. Columns (3) and (4) include experience fixed effects (*e.g.*, months and 6-month bands, respectively). Column (5) contains USPC fixed Effects. Regressions in this table correspond to modified versions of equation 3.4.

Table B.2: Robustness Check - "True Rubber Stamp" Allowance (Dependent Variable: RS_Allow_{eit})

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00303**	0.000340	-0.00326**	-0.000420
	(0.00100)	(0.00117)	(0.00102)	(0.00116)
Grade: GS-11	0.00439***	0.00200	0.00413***	0.00277**
	(0.000849)	(0.00105)	(0.000900)	(0.00107)
Grade: GS-12	0.00934***	0.00147	0.00805***	0.00305
	(0.00115)	(0.00140)	(0.00142)	(0.00158)
Grade: GS-13	0.0151***	0.00398*	0.0140***	0.00717**
	(0.00146)	(0.00176)	(0.00195)	(0.00221)
Grade: GS-14	0.0526***	0.0362***	0.0422***	0.0325***
	(0.00213)	(0.00266)	(0.00289)	(0.00320)
Exper	0.000250***	0.000278***	0.000335***	0.000269**
	(4.69e-05)	(7.94e-05)	(6.06e-05)	(8.97e-05)
ICC	-0.00134*	-0.00202***	-0.00139***	-0.00116***
	(0.000617)	(0.000215)	(0.000244)	(0.000146)
ICL	0.000361***	0.000645***	0.000344***	0.000537***
	(3.39e-05)	(1.52e-05)	(3.94e-05)	(1.36e-05)
USPC Spec. (1-20)	0.00257*	0.00485***	0.00440***	0.00400**
	(0.00116)	(0.00132)	(0.00109)	(0.00123)
USPC Spec. (21-50)	0.00800***	0.00680***	0.00805***	0.00615***
	(0.00103)	(0.00120)	(0.000985)	(0.00118)
USPC Spec. (51-100)	0.0102***	0.00683***	0.00757***	0.00535***
	(0.00110)	(0.00130)	(0.00104)	(0.00127)
USPC Spec. (101-150)	0.0109***	0.00947***	0.00627***	0.00493*
	(0.00137)	(0.00182)	(0.00139)	(0.00193)
USPC Spec. (>150)	0.00905***	0.00979***	0.00494**	0.00406
	(0.00186)	(0.00259)	(0.00186)	(0.00257)
Constant	0.0534***	-0.0122***	0.0413***	-0.0104*
	(0.00507)	(0.00309)	(0.00608)	(0.00458)
Obs.	4,610,715	1,025,762	2,764,280	671,699
R-squared	0.029	0.041	0.032	0.038
Examiners	13,629	13,415	12,816	12,574
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. USPC Subclass Specialization FE is defined as the number of classes in which an examiner examined during the previous calendar year, relative to zero classes. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to a modified version of equation 3.2.

Table B.3: Robustness Check - First-action Allowance Regressions (Dependent Variable: FA_Allow_{eit}) - Includes Subclass Specialization

B.4 Examiner Specialization Tables

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	0.000324	0.00100	9.37e-05	0.000966
	(0.000519)	(0.000665)	(0.000526)	(0.000678)
Grade: GS-11	0.00232***	0.00213***	0.00222***	0.00213**
	(0.000458)	(0.000616)	(0.000480)	(0.000652)
Grade: GS-12	0.00456***	0.00326***	0.00396***	0.00334***
	(0.000587)	(0.000777)	(0.000730)	(0.000913)
Grade: GS-13	0.00868***	0.00627***	0.00782***	0.00668***
	(0.000735)	(0.000923)	(0.000982)	(0.00127)
Grade: GS-14	0.0148***	0.0127***	0.0137***	0.0136***
	(0.00109)	(0.00135)	(0.00145)	(0.00186)
Exper	0.000245***	0.000194***	0.000235***	0.000194***
	(2.56e-05)	(4.57e-05)	(3.34e-05)	(5.22e-05)
ICC	-0.000231**	-8.35e-05	-0.000188**	6.77e-05
	(8.13e-05)	(5.67e-05)	(6.46e-05)	(6.54e-05)
ICL	8.77e-05***	0.000162***	9.62e-05***	0.000154***
	(8.34e-06)	(5.01e-06)	(1.11e-05)	(5.41e-06)
USPC Spec. (1-20)	0.00374***	0.00252***	0.00370***	0.00231**
	(0.000589)	(0.000714)	(0.000600)	(0.000730)
USPC Spec. (21-50)	0.00468***	0.00371***	0.00450***	0.00403***
	(0.000538)	(0.000683)	(0.000537)	(0.000706)
USPC Spec. (51-100)	0.00457***	0.00308***	0.00310***	0.00234**
	(0.000559)	(0.000730)	(0.000578)	(0.000769)
USPC Spec. (101-150)	0.00486***	0.00337***	0.00262***	0.00193
	(0.000689)	(0.000931)	(0.000735)	(0.00109)
USPC Spec. (>150)	0.00551***	0.00319*	0.00317***	0.00194
	(0.000922)	(0.00124)	(0.000951)	(0.00142)
Constant	-0.0160***	-0.0211***	-0.00389	-0.00989***
	(0.00139)	(0.00120)	(0.00216)	(0.00233)
Obs.	4,610,715	1,025,762	2,764,280	671,699
R-squared	0.008	0.011	0.010	0.011
Examiners	13,629	13,415	12,816	12,574
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. USPC Subclass Specialization FE is defined as the number of classes in which an examiner examined during the previous calendar year, relative to zero classes. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to a modified version of equation 3.3.

Table B.4: Robustness Check - Examiner Amendment Regressions (Dependent Variable: $Exam\_Amend_{eit}$) - Includes Subclass Specialization

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00336***	-0.000656	-0.00336***	-0.00137
	(0.000805)	(0.000929)	(0.000809)	(0.000910)
Grade: GS-11	0.00207**	-0.000147	0.00190**	0.000629
	(0.000669)	(0.000830)	(0.000697)	(0.000837)
Grade: GS-12	0.00477***	-0.00180	0.00408***	-0.000313
	(0.000942)	(0.00113)	(0.00111)	(0.00123)
Grade: GS-13	0.00643***	-0.00230	0.00622***	0.000469
	(0.00125)	(0.00147)	(0.00157)	(0.00172)
Grade: GS-14	0.0378***	0.0235***	0.0286***	0.0189***
	(0.00187)	(0.00225)	(0.00234)	(0.00248)
Exper	3.21e-06	8.35e-05	9.91e-05*	7.40e-05
	(4.05e-05)	(6.81e-05)	(4.93e-05)	(7.43e-05)
ICC	-0.00111*	-0.00193***	-0.00120***	-0.00123***
	(0.000545)	(0.000197)	(0.000187)	(0.000121)
ICL	0.000273***	0.000483***	0.000248***	0.000383***
	(2.58e-05)	(1.22e-05)	(2.85e-05)	(1.07e-05)
USPC Spec. (1-20)	-0.00118	0.00234*	0.000691	0.00171
	(0.000961)	(0.00108)	(0.000866)	(0.000966)
USPC Spec. (21-50)	0.00331***	0.00309**	0.00354***	0.00212*
	(0.000862)	(0.000955)	(0.000794)	(0.000909)
USPC Spec. (51-100)	0.00565***	0.00375***	0.00446***	0.00301**
	(0.000911)	(0.00105)	(0.000832)	(0.000984)
USPC Spec. (101-150)	0.00607***	0.00611***	0.00365**	0.00303
	(0.00116)	(0.00158)	(0.00115)	(0.00159)
USPC Spec. (>150)	0.00354*	0.00662**	0.00176	0.00214
	(0.00158)	(0.00225)	(0.00147)	(0.00218)
Constant	0.0694***	0.00890**	0.0451***	-0.000530
	(0.00417)	(0.00272)	(0.00469)	(0.00393)
Obs.	4,610,715	1,025,762	2,764,280	671,699
R-squared	0.023	0.031	0.023	0.027
Examiners	13,629	13,415	12,816	12,574
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. USPC Subclass Specialization FE is defined as the number of classes in which an examiner examined during the previous calendar year, relative to zero classes. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to a modified version of equation 3.4.

Table B.5: Robustness Check - "True Rubber Stamp" Allowance (Dependent Variable: RS_Allow_{eit}) - Includes Subclass Specialization

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00477***	0.000747	-0.00436***	0.000730
	(0.00127)	(0.00157)	(0.00126)	(0.00153)
Grade: GS-11	0.00479***	0.00181	0.00428***	0.00257*
	(0.000948)	(0.00119)	(0.00103)	(0.00124)
Grade: GS-12	0.00997***	0.00176	0.00831***	0.00328
	(0.00122)	(0.00148)	(0.00155)	(0.00174)
Grade: GS-13	0.0160***	0.00408*	0.0145***	0.00714**
	(0.00152)	(0.00185)	(0.00211)	(0.00244)
Grade: GS-14	0.0534***	0.0361***	0.0427***	0.0320***
	(0.00220)	(0.00274)	(0.00310)	(0.00347)
Exper	0.000209***	0.000260**	0.000286***	0.000270**
	(4.83e-05)	(8.38e-05)	(6.41e-05)	(9.71e-05)
ICC	-0.00141*	-0.00226***	-0.00153***	-0.00138***
	(0.000661)	(0.000253)	(0.000277)	(0.000166)
ICL	0.000368***	0.000678***	0.000356***	0.000577***
	(3.60e-05)	(1.66e-05)	(4.40e-05)	(1.50e-05)
Mean Sim.	-0.0757***	-0.0800**	-0.0508**	-0.0577*
	(0.0197)	(0.0256)	(0.0188)	(0.0276)
Var. Sim.	0.200***	0.193*	0.164**	0.191*
	(0.0574)	(0.0784)	(0.0551)	(0.0780)
Constant	0.0633***	-0.00674	0.0501***	-0.00685
	(0.00547)	(0.00363)	(0.00692)	(0.00517)
Obs.	4,274,690	924,390	2,445,179	574,740
R-squared	0.029	0.043	0.031	0.040
Examiners	12,399	12,160	11,581	11,314
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Similarity measures are defined as the average (Mean Sim.) and variance (Var. Sim.) of the pairwise TF-IDF cosine similarity for all applications with a first action decision by a given examiner during the previous year. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to a modified version of equation 3.2.

Table B.6: Robustness Check - First-action Allowance Regressions (Dependent Variable: FA_Allow_{eit}) - Includes Similarity Specialization

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00133*	0.00115	-0.000904	0.00183*
	(0.000627)	(0.000866)	(0.000653)	(0.000891)
Grade: GS-11	0.00201***	0.00173*	0.00177**	0.00162*
	(0.000505)	(0.000696)	(0.000543)	(0.000748)
Grade: GS-12	0.00426***	0.00320***	0.00328***	0.00291**
	(0.000622)	(0.000822)	(0.000793)	(0.00100)
Grade: GS-13	0.00833***	0.00614***	0.00688***	0.00592***
	(0.000765)	(0.000973)	(0.00105)	(0.00139)
Grade: GS-14	0.0144***	0.0124***	0.0122***	0.0123***
	(0.00111)	(0.00139)	(0.00153)	(0.00200)
Exper	0.000235***	0.000199***	0.000238***	0.000230***
	(2.64e-05)	(4.83e-05)	(3.54e-05)	(5.69e-05)
ICC	-0.000243**	-0.000113	-0.000218**	4.28e-05
	(8.80e-05)	(6.21e-05)	(7.14e-05)	(7.45e-05)
ICL	8.86e-05***	0.000168***	9.85e-05***	0.000162***
	(8.77e-06)	(5.39e-06)	(1.23e-05)	(5.92e-06)
Mean Sim.	-0.00993	0.00191	-0.00305	-0.0155
	(0.00969)	(0.0147)	(0.00949)	(0.0137)
Var. Sim.	0.0113	-0.0293	0.0368	0.0299
	(0.0294)	(0.0403)	(0.0310)	(0.0392)
Constant	-0.0132***	-0.0199***	-0.00161	-0.00632*
	(0.00156)	(0.00147)	(0.00245)	(0.00255)
Obs.	4,274,690	924,390	2,445,179	574,740
R-squared	0.008	0.011	0.009	0.011
Examiners	12,399	12,160	11,581	11,314
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Similarity measures are defined as the average (Mean Sim.) and variance (Var. Sim.) of the pairwise TF-IDF cosine similarity for all applications with a first action decision by a given examiner during the previous year. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to a modified version of equation 3.3.

Table B.7: Robustness Check - Examiner Amendment Regressions (Dependent Variable: $Exam\_Amend_{eit}$) - Includes Similarity Specialization

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-0.00344***	-0.000365	-0.00346***	-0.00106
	(0.00104)	(0.00128)	(0.00103)	(0.00124)
Grade: GS-11	0.00277***	7.29e-05	0.00250**	0.000937
	(0.000763)	(0.000941)	(0.000810)	(0.000967)
Grade: GS-12	0.00570***	-0.00145	0.00501***	0.000366
	(0.00100)	(0.00120)	(0.00122)	(0.00135)
Grade: GS-13	0.00763***	-0.00206	0.00756***	0.00120
	(0.00131)	(0.00155)	(0.00171)	(0.00190)
Grade: GS-14	0.0390***	0.0237***	0.0304***	0.0197***
	(0.00194)	(0.00232)	(0.00251)	(0.00271)
Exper	-2.75e-05	6.05e-05	4.72e-05	4.01e-05
	(4.18e-05)	(7.19e-05)	(5.24e-05)	(8.04e-05)
ICC	-0.00117*	-0.00215***	-0.00132***	-0.00142***
	(0.000582)	(0.000230)	(0.000213)	(0.000138)
ICL	0.000279***	0.000511***	0.000258***	0.000415***
	(2.74e-05)	(1.33e-05)	(3.19e-05)	(1.19e-05)
Mean Sim.	-0.0658***	-0.0822***	-0.0479**	-0.0427
	(0.0164)	(0.0208)	(0.0157)	(0.0231)
Var. Sim.	0.189***	0.223***	0.128**	0.163**
	(0.0450)	(0.0636)	(0.0409)	(0.0627)
Constant	0.0765***	0.0132***	0.0517***	-0.000530
	(0.00453)	(0.00322)	(0.00540)	(0.00447)
Obs.	4,274,690	924,390	2,445,179	574,740
R-squared	0.023	0.033	0.023	0.029
Examiners	12,399	12,160	11,581	11,314
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. Similarity measures are defined as the average (Mean Sim.) and variance (Var. Sim.) of the pairwise TF-IDF cosine similarity for all applications with a first action decision by a given examiner during the previous year. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to a modified version of equation 3.4.

Table B.8: Robustness Check - "True Rubber Stamp" Allowance (Dependent Variable: RS_Allow_{eit}) - Includes Similarity Specialization

B.5 Examination Quality Regressions

VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Exam_Amend	-15.45***	0.587	-16.23***	16.43
	(0.820)	(5.610)	(0.749)	(12.18)
Exper	0.0458*	0.0391*	-0.0519	-0.0506
	(0.0197)	(0.0192)	(0.0391)	(0.0398)
ICC	0.463***	0.437***	-1.218***	-1.280***
	(0.113)	(0.0245)	(0.143)	(0.0896)
ICL	-0.186***	-0.191***	-0.154***	-0.168***
	(0.0196)	(0.00180)	(0.0101)	(0.00518)
Constant	48.54***	49.07	50.18***	49.46
	(2.470)	(63.00)	(4.090)	(57.48)
Obs.	1,032,745	1,020,144	207,958	204,376
R-squared	0.084	0.0688	0.049	0.0520
Examiners	12,700	12,043	10,848	10,326

Significant at *** p<0.01, ** p<0.05, * p<0.1. The sample for each regression in this table includes all applications with a first-action allowance with an examiner's amendment or a single non-final rejection and subsequent allowance. The sample is further restricted to exclude any applications with a claim amendment filing by the applicant between the pre-grant publication (PGPub) date and the first-action date. Regressions include first-action year, examiner, GS-level, and specialization fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Columns (1) and (3) contain the OLS estimates and Columns (2) and (4) contain the IV estimates. Regressions in this table correspond to equation 3.5.

Table B.9: Examination Quality (Dependent Variable: ΔICL) Between Allowed Patent Applications With One Rejection and FA Allowances with an Examiner's Amendment (APPFT)

VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Exam_Amend	-0.423***	-0.277	-0.478***	-0.753
	(0.0186)	(0.273)	(0.0206)	(0.560)
Exper	-0.0129***	-0.0132***	-0.00893***	-0.00924***
	(0.00103)	(0.000937)	(0.00182)	(0.00183)
ICC	-0.546***	-0.549***	0.370***	0.375***
	(0.151)	(0.00119)	(0.0505)	(0.00412)
ICL	-0.00223***	-0.00229***	-0.000646**	-0.000559*
	(0.000531)	(8.76e-05)	(0.000211)	(0.000238)
Constant	4.141***	4.207	1.937***	1.991
	(0.464)	(3.068)	(0.283)	(2.643)
Obs.	1,032,756	1,020,155	207,961	204,379
R-squared	0.188	0.130	0.062	0.0370
Examiners	12,700	12,043	10,848	10,326

Significant at *** p<0.01, ** p<0.05, * p<0.1. The sample for each regression in this table includes all applications with a first-action allowance with an examiner's amendment or a single non-final rejection and subsequent allowance. The sample is further restricted to exclude any applications with a claim amendment filing by the applicant between the pre-grant publication (PGPub) date and the first-action date. Regressions include first-action year, examiner, GS-level, and specialization fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Columns (1) and (3) contain the OLS estimates and Columns (2) and (4) contain the IV estimates. Regressions in this table correspond to equation 3.5.

Table B.10: Examination Quality (Dependent Variable: ΔICC) Between Allowed Patent Applications With One Rejection and FA Allowances with an Examiner's Amendment (APPFT)

VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Exam_Amend	-13.55***	1.613	-13.87***	9.582
	(0.806)	(4.918)	(0.685)	(9.082)
Exper	0.0498*	0.0405*	-0.0440	-0.0481
	(0.0195)	(0.0192)	(0.0386)	(0.0395)
ICC	0.491***	0.465***	-1.163***	-1.208***
	(0.119)	(0.0244)	(0.140)	(0.0874)
ICL	-0.183***	-0.188***	-0.155***	-0.167***
	(0.0193)	(0.00180)	(0.00977)	(0.00485)
Constant	47.91***	48.69	49.28***	48.95
	(2.465)	(63.14)	(4.091)	(57.40)
Obs.	1,055,264	1,042,554	212,990	209,376
R-squared	0.083	0.0671	0.050	0.0559
Examiners	12,712	12,053	10,879	10,358

Significant at *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The sample for each regression in this table includes all applications with a first-action allowance with an examiner's amendment or a single non-final rejection and subsequent allowance. Regressions include first-action year, examiner, GS-level, and specialization fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Columns (1) and (3) contain the OLS estimates and Columns (2) and (4) contain the IV estimates. Regressions in this table correspond to equation 3.5.

Table B.11: Examination Quality (Dependent Variable: ΔICL) Between Allowed Patent Applications With One Rejection and FA Allowances with an Examiner's Amendment

VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Exam_Amend	-0.428***	-0.266	-0.522***	-0.608
	(0.0172)	(0.238)	(0.0186)	(0.415)
Exper	-0.0128***	-0.0132***	-0.00876***	-0.00907***
	(0.00101)	(0.000926)	(0.00178)	(0.00180)
ICC	-0.541***	-0.545***	0.370***	0.375***
	(0.151)	(0.00118)	(0.0498)	(0.00399)
ICL	-0.00219***	-0.00227***	-0.000608**	-0.000585**
	(0.000526)	(8.71e-05)	(0.000206)	(0.000221)
Constant	4.144***	4.214	1.956***	2.013
	(0.464)	(3.052)	(0.279)	(2.621)
Obs.	1,055,275	1,042,565	212,993	209,379
R-squared	0.185	0.128	0.064	0.0388
Examiners	12,712	12,053	10,879	10,358

Significant at *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The sample for each regression in this table includes all applications with a first-action allowance with an examiner's amendment or a single non-final rejection and subsequent allowance. Regressions include first-action year, examiner, GS-level, and specialization fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Columns (1) and (3) contain the OLS estimates and Columns (2) and (4) contain the IV estimates. Regressions in this table correspond to equation 3.5.

Table B.12: Examination Quality (Dependent Variable: ΔICC) Between Allowed Patent Applications With One Rejection and FA Allowances with an Examiner's Amendment

B.6 Examiner's Amendment Quality by Grade and Experience Regressions

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	-3.794	-10.29*	-3.718	-9.318
	(2.423)	(5.626)	(2.583)	(5.956)
Grade: GS-11	1.894	-5.298	1.192	-7.301
	(1.944)	(5.582)	(2.079)	(6.061)
Grade: GS-12	4.629**	5.824	3.790*	4.951
	(1.890)	(5.414)	(2.218)	(6.702)
Grade: GS-13	2.891	1.986	1.365	-1.101
	(1.847)	(5.144)	(2.426)	(7.546)
Grade: GS-14	0.176	-5.671	-2.562	-11.35
	(2.043)	(5.188)	(3.258)	(10.14)
Exper	0.0143	-0.142	-0.0195	-0.233
	(0.0668)	(0.193)	(0.113)	(0.384)
ICC	1.857***	1.902***	2.203***	2.214**
	(0.558)	(0.635)	(0.310)	(1.031)
ICL	-0.101***	-0.0746***	-0.116***	-0.0742***
	(0.0102)	(0.0141)	(0.0172)	(0.0258)
Constant	72.15***	11.47	57.18***	-0.624
	(12.53)	(13.63)	(13.02)	(21.60)
Obs.	73,951	12,053	37,391	6,468
R-squared	0.053	0.028	0.058	0.028
Examiners	7,810	3,934	6,517	2,885
Parent Type FE	YES	NO	YES	NO

Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. The sample for each regression in this table includes all applications with a first-action allowance with an examiner's amendment. The sample is further restricted to exclude any applications with a claim amendment filing by the applicant between the pre-grant publication (PGPub) date and the first-action date. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to equation 3.4.

Table B.13: Examiner's Amendment Quality and ΔICL (Dependent Variable: ΔICL)

VARIABLES	(1) All	(2) New Applications	(3) 3-year	(4) New Apps/3-year
Grade: GS-7	0.0385	0.125*	0.0365	0.187**
	(0.0388)	(0.0730)	(0.0358)	(0.0767)
Grade: GS-11	0.00124	0.0409	0.000815	0.0694
	(0.0313)	(0.0637)	(0.0297)	(0.0678)
Grade: GS-12	-0.00668	0.00755	0.0209	0.0293
	(0.0322)	(0.0617)	(0.0344)	(0.0730)
Grade: GS-13	-0.00428	0.0622	0.0562	0.123
	(0.0329)	(0.0618)	(0.0372)	(0.0845)
Grade: GS-14	0.0195	0.0702	0.107**	0.150
	(0.0351)	(0.0661)	(0.0479)	(0.111)
Exper	0.000726	0.00356	0.00184	0.00335
	(0.00116)	(0.00236)	(0.00161)	(0.00449)
ICC	-0.591***	-0.263***	-0.397***	-0.315***
	(0.132)	(0.0331)	(0.0306)	(0.0587)
ICL	-0.000456	0.000197	0.000140*	0.000109
	(0.000377)	(0.000136)	(7.47e-05)	(0.000193)
Constant	0.538	0.547	-0.391	0.425
	(0.700)	(0.399)	(0.427)	(0.518)
Obs.	73,951	12,053	37,391	6,468
R-squared	0.562	0.205	0.361	0.254
Examiners	7,810	3,934	6,517	2,885
Parent Type FE	YES	NO	YES	NO

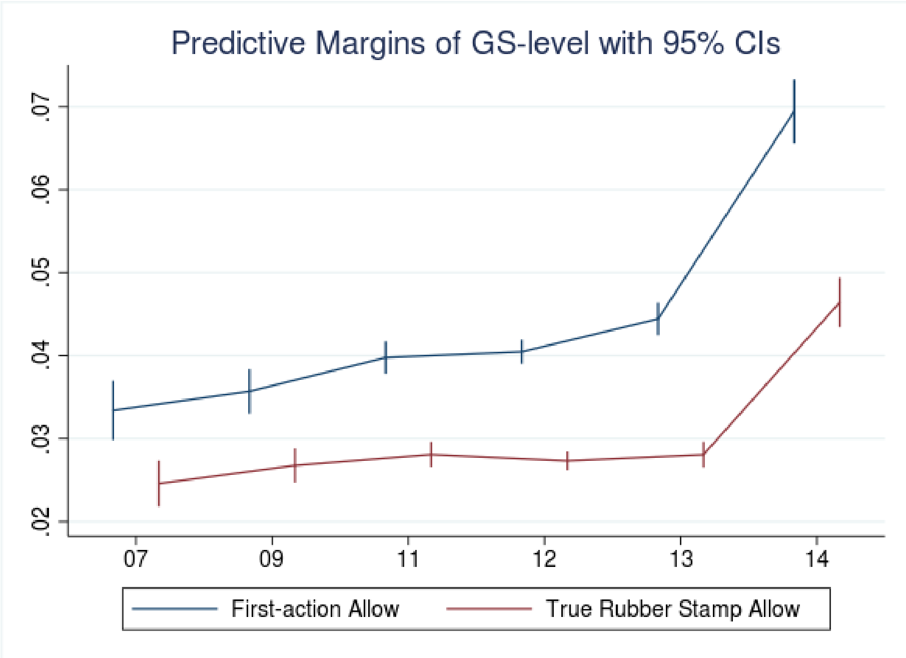
Significant at *** p<0.01, ** p<0.05, * p<0.1. Regressions include first-action year and examiner fixed effects. GS-level coefficients are relative to GS-9. The sample for each regression in this table includes all applications with a first-action allowance with an examiner's amendment. The sample is further restricted to exclude any applications with a claim amendment filing by the applicant between the pre-grant publication (PGPub) date and the first-action date. Robust standard errors are clustered by examiner and are reported in parentheses. Column (1) contains all applications in Public Pair with an observed first-action decision between 2001 and 2017. Column (2) includes only new applications without a priority. Column (3) includes applications where the first-action decision occurred within the first 3 years of promotion to the examiner's current grade. Column (4) includes the intersection of the samples used in Columns (2) and (3). Regressions in this table correspond to equation 3.4.

Table B.14: Examiner's Amendment Quality and ΔICC (Dependent Variable: ΔICC)

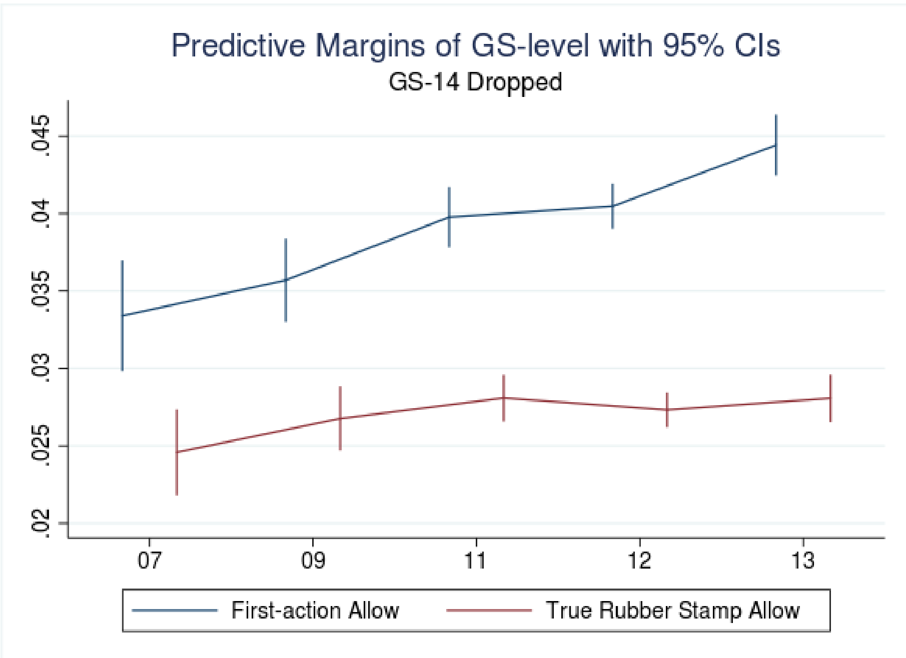
VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Exam_Amend	-0.789***	-0.737***	-0.783***	-0.798***
	(0.00214)	(0.0223)	(0.00408)	(0.0474)
Exper	0.00123***	0.00121***	0.000968***	0.000999***
	(9.12e-05)	(8.70e-05)	(0.000207)	(0.000205)
ICC	0.00314***	0.00307***	0.00601***	0.00613***
	(0.000409)	(0.000111)	(0.000535)	(0.000454)
ICL	-8.70e-05***	-0.000105***	-0.000112***	-0.000104***
	(8.98e-06)	(8.17e-06)	(1.30e-05)	(2.53e-05)
Constant	2.269***	2.271***	2.176***	2.174***
	(0.00934)	(0.286)	(0.0196)	(0.298)
Obs.	1,054,801	1,042,092	212,949	209,340
R-squared	0.416	0.374	0.380	0.351
Examiners	12,711	12,052	10,876	10,358

Significant at *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The sample for each regression in this table includes all applications with a first-action allowance with an examiner's amendment or a single non-final rejection and subsequent allowance. Regressions include first-action year, examiner, GS-level, and specialization fixed effects. Robust standard errors are clustered by examiner and are reported in parentheses. Columns (1) and (3) contain the OLS estimates and Columns (2) and (4) contain the IV estimates. Regressions in this table correspond to equation 3.6.

Table B.15: Examiner Amendments and Log Post-first-action Pendency (Dependent Variable: $ln(PEND_{eit})$)



(a) All GS-Levels



(b) GS-levels 7 Through 13

Figure B.13: GS-Level Effect for (a) All GS-Levels and (b) GS-levels 7 Through 13

Appendix C

Patent Validity and Follow-on Patenting: Evidence From *Ex Parte* Reexamination at the USPTO

C.1 Matching Procedure

DiD-matching combines two popular econometric techniques, Difference-in-differences (DiD) and matching. This sections discusses the simple matching estimator, how the assumptions associated with this estimator fail when applied to the setting described in this paper, and how the matching algorithm of the DiD-matching estimator was executed. Typically matching estimators require unconfoundedness (Rosenbaum and Rubin 1983; Rubin 1990):

$$\{Y_i(0), Y_i(1)\} T_i | X_i \tag{C.1}$$

or in other words, conditional on the set of covariates (X_i), treatment assignment (T_i) is independent of outcomes. This process is also referred to as the Conditional Independence Assumption (Angrist and Pishcke 2009). Under equation C.1 and the overlap assumption ($0 < \mathbf{P}[T_i = 1|X_i] < 1$), one can use the propensity score to find suitable matches between the treatment and set of potential controls (Rosenbaum and Rubin 1983). To estimate a causal effect, both assumptions mentioned above must hold. In this paper, the unconfoundedness assumption is violated because there is almost certainly unobserved time-invariant heterogeneity (patent quality, innovative step, etc.) that is correlated with selection into reexamination. While the matching and DiD methods are not appropriate in this setting, econometricians have developed a method that combines features of the two estimation methods to produce a new type of estimator, DiD-matching.

I constructed a comparison set treated and non-treated observations, matched on the observable characteristics that might influence selection into reexamination, as discussed in Section 4.5. A combination propensity score and exact matching algorithm is used in the main empirical portion of this paper to ensure pre-treatment similarity of the treatment and control groups. The sets of treated and non-treated patents are initially matched directly on issue year, entity size, and NBER technology classification. This initial match limits the number of potential matches for each "treated" patent but ensures that each potential match will be similar in technological content and face a consistent USPTO examination landscape. The matching procedure was implemented using a propensity score matching package (matchit) in R. The propensity matching process includes regressing the probability of treatment on the set of observed covariates (family size, backward citations, pre-treatment citations,[1] ICL, ICC, pendency) within exact matching group, where the propensity score is the predicted probability of treatment. The propensity score in this instance was estimated with a logit regression and each treated patent was matched "to the nearest control unit on the unidimensional metric of the propensity score vector," (Sekhon 2011).[2] According to Sekhon (2011), in order to avoid the issue of compressed probability scores near 0 or 1 when using a logit model, the matched sets are

[1]Researchers using DiD-matching estimators often condition on pre-treatment outcomes when the conditional parallel trends assumption fails (Heckman, Ichimura, Smith and Todd 1997; Heckman, Ichimura, and Smith 1998; and Calel and Dechezleprêtre 2016). As Chabé-Ferret (2017) summarizes, "The theoretical argument suggests that combining DID with conditioning of pre-treatment outcomes combines the strengths of both methods: DID differences out the permanent confounders while conditioning on pre-treatment outcomes captures transitory ones." A working paper, Chabé-Ferret (2017), argues that this practice is flawed and might increase the bias of the difference-in-differences estimator. Chabé-Ferret (2017) suggests using "DID symmetrically around the treatment date," if the conditional parallel trends assumption fails, which was done in this paper. It should be noted that the paper has yet to be published and the debate surrounding this practice has not been settled.

[2]This process is also called "Nearest Neighbor Matching" or "NNM". The set of potential matches is restricted to one control per treated patent.

constructed using the linear predictor ($\hat{\mu} = X'\hat{\beta}$) and not the predicted probabilities.

C.2 Verifying Assumptions

C.2.1 Assumption 1

The SUTVA assumption requires “no interference”, or that successful reexamination does not affect the potential follow-on patenting outcomes of other patents. At first glance, one could argue that the validation of a patent through reexamination would send a signal of patent strength to competitors that operate in the surround technology space, violating Assumption 1. While this conclusion is possible, one could also argue that, due to large sets of available comparison patents, the control group could include patents representing a similar technology to the reexamined patent but not directly influenced by the reexamination process. A prior art citation consists of “patents or printed publications which that person believes to have a bearing on the patentability of any claim of a particular patent,” (35 USC 301). In other words, the claimed invention in the citing patent is directly or indirectly related to the citing patent’s claimed invention in at least some form. Prior art is cited a few ways, but the two main types of citations are examiner and applicant citations. The applicant, who has a duty to disclose all relevant prior art,[3] submits an Information Disclosure Statement containing all relevant prior art to the USPTO during prosecution. Typically before the first-action-on-the-merits, the examiner assigned to the patent application performs her own prior art search on the claimed invention and includes all relevant prior art in a PTO-892 form (MPEP 707.05). The combined prior art citations should include most relevant art related to the claimed invention, though errors can happen. To reduce the likelihood of violating the SUTVA, potential matches cited by or citing the reexamined patents were removed prior to matching.

[3] “Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability,” (37 CFR 1.56).

C.3 Robustness Checks

C.3.1 Parallel Trends Figures

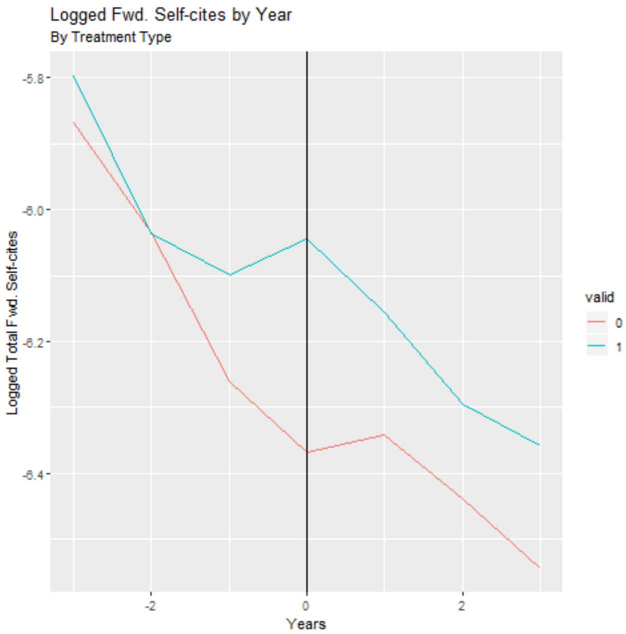


Figure C.1: Logged Annual Forward Self-citations - Treatment and Control Groups

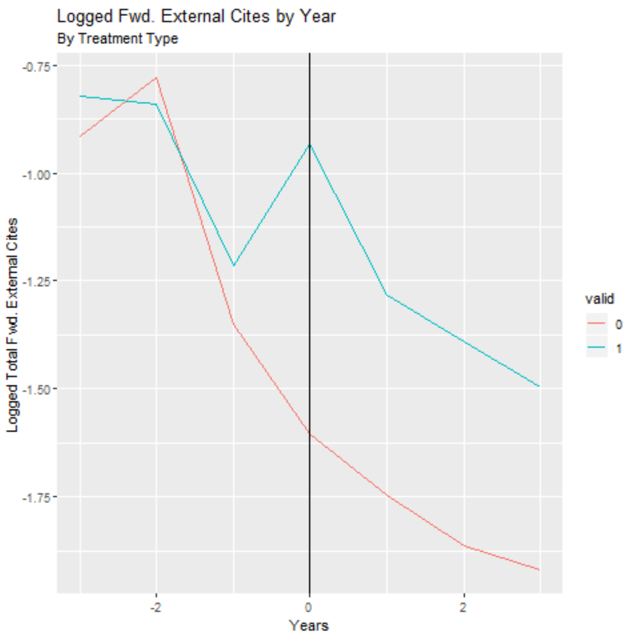


Figure C.2: Logged Annual Forward External Citations - Treatment and Control Groups

C.3.2 Regression Results

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.503***	0.126*	0.454***	0.371***	0.233	0.383**
	(0.112)	(0.070)	(0.113)	(0.143)	(0.160)	(0.150)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	9,562	9,562	9,562	2,732	2,732	2,732
R^2	0.028	0.018	0.027	0.005	0.025	0.005

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include subset of the main sample which includes treated patents that were reexamined a single time (and their matched pairs). Regression results shown in cols 4 through 6 include a subset of the main 2-period panel sample (citations three years before and three years after reexamination) which includes treated patents that were reexamined a single time (and their matched pairs). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.1: Matching-DiD Results - Single Reexamination

	Dependent variable:					
		Full Sample			2-Period	
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.488***	0.165**	0.416***	0.521***	0.258	0.537***
	(0.122)	(0.079)	(0.124)	(0.151)	(0.175)	(0.160)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	7,378	7,378	7,378	2,108	2,108	2,108
R^2	0.037	0.014	0.035	0.013	0.018	0.013

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a subset of the main sample. Regression results shown in cols 4 through 6 include a 2-period panel of the 702 matched patent pairs (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those reexamined patents that were reexamined between 2004 and 2010 (and their respected matched control patent). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.2: Matching-DiD Results - Reexam. Year 2004-2010

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.559**	0.039	0.567**	0.022	0.226	0.050
	(0.239)	(0.136)	(0.242)	(0.328)	(0.339)	(0.342)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	2,450	2,450	2,450	700	700	700
R^2	0.014	0.037	0.017	0.002	0.054	0.004

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a subset of the main sample. Regression results shown in cols 4 through 6 include a 2-period panel of the 702 matched patent pairs (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those reexamined patents that were reexamined between 1999 and 2003 (and their respected matched control patent). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.3: Matching-DiD Results - Reexam. Year 1999-2003

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.548***	0.136*	0.506***	0.438***	0.373**	0.451***
	(0.126)	(0.082)	(0.128)	(0.161)	(0.189)	(0.171)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	7,602	7,602	7,602	2,172	2,172	2,172
R^2	0.023	0.022	0.023	0.007	0.031	0.007

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a panel dataset of the 702 matched patent pairs. Regression results shown in cols 4 through 6 include a 2-period panel dataset of the 702 matched patent pairs (citations three years before and three years after reexamination). The sample is restricted to only those reexamined patents that were reexamined ten years or fewer years after issuance (and their respected matched control patent). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.4: Matching-DiD Results - $\leq$ 10 years

C.3.3 Regression Results - Non-litigated Patents

	Dependent variable:					
	Full Sample			Single Reexam.		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.572***	0.098	0.503***	0.398*	0.239	0.411*
	(0.158)	(0.093)	(0.161)	(0.218)	(0.219)	(0.227)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	5,208	5,208	5,208	1,488	1,488	1,488
R^2	0.024	0.020	0.023	0.005	0.034	0.005

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a subset of the main sample. Regression results shown in cols 4 through 6 include a 2-period panel of the non-litigated matched patent pairs (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those reexamined patents that had never been litigated (and their matched pairs). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.5: Matching-DiD Results - Non-litigated Patents - Main Results

	Dependent variable:					
		Full Sample			2-Period	
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.568***	0.097	0.504***	0.390*	0.240	0.403*
	(0.159)	(0.094)	(0.162)	(0.220)	(0.221)	(0.229)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	5,152	5,152	5,152	1,472	1,472	1,472
R^2	0.024	0.020	0.023	0.004	0.034	0.005

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a subset of the main sample. Regression results shown in cols 4 through 6 include a subset of the main 2-period sample (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those reexamined patents that had never been litigated and were reexamined only once (and their matched pairs). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.6: Matching-DiD Results - Non-litigated Patents - Single Reexam.

	Dependent variable:					
		Full Sample			2-Period	
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	1.251***	0.468*	1.087**	0.905*	1.103*	0.999**
	(0.433)	(0.260)	(0.445)	(0.484)	(0.639)	(0.502)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	756	756	756	216	216	216
R^2	0.081	0.063	0.080	0.040	0.089	0.047

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a subset of the main sample. Regression results shown in cols 4 through 6 include a subset of the main 2-period sample (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those reexamined patents that had never been litigated and are in the NBER Electrical and Electronics classification (and their matched pairs). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.7: Matching-DiD Results - Non-litigated Patents - NBER: Electrical and Electronics

	Dependent variable:					
		Full Sample			2-Period	
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.387	−0.218	0.327	−0.094	0.040	−0.134
	(0.334)	(0.209)	(0.339)	(0.382)	(0.472)	(0.414)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	1,176	1,176	1,176	336	336	336
R^2	0.033	0.047	0.030	0.0004	0.034	0.006

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a subset of the main sample. Regression results shown in cols 4 through 6 include a subset of the main 2-period sample (citations three years before and three years after reexamination). Both sets of regressions are restricted to only those reexamined patents that had never been litigated and are in the NBER Drugs and Medical classification (and their matched pairs). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.8: Matching-DiD Results - Non-litigated Patents - NBER: Drugs and Medical

C.3.4 Parallel Trends Figures - Alternative Matching Methods - Cumulative Citations

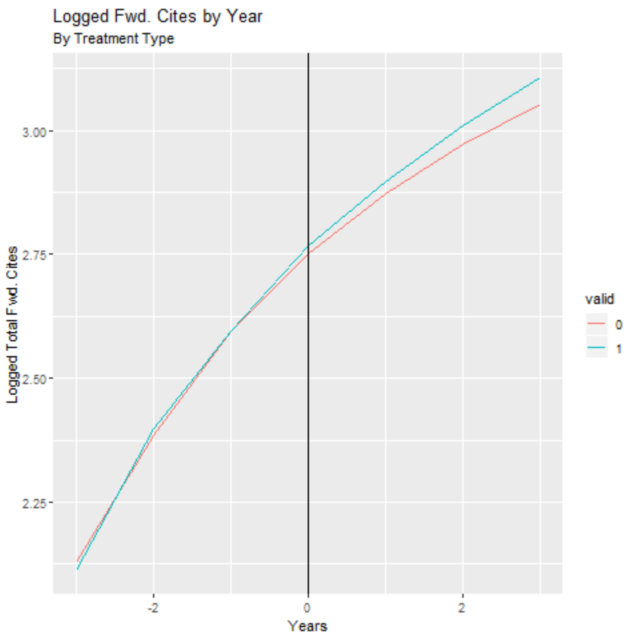


Figure C.3: Logged Total Forward Citations - Treatment and Control Groups

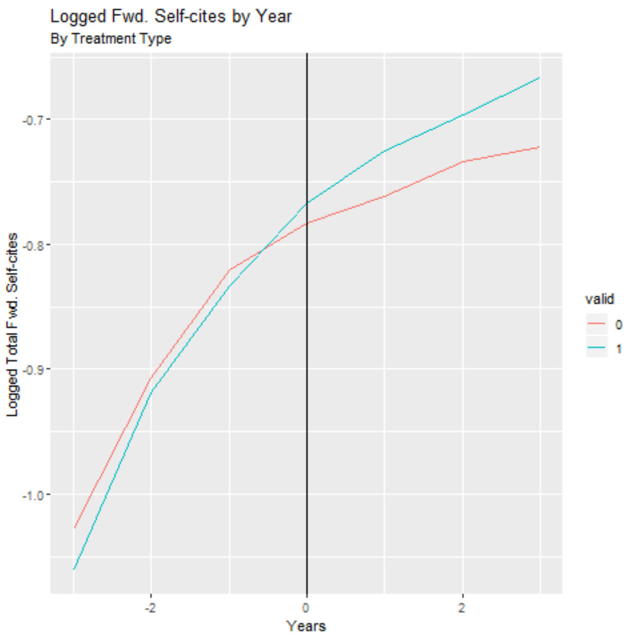


Figure C.4: Logged Total Forward Self-citations - Treatment and Control Groups

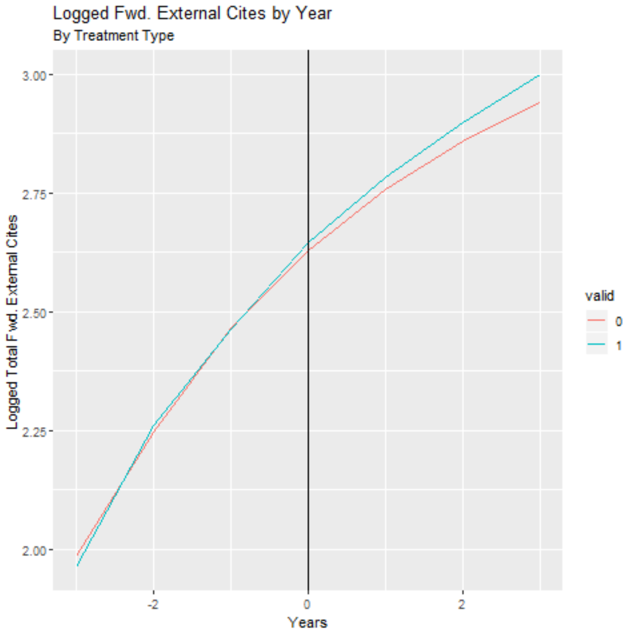


Figure C.5: Logged Total Forward External Citations - Treatment and Control Groups

C.3.5 Regression Results - Alternative Matching Methods - Cumulative Citations

	Dependent variable:
	Reexamination
Ln Forward Citations (t-1)	−0.003
	(0.010)
Small Entity	0.013
	(0.031)
Family Count	0.006
	(0.005)
ICC	−0.001
	(0.005)
ICL	−0.0001
	(0.0002)
Ln Backcites	0.001
	(0.001)
Obs.	1,404
R^2	0.003

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regressions include the 702 matched patent pairs. The dependent variable is an indicator variable equal to one if the observation was successfully confirmed through reexamination and zero otherwise. Robust standard errors are presented in parentheses.

Table C.9: Probability of Treatment (Matched Set) - Alternative Matching

	Dependent variable:					
	Full Sample			Single Reexam.		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.033**	0.056***	0.038**	0.030**	0.057***	0.035**
	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)
Obs.	9,828	9,828	9,828	9,562	9,562	9,562
R^2	0.506	0.110	0.496	0.504	0.111	0.494

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a panel dataset the 702 matched patent pairs. Regression results shown in cols 4 through 6 include only the reexamined patents that had been reexamined once and their respective matched non-reexamined patent. The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains year, patent, and period fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.10: Matching-DiD Results - Alternative Matching

	Dependent variable:					
		Mechanical			Computers	
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.077*	0.059*	0.089*	0.044**	0.046*	0.044**
	(0.047)	(0.032)	(0.050)	(0.019)	(0.024)	(0.020)
Obs.	1,330	1,330	1,330	2,492	2,492	2,492
R^2	0.452	0.106	0.449	0.489	0.115	0.464

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a panel dataset for reexamined patents (and the respective matches) in the Mechanical NBER technology classification. Regression results shown in cols 4 through 6 include a panel dataset for reexamined patents (and the respective matches) in the Computers and Communications NBER technology classification. The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains year, patent, and period fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.11: Matching-DiD Results - Mechanical & Computer - Alternative Matching

	Dependent variable:		
	Total	Internal	External
	(1)	(2)	(3)
Treatment	0.004	−0.003	0.025
	(0.032)	(0.034)	(0.035)
Obs.	2,002	2,002	2,002
R^2	0.598	0.116	0.581

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a panel dataset for reexamined patents (and the respective matches) in the Drugs and Medical NBER technology classification. The dependent variable are defined as the number of all (1), internal (2), and external (3) forward citations. Each regression contains year, patent, and period fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.12: Matching-DiD Results - Drugs Medical - Alternative Matching

	Dependent variable:					
		$\leq$ 10 years			> 10 Years	
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.034*	0.050***	0.044**	0.032**	0.075***	0.020
	(0.018)	(0.018)	(0.019)	(0.013)	(0.018)	(0.013)
Obs.	7,602	7,602	7,602	2,226	2,226	2,226
R^2	0.527	0.125	0.517	0.562	0.062	0.569

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols 1 through 3 include a panel dataset for reexamined patents (and the respective matches) where the patent was reexamined ten years or less after grant. Regression results shown in cols 4 through 6 include a panel dataset for reexamined patents (and the respective matches) where the patent was reexamined greater than ten years after grant. The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains year, patent, and period fixed effects. Standard errors are presented in parentheses and are clustered by patent.

Table C.13: Matching-DiD Results - Years Between Issuance and Reexamination - Alternative Matching

C.3.6 Regression Results - Abadie and Spiess (2019) Standard Errors

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.505***	0.134*	0.454***	0.397***	0.250*	0.416***
	(0.117)	(0.075)	(0.119)	(0.129)	(0.150)	(0.136)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	9,828	9,828	9,828	2,808	2,808	2,808
R^2	0.028	0.018	0.027	0.006	0.025	0.006

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols. 1 through 3 include an annual panel dataset of the 702 matched patent pairs. For cols. 1 through 3, the sample size includes seven years of observation for each patent (1404 focal patents - 702 matched pairs). Regression results shown in cols. 4 through 6 include a 2-period panel dataset of the 702 matched patent pairs (citations three years before and three years after reexamination). For cols. 4 through 6, the sample size includes 2 periods of observation (three years before and after) for each patent (1404 focal patents - 702 matched pairs). The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by "validated" patent, allowing for estimators that are robust to misspecification (Abadie and Spiess 2019).

Table C.14: Matching-DiD Results - All Patents - Abadie and Spiess (2019) Standard Errors

	Dependent variable:					
	Full Sample			2-Period		
	Total	Internal	External	Total	Internal	External
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.572***	0.098	0.503***	0.398**	0.239	0.411**
	(0.179)	(0.103)	(0.183)	(0.200)	(0.216)	(0.207)
Period FE	Yes	Yes	Yes	No	No	No
Post FE	No	No	No	Yes	Yes	Yes
Obs.	5,208	5,208	5,208	1,488	1,488	1,488
R^2	0.016	0.016	0.012	0.005	0.034	0.005

Significant at * p<0.1, ** p<0.05, *** p<0.01. Regression results shown in cols. 1 through 3 include an annual panel dataset of the 702 matched patent pairs. For cols. 1 through 3, the sample size includes seven years of observation for each non-litigated patent. Regression results shown in cols. 4 through 6 include a 2-period panel dataset of the non-litigated matched patent pairs (citations three years before and three years after reexamination). For cols. 4 through 6, the sample size includes 2 periods of observation (three years before and after) for each non-lititgated patent. The dependent variable are defined as the number of all (cols. 1 and 4), internal (cols. 2 and 5), and external (cols. 3 and 6) forward citations. Each regression contains grant year and patent fixed effects. Standard errors are presented in parentheses and are clustered by "validated" patent, allowing for estimators that are robust to misspecification (Abadie and Spiess 2019).

Table C.15: Matching-DiD Results - Non-litigated Patents - Abadie and Spiess (2019) Standard Errors

C.3.7 Parallel Trends Figures - Full Sample Differences-in-Differences

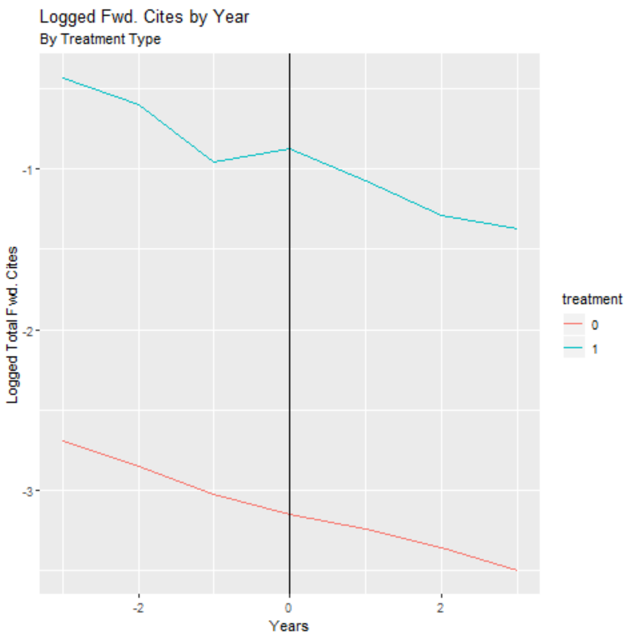


Figure C.6: Logged Annual Forward External Citations - Treatment and Control Groups - Full Sample DiD

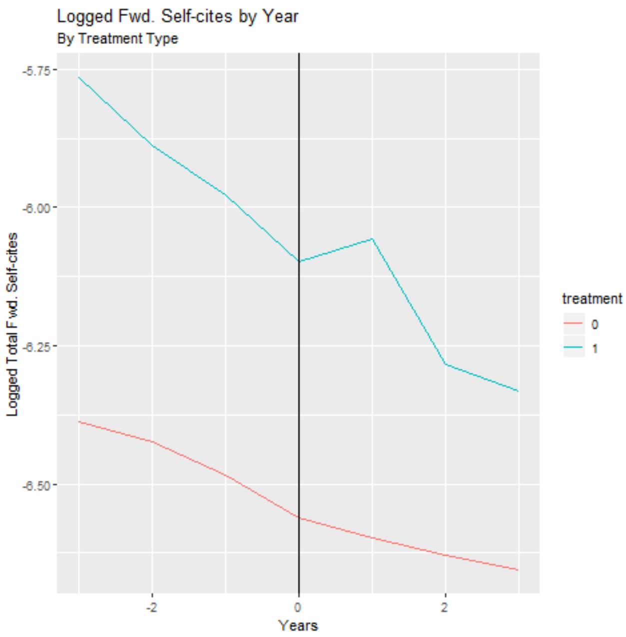


Figure C.7: Logged Annual Forward Self-citations - Treatment and Control Groups - Full Sample DiD

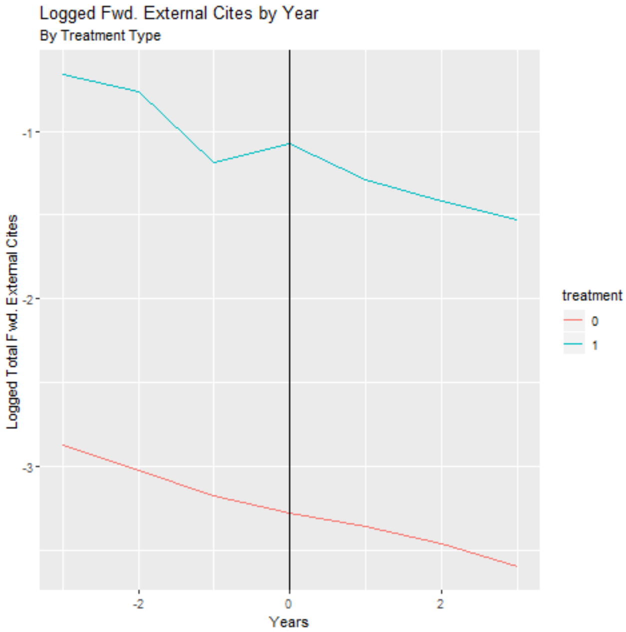


Figure C.8: Logged Annual Forward External Citations - Treatment and Control Groups - Full Sample DiD

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