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Abstract

Patents are monopolies granted to inventors in order to promote innovation, but they have a limited term because they also impose social costs. There is little empirical research on what constitutes an optimal patent term, or whether patent term should vary across industry categories.

We take a first step in studying these issues by examining cross-industry differences in patent term sensitivity. We take advantage of a change in law—the passage of the TRIPS agreement in 1994—that caused patent term to be measured from the date a patent application was filed rather than the date the patent was granted, thereby reducing patent term by the amount of time an application was pending before the U.S. Patent and Trademark Office. Using a new dataset, we determine what portion of this delay is attributable to the applicant for 307,597 issued patents filed in 1994-1996. This shows, for the first time, how patent applicants in different industries sped up their prosecution behavior in response to the change in law, which gives us a measure of industry sensitivity to patent term change.

We predict, via a formal model, that patent applicants in industries with higher profits toward the end of patent term are the applicants most likely to speed up patent prosecution after TRIPS. Our results show that pharmaceuticals patentees sped up patent prosecution significantly, which accords with prior theory on the primacy of patents in this industry. We find, however, that software patentees also significantly sped up prosecution, which is unexpected given prior theory suggesting patents are less important in spurring software development.

Additionally, our paper exploits another, separate aspect of the legal change that gave some firms longer patent term extensions vis-à-vis others. We perform an event study and find that firms receiving longer extensions tended to have higher market returns. We obtain similar results using a new empirical technique known as regression kink design, which addresses potential selection issues.

Finally, we test for and find a high degree of correlation between our two new measures of patent term sensitivity. This high correlation helps validate our formal model, suggesting that patentees in industries most likely to receive higher profits toward the end of patent term were the ones most sensitive to the change in patent term rules.

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1 Introduction

Technological innovation in products and processes has been a driving force in economic growth over the past five centuries (North 1981). Empirical evidence shows that such innovation can sometimes be incentivized by patents, which reward inventors with monopoly profits over their creations (Mansfield 1986). But it is not clear whether all patents are created equal – that is, patents may play a greater role in incentivizing innovation in some industries as compared to others. If an inventor would innovate regardless whether he receives monopoly power, the economic rationale for awarding him a patent would be much weaker. Accordingly, an optimal patent system might provide different levels of patent protection across industries or based on the characteristics of the underlying invention (Devlin and Sukhatme 2009).

A particularly important consideration is patent term. The monopoly power granted to a patentee does not last forever; it expires after a number of years. How does the length of patent term affect innovation? Do these effects vary across industries? Or put another way, do patentees in different industries have different sensitivities to patent term? The answers to these questions are important inputs in designing an optimal patent system.

In this paper, we use a natural experiment to measure patentees’ sensitivity to patent term. On December 8, 1994, the United States ratified The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), which, for the first time in over 130 years, changed the way patent term was calculated. Prior to TRIPS, a patent had a 17-year fixed term that began on the date it was granted by the U.S. Patent and Trademark Office (“PTO”). The date on which an inventor filed the patent application did not affect patent term. TRIPS, however, specified that patents filed on or after June 8, 1995, had a 20-year term that began from the date the inventor applied for the patent. After TRIPS, the time that a patent was pending before the PTO (known as “prosecution time”) reduced the total patent term that a patentee would receive. So a patent with a longer prosecution time received a shorter effective patent term than a patent with a shorter prosecution time.

We exploit this change in law to measure changes in applicant behavior across different industries. In particular, we examine how patentees in different industries changed the amount of time spent in patent prosecution in response to TRIPS. A patent applicant who especially cares about patent term would be more likely to speed up patent prosecution vis-à-vis a patent applicant who cares less about patent term. We formalize this intuition in a model, which predicts that patent applicants in industries with higher profits toward the end of patent term are the applicants most likely to speed up patent prosecution after TRIPS.

As we care how patent applicant behavior changed, we require a good measure of prosecution time attributable to the applicant (as compared prosecution time attributable to the PTO), both before and after the change in law. To do this, we construct a new dataset based on the transaction histories of 307,597 issued
patents filed between 1994 and 1996 in order to create the first measure of applicant prosecution time. In particular, for each of these patent applications, we apportion prosecution time between the applicant and the PTO. We link this data with patent-level data provided by the National Bureau of Economic Research (NBER) and test whether applicant prosecution time changed as a result of TRIPS. We also look at the differential impact of the change in law across industries.

Our empirical results support previous theory, with a few surprises. Previous scholars have suggested that pharmaceutical patentees should be especially sensitive to patent term, given the primacy of patents in that industry and the lengthy regulatory approval process for drugs (Grabowski 2002). Our results suggest this is correct, as drug companies were more likely to speed up patent prosecution in response to the change in law than inventors in most other categories. Scholars have also suggested that software and electronics are less sensitive to patent term, as these industries are characterized by rapid development and obsolescence cycles (Wagner 2006). Our results suggest this theory might not reflect actual applicant behavior: software and electronics patentees appeared more likely to speed up patent prosecution than other groups, indicating that they care more about patent term than previously suggested by scholars.

In the final section of the paper, we further exploit the change in law to provide a rough estimate of the value of patent term extensions as measured in equity markets. We take advantage of the fact that in addition to changing patent term prospectively for new patentees, TRIPS allowed patentees of already issued but not-expired patents to claim a term that was the longer of 17 years from patent issuance and 20 years from patent filing. As such, the law extended patent term for already-issued patents whose prosecution time happened to be less than three years. Using patent data provided by NBER and linked to Compustat (Hall et al. 2001), we perform an event study around December 8, 1994 (the date TRIPS was ratified). Our results suggest that equity prices increased more for firms receiving longer extensions (i.e., those who benefited more from the change in law) as compared to those who received shorter extensions. We also account for heterogeneity in patent values through the use of patent citation weights, which previous scholars have used as a proxy for measuring patent value (Abrams 2009, Jaffe et al. 1993, Trajtenberg 1990).

In addition, we use a recently developed empirical technique known as regression kink design (“RKD”), pioneered by Card et al. 2012, to derive an independent estimate of the value of patent term extension. An advantage of RKD is that it allows us to address potential selection issues related to prosecution time in the underlying patents, similar to the benefits that regression discontinuity confers in other empirical settings. Using RKD, we obtain similar estimates as in our event study.

Finally, we test for and find a high degree of correlation between our two new measures of patent term sensitivity. As noted, our first measure examines how applicants in different industries sped up prosecution after TRIPS; our second
measure estimates the value of additional patent term across different industries using stock market data. The high correlation between our two measures helps validate our formal model, suggesting that patentees in industries most likely to receive higher profits toward the end of patent term were the ones most sensitive to the change in patent term rules.

2 Patent Term and Innovation

Patents incentivize invention by enabling patentees to monetize and otherwise capture the value of their creations. During the term of a patent, no one can make, use or sell a product containing the invention or perform a method covered by the patent without the patentee’s approval. Without patents, another individual could copy an invention immediately after it became public. Knowing this, the inventor might refrain from producing the invention in the first place, and society would be worse off. So patents can improve social welfare by encouraging the production of new inventions.

Patents also generate a number of costs. These costs certainly include the deadweight loss caused by heightened monopoly pricing. But patents can generate other, less apparent, social costs as well. Too many patents in a technological area increases the risk of inadvertent infringement and can lead to patent thickets, where multiple parties have overlapping sets of patent rights (Shapiro 2001). This can cause holdup problems for new innovators, since those seeking to commercialize a new technology must obtain licenses from multiple patentees (Farrell et al. 2007). Additionally, the uncertainty and high costs associated with patent litigation, even if the underlying patent is weak or actually invalid, can stifle investment and innovation. In particular, suits by patent “trolls” – entities that do not develop technology and acquire patents solely to sue target companies and extract monopoly rents – are a wasteful byproduct of the patent system (Bessen et al. 2012).

One way in which the patent system balances the costs and benefits of patents is by limiting their term. Indeed, Western society has long used patent term to strike this balance. For example, inventors in the ancient Greek city of Sybaris were allowed to collect all profits of any new refinement in luxury, but this right was limited to one year (Anthon 1841). More recently, the U.S. Constitution recognized this balance between incentivizing invention and limiting patent duration, as Article 1, Section 8 authorized Congress, “To promote the Progress of Science and useful Arts, by securing for limited Times to ... Inventors the exclusive Right to their ... Discoveries.”

Despite the long tradition of term limits on patent rights, it is unclear what constitutes an optimal patent term. From a social welfare perspective, a patent should be valid only as long as necessary to incentivize invention and no longer, as a longer term only serves to provide excess monopoly rents to the patentee and incurs the costs described above. And if an invention would be produced even
in the absence of patent protection, then it should not receive patent protection at all (Devlin and Sukhatme 2009).

So an important unanswered question is: what patent terms optimally balance the benefits and costs associated with patents? And is the current system optimal? There are reasons to doubt this is the case, in the United States or elsewhere.

First, with just a few exceptions, all inventions receive the same patent term, regardless of the industry in which they are situated. Whatever one’s position might be on what constitutes optimal patent length or whether patents are even necessary, it seems unlikely that very different inventions would optimally receive the same protection for the same amount of time. In some industries, a patent might outlive the usefulness of its underlying invention. For example, in a fast-moving technological field, an invention that is patented might be obsolete well before the end of its term. Such an invention will not yield any profits from sales in the last years of its patented life.

In other technological fields, however, every day of patent term might mean millions of dollars to a company. The paradigmatic example of this is pharmaceuticals – due to the long regulatory approval process before the Food and Drug Administration, a drug may not even be salable for years into its patent term. Indeed, much of the profit for the drug might be obtained in the very last years of its patent term.

So it seems plausible that in an ideal world, the length of patent term would be tailored across different industries. Industries with very high fixed costs, slow obsolescence or long regulatory delays would feature longer patent terms than industries with lower fixed costs, fast obsolescence and no regulatory delays.

Second, the length of patent term is changed very rarely, suggesting it is not updated in response to changes in technology, society or the legal system. For example, in the United States, Congress established the patent system in the Patent Act of 1790, which established a term of 14 years from the date a patent issued. Since then, the baseline term for a patent has changed only three times: 1836 (increase to 21 years from patent issuance), 1861 (decrease to 17 years from patent issuance), and 1995 (20 years from patent application date). Clearly, many technological, societal and legal changes have occurred since the founding of the United States, yet the baseline patent term has changed only three times.

So it seems likely that the length of patent term under existing law may not be optimal, particularly when comparing terms across industries. To find out

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1Congress has allowed some subcategories of inventions to have slightly longer patent terms, to account for time lost in regulatory approval before the PTO or another federal agency. For example, the Drug Price Competition and Patent Term Restoration Act of 1984 ("Hatch-Waxman Act") allowed certain “pioneer drugs” to receive patent term extensions equal to one-half of the time they spend in the investigational new drug period before the Food and Drug Administration. The American Inventors Protection Act of 1999 (35 U.S.C. § 154(b)) enabled patentees to recover some patent term for applications that take too long to process by the PTO. And Congress on occasion passes bills that extend terms on particular patents after being lobbied by the companies who own those patents.
whether this is actually true, we need to know the sensitivity of inventors across different industries to changes in patent term.

Unfortunately, few empirical papers have focused on the impact of patent term on innovation, let alone the sensitivity of applicants to changes in patent term. The principal exception is Abrams 2009, which was the first paper to test how changes in patent term caused by TRIPS affected innovation in different industries. Abrams noted that average total pendency (time between patent application filing and patent issuance) was less than three years, with certain patent classes having shorter average pendencies than others. Accordingly, he suggested that these patent classes would benefit disproportionately from the change in law, since they would receive longer patent term extensions on average due to the change in patent term rules brought by TRIPS. He showed that innovation, as measured by unweighted and citation-weighted patent application counts, in fields with lower pendency increased disproportionately after TRIPS relative to application counts in fields with longer prosecution times.

Abrams 2009 set the stage for the present paper. In particular, our paper tests a prediction made by Lemley 1994, which is that after TRIPS, patent applicants would speed up patent prosecution. Prior to TRIPS, patent term was a fixed 17-year term measured from the date on which the PTO granted the patent application. After TRIPS, patent terms were 20 years, measured from the date the inventor applied for the patent. Figure 1 on the following page illustrates how patent term changed for patents with two and four-year prosecution times, respectively. Regardless whether patent prosecution took two years or four years, patent term remained 17 years before TRIPS went into effect. However, after TRIPS, every day of patent prosecution decreased patent term by one day. So if patent prosecution took two years, then a patentee would have 18 years of effective patent life, whereas if prosecution took four years, then a patentee would have only 16 years of effective patent life.

As Figure 1 indicates, patent prosecution is a back-and-forth process between the applicant and the PTO – at some points in time, it is the applicant’s turn to act and at others, it is the PTO’s. Hence, the time that a patent is pending can be apportioned between the applicant and the PTO.

Lemley’s prediction regarding changes in patent prosecution speed has remained untested until now, since there was no way to determine what portion of prosecution time could be attributed to an applicant. We are the first paper to test his hypothesis because we are the first to apportion, between the applicant and the PTO, the time between patent application filing and patent issuance.

As discussed in more detail, our results strongly validate Lemley’s prediction and suggest that applicants did indeed respond to the change in law by speeding up prosecution. That this change in applicant behavior varied across industries is what allows us to measure cross-industry patent term sensitivities. In particular, industries in which patent applicants sped up prosecution more can be viewed as more sensitive to patent term; industries in which applicants sped up prosecution less might be viewed as less sensitive.
Figure 1: Effect of TRIPS on patent term

Pre-TRIPS

Filed: 2 years
Issues: 4 years
Time patentee can sue: 17 years
19 years
Ends

Filed
Issues
20 years
Ends

Post-TRIPS

Filed: 2 years
Issues: 4 years
Time patentee can sue: 18 years
20 years
Ends

Filed
Issues
20 years
Ends

= PTO
= Applicant
Before proceeding to the empirics, however, it is useful to model applicants’ decisions regarding their choice of prosecution time. This helps us understand how TRIPS changed the behavior of patent applicants, and it is the subject of the next section.

3 Model of Patent Prosecution Time

In a simple model, a firm \(i\) in industry \(j\) files a patent application and chooses the amount of time, \(\tau\), it spends prosecuting this application. We assume that the firm’s total cost of getting a patent through the patent office is a function of \(\tau\) as well as three parameters: an industry-specific fixed cost, \(s_j\), and two firm-specific parameters that influence how costs evolve over time \(\alpha^i_0\) and \(\alpha^i_1\). The industry-specific component, \(s_j\), captures the fact that patenting in certain industries requires more prosecution time than patenting in others, perhaps due to heightened technical complexity or the prevalence of prior art that makes obtaining a patent more difficult. The firm-specific parameters capture firm-specific behavior that might influence the level and evolution of patent prosecution costs. As a first pass, we assume a flexible quadratic specification for the cost function, with industry-specific parameter \(s_j > 0\) and individual-specific parameters \(\alpha^i_0 > 0\) and \(\alpha^i_1 < 0\):

\[
C^i_j(\tau; \alpha^i_0, \alpha^i_1, s_j) = \alpha^i_0 + \alpha^i_1 \tau + s_j \tau^2
\]  

This functional form reflects a reality for many patentees—total prosecution costs tend to increase as a patent application is pending, but a patentee who acts very quickly in prosecution also incurs heightened costs. Prosecution costs are minimized at some \(\tau > 0\). Figure 2 on the next page illustrates what a firm’s prosecution costs might look like as a function of \(\tau\).

3.1 Model with Patent Revenue Independent of Prosecution Time

We begin with the situation where a firm’s revenue from a patent does not depend on the time that was spent prosecuting the patent application. This was how things were in the United States prior to TRIPS, when patent term was always 17 years as measured from the date of issuance. Accordingly, in such a situation, the optimal choice of \(\tau\) is the one that minimizes prosecution costs. We solve for the optimal prosecution time \(\tau^*_{i,old}\), by taking the first order condition of the cost function, which yields:

\[
\tau^*_{i,old} = -\frac{\alpha^i_1}{2s_j}
\]  

We can see that \(\tau^*_{i,old} > 0\), since \(s_j > 0\) and \(\alpha^i_1 < 0\). As industry-specific fixed costs \(s_j\) increase, \(\tau^*_{i,old}\) decreases, reflecting the fact that a larger quadratic
Figure 2: Example relationship between prosecution cost and time

The steepness of the curve (corresponding to heightened prosecution costs in a particular industry), will cause applicants to prosecute applications quicker. Additionally, as the firm-specific parameter $\alpha^*_i$ becomes more negative, $\tau^*_{i,old}$ increases. This reflects the fact that a more negative linear term means that the firm can lower costs quicker by slowing down prosecution, which drives down the firm-specific cost $\alpha^*_i$ that it would pay if $\tau=0$.

3.2 Model with Patent Revenue Dependent on Prosecution Time

Next we see how the firm’s behavior changes once patent revenue becomes dependent on the amount of time the firm spends in patent prosecution. This became the situation in the United States after TRIPS went into effect. In particular, as prosecution time $\tau$ increases, effective patent term decreases, since the beginning of the fixed patent term is measured from the application filing date. Accordingly, we must also model a firm’s revenue in order to predict what the firm’s optimal prosecution time would be.

Similar to costs, we assume that a firm’s revenue from a patent at a particular time is a function of three parameters: an industry-specific fixed-effect, $z_j$, and two firm-specific revenue depreciation parameters, expressed by $\beta^*_1$ and $\beta^*_2$. Let $T$ be the total potential patent term for a patent (in the context of the United States, after TRIPS, $T = 20$). The effective patent term is then $T - \tau - \tau_{PTO}$, where $\tau_{PTO}$ represents delays in prosecution attributable to the patent office.
Once again we assume a flexible quadratic form for the firm’s revenue from the patent at time $t$:

$$\pi_j^i(t; \beta_1^i, \beta_2^i, z_j) = z_j + \beta_1^i t + \beta_2^i t^2$$

We assume that $\beta_1^i > 0$ and $\beta_2^i < 0$, which accords with the common situation in which a firm’s revenues from patents increase in the beginning, peak after some point, and then decrease in the long-run due to technology obsolescence or some other factor. As a simplifying assumption, we assume that each patent in a particular industry starts off producing the same revenue $z_j \geq 0$, but then individual-specific effects $\beta_1^i$ and $\beta_2^i$ cause the patents to produce different revenues over time. Figure 3 shows an example of a revenue curve.

![Figure 3: Example of patent revenue evolution over time](image)

The goal is to find optimal $\tau$, denoted $\tau_{i,\text{new}}^{j*}$, which is the solution to the following:

$$\tau_{i,\text{new}}^{j*} = \arg \max_{\tau} \int_0^{T-\tau-\tau_{\text{PTO}}} \pi_j^i(t; \beta_1^i, \beta_2^i, z_j) dt - C_j^i(\tau; \alpha_1^i, \alpha_2^i, s_j)$$

We see that marginal profit of the patent will equal marginal cost of prosecution at the optimal $\tau_{i,\text{new}}^{j*}$. Applying Leibniz integral rule when differentiating, we see $\alpha_1^i + 2s_j \tau_{i,\text{new}}^{j*} = -\pi(T - \tau_{i,\text{new}}^{j*} - \tau_{\text{PTO}}; \cdot)$. By adding and subtracting $2s_j \tau_{i,\text{old}}^{j*}$ on the left-hand side, we can see:
\[ \alpha_i + 2 s_j \tau^{j*}_{i,old} + 2 s_j \left( \tau^{j*}_{i,new} - \tau^{j*}_{i,old} \right) = -\pi(T - \tau^{j*}_{i,new} - \tau_{PTO}; \cdot) \]

\[ \leftrightarrow \tau^{j*}_{i,new} = \tau^{j*}_{i,old} - \frac{\pi(T - \tau^{j*}_{i,new} - \tau_{PTO}; \cdot)}{2 s_j} \] (5)

because \( \alpha_i + 2 s_j \tau^{j*}_{i,old} = 0 \). Since \( \pi(T - \tau^{j*}_{i,new} - \tau_{PTO}; \cdot) \geq 0 \) and \( s_j > 0 \), this implies \( \tau^{j*}_{i,new} \leq \tau^{j*}_{i,old} \).

So we can see that patent applicants will speed up patent prosecution when patent revenue depends on prosecution time. The amount that they speed up will depend on: (1) \( \pi(T - \tau^{j*}_{i,new} - \tau_{PTO}; \cdot) \), the profits they lose at the end of their term because of delay; and (2) \( s_j \), the quadratic term in their cost function, which determines how quickly their prosecution costs increase as a function of time.

This leads to testable predictions in terms of applicants’ response to TRIPS. We should expect that on average, patent applicants will speed up prosecution after TRIPS relative to before. In particular, applicants in industries that yield more profits toward the end of patent term (e.g., the right hand tail of the profit function shown in Figure 3 on the previous page is thicker) will speed up prosecution more than applicants in industries where inventions lose value quicker and patents are relatively valueless toward the end of term. The reason for this is intuitive: industries where patents generate more revenue toward the end of term have more to lose by decreases in patent term; hence, they will be more likely to speed up patent prosecution in response to TRIPS.

The empirical portion of our paper ties together the two pieces of this model. In the following section, we measure how patentees in different industries varied in terms of speeding up patent prosecution in response to TRIPS. In the final section, we measure how additional patent term was valued across these same industries, as measured by market returns. We find that our two measures of patent term sensitivity are highly correlated, thereby providing support for our model.

4 Measuring Applicant Delay in Patent Prosecution

4.1 Dataset and Empirical Strategy

Our model predicts that, to the extent patent applicants care about patent term, they will speed up patent prosecution after TRIPS relative to their prosecution speed before. If an applicant particularly cares about patent term – in particular, if the applicant cares about the additional days, months or years of patent
term that are lost as patent prosecution is extended – then we would expect an applicant to speed up patent prosecution relative to an applicant who does not care about the additional term.

Measuring changes in patent applicant behavior requires us to measure how long an applicant takes to prosecute a patent application. To do this, we use data compiled by Google on the USPTO’s Public PAIR (Patent Access Information Retrieval) system. PAIR includes public information on all issued patents including their transaction history, which details every substantive or procedural action taken by the applicant or the PTO. A sample transaction history is shown in Figure 4.²

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>27. 10-13-2011</td>
<td>Change in Power of Attorney (May Include Associate POA)</td>
</tr>
<tr>
<td>25. 07-22-1998</td>
<td>Preexamination Location Change</td>
</tr>
<tr>
<td>24. 07-02-1996</td>
<td>Recordation of Patent Grant Mailed</td>
</tr>
<tr>
<td>23. 05-28-1996</td>
<td>Issue Notification Mailed</td>
</tr>
<tr>
<td>22. 04-15-1996</td>
<td>Issue Fee Payment Verified</td>
</tr>
<tr>
<td>21. 03-13-1996</td>
<td>Power to Make Copies and/or Inspect</td>
</tr>
<tr>
<td>20. 02-29-1996</td>
<td>Mail Notice of Allowance</td>
</tr>
<tr>
<td>19. 02-29-1996</td>
<td>Notice of Allowance Data Verification Completed</td>
</tr>
<tr>
<td>18. 12-29-1995</td>
<td>New or Additional Drawing Filed</td>
</tr>
<tr>
<td>17. 02-08-1996</td>
<td>Data Forwarded to Examiner</td>
</tr>
<tr>
<td>16. 12-29-1995</td>
<td>Response after Non-Final Action</td>
</tr>
<tr>
<td>15. 12-29-1995</td>
<td>Request for Extension of Time - Granted</td>
</tr>
<tr>
<td>13. 09-05-1995</td>
<td>Non-Final Rejection</td>
</tr>
<tr>
<td>12. 07-06-1995</td>
<td>Date Forwarded to Examiner</td>
</tr>
<tr>
<td>11. 06-12-1995</td>
<td>Response to Election / Restriction Filed</td>
</tr>
<tr>
<td>10. 05-10-1995</td>
<td>Mail Restriction Requirement</td>
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<tr>
<td>9. 05-10-1995</td>
<td>Restriction/Election Requirement</td>
</tr>
<tr>
<td>8. 02-27-1995</td>
<td>Case Docketed to Examiner in GAN</td>
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<tr>
<td>7. 12-02-1994</td>
<td>Information Disclosure Statement (IDS) Filed</td>
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<td>6. 12-02-1994</td>
<td>Information Disclosure Statement (IDS) Filed</td>
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<td>5. 11-14-1994</td>
<td>Information Disclosure Statement (IDS) Filed</td>
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<td>4. 11-14-1994</td>
<td>Information Disclosure Statement (IDS) Filed</td>
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<td>3. 01-12-1995</td>
<td>Application Captured on Microfilm</td>
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<tr>
<td>1. 10-05-1994</td>
<td>Notice Mailed—Application Incomplete—Filing Date Assigned</td>
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</table>

The sample transaction history illustrates how we might apportion time between the PTO and the patent applicant. After the patent application is filed, the ball is in the PTO’s court, as the applicant typically waits for the PTO to either issue a rejection, approve the patent claims, or issue something known as a restriction requirement. A restriction requirement is sent by the PTO when an applicant claims more than one “independent and distinct invention in a single application,” and when the patent examiner would face a “serious burden” if forced to examine each of these inventions. Here, the first substantive action taken by the PTO was a restriction requirement, mailed to the applicant on May

²We are already using this data for a number of follow up projects, including the effect of patent examiners on the characteristics of approved patents, and the effect of prevailing economic conditions on the selection of and behavior of patent examiners.
10, 1995. In our data, about 9.1% of patent applications received a restriction requirement at some point during patent prosecution.

In response to a restriction, a patent applicant might traverse, or dispute the restriction, or the applicant might file an election, which means that the applicant has decided to pursue just one of the inventions in the present application and can pursue the other inventions, if desired, in separate continuation applications later. The applicant is generally given one month to respond from the date of mailing of the restriction requirement, although the applicant can pay a fee and request an extension of up to five months, giving him up to a total of six months to respond. In the sample transaction history, we can see that the applicant filed his response within the one-month period, on June 12, 1995.3

After the applicant filed his response, the next substantive action taken by the PTO was a non-final rejection, issued by the PTO on September 15, 1995. In our data, approximately 72.2% of patent applications received a non-final rejection like this at some point during patent prosecution.

To avoid abandonment of the patent application, an applicant is required to respond to such a rejection with an argument and/or an amendment to her patent claims, which define her invention. Applicants are typically given three months from the date a non-final rejection is mailed to file such a response, though they can pay a fee and request an extension of up to three months, giving them up to a total of six months to respond.

Here, we can see that the applicant did not respond by December 15, 1995, the three-month deadline. Instead, the applicant requested and received an extension, and he filed his response on December 29, 1995.

This back-and-forth process with the PTO nicely illustrates three potential ways of measuring applicant delay. First, we can measure the amount of time that an applicant takes to respond to a restriction requirement. Second, we can measure the amount of time that an applicant takes to respond to a non-final rejection.4 And finally, we can measure whether an applicant has requested an extension when prosecuting an application, and if so, the number of extensions he has requested.

After TRIPS, every day that an applicant takes to respond to a PTO action results in one less day of patent term. Prior to TRIPS, this was not the case. So we would expect to see the average response time to non-final rejections and

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3If a response date falls on a weekend or a federal holiday, an applicant can timely file his response on the next business day. Here, the applicant’s response would have been due on June 30, 1995, one month after the mailing of the restriction requirement, but since June 30 was a Saturday the response was in fact due on Monday, June 12, instead.

4Frakes and Wasserman 2013 recently used a related variable, the average amount of time that the PTO takes to issue its first office action, as a measure of delay by the PTO. Their data was annual summary data, disaggregated at the patent class and entity size level (e.g., average amount of time that the PTO took to issue a first office action for large-entity applicants filing patent applications related to cryptography in 1997), and was obtained via Freedom of Information Act requests.
restriction requirements decrease after TRIPS relative to before, with the effect most pronounced in the categories in which inventors are most sensitive to patent term. Relatedly, all else being equal, we should expect to see fewer extensions requested by patent applicants when responding to non-final rejections, since pursuing an extension involves increasing prosecution time and hence decreasing patent term.5

Returning to the sample transaction history, we can see that the patent application here was eventually granted by the PTO. On February 29, 1996, the PTO mailed a notice of allowance to the applicant. A notice of allowance indicates to an applicant that the PTO has found the applicant’s claims suitable for granting. Before the patent can issue, however, the applicant must pay an issue fee.6

An applicant has up to three months to pay an issue fee or else the application is abandoned. After the applicant pays the issue fee, the PTO records payment in the transaction history as “Issue Fee Payment Verified,” which happened here on April 15, 1996. Previous empirical work has indicated that the patent will then issue, on average, about 6-8 weeks later (Crouch June 9, 2010). For our sample, we find that the time between payment of the issue fee and patent issuance is positively correlated (0.2883) with the time between mailing of the notice of allowance and patent issuance. Appendix Figure A.1 on page 47 shows the nearly linear relationship between when the issue fee is paid and the average time when the patent issues.

The amount of time that applicants take to pay an issue fee is a fourth way of measuring applicant sensitivity to patent term. If a patent applicant wants her application to issue quickly after receiving a notice of allowance, she will pay her issue fee quickly. Post-TRIPS, if the applicant cares less about the additional two or three months that she might gain by acting quickly, then she might not hurry in paying the fee. In our sample, about 57.2% of the applicants waited at least 80 days to pay the issue fee prior to TRIPS; 55.2% waited at least 80 days after TRIPS.7

Our theory suggests that applicants who care about the few

---

5For present purposes, we are not considering applicant responses to “final” rejections by the PTO. The reason for this is that applicant responses to such rejections can be quite varied and difficult to categorize. In response to final rejections, applicants might file something called a “continuing prosecution application” – essentially, applicants pay an additional fee to get another crack at prosecuting before the examiner. Alternatively, applicants might file an appeal to the Board of Patent Appeals and Interferences. An applicant might also abandon his patent application. In an extension to our present work, we are examining how applicant responses to final rejections, including their propensity to file continuations and appeals, changed as a result of TRIPS.

6The amount of the issue fee has varied over time and varies depending on whether or not an applicant is a “small entity.” On March 16, 2013, a “micro” entity class was also created as part of the implementation of the America Invents Act, which was passed by Congress and signed into law in late 2011.

It is not totally clear why so many people wait until the end of the term. One possibility is that applicants must file any continuation patent application – new applications with different patent claims that use the same disclosure as a currently pending patent application and obtain the same priority date as that application – before the parent patent application issues. By delaying payment of the issue fee, applicants might be increasing the time for filing such continuation applications. As part of our extension regarding continuations, we plan to
days or months they could gain from acting faster regarding payment of issue fees will speed up their payment of such fees after TRIPS.\textsuperscript{8}

Accordingly, our baseline empirical strategy is clear – look at the average time that patent applicants take in responding to restriction requirements, non-final rejections and in paying their issue fees, and see if this average decreased after TRIPS. Alternatively, we can look at the number of extensions requested post-TRIPS and see if that number decreased. We can also add up the total amount of prosecution time attributable to the patent applicant and see if that decreased as well.\textsuperscript{9}

4.2 Summary Statistics and Non-Parametric Graphs

Before proceeding to our analysis and results, we show some summary statistics and non-parametric graphs that help describe the data. Figure 5 on the following page shows how application pendency – the total time between patent application filing and patent application issuance – and total applicant delay – the measure of applicant delay that we created using a detailed transaction history for each patent – evolve for patent applications filed between 1994 and 1996.

As the graphs show, pendency increased steadily throughout 1994 and into 1995. Meanwhile, total applicant delay remained steady or perhaps even decreased a bit. This suggests that increases in pendency during this time were not due to applicant delays in prosecution. Rather, the PTO was taking longer to examine applications during this time period, while applicants were taking about the same amount of time to prosecute their applications.\textsuperscript{10}

It is somewhat puzzling why applicants have not sped up behavior more in the pharmaceutical context (in the drugs subcategory, 66.7% waited at least 80 days to pay the issue fee pre-TRIPS and 63.4% did the same post-TRIPS). One explanation might relate to the fact that the inventions underlying these patents typically must obtain separate regulatory approval by the Food and Drug Administration. Hence, it may not matter if a pharmaceutical company speeds up patent prosecution, either before or after TRIPS, because it cannot market the product without FDA approval anyway. It is also plausible that continuation applications play a more important role in the pharmaceutical context.

One might note that an applicant may have an incentive to prosecute a patent application quickly even when it does not increase term length. If an applicant cares about receiving a patent sooner rather than later – perhaps because she is trying to obtain a patent as an asset, use it to persuade would-be investors for funding, or simply to advertise or promote the product as “patented” as compared to “patent pending” – then we would expect the applicant to hurry up and not waste time during patent prosecution. This incentive, however, would have existed both before and after the change in law embodied by TRIPS. In other words, if an applicant sped up patent prosecution simply because she wanted to get the patent quickly, not because she cared about patent term, then she would have done so regardless how patent term was calculated. That applicants sped up patent prosecution after TRIPS as compared to before suggests that the real motivator behind the change in behavior was the change in rules regarding patent term.

One possible reason for this delay is that the PTO's workload was growing during this time period because the number of filed applications was increasing in the early 90s, as shown in Appendix Figure A.2 on page 48.
Figure 5: Pendency and Total Applicant Delay for applications from 1994-1996

The left y-axis is in days of total applicant delay; the right y-axis is in days of pendency. ‘0’ represents June 8, 1995, which is when the new TRIPS regime went into effect. The gray area around each line represents 95% confidence interval bands.
As June 8, 1995, approaches, we see a spike in both total applicant delay and application pendency. This spike is suggestive of selection by applicants. TRIPS was signed into law on December 8, 1994. The law provided that any application filed prior to June 8, 1995, would receive the longer of 17 years from patent issuance and 20 years from patent filing. It is quite possible that some applicants took advantage of this provision by choosing to file patent applications with expected longer pendencies prior to the change in law. For example, if an applicant had a portfolio of potential applications that he might file, an applicant might choose to file prior to the law change the applications that he expects would take longer than three years to prosecute. Such applications might involve, for example, more complicated or pioneering inventions that the applicant expects will require more back-and-forth with the PTO, or they might be inventions in a crowded field with other prior art that makes obtaining a patent a longer and more difficult process. The last months before June 8, 1995, would have also been a good chance for applicants to file “submarine patents” – patent applications that inventors keep pending in the PTO for a very long time but receive a full 17-year term when they finally issue. This delay might be intentional, so that when the patent finally emerges from prosecution, it enters an already-mature industry in which competitors must now pay to license the technology. Lemley 1994

We account for this potential selection effect in our regression analysis by excluding in many specifications those patent applications filed between December 8, 1994 and June 7, 1995. As discussed below, our results remain robust to this change.

Looking again at Figure 5, we see that both pendency and total applicant delay drop abruptly after June 8, 1995. Both graphs then become quite stable, with perhaps a slight decrease over time. So the graphs suggest there was a trend break in both pendency and total applicant delay around June 8, 1995. Applicants on average took less time to prosecute their applications after the law change as compared to before, in accordance with the theory discussed above. Pendency also switches from increasing steadily to slightly decreasing.

We might be curious whether this trend break only affects certain categories of inventions, or whether its effect is more widespread. Figures 6 and 7 break down by category changes in applicant delay and pendency, respectively. As we can see, pendency was increasing across all categories prior to the law change. Pendency appears to decrease slightly across most categories after TRIPS goes into effect. Total applicant delay drops significantly, particularly for the Drugs & Medicine and the Computer & Communications categories. The Mechanical and Others categories appear to be the least affected groups, and Electrical and Chemicals fall in the middle. We will discuss these results in more detail in section 4.5 below.

We can also test for a trend break due to TRIPS using non-parametric methods. In Figure 8 on page 19, we show local polynomials with standard error bands that plot total applicant delay relative to time. The polynomial on the left runs
Figure 6: Pendency by category

Figure 7: Total Applicant Delay by category
from January 1, 1994 to June 7, 1995; the polynomial on the right runs from June 8, 1995, to December 31, 1996. As the figure illustrates, there appears to be a break between the two graphs, where the local polynomial after June 8 is significantly lower than the polynomial before June 8.

The left hand polynomial tips upward prior to the cut date, suggesting some applicants may have chosen to file some especially long pending applications during this time. But the break appears to be significant even accounting for this transitory increase. Moreover, total applicant delay drops precipitously after June 8, suggesting that applicants quickly changed their behavior and sped up patent prosecution under the new regime. Indeed, applicants took on average about 10 days less to prosecute their patent applications after TRIPS (drop from about 170 total applicant delay days through most of 1994 to about 158-160 days by the end of 1996).

Figure 8: Local polynomial test for trend break

4.3 Results Using Total Measure of Applicant Delay

To validate the suggestive graphical evidence from the previous section, we present a number of ordinary least squares (OLS) regressions that test how applicant behavior changed around the passage of TRIPS. As shown in Table 1, our preferred measure of applicant behavior, total applicant delay, changed
significantly around the passage of TRIPS. We see this by looking at the coefficient on "Post-TRIPS"- a dummy variable that specifies whether a patent application was filed on or after June 8, 1995, when the new patent term regime went into effect. In our most parsimonious model in column (1), the average amount of delay attributable to the applicant fell by about 2.4 days following the implementation of TRIPS. Column (4) shows that this result holds with the inclusion of fixed-effects, which control for the patentee's country of origin and the patent class of the invention, as coded by the PTO.

Due to possible concerns about selection around the implementation of TRIPS, we also present specifications where we exclude periods during which one might worry most about changed applicant behavior. Our results remain highly significant and of a similar order of magnitude when we exclude either the period between December 8, 1994, and June 7, 1995, (columns (2) and (5)), which is the period between when TRIPS was enacted and when it went into effect, or when we exclude all of the data from 1995 (columns (3) and (6)).

Because an applicant's total delay likely depends on the number of back-and-forth interactions he has with the PTO, we have also included controls for number of non-final office actions and number of restriction requirements for each patent application. The results are robust whether we include these controls or not, or whether we limit to individuals who received at least one non-final office action and/or restriction requirement or not. In short, all of our specifications indicate there was a significant change in applicant behavior to expedite claims through the PTO.

To help visualize the dramatic impact of TRIPS, we can also use a parametric approach to illustrate the trend break, as shown in Figure 9 on page 22. In essence, Figure 9 summarizes the results of 365 regressions using the specification in column (1) above. However, instead of using our post-TRIPS dummy variable (which is "1" for patents filed on or after June 8, 1995, and "0" for patents filed before), we slide the dummy variable day-by-day from January 1, 1995, up to December 31, 1995. So, for example, if we choose a dummy around March 15, 1995, the coefficient on the dummy is about -1, with a 95% standard error band ranging from about -1.5 to -0.5. This means that, controlling for all covariates, patents filed between March 15, 1995, and the end of our sample period were prosecuted for about 1 less day on average than patents filed from the beginning of our sample period up to March 14, 1995.

If we expect that something significant happened on June 8, 1995, then we should expect a significant drop in our dummy coefficient on that date, and that the coefficient would have its lowest value around that time. This is exactly what Figure 9 shows - the precipitous decline in the dummy coefficient coincides directly with the blue line marking the start date of the new patent term regime. Applicants spent about 2.4 fewer days prosecuting patents filed on or after June

\[\text{11} \text{We also tested specifications where we controlled for the amount of delay attributable to the PTO, by subtracting the total applicant delay from the pendency of the application. Our results remained similar and highly significant.}\]
Table 1: Effect of TRIPS on Total Applicant Delay

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Clustered standard errors at patent class-day level in parentheses.

Fixed effects are at patent class and country level.

*** p<0.01, ** p<0.05, * p<0.1
8, 1995 as compared to before, corresponding with the coefficient on post-TRIPS in column (1) of Table 1 on the preceding page.

4.4 Results Using Disaggregated Measures of Patent Delay

To verify these results are a consequence of faster applicant behavior over the entire process of patent prosecution, Tables 2 and 3 present the outcome of similar regression analyses on disaggregated measures of applicant delay. In Table 2 “# of Ext.” and “Extension” are, respectively, the average number of extensions requested and a dummy-variable for whether an applicant ever requested an extension. An extension request (which is nearly always granted) provides an individual extra months to respond to a non-final office action or restriction requirement. So cutting down on extensions is a clear way for an applicant to decrease prosecution time.

Columns (1) through (3) show that the average number of extensions fell by about .03 after TRIPS, from a mean of .41 before the change in law. Columns (4) through (7) present the marginal effects of logistic regressions on whether an applicant applied for at least one extension before and after TRIPS. Once again the results are negative and highly significant, suggesting on average that
the share of applications with an extension fell by one percentage point. These results are consistent with a small percentage of patent applicants who change their behavior due to the change in rules regarding patent term because they highly value the last years or even months of patent duration.

As Table 3 shows, nearly every other measure of applicant delay decreased on average after TRIPS went into effect. “Total OA Resp Time” and “Total Restr. Resp. Time” are the total time a patent applicant took to respond to any non-final office actions or restriction requirements, respectively, that she received conditional on having received one. “Issue Fee Time” is the amount of time that the patent applicant took to pay her issue fee after a notice of allowance was mailed from the PTO.

As predicted by the model, patent applicants sped up their patent prosecution after TRIPS in a broad spectrum of areas. There is reason to believe that these measures, coupled with the measure of extension activity in Table 2, are the most consonant avenues through which many applicants would have delayed in the past. Columns (1) to (3), show that applicants on average took about 1.8 fewer days responding to office actions after TRIPS. Applicants also took about one fewer day paying their issue fee, as is seen in columns (7) to (9). The result remains highly statistically significant with the inclusion of fixed-effects and across different time periods.

The exception to this negative effect is the amount of time that applicants took in responding to restriction requirements, which is insignificant in two of our specifications (columns (4) and (5)) and becomes positive and significant in a third one (column (6)). This was unsurprising to us because the trend in the time to respond to restriction requirements had been increasing rapidly prior to TRIPS. The positive result in column (6) does not mean that there was an increase in this trend. The analysis in both Tables 1 and 3 was simply testing means before and after the implementation of TRIPS—there was no test for a trend-break.

This brings up a larger concern: it is possible that the above results were driven by a downward trend in some of these other variables, and most importantly, our preferred measure: total applicant delay. In other words, perhaps applicants were taking less time to prosecute applications as we moved forward in time during the 1990s. If so, the negative coefficients would be a function of this secular trend, not because of the change in law.

We can control for this possibility by including time variables in our OLS regressions. These specifications, which we show in Table 4 on page 27 help capture any secular trend that might have been occurring independent of the change in law. We do this by including a linear variable for time in one model and a linear and quadratic variable for time in a second model. To test for a break in trend, we also include interactions of time and time*time with Post-TRIPS (time*Post-TRIPS and time*time*Post-TRIPS, respectively) in our original models. Now, the statistic of interest is the F-test which tests for equality between the Post-TRIPS variable and its interactions with time, a continuation of trend. We see
Table 2: Effect of TRIPS on Applicant Requested Extensions

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Marginal effects and pseudo R² reported for logit
Clustered standard errors at patent class-day level in parentheses. Fixed effects at subcategory and country level.
*** p<0.01, ** p<0.05, * p<0.1
that the null hypotheses are rejected handily in all three specifications. This outcome also holds for the individual components of total applicant delay, helping to allay possible concerns about divergent trends having influenced our results.

Additionally, Table A.1 on page 49 in our Appendix shows that adding a time trend to our other measures of applicant delay allows us to reject the null hypothesis in most specifications, including those in which the dependent variable is delay time in response to a restriction requirement. The estimated effect of the change in law on June 8, 1995, can be estimated, and it is generally slightly higher than the coefficients in Table 3 (ranging from about -1 to -5 days).

Taken together, these different measures of applicant delay give a consistent picture: applicants appear to have sped up behavior across a number of different facets of patent prosecution in response to TRIPS. These results are robust to the inclusion of fixed effects for patentee’s country of origin and patent class of invention, controls for number of non-final office actions and restriction requirements received by a patent applicant, and various time trends.

4.5 Cross-Industry Differences in Prosecution Delay

We now see how applicants in different industries varied in their response to TRIPS by speeding up their patent prosecution behavior. When assembling the NBER dataset, Hall et al. 2001 consolidated the over 400 classes used by the PTO to categorize inventions into 37 subcategories and six categories. Figure 10 on page 28 below shows coefficients for the Post-TRIPS dummy variable with standard error bars for these six categories - Chemicals, Computers & Communication, Drugs & Medicine, Electrical, Mechanical, and Others (a residual category). The regression used is our preferred specification as shown in column (6) of Table 1 on page 21 above, where we use total applicant delay as our response variable, and number of office actions, number of restrictions, and fixed effects for country of origin of patentee and patent class. The left hand line for each category is a specification where we use all data from 1994-96; the right hand line is when we exclude time between when TRIPS was passed and when it went into effect (December, 8, 1994, to June 7, 1995).

As Figure 10 on page 28 shows, when using all the data from 1994-96, the largest effect (most significant decrease in total applicant delay) appears to be in the Computers & Communication category, followed by the Drugs & Medicine category and then the Chemical and Electrical categories. The Mechanical and Others categories appear to have been affected very little by TRIPS, suggesting that applicants in these categories are less sensitive to the change in patent term rules.

When excluding the data from December 8, 1994, to June 7, 1995, we see that the result for Drugs & Medicine disappears, but the other results appear similar. This suggests that selection might be particularly important for inventions in the Drugs & Medicine category. It is likely that patentees in this area might
Table 3: Effect of TRIPS on Applicant Delay Measures: Office Action Response Time, Restriction Response Time, and Issue Fee Payment Time

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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>43.61***</td>
<td>43.45***</td>
<td>41.98***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1.613)</td>
<td>(1.772)</td>
<td>(1.970)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>-4.844***</td>
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<td>-1.668**</td>
<td>-9.015***</td>
<td>-9.134***</td>
<td>-8.824***</td>
<td>73.87***</td>
<td>74.18***</td>
<td>74.21***</td>
</tr>
<tr>
<td>(0.551)</td>
<td>(0.592)</td>
<td>(0.655)</td>
<td>(1.655)</td>
<td>(1.815)</td>
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<td>(0.0661)</td>
<td>(0.0649)</td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs.</td>
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<td>187,176</td>
<td>155,262</td>
<td>28,135</td>
<td>24,409</td>
<td>20,072</td>
<td>307,597</td>
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<td>216,166</td>
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<tr>
<td>R-squared</td>
<td>0.532</td>
<td>0.588</td>
<td>0.589</td>
<td>0.101</td>
<td>0.247</td>
<td>0.256</td>
<td>0.001</td>
<td>0.094</td>
<td>0.097</td>
</tr>
</tbody>
</table>

Clustered standard errors at patent class-day level in parentheses. Fixed effects are at patent class and country level. (1)-(3) and (4)-(6) include applicants who received at least one non-final rejection and at least one restriction, respectively. *** p<0.01, ** p<0.05, * p<0.1
Table 4: Effect of TRIPS on Total Applicant Delay with time trend corrections

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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<tbody>
<tr>
<td></td>
<td>Total Delay</td>
<td>Total Delay</td>
<td>Total Delay</td>
</tr>
<tr>
<td>Post-TRIPS</td>
<td>-3.637***</td>
<td>-4.955***</td>
<td>0.938</td>
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<td></td>
<td>(0.806)</td>
<td>(0.837)</td>
<td>(4.191)</td>
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<td>time*Post-TRIPS</td>
<td>-0.000572</td>
<td>0.00788***</td>
<td>0.00271</td>
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<tr>
<td></td>
<td>(0.00135)</td>
<td>(0.00206)</td>
<td>(0.0111)</td>
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<tr>
<td>time<em>time</em>Post-TRIPS</td>
<td></td>
<td></td>
<td>-2.52e-5***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(9.58e-6)</td>
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<tr>
<td>time</td>
<td>0.00333***</td>
<td>-0.00495***</td>
<td>-0.0157***</td>
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<tr>
<td></td>
<td>(0.00104)</td>
<td>(0.00186)</td>
<td>(0.00404)</td>
</tr>
<tr>
<td>time*time</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(7.34e-6)</td>
</tr>
<tr>
<td># OAs</td>
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<td>106.6***</td>
<td>107.3***</td>
</tr>
<tr>
<td></td>
<td>(0.260)</td>
<td>(0.268)</td>
<td>(0.260)</td>
</tr>
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<td>40.15***</td>
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<td>(0.442)</td>
<td>(0.479)</td>
<td>(0.442)</td>
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<td>74.86***</td>
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<td></td>
<td>(0.364)</td>
<td>(0.412)</td>
<td>(0.487)</td>
</tr>
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<td></td>
<td>6/7/95 out</td>
<td></td>
</tr>
<tr>
<td>Fixed Eff.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs.</td>
<td>260,179</td>
<td>216,166</td>
<td>260,179</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.714</td>
<td>0.715</td>
<td>0.714</td>
</tr>
<tr>
<td>F-Test</td>
<td>39.15</td>
<td>17.78</td>
<td>30.53</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0</td>
<td>1.90e-8</td>
<td>0</td>
</tr>
<tr>
<td>Est. Effect on 6/8/1995</td>
<td>-3.936</td>
<td>-0.834</td>
<td>-4.538</td>
</tr>
</tbody>
</table>

Clustered standard errors at patent class-day level in parentheses.
Fixed effects are at patent class and country level.
F-Test is for Post-TRIPS, time*Post-TRIPS and time*time*Post-TRIPS (when used)
*** p<0.01, ** p<0.05, * p<0.1
Figure 10: Cross-industry differences in Total Applicant Delay (Post-TRIPS coeff.)
have deliberately filed, prior to the change in law, applications that would likely have a long prosecution time. These applications might take longer because they anticipated a lengthy review from the PTO (perhaps because the inventions were more complicated or difficult to review). Or it is possible that these patentees deliberately delayed prosecution of these applications because they did not want their patent term to begin until later – such a story would be consistent, for example, with a pharmaceutical patentee deliberately slowing down prosecution of his patent application prior to TRIPS because he still needs to get regulatory approval from the FDA and does not want his patent to issue until such approval has been received. We are exploring these issues in more detail in a follow-up paper.

Still, one might have expected the effect for Drugs & Medicine to be somewhat stronger, since patents are believed to be important in that industry. A major reason for the results we see here is the way the Drugs & Medicine category was constructed. If one breaks down Drugs & Medicine into its component subcategories (see Appendix Table A.3 on page 51), we see that the subcategories “drugs” and “genetics” have very significant, negative coefficients (-3.18 and -10.36), respectively. The coefficient appears to be weakened because “surgery and medical equipment” has been bundled into the Drugs & Medicine category, and this is one of the few categories with a significant and positive Pre-TRIPS coefficient (4.78). Accordingly, some of the weaker-than-expected results is attributable to this grouping of pharmaceutical drugs with surgery and medical equipment, areas that are not thought to rely as much on patent protection.

The results in Figure 10 on the previous page are robust to changes in the response variable. For example, Figure 11 on the following page shows a similar graph, except this time the variable of interest is the number of extensions requested by applicants before and after TRIPS. The left hand line in each category again reflects the specification where we use all data from 1994-96; the right hand line is when we exclude time between when TRIPS was passed and when it went into effect (December 8, 1994, to June 7, 1995).

The results shown in Figure 11 are quite similar to those shown in Figure 10, with Computers & Communications having relatively strong coefficients, followed by Drugs & Medicine, Electricity and then Chemical and Mechanical. As before, the Others category appears to have no effect.

Figure 12 on the next page shows a moving cutpoint test similar to the one discussed above in section 4.3, this time with patents separated by invention category. One can see that the effect on the Drugs & Medical coefficient is especially strong. Chemicals also appear to respond strongly, whereas Computers & Communications respond less but are negative throughout 1995 (see Figure 12 on the following page).

It is somewhat surprising that all of these graphs show such a strong effect for inventions in the Computers & Communications category. Some of this effect is due to a time-trend – total applicant delay in these categories appears to
have been trending downward before and after TRIPS. Still, if one runs a time-trend test similar to the one described in section 4.4, with inventions divided at the category, one can see that the result for Computers & Communication is weakened, though still remains significant and negative level (see Appendix Table A.2 on page 50). As predicted by prior theory, Drugs & Medical have the largest negative effect, meaning that applicants in those categories appear to be the most sensitive to the change in law.

4.6 Other Changes in TRIPS

Although the changes to patent term were the most important provisions in TRIPS, there were other changes made by the law (Van Horn 1995), and we should see whether those changes might affect our results. First, TRIPS changed rules relating to establishing an invention date by allowing (for the first time) applicants to establish patent priority based on inventive activity outside of the United States, not just limited to the filing of an international application under the Patent Cooperation Treaty or the filing of a foreign patent application. This seems unlikely to systematically affect the prosecution time of applicants. Moreover, controlling for the country of origin of the patent applicant (something we include in our fixed effects) should capture at least some of this effect.

TRIPS also allowed patentees to obtain extensions to their patent term in certain limited situations – when patent issuance is delayed due to an interference proceeding (where two separate inventors dispute who invented first and go through an extensive regulatory process to determine who has priority), a secrecy order (which requires a patent prosecution to remain secret if a government agency believes it to be in the interests of national security), and a successful appellate review. Interferences are very rare – between 1991 and 1994, there were only 718 interferences, much less than 1% of all applications (Calvert and Sofocleous 1995). Secrecy orders appear to be even rarer (at least prior to September 11, 2001), and most of these cases are unlikely to appear in our sample. Regarding appeals, these generally involve very few cases, and even fewer are affirmed (e.g., in fiscal year 1998, there were 3779 appeals received and only 1239 reversed (U.S. Patent & Trademark Office 1998)). At any rate, cases involving appeals have been excluded from our sample, so they do not directly affect our results here.

TRIPS also created a new type of patent application known as a provisional patent application, which is a simplified patent application (typically without formal claims) that establishes a priority date for the applicant. Provisional applications do not extend patent term; they simply provide a placeholder for applicants to follow up within one year with a standard, non-provisional application. An applicant who files a provisional and then a follow-up non-provisional within one year gets the priority date of the provisional filing, but receives the standard term of 20 years from the filing of the non-provisional application. Provisional applications that are not followed up with a non-provisional application
are abandoned.

Our sample does not cover provisional applications, so one concern would be if provisional applications systematically differ in terms of applicant delay from non-provisional applications. It is unclear whether this is a serious issue, since an applicant who files a provisional application and follows up with a non-provisional receives the same patent term as an applicant who just files a non-provisional application. Moreover, as a practical matter, provisional applications were seldom used at first, as only 5,000 such applications were filed in 1995 (as compared to 212,377 non-provisional applications) (Crouch November 26, 2012, U.S. Patent & Trademark Office 2012). These numbers increased in 1996 (20,000 provisional versus 195,187 non-provisional), so as a robustness check we ran our preferred specification excluding 1996. The results are similar and still highly significant, suggesting the effect of provisional applications is limited.

5 Market Valuation of The Last Years of Patent Life

5.1 Analysis Using TRIPS

In this section, we apply various econometric methodologies to PTO and stock market data in order to estimate the monetary value of the last years of patent term. As mentioned above, in addition to changing patent term prospectively, TRIPS also retroactively changed the term of already-existing patents based on their previous prosecution time. In particular, TRIPS allowed patentees of already-issued but not-expired patents to claim a term that was the longer of 17 years from patent issuance and 20 years from patent filing. This adjustment was done automatically and mechanically by the PTO, and it went into effect on December 8, 1994, when TRIPS was signed into law.

We believe this change is an ideal natural experiment to measure the monetary value of increased patent duration. The ratification of TRIPS, along with its provision to change duration for patents that had already been issued, was arguably not anticipated throughout much of 1994. It certainly would not have been anticipated in the 1980s or late 1970s, when many of the patents in effect in 1994 were being prosecuted before the PTO. In addition, the way in which additional patent term was awarded could plausibly be considered exogenous to firm characteristics, as we will describe further below.

In our first empirical approach, we perform regression analysis at the firm level, both for firms that had one patent and ones owning multiple patents. We measure how much excess duration the firm was given mechanically following TRIPS and test if the firms that were given relatively more duration — both with and without controls for patent count and other firm covariates — performed
better in the stock market and by how much. This simple regression represents one of the most feasible measures of the value of late-term patent length that we have seen in the literature not based on maintenance fees. Our results suggest that there are small but positive and significant effects to increased patent term.

In our second approach, we focus on public firms that held only one effective patent when TRIPS was enacted. As Figure 13 demonstrates, the function that determines how excess duration was awarded to these firms is kinked at 0.

Figure 13: Excess patent duration awarded by TRIPS as a function of application pendency

We take advantage of this feature and use a new empirical technique known as regression kink design ("RKD") to estimate how firms’ performance varied with the percentage increase in duration awarded to their patent. After briefly discussing the technique, we present results suggesting that excess patent term had a positive effect on market valuation.

As is the case in most event studies using stock data, it is not entirely clear what is the relevant window to investigate the effect of the December 8, 1994, reform. Based on our reading of the literature and primary sources, we believe that most of the uncertainty surrounding the ratification of TRIPS was dissipated between November 22 and December 8, 1994. Although President Bill Clinton supported TRIPS, as did a majority of the House of Representatives, there was considerable uncertainty prior to November 22 whether TRIPS would pass the Senate.

On November 22 and the following day, Thanksgiving, incoming Senate Majority Leader Robert Bob Dole met with President Clinton and issued a statement
suggesting that an agreement had been reached and that TRIPS would pass the Senate (Lin and Rankin November 24, 1994). Given that the President still had solid standing with Democrats despite his midterm setback and that Mr. Dole was one of the de facto spokesmen of the Republican Party, it seems reasonable to treat the period following this meeting but before the actual ratification of TRIPS as the “treatment” period. Over this period, the S&P 500 fell by 1.5%.

5.2 Calculating Term Extension

Using the NBER patent database, we matched all patents that were owned by publicly-traded companies to stock market data using Compustat. We coupled this with the pendency (i.e., prosecution time) for each patent. We then used the same methodology as the PTO in calculating the extension that each active patent received after TRIPS passed. To be clear, the formula for patent duration is the maximum of 17 years from the date of issuance (patent term prior to TRIPS) and 20 years from the date of application (patent term after TRIPS):

\[ \text{Term} = \max(20 \text{ years from Issuance} - \text{Pendency}, 17 \text{ years from Issuance}) \]

The term extension that a patent receives is thus:

\[ \text{Extension} = \max(3 - \text{years} - \text{Pendency}, 0) \]

For the median patent issued in 1994, pendency was about 606 days (about 1 year, 8 months). For that patent, the passage of TRIPS resulted in an addition of about 1 year, 4 months of term length.

To compare firms, we must aggregate patent level term gains to the firm level. In our sample, the median firm held six patents, while on average each firm held 142 patents, due to the large number of firms that held one or two patents and large outliers on the right tail (General Electric, for example, held 12,646 patents in 1994). The average firm in our sample received 2,702 days, in excess of 7 years and 4 months, of patent duration after the reform.

Following the existing patent literature, we might be concerned that our effects will be confounded by “useless” patents that have little or no value, as the distribution of patent values is believed to be very skewed with only a few very valuable ones (Moore 2005). To address this issue, we weighted the amount of extension a patent received by the number of citations the patent had received prior to TRIPS. The average patent in effect at the time of TRIPS had been cited 4.6 times.

An issue with patent citations is that they monotonically increase over time, so static levels of citations will not allow us to weight properly. To rectify this shortcoming, we follow Abrams 2009 and normalize by dividing the number of citations a patent has by the average number of citations for patents that
were issued in the same month. As pointed out by Abrams 2009, this approach reshapes the distribution of patents in an unusual way, since there are many patents with zero citations originally. This is not a focus of our paper so we do not presently delve into more issues related to this.

5.3 OLS Regression Analysis

We first perform basic ordinary least squares (OLS) regressions to investigate the relationship between firm stock performance and the length of patent term gained. There are 2,213 firms in our sample. The biggest concern with this methodology is that companies that get more patent length might be more efficient and thus able to better expedite their patent claims. They might, therefore, have performed better during our sample window regardless of any additional patent term received, which would in turn tarnish our estimates by omitted variable bias.

We do not find much evidence to suggest this is an issue. Prosecution length did not seem to vary much based on different firm characteristics before the change, which does not support the notion that more productive firms were better able to push the average patent through the PTO (e.g., see Appendix Figures A.4 and A.5). We also find evidence that a significant amount of variation in prosecution time was within firms—an analysis of variance showed that only about one-sixth of estimated total variance was found across firms. Accordingly, it seems that prior to TRIPS, prosecution time was largely determined by the PTO on a patent-by-patent basis.

We first test how firm performance varied by total extension. The result in column (1) is highly significant, but not particularly large—suggesting that the average firm did only 1.1% better than a firm that did not receive any extensions, of which there were 52 in our sample. Given the large market capitalization of these firms, this small increase still might translate to a large sum of money. For example, the median firm had a value of $162 million; a mean extension for the firm would equal $648,000. The mean firm had a much larger value, $2.07 billion, so a mean extension would be worth $8,280,000. Clearly one should be concerned that these estimates could just reflect valuation in firms that held more patents, so we control for firm-level patent count in column (2). Once again the results are still statistically significant—though slightly less than before—and the estimate on total firm-level patent term gain is roughly double the magnitude as before.

We think the increase in term given to each patent might be thought of as exogenous to the firm, eliminating the need for further controls, but we include other firm-level data, including total employment, cash, total assets, current assets, earnings per share in the previous period, and earnings before interest, taxes, depreciation and amortization (EBITDA) in column (3). Our results remain positive and significant. Taken together, this is evidence that supports the notion that patents may retain value in their final years. Still, the low
point estimates suggest there are many patents for which longer duration does not materially affect the fortunes of the parent company, in line with previous literature.

We also test whether term gain is more valuable when received on patents with higher normalized citations (term gain received on each patent multiplied its normalized weight, and summed at the firm level). The results seem to reverse themselves, though not in a statistically significant manner. This might suggest, as others have pointed out, that citations are not a clean measure of actual profits in the final years of patent term.

As a robustness check, we run the same regressions using instead total delay attributable to the firm as the dependent variable. This is a test if firms who got their applications through fastest were the ones that performed best. We found that the result was not significant, suggesting again that it appears to be the delay of the PTO and its mechanical adjustment that created value.

5.4 Regression Kink Design Methodology Background

RKD is a recently developed empirical technique that helps account for potential endogeneity in observational studies. Before discussing RKD, it is instructive to review the related and more widely used technique of Regression Discontinuity (RD) design. A paradigmatic example of RD, as discussed in Lee and Lemieux 2010, relates to elections. If one compares candidates right before an election, the individuals who barely win (e.g., win by a vote share margin of victory < 1%) are on average likely to be very similar to the individuals who barely lose, on a number of observable and unobservable dimensions. But candidates who win have the advantages/disadvantages of incumbency in future elections. So if we want to estimate the effect of incumbency on electoral outcomes, it makes sense to compare future election outcomes for candidates who barely won in a previous election to candidates who barely lost in a previous election.

More formally, a treatment dummy variable \( D \) (e.g., winning or losing an election) jumps when a running variable \( x \) (e.g., vote share margin of victory) crosses a certain threshold (e.g., \( D = 1(x \geq 0) \)). We can plot a response variable \( Y \) (e.g., whether the candidate wins a future election) against \( x \), and see if there is a jump near the discontinuity. Such a jump would estimate the effect, \( \tau \), of the treatment, \( D \), on the response variable, \( Y \) – that is, the effect of incumbency on winning a future election. More generally, a discontinuity in the running variable \( x \) at point \( c \) can be used to calculate \( \tau \) as follows:

\[
\tau = \lim_{\epsilon \downarrow 0} E[Y|x = c + \epsilon] - \lim_{\epsilon \uparrow 0} E[Y|x = c + \epsilon]
\]  

(6)

RKD is similar to RD, but instead of using a discontinuity, RKD takes advantage of a kink in a formula that relates two variables (Card et al. 2012). For example, the amount of unemployment benefits that a person receives (a “policy variable”)
Table 5: Effect of Patent Term Gain at Firm Level on Change in Stock Market Price

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3) *</th>
<th>(5)</th>
<th>(6)</th>
</tr>
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<tbody>
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<td>3.03e-08</td>
<td>-1.46e-08</td>
<td>-1.84e-08 *</td>
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<td>(9.54e-09)</td>
<td>(1.01e-08)</td>
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<td>Total Firm Term Gain</td>
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<td>(4.71e-06)</td>
<td></td>
</tr>
<tr>
<td>% Stock Chg.</td>
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<td>-8.28e-06</td>
<td>1.19e-05 ***</td>
<td>1.23e-05***</td>
<td></td>
</tr>
<tr>
<td>% Stock Chg.</td>
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<td>(1.32e-05)</td>
<td>(4.29e-06)</td>
<td>(4.71e-06)</td>
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<td></td>
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<td>EBITDA</td>
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<td>7.09e-06 **</td>
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<td>Employment</td>
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<td>4.95e-05</td>
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<td>Current Assets</td>
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<td>1,924</td>
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<td>0.001</td>
<td>0.009</td>
<td>0.001</td>
<td>0.003</td>
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</tbody>
</table>


* (3) Includes exchange fixed effects (results robust to their inclusion)

*** p<0.01, ** p<0.05, * p<0.1
is often a linear and increasing function of his prior income (running variable), beginning at some minimum value and capped at some maximum amount. In such a scenario, there will be a kink in the function that relates unemployment benefits and income at the point where this minimum or maximum occurs.

If the amount of unemployment benefits that a person receives has some effect on the duration of that person’s unemployment (outcome variable), then we might expect to see a kink in the relationship between unemployment duration and income near the same point where the kink occurs in the relationship between unemployment benefits and income. More generally, a kink that we see in the relation between the policy variable and the running variable might appear, in some form, in the relationship between the outcome variable and the running variable.

Since we have a kink instead of a jump with RKD, the RD formula must be adjusted to estimate slopes on either side of the kink and see how they vary. In particular, with the running variable as the x-axis variable, one can calculate the ratio of: (1) the difference in slope of the outcome variable on the right side of the kink versus the slope of the outcome variable on the left side of the kink, and (2) the difference in slope of the policy variable on the right side of the kink versus the slope of the policy variable on the left side of the kink.

More formally, Nielsen et al. 2010 model the outcome variable $Y$ as follows:

$$Y = \tau B + g(V) + \varepsilon$$

where $B = b(V)$ is assumed to be a deterministic and continuous function of running variable $V$ with a kink at $v_0 \equiv V = 0$, and $g(\cdot)$ and $E[\varepsilon|V = v]$ have derivatives that are continuous in $v$ at $v = 0$. The treatment effect, $\tau$ – which can be viewed as a version of a Wald estimator – is:

$$\tau = \left. \lim_{v_0 \downarrow 0} \left. \frac{dE[Y|V=v]}{dv} \right|_{v=v_0} - \lim_{v_0 \uparrow 0} \left. \frac{dE[Y|V=v]}{dv} \right|_{v=v_0} \right) \frac{\lim_{v_0 \downarrow 0} b'(v_0) - \lim_{v_0 \uparrow 0} b'(v_0)}{(1)}$$

In our application, we have a kink in the relationship between amount of patent term added by TRIPS (policy variable) and patent prosecution time (running variable) at the point where prosecution time exceeds 3 years (1095 days if no leap year; 1096 days otherwise) (see Figure 13 on page 33). In particular, patents that were prosecuted for more than 3 years received no additional patent term, whereas patents that were prosecuted for less than 3 years received one day of additional term for every day that patent prosecution was less than 3 years.

Applied to our natural experiment, patents assigned to the different sides of the kink can be thought of as being “as good as randomly” assigned, as outlined in Card et al. 2012. The denominator for equation 7 in our application is $+1$, since the slope for added patent term on the right side of the kink is 0, the slope on the left side is $-1$, and $0 - (-1) = 1$. So our RKD estimator is simply the numerator, which measures how the outcome variable-market price in our
case—varies with term extension on either side of the kink. This provides a quasi-experimental estimate of how the outcome variable varies with the (perhaps) endogenous dependent variable.

5.5 Regression Kink Design Results

As before, we use market data from Compustat, which allows us to estimate the following equation:

\[ PriceChange_i = \beta_1 + \beta_2 TimeGrant_i + \beta_3 TimeGrant_i \times (Pos_i) + \varepsilon_i \]

where firms are indexed by \( i \). \( PriceChange_i \) is the percentage change in stock market price from right before Senator Dole and President Clinton’s meeting (November 22, 1994) to the day when TRIPS was signed into law (December 8, 1994). \( TimeGrant_i \) is three years minus the prosecution time of the patent (one can think of this as the change in patent term if the law had retroactively altered term from 17 years from the patent issuance date to 20 years from the application date). \( Pos_i \) is an indicator variable for whether \( TimeGrant_i \) is negative.

The term of interest in the RKD analysis is \( \beta_3 \)—this tells us how the relationship between \( TimeGrant_i \) and the running variable changes around the kink. Because many firms hold multiple patents, introducing the possibility that they own patents on both sides of the kink, we focus our analysis on firms that held only one patent that was affected by the change in law. This leaves us with a subsample of 406 firms. Within this subsample, we do not see any kinks or jumps in the density of covariates that we might think might have an effect on our outcome variable.

In column (1), we present a sparse specification that does not control for a number of covariates. Card et al. 2012 argue that such a specification should give consistent estimates if there are no discontinuities in the density function of covariates, and if the linear model is an accurate approximation. Our only control is a fixed effect for the year in which the patent was granted. This is necessary because an increase in patent term will likely have more or less impact on firm value depending on the amount of term remaining. For example, there should be less of an increase in value for a patent that was scheduled to last 16 years and will now last 17 years thanks to the change in law (the patent receives a term increase of just \( \frac{(17-16)}{16} \times 100\% = 6.26\% \)), as compared to a patent that was supposed to last just one more year and will now last two more years \( \left(\frac{2-1}{1}\right) \times 100\% = 100\% \) term increase). Hence, it makes sense that we find a coefficient on later years that is negative.

Column (1) suggests that increased patent length is associated with better market performance. But our results are limited by our small sample size—we have only 406 firms that held just one patent at the time of TRIPS, and 40 of these
held patents that did not receive time extensions. Controlling for covariates should isolate the parameter of interest and decrease sampling variability, as argued by Lee and Lemieux 2010 in the context of RD. Accordingly, we also present a regression in column (2) that adds controls to our preferred specification. These controls are total employment, current assets, EBITDA, total assets, cash, capital expenditures, earnings per share, and exchange fixed effects. Our results are stronger than for our specification in column (1), with a positive and highly significant effect of term gain on stock market performance.

Another way to examine the relationship between term gain and market performance is shown in column (3), where we regressed stock market performance on the covariates in column (2), then took the residuals from that regression and regressed them against the running variable (Appendix Figure A.3 on page 48). Again we find a positive and significant effect of term gain on stock market performance.

Taken together, our results suggest that firms that received higher term gain tended to perform better over the period in which we conducted this event study. Although small sample size limits the ability to draw conclusions from our study, the RKD suggests that an extra year of duration would improve a firm’s stock market performance from between 2.1 and 3.5 percentage points over the relevant period. For the firms in our subsample, the mean market capitalization was $570 million, which means that a year of excess duration was associated with a increased value of around $12 million. This estimate is on the same order of magnitude as our earlier results in section 5.3, where we performed OLS on the full sample and found that the mean firm gained about $8.28 million for every additional year of patent term awarded.

5.6 Correlation Between Patent Delay Coefficient and % Stock Change Coefficient

The two empirical parts of this paper investigate different responses to changes in patent duration: applicant behavior and market pricing, respectively. Both measures can be used to create a ranking of which subcategories experienced the largest changes following the ratification of TRIPS, indicative of the importance of profits from late in the patent term. Assuming complete information, risk-neutrality, and rational expectations, since the market knows as much about patent value as the applicant, the ordering of the categories should be the same using either technique.

When we cross-check the results against one another – namely, when we compute the correlation between: (1) the coefficient on the Post-TRIPS variable in the total applicant delay regression by subcategory (where more negative values correspond to larger decreases in total applicant delay) and (2) the cross-sectional stock market performance regressions on term gain by subcategory (where higher values correspond to larger increases in stock market performance), we find that the correlation coefficient is -.46 or -.56 depending on
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Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1
which time period is estimated. This means that in categories where applicants sped up the most, stock prices increased the most.

The above correlation is significant at the 1% level. This result is especially noteworthy given the few number of subcategories being compared (37) and the fact that the two measures of patent term sensitivity were derived independently. This cross-validation supports the model that we derived in section 3 above, which relates applicant delay to patentee profits at the end of patent term. The high degree of correlation also gives us more confidence in both of our measures, suggesting that applicants and the market both value the same types of patents highly toward the end of their term.

6 Conclusion

Since at least Nordhaus 1967 and Scherer 1972, scholars have recognized that the design of optimal patent policy depends crucially on the private gains reaped by innovators from monopoly protection. This protection is thought by many to be socially beneficial because it is viewed as a key driver of the technological innovation in products and processes that have been the sine qua non of modern economic growth. This proposition has become subject to dispute recently, with some notable economists advocating drastic curtailments of patent protection (e.g., Tabarrok 2011).

Regardless of one’s predilections or preferred model, evidence about how changes in patent term affect patenting behavior and profits is of first-order importance. In this paper, we use a natural experiment—the first change in the way patent term was calculated in over 130 years and its accompanying programmatic kinks—to measure applicants’ sensitivity to patent term.

In the first part of the paper, we examine how patentees in different industries changed the amount of time spent in patent prosecution after a change in law that, for the first time, decreased patent length one day for every day the patent was prosecuted. Recognizing that applicants had some control over the length of prosecution, we present a model predicting that an applicant who stands to gain more profits later in patent term would be more likely to speed up patent prosecution vis a vis an applicant who has little to gain financially from a longer term.

We then test this model in two different ways. First, we construct a novel dataset based on the transaction histories of 307,597 issued patents filed between 1994 and 1996. We apportion the prosecution process between the PTO and applicant and sum the time attributable to the applicant, thereby creating the first measure of applicant prosecution time. We then test whether applicant prosecution time changed following the law and look at the differential impact of the change in law across industries. Our empirical results generally support previous theory, with the exception that computer and software products appear
to be more sensitive to patent term than has previously been appreciated. These results are robust across a number of different empirical specifications.

In the second empirical portion of the paper, we further exploit the change in law to provide a rough estimate of the value of patent term extensions as measured by equity markets. We take advantage of the fact that in addition to changing patent term prospectively for new patentees, the 1994 law retroactively lengthened the term of already-issued but not-expired patents that had been prosecuted in the PTO for less than three years. Using patent data provided by NBER and linked to Compustat, we perform an event study around December 8, 1994 (the date the law was passed). Our results suggest that equity prices increased more for firms receiving longer extensions (i.e., those who benefited more from the change in law) as compared to those who received shorter extensions. We also account for heterogeneity in patent values through the use of patent citation weights, which previous scholars have used as a proxy for measuring patent value; our results are consonant with some recent findings that citations might not be the best measure of profitability (Abrams et al. April 8, 2013).

In addition, we use a recently developed empirical technique known as regression kink design ("RKD"), pioneered by Card et al. 2012, to derive an independent estimate of the value of patent term. We apply this technique to firms that held only one effective patent at the time of the law change. After controlling for firm-level covariates, we obtain even stronger results using RKD than in our event study.

The two empirical parts of this paper investigated different responses to changes in patent duration: applicant behavior and market pricing, respectively. But both measures give us a sense of which type of patents are most reliant on profits from the end of a patent life. When we cross-check the results of both measures at the subcategory level (37 subcategories), we find a very strong correlation of about -0.46 or -0.56, depending on the specification, and both significant at the 1% level. This correlation suggests that subcategories in which applicants sped up prosecution the most (in order to gain more patent term) are the same subcategories in which stock values increased the most when firms received exogenous term extensions. This cross-validation matches the prediction of our model and gives us more confidence that our measures are a strong step toward accurately assessing the importance of patent term to patentees.

References


David S. Abrams, Ufuk Akcigit, and Jillian Popadak. Understanding the Link
between Patent Value and Citations: Creative Destruction or Defensive Disruption? April 8, 2013.

Charles Anthony. *A Classical Dictionary: Containing An Account Of The Principal Proper Names Mentioned in Ancient Authors, And Intended To Elucidate All The Important Points Connected With The Geography, History, Biography, Mythology, And Fine Arts Of The Greeks And Romans Together With An Account Of Coins, Weights, And Measures, With Tabular Values Of The Same.* Harper & Bros, 1841.


Appendix

Figure A.1: Relationship between issue fee payment date and average patent issuance date (as measured from mailing date of notice of allowance)

Graph excludes about 2.3% observations (12,433 of 530,173) for which time between mailing of notice of allowance and issue fee payment exceeded 100 days. Such applications may have incorrect dates or correspond to extraordinary cases in which applicants failed to pay their issue fee in a timely manner and had to petition the PTO for late payment.
Figure A.2: Number of patents filed prior to TRIPS - 1990-1994

Figure A.3: Regression Kink Design
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| Clustered standard errors at patent class-day level in parentheses.

Fixed effects are at patent class and country level.

F-Test is for Post-TRIPS, time*Post-TRIPS and time*time*Post-TRIPS (when used)

*** p<0.01, ** p<0.05, * p<0.1
Table A.2: Total Applicant Delay by category with time trend corrections

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<td>Est. effect</td>
<td>0.4106</td>
<td>-1.50251</td>
<td>-4.37101</td>
<td>-2.14133</td>
<td>0.5842</td>
<td>2.3498</td>
</tr>
</tbody>
</table>

Clustered standard errors at patent class-day level in parentheses.

Fixed effects are at patent class and country level.

F-Test is for Post-TRIPS, time*Post-TRIPS and time*time*Post-TRIPS (when used)

*** p<0.01, ** p<0.05, * p<0.1
Table A.3: Coefficient comparison across subcategories: Chemicals, Computers & Communications, and Drugs & Medical

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Post-TRIPS</th>
<th>Term gain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemicals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agric., Food, Textiles</td>
<td>0.78 (-3.18)</td>
<td>-5.29e-8 (-1.88e-7)</td>
</tr>
<tr>
<td>Coating</td>
<td>1.72 (1.75)</td>
<td>9.18e-8 (-4.06e-7)</td>
</tr>
<tr>
<td>Gas</td>
<td>0.78 (3.87)</td>
<td>2.82e-7 (-3.20e-7)</td>
</tr>
<tr>
<td>Organic Compounds</td>
<td>-1.14 (1.48)</td>
<td>5.58e-8 (-1.12e-7)</td>
</tr>
<tr>
<td>Resins</td>
<td>-0.14 (1.33)</td>
<td>-6.07e-8 (-6.95e-8)</td>
</tr>
<tr>
<td>Chem.-Misc.</td>
<td>-1.56** (0.78)</td>
<td>3.31e-8 (-4.48e-8)</td>
</tr>
<tr>
<td><strong>Comp. and Comm.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communications</td>
<td>-4.47*** (0.86)</td>
<td>1.63e-10 (-8.55e-8)</td>
</tr>
<tr>
<td>Comp. Hard. &amp; Software</td>
<td>-4.08*** (0.90)</td>
<td>7.94e-8 (-1.39e-7)</td>
</tr>
<tr>
<td>Computer Peripherals</td>
<td>-3.58** (1.46)</td>
<td>-5.62e-9 (-2.31e-7)</td>
</tr>
<tr>
<td>Information Storage</td>
<td>-5.37*** (1.13)</td>
<td>1.17e-7 (-1.76e-7)</td>
</tr>
<tr>
<td><strong>Drugs and Medical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drugs</td>
<td>-3.18*** (1.02)</td>
<td>1.15e-7 (-7.33e-8)</td>
</tr>
<tr>
<td>Surgery &amp; Med Inst.</td>
<td>4.78*** (1.28)</td>
<td>8.70e-8 (-1.25e-7)</td>
</tr>
<tr>
<td>Genetics</td>
<td>-10.36** (5.13)</td>
<td>3.66e-6 (-7.87e-7)</td>
</tr>
<tr>
<td>Drugs and Med.-Misc.</td>
<td>2.73 (3.24)</td>
<td>7.32e-7 (-9.44e-7)</td>
</tr>
</tbody>
</table>

Post-TRIPS: Clust. SEs at patent class-day level in parentheses.
Post-TRIPS: Fixed effects are at patent class and country level.
Post-TRIPS: Time is 1994-96, excluding 12/8/94-6/7/95

*** p<0.01, ** p<0.05, * p<0.1
Table A.4: Coefficient comparison across subcategories: Mechanical, Electrical, and Others

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Post-TRIPS</th>
<th>Term gain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Devices</td>
<td>-1.145 (1.120)</td>
<td>-2.69e-8 (-9.19e-8)</td>
</tr>
<tr>
<td>Electrical Lighting</td>
<td>0.764 (1.751)</td>
<td>2.23e-7* (-1.30e-7)</td>
</tr>
<tr>
<td>Measuring and Testing</td>
<td>-3.806*** (1.284)</td>
<td>6.15e-7** (-2.63e-7)</td>
</tr>
<tr>
<td>Nuclear &amp; X-rays</td>
<td>0.652 (1.530)</td>
<td>-3.71e-7** (-1.63e-7)</td>
</tr>
<tr>
<td>Power Systems</td>
<td>-0.990 (1.080)</td>
<td>-8.99e-8 (-1.31e-7)</td>
</tr>
<tr>
<td>Semiconductor Devices</td>
<td>-3.036*** (1.107)</td>
<td>-2.26e-8 (-1.60e-8)</td>
</tr>
<tr>
<td>Elec.-Misc.</td>
<td>-0.282 (1.280)</td>
<td>-5.21e-8 (-8.36e-8)</td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mat. Proc &amp; Handling</td>
<td>-0.096 (1.109)</td>
<td>1.28e-7 (-1.27e-7)</td>
</tr>
<tr>
<td>Metal Working</td>
<td>-0.89 (1.329)</td>
<td>7.75e-9 (-1.92e-7)</td>
</tr>
<tr>
<td>Motors &amp; Engines + Parts</td>
<td>-0.12 (1.080)</td>
<td>-1.21e-7 (-8.27e-8)</td>
</tr>
<tr>
<td>Optics</td>
<td>-3.58** (1.821)</td>
<td>5.17e-9 (-3.03e-7)</td>
</tr>
<tr>
<td>Transportation</td>
<td>-0.16 (1.488)</td>
<td>3.40e-7** (-1.68e-7)</td>
</tr>
<tr>
<td>Mech.-Misc.</td>
<td>1.11 (1.183)</td>
<td>-4.77e-7** (-2.04e-7)</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agric., Husbandry, Food</td>
<td>-1.60 (2.20)</td>
<td>-1.12e-7 (-2.04e-7)</td>
</tr>
<tr>
<td>Amusement Devices</td>
<td>11.13*** (3.14)</td>
<td>-9.83e-7 (-8.51e-7)</td>
</tr>
<tr>
<td>Apparel &amp; Textile</td>
<td>2.55 (2.25)</td>
<td>-2.47e-7 (-3.94e-7)</td>
</tr>
<tr>
<td>Earth Working &amp; Wells</td>
<td>-0.54 (2.52)</td>
<td>-1.48e-7* (-8.57e-8)</td>
</tr>
<tr>
<td>Furniture, House Fixtures</td>
<td>0.078 (2.08)</td>
<td>-2.41e-7 (-3.20e-7)</td>
</tr>
<tr>
<td>Heating</td>
<td>-1.24 (2.62)</td>
<td>2.23e-7 (-3.60e-7)</td>
</tr>
<tr>
<td>Pipes &amp; Joints</td>
<td>-1.50 (2.93)</td>
<td>1.65e-6* (-9.03e-7)</td>
</tr>
<tr>
<td>Receptacles</td>
<td>-2.01 (1.98)</td>
<td>5.32e-7** (-2.27e-7)</td>
</tr>
<tr>
<td>Other-Misc.</td>
<td>-1.10 (0.93)</td>
<td>7.39e-8 (-1.08e-7)</td>
</tr>
</tbody>
</table>

Post-TRIPS: Clust. SEs at patent class-day level in parentheses.
Post-TRIPS: Fixed effects are at patent class and country level.
Post-TRIPS: Time is 1994-96, excluding 12/8/94-6/7/95

*** p<0.01, ** p<0.05, * p<0.1

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