Online Appendix

To

A PRESCRIPTION FOR RISING DRUG PRICES: PATENT OFFICE REFORM

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Specification Underlying Figure I

In this subsection of the Online Appendix, we formalize the regression specification underlying Figure I. In particular, we estimate the following specification, focusing on the sub-sample of U.S.-issued patents that are listed in the Orange Book and that are part of a family of applications at both the U.S. Patent Office and the EPO:¹

\[
VALID_{ait} = \alpha + \delta_{kt} + \beta_1 GS_{it} + \beta_2 EXPER_{it} + \beta_3 COHORT_i + \beta_4 TENURE_i + \beta_5 X_{ait} + [Y_i] + \epsilon_{ait}
\]

where \(i\) denotes the individual examiner, \(a\) denotes the individual patent, \(k\) denotes the relevant technology group, and \(t\) denotes the year of patent issuance. \(VALID\) is an indicator for whether or not the U.S. patent at issue was also allowed at the EPO. \(GS\) is a vector of indicator variables for the various GS-levels. Given that examiners reviewing pharmaceutical patents typically enter the Patent Office with advanced degrees and thus start at the Patent Office at GS-level 11 or 12, we focus this analysis on those examiners between GS-levels 11 and 14. We exclude a dummy variable for GS-11 to leave it as the reference group, in which event the coefficients for the GS-12, 13 and 14 dummies can be interpreted as the likelihood of EPO-allowance for the indicated GS-level relative to that of GS-11. Technology-by-year fixed effects are captured by \(\delta_{kt}\), ensuring, as above, that we perform these comparisons across GS-levels within a given technology-by-year group (thereby allowing for fixed differences in validity likelihoods across these groupings).

This specification accounts for the above-stated correlates with GS levels by including experience-level fixed effects (\(EXPER\)), hiring-year cohort fixed effects (\(COHORT\)), and tenure-at-office fixed effects (\(TENURE\)), accounting for fixed differences in validity outcomes for different levels of experience, different hiring years of examiners and different lengths of time that examiners ultimately stay with the Patent Office.

¹ Primarily, we estimate linear probability models, though the results are nearly unchanged when estimate logit specifications. We cluster the standard errors at the level of assignment to account for correlation in unobservables within assignment groups.
Given an application assignment process that is tangential to patent worthiness, there is arguably little concern of bias arising from unobservable application characteristics. Nonetheless, we do control for a range of observable characteristics in the vector $\mathbf{X}$, including such characteristics as small-entity-size status, the total number of claims, number of dependent claims, the total (and average) length of all claims and of dependent claims, and the minimum word count per claim for all claims and for dependent claims.

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2 Entities defined by the PTO as “small” include individuals, nonprofit corporations, or corporations which qualify as small businesses under the Small Business Act. 37 C.F.R. § 1.27(a)(1)-(3).
Most examiners practicing in the pharmaceutical Art Units are hired with advanced degrees and begin practicing at the Patent Office at GS-level 11. While promotions at lower pay grades—which are more relevant for examiners in non-pharmaceutical Art Units—occur within a year, promotions (e.g., promotions to GS-12, 13 or 14) at higher pay grades often require more time. For instance, over 97 percent of the promotions from GS-11 to GS-12 occur after at least a year’s time, with the average length of time during GS-11 being roughly 1.2 years. Nearly 100 percent of the promotions from GS-12 to GS-13 occur after at least a year’s time with the average length of time at GS-12 of nearly 1.4 years. Nearly 100 percent of the promotions from GS-13 to GS-14 likewise occur after at least a year, with the average time at GS-13 being roughly 2.8 years. Factors contributing to promotions include meeting workload expectations, quality evaluations (based on random reviews of a subset of examiner work product), and the completion of additional testing or programs.

While our review of the Patent Office’s personnel practices suggests that the most significant change subsequent to a promotion that bears on the examiner’s decision to grant a patent application is the time allocated to review an application, there is, upon promotion to GS-14, also a change in the scrutiny of their work. Examiners at pay grades GS-13 and below must subject their decisions to a supervisory review by an examiner that has “full signatory authority.” Upon promotion to GS-14, examiners are extended full signatory authority and no longer must subject their own decisions to supervisory review. The opportunity to review responses to promotions that do not carry changes in supervision allows us to help disentangle a time- allocation interpretation of our findings from a change-in-supervision interpretation. To our knowledge, nothing else changes upon GS-level promotions that would affect the manner in which examiners conduct their examinations. Through our review of examiner compensation materials made available by the Patent Office and through our interviews with former SPEs, we have determined that the basic structure of overtime and bonuses remains constant upon GS-level promotions as does the ways in which examiners earn work credits.
Supporting the Assumption of Effectively Random Assignment of Applications to Examiners: Testing for Balance in Application Characteristics

**GS-Level Analysis**

To support the assumption that applications are randomly assigned—and thus to alleviate concerns over the potentially confounding influence of unobservable application characteristics—we validate the GS-level exercise underlying Figure I in the Article by conducting a preliminary exercise in which we test for balance across GS-levels in those application characteristics that we *can* observe—that is, those measures included in $X$ from specification(1). In order to demonstrate such balance in a simple figure, we take an omnibus approach in which we plot the relationship between examiner GS-level and predicted EPO-allowance outcomes for each Orange Book patent, where these predictions are formed after regressing the incidence of the U.S.-issued Orange Book patent also being allowed at the EPO on this full set of application characteristics along with a set of Art-Unit-by-year fixed effects. This predicted EPO-allowance outcome can be seen as a collective reflection of those various application characteristics. As demonstrated by Figure A1, these predicted rates of EPO allowance remain flat across examiners at different grades, suggesting a lack of variation in fundamental application characteristics across GS levels, consistent with the random-assignment assumption.

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**Figure A1. Covariate-Balance Analysis: Relationship Between Predicted Likelihood of EPO Allowance of Twin of U.S.-Issued Orange Book Patent and Grade-Level of Examiner Assigned to Relevant U.S. Patent**

![Graph showing predicted likelihood of EPO allowance](image)

Notes: results are from a sample of 3,322 Orange Book patents (secondary and primary) issued in the U.S. and part of a family of applications at both the U.S. Patent Office and the European Patent Office. For each such patent, we form a predicted likelihood of allowance at the EPO based on a regression of the incidence of EPO allowance on the full set of covariates and on Art-Unit-by-year fixed effects. We then regress this predicted measure on the set of GS-level dummies and plot the resulting coefficients.
Dynamic-Event Study Analysis

To support the dynamic event-study analysis underlying Figure II of the Article, we again attempt to validate the assumption of effective random assignment of applications across examiners and demonstrate balance in observable application characteristics across the different quarters within the promotion window. For these purposes, we return to the methods underlying Figure A1 above and plot predicted EPO allowance outcomes for each secondary Orange Book patent across the various quarters around the promotion event. As before, this predicted measure offers a collective reflection of the various application characteristics used to form the basis of the predictions. Encouragingly, as demonstrated by Figure A2, we document virtually no differences in application characteristics in the time leading up and following GS-level promotions.

Figure A2. Covariate-Balance Analysis for Dynamic Event-Study Analysis: Trend in Predicted EPO-Allowance Likelihood in Period of Time Leading up to and Following GS-Level Promotion, Secondary Patents

Notes: predicted EPO allowance outcomes are calculated as in Figure A1. Figure A2 then plots the trend in these predicted outcomes over a generalized event window centered around GS-level promotions (in quarter increments).

2010 Reform Analysis

Finally, in Figure A3, we demonstrate that these dynamic 2010-reform results presented in Figure III are not due to differences in fundamental patent characteristics across the event window. For these purposes, we follow the approaches set forth above and plot a corresponding time trend in predicted EPO allowance rates (based on the observable covariates). Consistent with the similar falsification tests conducted above, we find stability in predicted EPO allowance outcomes across this time window.
Notes: predicted EPO allowance outcomes are calculated as in Figure A1. Figure A3 then plots the trend in these predicted outcomes over an event window centered around the reform in February 2010 in which examiners were extended two additional hours to review applications.
Tabular Results underlying Figure I of Article

In Column 1 of Table A1, we present the results underlying Figure I of the text, allowing us to present the estimated coefficients for the covariates, except for the coefficients of the Art-Unit-by-year and experience fixed effects, which are omitted for brevity purposes.

In Column 2, we estimate a series of experience bins instead of a full set of fixed effects for each experience year. We do this to allow an observation of estimated experience effects without overburdening the size of the table.

Column 3 adds control variables with various characteristics of the patent claims. We add these in separately as we only have data for these measures for a subset of our Orange Book patents. With an already small sample size, we wanted to show results without such measures as our baseline specification. Given random assignment of applications to examiners, there is little concern over bias in estimating specifications without these controls. Nonetheless, we do offer a set of results including these measures to demonstrate the robustness of our findings to their inclusion.

Our aim with these latter controls is to account for fundamental differences in the nature of the applications that do happened to be assigned—even if by chance—to the different grade levels. Claim characteristics generally evolve over the course of the examination process, as applicants may make claim modifications to respond to examiner comments and rejections. In order to provide an exogenous measure of these characteristics—one that is not impacted by the amount of time allocated to examiners—we aim to capture claim characteristics at the time of filing. For these purposes, we turn to the Patent Claims Research Database put out by the Office of the Chief Economist at the Patent Office. The document level file of this dataset contains application-level information on the number of claims and the length of the claims. While it does not necessarily contain this information at the time of filing, it does report these measures at the time in which the application is “published” by the Patent Office, which is a decent approximation of these measures at the time of filing (Frakes and Wasserman 2020).

In the interests of brevity, we present these results only for the case of secondary Orange Book patents.

Additional Reference:

<table>
<thead>
<tr>
<th>Table A1. Full Results: Relationship between Likelihood of EPO Allowance of Twin of U.S.-Issued Secondary Orange Book Patent and Grade Level of Examiner Assigned to Relevant U.S. Patent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Omitted: GS-11</strong></td>
</tr>
<tr>
<td>GS-12                         &amp; -0.047 &amp; -0.049 &amp; -0.059</td>
</tr>
<tr>
<td>&amp; (0.038) &amp; (0.037) &amp; (0.042)</td>
</tr>
<tr>
<td>GS-13                         &amp; -0.070* &amp; -0.061 &amp; -0.073*</td>
</tr>
<tr>
<td>&amp; (0.038) &amp; (0.037) &amp; (0.043)</td>
</tr>
<tr>
<td>GS-14                         &amp; -0.096** &amp; -0.094** &amp; -0.115**</td>
</tr>
<tr>
<td>&amp; (0.042) &amp; (0.042) &amp; (0.047)</td>
</tr>
<tr>
<td><strong>Omitted: (Tenure &lt; 2 Years)</strong></td>
</tr>
<tr>
<td>Tenure 2-4 Years             &amp; -0.300** &amp; -0.350*** &amp; -0.227</td>
</tr>
<tr>
<td>&amp; (0.129) &amp; (0.121) &amp; (0.175)</td>
</tr>
<tr>
<td>Tenure 4-6 Years              &amp; -0.100 &amp; -0.128 &amp; 0.032</td>
</tr>
<tr>
<td>&amp; (0.116) &amp; (0.102) &amp; (0.106)</td>
</tr>
<tr>
<td>Tenure 6-8 Years              &amp; -0.150 &amp; -0.202* &amp; -0.028</td>
</tr>
<tr>
<td>&amp; (0.121) &amp; (0.105) &amp; (0.096)</td>
</tr>
<tr>
<td>Tenure 8-10 Years             &amp; -0.160 &amp; -0.202** &amp; -0.019</td>
</tr>
<tr>
<td>&amp; (0.112) &amp; (0.101) &amp; (0.041)</td>
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<tr>
<td>Tenure 10+ Years              &amp; -0.136 &amp; -0.180** &amp; -</td>
</tr>
<tr>
<td>&amp; (0.102) &amp; (0.89) &amp; -</td>
</tr>
<tr>
<td><strong>Omitted: (Hiring Cohort 1980-1985)</strong></td>
</tr>
<tr>
<td>Hiring Cohort 1985-1990       &amp; 0.019 &amp; 0.042 &amp; 0.033</td>
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<tr>
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</tr>
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<td>Hiring Cohort 1990-1995       &amp; 0.034 &amp; 0.043 &amp; -0.008</td>
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<tr>
<td>&amp; (0.093) &amp; (0.057) &amp; (0.106)</td>
</tr>
<tr>
<td>Hiring Cohort 1955-2000       &amp; 0.062 &amp; 0.069 &amp; 0.044</td>
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<td>&amp; (0.141) &amp; (0.055) &amp; (0.151)</td>
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<tr>
<td>Hiring Cohort 2000-2005       &amp; 0.005 &amp; 0.016 &amp; -0.070</td>
</tr>
<tr>
<td>&amp; (0.167) &amp; (0.054) &amp; (0.178)</td>
</tr>
<tr>
<td>Hiring Cohort 2005-2010       &amp; 0.017 &amp; 0.039 &amp; -0.065</td>
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<tr>
<td>&amp; (0.200) &amp; (0.066) &amp; (0.214)</td>
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<td>Hiring Cohort 2001+           &amp; -0.023 &amp; 0.013 &amp; -0.161</td>
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</tr>
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<td><strong>Omitted: (Experience Bin &lt; 2 Years)</strong></td>
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<td>Experience Bin: 2-4 Years     &amp; - &amp; 0.040 &amp; -</td>
</tr>
<tr>
<td>&amp; - &amp; (0.070) &amp; -</td>
</tr>
<tr>
<td>Experience Bin: 4-6 Years      &amp; - &amp; 0.064 &amp; -</td>
</tr>
<tr>
<td>&amp; - &amp; (0.078) &amp; -</td>
</tr>
<tr>
<td>Experience Bin: 6-8 Years      &amp; - &amp; 0.081 &amp; -</td>
</tr>
<tr>
<td>&amp; - &amp; (0.084) &amp; -</td>
</tr>
<tr>
<td>Experience Bin: 8-10 Years     &amp; - &amp; 0.087 &amp; -</td>
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<tr>
<td>&amp; - &amp; (0.084) &amp; -</td>
</tr>
<tr>
<td>Experience Bin: 10+ Years      &amp; - &amp; 0.106 &amp; -</td>
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<td>&amp; - &amp; (0.087) &amp; -</td>
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<tr>
<td><strong>Small Entity Applicant</strong>   &amp; -0.123*** &amp; -0.123*** &amp; -0.097***</td>
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<td>&amp; (0.038) &amp; (0.039) &amp; (0.048)</td>
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<td><strong>Number of claims (100s)</strong> &amp; - &amp; - &amp; -0.645*</td>
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<td><strong>Number of dependent claims (100s)</strong></td>
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<tr>
<td><strong>Total number of words in dependent claims (10000s)</strong></td>
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<tr>
<td>--------------------------------</td>
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<tr>
<td>Minimum number of words per claim across claims (1000s)</td>
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<td></td>
</tr>
<tr>
<td>Minimum number of words per claim across dependent claims (1000s)</td>
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<tr>
<td>Average number of words per claim (1000s)</td>
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<tr>
<td>Art-Unit-by-Year Fixed Effects</td>
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<tr>
<td>Experience-In-Single-Year Fixed Effects</td>
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<tr>
<td>Number of Observations</td>
</tr>
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* significant at 10%; ** significant at 5%; *** significant at 1%. Standard deviations are indicated in parenthesis and are clustered at the unit of assignment—i.e., at the Group Art Unit-by-year level to account for correlation in unobservables within assignment groups. The dependent variable indicates the incidence of allowance at the EPO among the sample of U.S.-issued secondary Orange Book patents that are part of a family of applications between the U.S. Patent Office and the EPO.
Examiner Fixed Effects

We begin by estimating a counterpart to specification (1)—and to present results to complement Figure I in the text—while including examiner fixed effects. While examiner fixed effects obviate the need to control for hiring-year cohorts and ultimate examiner tenure, we continue to control for experience fixed effects in this examiner fixed effects specification. Since we are attempting to trace effects over an examiner’s career, as opposed to within a given Art-Unit-by-year, we no longer control for technology-by-year fixed effects, but instead separately control for technology fixed and year fixed effects. In this specification, we cluster standard errors at the examiner (results robust to clustering at the Art Unit level). Moreover, considering that we only observe a GS-level relationship in the case of secondary patents and considering the already strained sample size for active-ingredient patents, we reserve this exercise for the secondary patent sample only.

We present results from this exercise in Figure A4, where each panel of this figure replicates the exercise from Panel A of Figure I but making the following adjustments: (1) including examiner fixed effects, (2) including examiner fixed effects but limiting ourselves to examiners who have reviewed at least 10 secondary Orange Book patents over their career (a restriction which drops the sample size by 35%) to address the above-stated concern over some examiners reviewing only a limited number of Orange Book-listed patents, and (3) including examiner fixed effects but limiting ourselves to examiners who have reviewed at least one secondary Orange Book patent at each of GS level 11, 12, 13, and 14 over their observable careers (a restriction which drops the sample size by roughly 90%), a balanced approach that likewise addresses concerns over limited Orange Book-listed experience. The results from Figure I appear to be generally robust to this alternative approach as we continue to document a downward relationship between GS-level and the EPO allowance rate (our validity marker). The magnitude of this relationship is especially pronounced in the balanced approach from Panel C, though we acknowledge that this specification is estimated over a far more limited sub-sample of examiners.
FIGURE A4. RELATIONSHIP BETWEEN LIKELIHOOD OF EPO ALLOWANCE OF TWIN OF U.S.-ISSUED SECONDARY ORANGE BOOK PATENT AND GRADE-LEVEL OF EXAMINER ASSIGNED TO RELEVANT U.S. PATENT, WITH EXAMINER FIXED EFFECTS

Notes: results in Panel A are from a sample of 2,678 secondary Orange Book patents issued in the U.S. and part of a family of applications at both the U.S. Patent Office and the European Patent Office. Results in Panel B restrict this sample to examiners who review at least 10 Orange Book patents over their careers. Results in Panel C restrict this sample to those who have reviewed a secondary Orange Book patent at least once during each of the indicated GS-levels. The plotted coefficients represent the coefficients of the GS-level indicator variables from specification (1), including examiner fixed effects. 95% confidence intervals are indicated by the vertical bars. Standard errors are clustered at the examiner level.

Next, we include examiner fixed effects in the stacked event study estimated in Table I in the text. We present the results of this exercise in Table A2. In Column 1, we modify the results from Column 1 in Table I of the text to simply include examiner fixed effects. We continue to find meaningful and statistically significant declines in our validity marker in the post-promotion period. One benefit of the stacked event-study approach that generalizes over promotions is that it becomes arguably more straightforward to impose a balance condition. In this light, in Column 2, we require that we observe for each examiner at least one review in the pre- and post-promotion period. The results are nearly unchanged with this condition.
### Table A2: Relationship Between Likelihood of EPO Allowance of Twin of U.S.-Issued Secondary Orange Book Patent and Grade-Level Promotion Event, Stacked Event Study Results with Examiner Fixed Effects

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<th>Panel A: Two-Year Event Window (One Year Pre- and Post-Event)</th>
<th>(1)</th>
<th>(2)</th>
</tr>
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<tr>
<td>Post Promotion Event</td>
<td>-0.044**</td>
<td>-0.045**</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>N</td>
<td>1,069</td>
<td>951</td>
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</table>

<table>
<thead>
<tr>
<th>Panel B: Four-Year Event Window (Two Years Pre- and Post-Event), Excluding Patents Issued by Examiners Promoted Again During Post-Event Window of any Event Sub-Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Promotion Event</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>N</td>
</tr>
</tbody>
</table>

Examined Fixed Effects

Conditioned on Examiners with at least 1 Review in the Pre-Promotion Period and 1 Review in the Post-Promotion Period

<table>
<thead>
<tr>
<th>Mean of Dependent Variable</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.84</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Notes: results are from a stacked sample of secondary Orange Book patents disposed of in a two-year (one on each side) event window (Panel A) or a four-year (two on each side) event window (Panel B) around the reviewing examiners’ promotions to GS-12, 13 and 14. The estimated specification also include the control variables included in Table II of the text. Specifications include examiner fixed effects. Standard errors are reported in parentheses and are clustered at the examiner level. * significant at 10%; ** significant at 5%; *** significant at 1%.

We also estimate a dynamic counterpart to Figure II from the text but from a specification likewise including examiner fixed effects. We present the results from this analysis in Figure A5. We continue to document a drop down in our patent validity marker upon the moment of the promotion itself, though the point estimates for each event indicator are estimated with less precision in this approach relative to that estimated in Figure II.
Figure A5. Event-Study Analysis: Trend in EPO-Allowance Likelihood in Period of Time Leading Up to and Following GS-Level Promotion, Secondary Patents with Examiner Fixed Effects (Quarter Increments, 2-Year Window)

Notes: Results are from a stacked sample of secondary Orange Book patents disposed of in a two-year (one on each side) event window around the reviewing examiners’ promotions to GS-12, 13 and 14 (N=1069). The plotted coefficients represent the estimated coefficients of the event-time indicators from the regression specification described in Part IV(C) of the text, with the inclusion of examiner fixed effects.
Alternative Clustering of Standard Errors

In the text of the Article, unless otherwise indicated, we have clustered our standard errors at the level in which applications are assigned at the PTO—i.e., at an Art Unit-by-year level—to account for correlation in unobservables within assignment groups. We note, however, that our results are robust to alternative ways of clustering standard errors, including clustering just at the Art Unit level (with the caveat that this arguably leaves a small number of clusters) and two-way clustering at the Art Unit and year level together (as distinct from one-way clustering at the Art-Unit-by-year level). For instance, consider a replication of Figure I from the Article that instead clusters at the Art Unit level (Figure A6) and that instead two-way clusters at the Art Unit and year level (Figure A7).

**Figure A6. Relationship Between Likelihood of EPO Allowance of “Twin” of U.S.-Issued Orange Book Patent and Grade-Level of Examiner Assigned to Relevant U.S. Patent, Cluster at Art-Unit Level**
FIGURE A7. RELATIONSHIP BETWEEN LIKELIHOOD OF EPO ALLOWANCE OF “TWIN” OF U.S.-ISSUED ORANGE BOOK PATENT AND GRADE-LEVEL OF EXAMINER ASSIGNED TO RELEVANT U.S. PATENT, TWO-WAY CLUSTER AT ART-UNIT AND YEAR LEVEL

Panel A: Secondary Patents Issued in U.S.

Panel B: Active-Ingredient Patents Issued in U.S.
Experience Effects

In Figure A8, we present estimated experience effects from specification (1). These serve as a complement to Figure I of the text which presents the estimated GS-level effects from the same specification.

**Figure A8. Relationship Between Likelihood of EPO Allowance of Twin of U.S.-Issued Orange Book Patent and Experience Level (In Year Blocks) of Examiner Assigned to Relevant U.S. Patent**

![Graph showing the relationship between likelihood of EPO allowance of twin of U.S.-issued Orange Book patent and experience level of examiner assigned to relevant U.S. patent.](chart.png)
Alternative Windows for Event-Study Analysis, Secondary Patent Analysis

In the proceeding figures, we replicate the event-study analysis depicted in Figure II of the text, but using different event windows. First, we focus on the 1-year window around the promotion—i.e., the half-year prior and the half-year post—focusing on how EPO allowance rates evolve in 45-day increments. As demonstrated by Figure A9, we continue to see a drop in EPO allowance rates that arises upon the GS-level promotion and not prior, consistent with a causal response to the promotion. However, the confidence intervals grow with this approach, leaving us with less ability to make inferences in the period by period movements. This loss of precision is to be expected given that this tighter window requires us to drop even more secondary patents from the investigation and given that our use of shorter increments leaves us with smaller samples per increment. It is nonetheless encouraging—and thus supportive of the results from the broader window—that we document a similar pattern of point estimates in the period of time surrounding the promotion event.

Second, we focus on the 4-year window around the promotion—i.e., two years prior and two years post—focusing on how EPO allowance rates evolve in 6-month increments.

**Figure A9. Event-Study Analysis: Trend in EPO-allowance likelihood in period of time leading up to and following GS-level promotion, secondary patents (45-day increments, 1-year window)**
FIGURE A10. EVENT-STUDY ANALYSIS: TREND IN EPO-ALLOWANCE LIKELIHOOD IN PERIOD OF TIME LEADING UP TO AND FOLLOWING GS-LEVEL PROMOTION, SECONDARY PATENTS (1/2 YEAR INCREMENTS, 4-YEAR WINDOW)
In Figure A11, we replicate the event-study analysis from Figure II in the text, but instead focus on the sample of active-ingredient patents. Unfortunately, given the restrictions involved in creating these event windows, this entails investigating outcomes for only 192 active-ingredient patents. We do not observe the same pattern that we do in the case of secondary patents. That is, we do not observe a strong drop in EPO allowance outcomes for those patents issued immediately upon receiving a GS-level promotion. The point estimate for the second quarter following the promotion does suggest a strong drop at that point. However, the confidence interval is rather large for this estimate. Moreover, considering the findings from Figure I which demonstrate no general GS-level pattern with active-ingredient patterns, the findings from Table II which demonstrate no increase in validity likelihoods for active-ingredient patents following the 2010 two-hour increase, and the findings from Table I which demonstrate near-zero changes in average validity rates before and after a GS-level promotion (in a binary sense), it may not be reasonable to draw very strong inferences on the drop in the point estimate for the second quarter post-event coefficient. All told, across all of these approaches we find little evidence to support a time allocation effect on examination quality in the case of active-ingredient patents.

**Figure A11. Event-Study Analysis: Trend in EPO-Allowance Likelihood in Period of Time Leading up to and Following GS-Level Promotion, Active-Ingredient Patents (Quarter Increments, 2-Year Window)**
Litigation Analysis

In this part, we build on the litigation analysis from Part IV.G of the text. In Columns 2 and 3 of Table A3, we replicate Table III of the text. We also add a set of Ordinary Least Squares results. In Column 1, we use as the dependent variable, the number of times asserted in litigation at any point over the sample period—i.e., not just in the post-AIA period.

We also present results from an event study analysis in Figure A12, where we demonstrate the evolution of the litigation count of a given issued Orange Book patent (secondary) before and after GS-level promotions. For the purposes of brevity, we show only the graph for the negative binomial results using post-AIA litigation counts. The other figures demonstrate similar findings. Moreover, we show results from an event-study graph using a 4-year window with 6-month increments, instead of a 2-year window with quarter increments. We use a longer window in the litigation analysis given that the increase in invalidity markers upon the GS-level promotion and subsequent retreat back to baseline occurs over a longer time horizon in the case of the litigation results than in the case of the EPO-allowance results. Nonetheless, when estimating a similar graph using a 2-year window, we demonstrate consistent results, though we simply do not yet begin to observe the validity marker begin to the return to its pre-promotion level.

As demonstrated by Table A3, we find an increase in litigation frequency as examiners ascend the GS-scale, consistent with the patterns documented in our previous research focusing on all technologies across the Patent Office. This relationship is stronger—and is only statistically distinguishable from zero—in those specifications focusing on post-AIA litigation counts. Considering that higher litigation rates per average patent can be seen as a marker for weaker validity on average—as discussed in the text of the Article—these results are consistent with the EPO-allowance analysis in suggesting that as examiners are given less time to review applications, they issue patents with more questionable validity.

We bolster this finding in the event-study graph depicted in Figure A12, which demonstrates that examiners issue patents over time with litigation rates that tend to fall, suggesting an improvement in examination quality with experience. However, when examiners experience an examination-time-reducing promotion, we observe a large increase in litigation rates, suggesting a negative shock in the quality of their reviews and a disruption of this general improvement process.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ordinary Least Squares Regressions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omitted: GS-11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS 12</td>
<td>0.186</td>
<td>0.277</td>
<td>0.043</td>
</tr>
<tr>
<td>(0.346)</td>
<td>(0.216)</td>
<td>(0.331)</td>
<td></td>
</tr>
<tr>
<td>GS-13</td>
<td>0.437</td>
<td>0.594**</td>
<td>0.508</td>
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<tr>
<td>(0.382)</td>
<td>(0.255)</td>
<td>(0.416)</td>
<td></td>
</tr>
<tr>
<td>GS-14</td>
<td>0.472</td>
<td>0.737**</td>
<td>1.08***</td>
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<tr>
<td>(0.420)</td>
<td>(0.299)</td>
<td>(0.385)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3,126</td>
<td>3,126</td>
<td>1,810</td>
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<tr>
<td><strong>Negative Binomial Regressions, Coefficients Reported as Incidence Rate Ratios</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omitted: GS-11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS 12</td>
<td>1.111</td>
<td>1.379</td>
<td>1.010</td>
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<tr>
<td>(0.266)</td>
<td>(0.326)</td>
<td>(0.294)</td>
<td></td>
</tr>
<tr>
<td>GS-13</td>
<td>1.236</td>
<td>1.709*</td>
<td>1.372</td>
</tr>
<tr>
<td>(0.339)</td>
<td>(0.486)</td>
<td>(0.467)</td>
<td></td>
</tr>
<tr>
<td>GS-14</td>
<td>1.504</td>
<td>2.027**</td>
<td>2.347***</td>
</tr>
<tr>
<td>(0.432)</td>
<td>(0.586)</td>
<td>(0.756)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>3,126</td>
<td>3,126</td>
<td>1,810</td>
</tr>
</tbody>
</table>

Notes: Results are from a specification analogous to that estimated in Panel A of Figure I, though using the count of the times litigated post-AIA as the dependent variable. Estimated coefficients for the other variables in specification (1) are omitted for brevity purposes. Standard errors are indicated in parentheses and are clustered at the Art-Unit-by-year level.
Note, we do not consider the 2010 two-hour reform for this litigation exercise given that the AIA was passed over the window of time used for this event study, potentially confounding that time-series analysis.
Results using Allowance at Both the EPO and the JPO as a Validity Indicator

As discussed in the text, we also consider an alternate approach where we use a marker of validity whether the focal U.S.-issued Orange Book was part of a family of applications at the U.S. Patent Office, the EPO and the JPO and was allowed at all three of these world offices. In Figure A13, we replicate Figure I of the Article but using this alternative dependent variable. This specification follows our primary approach at clustering standard errors—i.e., at the unit of assignment, the Art-Unit-by-year level. Following from above in this Online Appendix, Figure A14 instead clusters the standard errors at the Art Unit level and Figure A15 instead two-way clusters at the Art Unit and year levels. As demonstrated by these Figures, this alternative marker for validity likewise trends downwards as GS-levels rise in the case of secondary patents, with no such discernable pattern (but large standard errors) in the case of active-ingredient Orange Book patents. Also as demonstrated, the precision in this downward trend is higher when either clustering at the Art Unit level or two-way clustering at the Art-Unit and year level. Overall, the evidence suggests that higher GS-levels are associated with lower likelihoods of issuing valid patents. As discussed in the text, we continue to focus on the EPO analysis as our primary approach given that the EPO both extends examiners more time and examines applications in teams.

We next estimate the stacked-event-study specifications—both in a binary and dynamic sense—but using the incidence of allowance at both the EPO and the JPO as the outcome variable. We present the counterpart to Table I in the text in Table A4 of this Online Appendix and the counterpart to Figure II in the text in Figure A16 of this Online Appendix. We find the same pattern of coefficients when looking at the binary reform indicator from this specification; however, the results are somewhat imprecise and we cannot distinguish the reform coefficient from 0 in the secondary patent sample. As with the GS-level figures, however, when we instead cluster the standard errors at the Art Unit level, we find that the drop in EPO and JPO allowance is significantly different from 0. In the dynamic event-study analysis, we find a very similar pattern between Figure II and Figure A16 and do document a statistically significant, large drop in the EPO/JPO allowance incidence upon the promotion event.

In Table A5, we replicate Table II from the text, whereby we explore the impact of the 2010 two-hour reform on the likelihood of patent validity, but now using allowance at both the EPO and the JPO as the validity indicator. As demonstrated, the results are nearly identical when taking this alternative approach.

Overall, the evidence from this alternative benchmarking approach are consistent with a story in which as examiners get less time to review applications, they issue secondary pharmaceutical patents of more questionable validity.
**Figure A13. Relationship Between Likelihood of Both EPO and JPO Allowance of Family of U.S.-Issued Orange Book Patent and Grade-Level of Examiner Assigned to Relevant U.S. Patent**

Notes: this figure presents results from a specification identical to that estimated in Figure I of the text but using the incidence of allowance at both the EPO and the JPO as the dependent variable.

**Figure A14. Relationship Between Likelihood of Both EPO and JPO Allowance of Family of U.S.-Issued Orange Book Patent and Grade-Level of Examiner Assigned to Relevant U.S. Patent, Cluster at Art-Unit Level**

Notes: this figure presents results from a specification identical to that estimated in Figure A13 but clustering the standard errors at the Art Unit level.
FIGURE A15. RELATIONSHIP BETWEEN LIKELIHOOD OF BOTH EPO AND JPO ALLOWANCE OF FAMILY OF U.S.-ISSUED ORANGE BOOK PATENT AND GRADE-LEVEL OF EXAMINER ASSIGNED TO RELEVANT U.S. PATENT, TWO-WAY CLUSTER AT ART-UNIT AND YEAR LEVELS

Notes: this figure presents results from a specification identical to that estimated in Figure A13 but clustering the standard errors two ways at the Art Unit level and the year level.
### Table A4: Relationship Between Likelihood of EPO and JPO Allowance of Family of U.S.-Issued Orange Book Patent and Grade-Level Promotion Event, Stacked Event Study Results

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Secondary Patents</td>
<td>Primary (Active-Ingredient) Patents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post Promotion Event</td>
<td>-0.056</td>
<td>-0.056**</td>
<td>-0.025</td>
<td>-0.025</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.023)</td>
<td>(0.071)</td>
<td>(0.080)</td>
</tr>
<tr>
<td>N</td>
<td>1,069</td>
<td>1,069</td>
<td>192</td>
<td>192</td>
</tr>
<tr>
<td>Panel B. Window: Two Years Pre- and Post-Event, Excluding Patents Issued by Examiners Promoted Again During Post-Event Window of any Event Sub-Sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post Promotion Event</td>
<td>-0.039</td>
<td>-0.039*</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.020)</td>
<td>(0.039)</td>
<td>(0.048)</td>
</tr>
<tr>
<td>N</td>
<td>1,821</td>
<td>1,821</td>
<td>329</td>
<td>329</td>
</tr>
<tr>
<td>Clustering of Standard Errors</td>
<td>Art-Unit-by-Year</td>
<td>Art Unit</td>
<td>Art-Unit-by-Year</td>
<td>Art Unit</td>
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<tr>
<td>Mean of Dependent Variable</td>
<td>0.76</td>
<td>0.76</td>
<td>0.90</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Notes: results are from a stacked sample of secondary (Columns 1 and 2) and primary (Columns 2 and 3) Orange Book patents disposed of in a two-year (one on each side) event window (Panel A) or a four-year (two on each side) event window (Panel B) around the reviewing examiners’ promotions to GS-12, 13 and 14. The estimated specification also includes the control variables included in Table I in the text. Standard errors are reported in parentheses and are clustered at the indicated level. * significant at 10%; ** significant at 5%; *** significant at 1%.
Notes: this figure presents results from a specification identical to that estimated in Figure II of the text but using the incidence of allowance at both the EPO and the JPO as the dependent variable.

**TABLE A5. CHANGE IN EPO AND JPO ALLOWANCE RATE OF FAMILY OF U.S.-ISSUED ORANGE BOOK PATENT FOLLOWING 2010 REFORM INCREASING TIME ALLOTMENTS BY TWO HOURS (FOUR-YEAR WINDOW)**

<table>
<thead>
<tr>
<th></th>
<th>SECONDARY PATENTS</th>
<th>ACTIVE INGREDIENT PATENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Hours Reform</td>
<td>0.099**</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td>(0.046)</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>545</td>
<td>196</td>
</tr>
</tbody>
</table>

* significant at 10%; ** significant at 5%; *** significant at 1%. Standard deviations are indicated in parenthesis and are clustered at the unit of assignment—i.e., at the Group Art Unit-by-year level to account for correlation in unobservables within assignment groups.
Alternative Assignments of Active-Ingredient and Secondary Patents

In our primary approach to classifying active-ingredient and secondary patents, we follow the drug-substance classification provided directly by the FDA in the Orange Book data. However, some of those patents listed as “drug substance” patents in the Orange Book data are not necessarily the first patent on the active ingredient itself. Some are likely patents on polymorphs of the active-ingredient—i.e., patents on different crystalline structures of the active ingredient. Unfortunately, we do not have readily available information identifying which of the “drug substance” patents are the truly original active ingredient patent and which are polymorphs. However, given the possibility that truly active-ingredient patents may be less time-consuming to review that patents on different crystalline forms of those ingredients, we make an attempt to separate out these two types of drug substance patents. Accordingly, we take the following approach to approximate such a classification—an approach which seems sensible based on taking several random draws of FDA drug products and reviewing the underlying patents: if a given FDA-approved drug product has two or more drug substance patent associated with it, we assume the later issued patents are polymorphs and the first issued patent is the original active-ingredient patent. We then assign the polymorphs to the group of secondary patents.

In Figure A17, we replicate Figure I of the text using these new assignments. In Panel A—demonstrating the relationship between EPO allowance outcomes and GS-levels for U.S.-issued secondary Orange Book Patents—we document a nearly unchanged pattern using this alternative assignment process, with a statistically significant coefficient of the GS-14 indicator suggesting a roughly 8 percentage-point lower likelihood of EPO allowance relative to the GS-11 group. We present results for the new assignment of active-ingredient patents in Panel B. We continue to document no discernable pattern in EPO outcomes across GS levels in the case of active-ingredient patents, though we of course acknowledge the very large standard errors in our estimates.

**Figure A17. Relationship Between Likelihood of EPO Allowance of “Twin” of U.S.-Issued Orange Book Patent and Grade-Level of Examiner Assigned to Relevant U.S. Patent, Reassigning Likely Polymorphs to Secondary Patent Groups**
The remainder of the figures presented throughout our analysis are also robust to this alternative approach to assignment. In the interests of brevity, we do not present all such results. However, by way of example, we do demonstrate the robustness of the event study analysis depicted in Figure II of the text to the use of this alternative construction of the secondary patent sample. As shown in Figure A18, the findings are nearly unchanged.

**Figure A18. Event-Study Analysis: Trend in EPO-Allowance Likelihood of Twin Of U.S.-Issued Secondary Orange Book Patent in Period of Time Leading up to and Following GS-Level Promotion, Reassigning Likely Polymorphs to Secondary Patent Groups**
Some drug products receiving approval from the FDA do not necessarily emanate from an original active ingredient patent. A brand name manufacturer may instead revisit an old ingredient and develop a new use based on a novel strength or formulation or an ingredient previously patented by another manufacturer (or simply based on an ingredient that has long been in the public domain). The original patents received by this new brand name manufacturer may indeed be categorized as a secondary patent in our database in that the patent is on a new formulation, strength and/or method of use. That manufacturer may then go on to obtain even more secondary patents in connection with this new drug product—e.g., a manufacturer may find a new use for an old ingredient and obtain a patent on it and subsequently patent an extended-release version of its drug. In an alternative approach to categorizing “secondary” patents, we exclude from this sample of secondary patents all such original patents for new drug products of this nature. In other words, we consider an alternative sample of original patents that includes (1) patents that are secondary to a previous active-ingredient patent by that manufacturer and (2) patents that are issued following an original patent obtained by a manufacturer to create a new drug product, but where that original patent is nonetheless not a patent on the original active-ingredient itself.

The essence behind this alternative approach is to view as “secondary” those patents that are truly secondary within a marketed drug. In Figure A19, we replicate Panel A of Figure I of the text focusing on this alternative formulation of secondary patents (ignoring Panel B of Figure I as our focus in this exercise is simply on an alternative set of secondary patents). As demonstrated by Figure A19, we find a nearly identical pattern in this instance.

The remainder of the secondary patent results are likewise robust to this alternative approach. In the interests of brevity, we will only show this for the case of the event-study graph analogous to Figure II in the text, which we demonstrate in Figure A20. As can be seen, this event-study figure is nearly identical to that presented in Figure II.
Figure A19. Relationship Between Likelihood of EPO Allowance of “Twin” of U.S.-Issued Orange Book Patent and Grade-Level of Examiner Assigned to Relevant U.S. Patent, Excluding Secondary Patents that Constitute Original Patents for New Drugs

Figure A20. Event-Study Analysis: Trend in EPO-Allowance Likelihood of Twin Of U.S.-Issued Secondary Orange Book Patent in Period of Time Leading up to and Following GS-Level Promotion, Excluding Secondary Patents that Constitute Original Patents for New Drugs
As indicated in Parts V and VI of the Article, we consider a hypothetical reform in which the Patent Office increases time allocations by 50% for each application, without sacrificing throughput, in which case, we contemplate a 50% increase in hours for each of 23,418 annual secondary pharmaceutical patent applications. To determine the costs associated with this reform, we begin by calculating the increase in hours this will entail broken out by examiner GS-level (Column 3), which in turn requires a breakdown of applications by GS-level per year (Column 1) and the number of hours assigned by GS-level (which is based on a weighted average of allocated examiner hours for that GS-level across the different Art Units comprising the set of pharmaceutical applications) (Column 2). In Column 4, we indicate the cost per hour to review an application broken down by GS-level. These estimates are from Frakes and Wasserman (2019), which uses federal salary scales (assuming step 5 salaries within each grade level) and uses a salary multiplier of 2.04 to determine associated benefits and overhead expenses associated with that hour of compensation. Multiplying Column 3 by Column 4 and then aggregating across GS-levels, we calculate that this 50% increase in examination time for secondary pharmaceutical applications will cost the Patent Office roughly $20 million per year.

Table A6. Estimated Personnel Costs associated with 50% Increase in Aggregate (and Per-Application) Examination Time

<table>
<thead>
<tr>
<th>GS-level</th>
<th>Number of Annual Dispositions by Examiners</th>
<th>Mean Number of Hours Assigned</th>
<th>Total Additional Hours After 50% Increase in Hours per Application</th>
<th>Examiner Cost per Hour (Salary, Benefits, and Other Costs)</th>
<th>Extra Costs when Doubling Examination Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS-11</td>
<td>1268</td>
<td>24.6</td>
<td>15,597</td>
<td>$57.58</td>
<td>$898,047</td>
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<tr>
<td>GS-12</td>
<td>3125</td>
<td>22.7</td>
<td>35,469</td>
<td>$68.99</td>
<td>$2,447,006</td>
</tr>
<tr>
<td>GS-13</td>
<td>5690</td>
<td>19.4</td>
<td>55,193</td>
<td>$82.05</td>
<td>$4,528,586</td>
</tr>
<tr>
<td>GS-14</td>
<td>13334</td>
<td>17.8</td>
<td>118,672</td>
<td>$96.96</td>
<td>$11,506,495</td>
</tr>
<tr>
<td>Total</td>
<td>23,418</td>
<td>19.2</td>
<td>224,931</td>
<td>$87.46</td>
<td>$19,672,465</td>
</tr>
</tbody>
</table>

The mean number of hours per grade is calculated using the PAIR sample after assigning hour allotments to each application in the PAIR database based on the associated technology group and examiner grade level.

Marginal versus Average Effects

The above analysis implies that as examiners are given less time to review secondary patents, the average patent that they issue is less likely to be valid. This average effect could be due to a situation in which an examiner issues the same number of patents regardless of her time allocation, but where increases in time pressures constrain her ability to narrow the claims of some of those patents, with the effect being that time pressures cause a greater portion of those patents to be invalid. Alternatively, the observed decline in average validity may be due to a situation in which the time pressures inhibit her ability to find bases to reject some applications that she otherwise would have rejected altogether if she had more time. This latter scenario could account for the above findings to the extent that the issuance of an additional set of invalid patents on the margin could lower the average likelihood of validity among the full set of issued patents.

Arguably, whether this decline in average quality is driven by insufficient claim narrowing among a consistent set of patents or insufficient rejecting among the set of applications is of no consequence in the aggregate. Either mechanism could account for the issuance of some amount of patents that lack legal validity. Nonetheless, in this sub-section, we attempt to shed light on this mechanism question and ascertain if at least some of the effects derived above arise from a situation in which examiners are issuing a greater number of invalid patents on the margin.

To explore this possibility, we follow the approach of Frakes and Wasserman (2017) and test whether the allowance rate of pharmaceutical patent applications increases as examiners ascend the GS-level scale. For these purposes, we need data at the level of the individual application, as distinct from the individual issued patent. We do have this data for all pharmaceutical applications—not necessarily the select subset of those that are likely to wind up being listed in the Orange Book. One advantage of working with this broader application sample is that each examiner reviews a meaningful number of pharmaceutical patents over their careers facilitating a straightforward estimation of an examiner fixed effects approach.

In Figure A21, we present results from a counterpart to specification (1) that instead uses the full pharmaceutical patent application sample and that uses the incidence of the application being allowed as the dependent variable. We find a strong increase in the rate of allowance—and thus the number of patents issued—as examiners experience grade-level promotions, consistent with the results we found across all technologies in Frakes and Wasserman (2017). These findings, in conjunction with the above findings, are consistent with a story in which, as examiners receive less time to review, they allow an additional set of invalid patents on the margin that lower the average likelihood of validity among issued patents.
Figure A21. Relationship Between Likelihood of Allowance at the U.S. Patent Office of Pharmaceutical Patent Applications and Grade-Level of Assigned Examiner, with Examiner Fixed Effects

Notes: results are from a sample of 310,531 patent applications identified as drug applications by the NBER technology sub-categories. Results are from a counterpart to specification (1) that uses this sample and that uses the incidence of allowance of the application as the dependent variable, while also including examiner fixed effects (and using Art Unit and year effects separately). Only the estimated coefficients of the GS-level dummies are presented. 95% confidence intervals are indicated by the vertical bars. Standard errors are clustered at the Art-Unit level.