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Staff White Paper

Econometric Analysis on the Initial Implementation of the New Specialists Requirements

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TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

The PCAOB is committed to understanding the initial impact of new requirements for auditing accounting estimates, including fair value measurements ("Estimates Requirements") and the auditor's use of the work of specialists ("Specialists Requirements"). These new requirements took effect for audits with fiscal years ending on or after December 15, 2020. In furtherance of that commitment, staff of the Office of Economic and Risk Analysis (OERA) has studied the initial implementation of these new requirements.

In this white paper we employ several commonly used econometric methods to estimate differences in specialist usage and hours associated with the implementation of the new Specialists Requirements.[2] The analysis presented in this paper is descriptive not causal in nature. That is, while we can describe trends in the data, we cannot say with certainty whether they are caused by the Specialists Requirements given the presence of contemporaneous changes in other auditing standards, accounting standards, and the broader economy at large.[3] Despite these challenges, the analysis provides valuable insight into changes in auditing practice related to auditors' use of the work of specialists. The new Estimates Requirements emphasize that auditors need to apply professional skepticism, including addressing potential management bias, when auditing accounting estimates. Given the lack of structured and systematic data to measure these emphases, the staff is not able to separately perform a large-sample statistical analysis to evaluate the initial impact of the new Estimates Requirements at this time. The staff will continue to monitor the implementation of the new Estimates Requirements and evaluate appropriate outcome variables, such as restatement of previously issued financial statements, for a more comprehensive, longer-term, post-implementation review to be conducted in the future.

This white paper is one part of OERA's contribution to the PCAOB's understanding of the initial impact of the Estimates Requirements and Specialists Requirements and should be read in conjunction with a set of companion documents released together with this white paper. Specifically, the PCAOB has published

[2] As defined in applicable PCAOB Standards, a specialist is a person (or firm) possessing special skills or knowledge in a particular field other than accounting. As described in the 2018 release, companies across many industries use various types of specialists to assist in developing accounting estimates in their financial statements. Companies may also use specialists to interpret laws, regulations, and contracts or to evaluate the characteristics of certain physical assets. Those companies may use a variety of specialists, including actuaries, appraisers, other valuation specialists, legal specialists, environmental engineers, petroleum engineers, and the like. Auditors often use the work of these companies' specialists as audit evidence. In addition, auditors frequently use the work of auditors' specialists to assist in their evaluation of significant accounts and disclosures, including accounting estimates in those accounts and disclosures. *See Amendments to Auditing Standards for Auditor's Use of the Work of Specialists*, PCAOB Release No. 2018-006 (Dec. 20, 2018) at 1. Consistent with the definition of "specialists" in the applicable PCAOB standards, the Specialists Requirements do not apply to persons or firms providing specialized skill or knowledge in income taxes or information technology.

[3] Specifically, the Specialists Requirements took effect at the same time as the Estimates Requirements and the effects could be attributed jointly to the two standards. But the effective date also fell during approximately the same period when auditors of issuers that are not Large Accelerated Filers (non-LAF) were implementing the PCAOB standard requiring disclosure of Critical Audit Matters (CAMs). Moreover, contemporaneously with the auditor's implementation of the new Specialists Requirements, issuers were implementing four new accounting standards: Financial Instruments—Credit Losses (often referred to by the name of the model used — Current Expected Credit Losses, or "CECL") (Topic 326), Intangibles—Goodwill and Other—Internal use Software (Subtopic 350-40), Compensation—Retirement Benefits—Defined Benefit Plans—General (Subtopic 715-20), and Fair Value Measurement (Topic 820). These standards may also have affected the auditor's use of specialists. For example, CECL may increase the demand for specialists when auditing CECL models, assumptions, and underlying data, independent of the new estimates and specialists audit requirements. Finally, we expect the COVID-19 pandemic affected the nature and extent of audit work performed on accounting estimates and specialist usage (*i.e.*, due to increased risk of asset impairments and changes to expected cash flows).

an interim analysis report that summarizes additional evidence on the impact of the Estimates Requirements and Specialists Requirements. Another white paper, *Stakeholder Outreach on the Initial Implementation of Estimates and Specialists Audit Requirements* ("2022 Outreach Analysis"), presents results from econometric analysis on the initial effects of Estimates Requirements and Specialists Requirements implementation on audits and capital markets.

Key Findings

- **Our analysis finds evidence that the probability of using one or more specialists on an audit engagement increased following implementation of the new Specialists Requirements.**[4]

    - We find that the probability that an auditor used an *auditor-employed specialist* on an audit engagement increased by a statistically significant 4.8 percentage points in the post-implementation period. That difference was driven by an increase of 8.8 percentage points among engagements performed by firms that are not affiliated with a major global network ("NAF engagements"); there was not a statistically significant difference for audit engagements performed by U.S. firms that are members of global networks ("GNF engagements").[5]

    - Our results also suggest an increased probability in the post-implementation period that an auditor used an *auditor-engaged specialist*, but that increase was not significant at conventional levels of statistical significance.

    - We also find that the probability of an auditor using the work of a *company specialist* increased in the post-implementation period by a statistically significant 10.5 percentage points, driven by an increase among NAF engagements of 11.2 percentage points.

- **Our results suggest that, on average, the new Specialists Requirements did not result in a significant change in specialist hours.** Among engagements in our sample that used auditor-employed specialists, we estimate pre-post differences in specialist hours and find no statistically significant differences for the full sample or separately for GNF and NAF engagements.

- **While the proportion of auditor-employed specialist hours allocated to the quarterly review and preliminary phases of the audit increased on average in the post-implementation period, this change is consistent with a broader shift in the allocation of total audit hours to earlier phases of the audit**.

    - Among GNF engagements that used auditor-employed specialists, we find a statistically significant 2.8 percentage point increase in the proportion of auditor-employed specialist

[4] In this paper, we examine specialists employed by the audit firm ("auditor-employed specialists"), third-party specialists contracted by the audit firm ("auditor-engaged specialists"), and specialists employed or engaged by an issuer ("company specialists") whose work is used by the auditor as audit evidence. The Specialists Requirements for the three types of specialists appear in Appendix C of AS 1201 *Supervision of the Audit Engagement*, AS 1210 *Using the Work of an Auditor-Engaged Specialist*, and Appendix A of AS 1105 *Audit Evidence*, respectively.

[5] Global Network Firms (GNFs) consist of the network of firms affiliated with the six largest global networks: BDO International Limited, Deloitte Touche Tohmatsu Limited, Ernst & Young Global Limited, Grant Thornton International Limited, KPMG International Cooperative, and PricewaterhouseCoopers International Limited. Non-affiliate firms are registered audit firms that are not associated with these global networks.

hours allocated to the quarterly review phase of the audit and a statistically significant increase of 2.3 percentage points in the proportion allocated to the preliminary phase of the audit. We find a corresponding decrease of 4.1 percentage points in the proportion of auditor-employed specialist hours allocated to the final phase of the audit.

- Among GNF engagements that used auditor-employed specialists, we also find a statistically significant increase in the proportion of total audit hours allocated to the preliminary phase of the audit of 3.5 percentage points, along with a corresponding decrease in the proportion of total hours allocated to the final phase of 2.8 percentage points.

- We estimate pre-post differences in the relative shares of auditor-employed specialist hours to total audit hours in each phase and find a statistically significant 0.4 percentage point increase in the share of total audit hours allocated to auditor-employed specialists in the quarterly review phase. However, we find no statistically significant differences in the preliminary, interim, or final phases of the audit.

II. SCOPE AND ANALYTICAL FRAMEWORK

In this paper, we perform an econometric analysis to examine pre-post differences in specialist usage and hours associated with the implementation of the new Specialists Requirements. Large sample statistical analysis of PCAOB inspections data complements the stakeholder outreach and analysis released in conjunction with this white paper, without the inherent small sample limitations. This analysis is intended to be descriptive — not causal — in nature. Because the new Specialists Requirements and Estimates Requirements are necessarily interrelated and have the same effective date, the pre-post differences estimated in this paper could be attributed jointly to these new requirements. Moreover, upon adoption, the new Specialists Requirements were effective for all audit engagements with fiscal years ending on or after December 15, 2020 — the same effective date as the PCAOB standard requiring communication of critical audit matters (CAMs) for smaller issuers and approximately the same date as four accounting standards.[6] Because the new Specialists Requirements did not feature phased implementation, there is no natural control group for performing a quasi-experimental study. Therefore, any econometric analysis aimed at identifying and estimating causal relationships between the implementation of the new Specialists Requirements and economic outcomes of interest would be confounded by contemporaneous changes in these other auditing and accounting regulations, as well as the economic impact of the ongoing COVID-19 pandemic. Nevertheless, descriptive analysis is valuable for analyzing changes in audit practice and understanding relationships in our data and can provide the Board and the broader auditing and investment community with an initial assessment of how implementation is associated with outcomes of interest.

The rest of this paper proceeds as follows. Section III provides a brief overview of the relevant academic literature on the use of specialists. Section IV provides a description of the dataset, including the construction of the outcome variables of interest and the independent variables used in the econometric models. Section V presents summary statistics for the outcomes of interest — in particular, specialist usage by type, auditor-employed specialist hours, and auditor-employed specialist hours by audit phase — and the results of univariate statistical tests relevant to the econometric analysis. In Section VI, we employ several commonly used econometric methods to estimate pre-post differences in

[6] See Appendix D for a discussion of specific confounding factors and efforts that were made to mitigate their impact on the results.

specialist usage and specialist hours among inspected engagements, while controlling for engagement-level factors that could impact the outcomes of interest. First, we analyze pre-post differences in specialist usage by type of specialist. Next, for engagements that reported using auditor-employed specialists, we estimate pre-post differences in auditor-employed specialist hours in levels and as a share of total audit hours. Where the data allow, we estimate these differences separately for GNF and NAF engagements to understand the extent to which changes may have disproportionately affected smaller audit firms. Finally, for the subset of inspected GNF engagements that reported using auditor-employed specialists, we estimate pre-post differences in the allocation of specialist hours to various phases of the audit.

III. RELATED ACADEMIC RESEARCH

There are relatively few empirical studies on the use of specialists in the auditing literature. Due to the interrelated nature of auditing accounting estimates and the use of specialists, most of the studies that examine specialist usage do so in the context of complex estimates and fair value measurements (FVMs). Moreover, because of the lack of publicly available archival data on the use of specialists, the extant literature on specialist usage is disproportionately weighted toward studies that rely on interviews and surveys. There are relatively few observational studies in this space.

This paper complements the extant literature by analyzing proprietary administrative data collected through the PCAOB's inspection program, including data on specialist usage and specialist hours. This paper is the first observational study to analyze the association between PCAOB's new Specialists Requirements and the use of specialists. A discussion of relevant academic literature on the use of specialists is provided in Appendix C.

IV. DATA

The analysis in this paper relies primarily on engagement-level administrative data collected through PCAOB's GNF and NAF inspections programs for inspection years 2018 through 2021. This dataset was combined with third-party audit fees data published by Audit Analytics and issuer-level financial data and industry classifications published by S&P Capital IQ. This section provides a basic description of the specialists dataset, as well as summary statistics and significance tests for the three primary outcomes of interest in this paper: specialist usage, specialist hours, and specialist hours by audit phase.

Outcomes of Interest

For inspected engagements, the PCAOB staff collects data on whether specialists were used and classifies them into one of three categories: auditor-employed specialists, auditor-engaged specialists, and company specialists.[7] To measure the extent to which the new Specialists Requirements are associated with changes in the propensity to use each type of specialist, we construct binary variables for each specialist type that are equal to one if the specialist in question is used on an engagement and zero otherwise.

[7] For each of the three specialist types, PCAOB staff collects binary (yes / no) data on whether each type of specialist was used on an inspected engagement. The data are provided directly by the audit firms and the categories are not mutually exclusive.

For inspected engagements that use auditor-employed specialists, the PCAOB staff collects data on specialist hours.[8] We use two outcome variables to measure the extent to which the new Specialists Requirements are associated with changes in the intensity of auditor-employed specialist usage: (1) the natural log of auditor-employed specialist hours, and (2) the proportion of auditor-employed specialist hours to total audit hours.

Finally, for inspected GNF engagements on which auditor-employed specialists were used, the PCAOB staff collects data on the total specialist hours allocated to each of five phases of the audit: preliminary planning, quarterly review, interim field work, final field work, and hours incurred after the issuance of the report.[9] We use this data to construct two outcome variables: (1) the share of auditor-employed specialist hours allocated to each phase of the audit and (2) the proportion of auditor-employed specialist hours to total audit hours for each phase of the audit. We use these outcome variables to measure the extent to which the new Specialists Requirements are associated with changes in the allocation of specialist hours to each phase of the audit.

Independent Variables

In selecting control variables for the econometric models in Section VI, we follow well-established literature in the auditing field (see, *e.g.*, DeFond and Zhang (2014), Zimmerman *et al*. (2021)).

At the issuer level, we control for variations in issuer size and financial characteristics using *Log Total Assets,* measured as the natural log of an issuer's total assets in millions of U.S. dollars. To control for the profitability of the issuer we use *Return on Assets*, computed as the net income of the issuer divided by their total assets. To control for long-term debt levels, we include an estimate of the issuer's *Leverage Ratio*, calculated as the issuer's total debt divided by the sum of their total debt plus total equity.

To control for issuer characteristics that increase the complexity of the audit process or that are related to complex estimates and fair value measurements which may drive specialist usage, we use three separate variables: *FV Assets to Total Assets* (measured as the ratio of fair value assets to total assets), *FV Liabilities to Total Assets* (measured as the ratio of fair value liabilities to total assets), and *Intangibles to Total Assets* (measured as the sum of goodwill and intangible assets divided by total assets).

Because mergers, acquisitions, and restructuring events often drive additional audit effort and may also affect the decision to use specialists on an engagement, we include an indicator variable, *Merger and Restructuring*, which is equal to one if an issuer reported merger or restructuring charges and zero otherwise. Similarly, we may expect to observe differences in specialist usage and specialist hours for issuers that reported a loss in the current year (*Net Loss*), are a new client for the auditor (*New Client*), or have a December fiscal year end that aligns with the auditor's busiest season (*December FYE*). We control for each of these cases in our models with an indicator variable equal to one if the condition exists and zero otherwise.

[8] The PCAOB staff collects data on specialist hours only for auditor-employed specialists. For the inspection years discussed in this paper, PCAOB staff did not collect hours data for auditor-engaged or company specialists.

[9] The PCAOB staff collects data on specialist hours by audit phase only for GNF engagements. For the inspection years discussed in this paper, PCAOB staff did not collect data on hours by audit phase for NAF engagements.

Finally, to adjust for variations across industries, we employ fixed effects by including the eleven industry sector classifications assigned to issuers by S&P Capital IQ. Similarly, in our analysis of specialist hours by audit phase, where our sample is limited only to GNF engagements, we use firm fixed effects to account for variations among the Big-6 auditors. A full set of variable definitions and descriptions can be found in Appendix A.

V. SUMMARY STATISTICS

The specialists dataset consists of data from 1,643 inspected engagements, distributed roughly equally across inspection years 2018 through 2021 (see **Table 1**).[10] For the purposes of this paper, engagements with fiscal years ending on or after December 15, 2020 — the effective date for the new Specialists requirements — are referred to as "post-implementation" or "post-period" observations. Engagements with fiscal years ending prior to that date are referred to as "pre-implementation" or "pre-period" observations. Pre-implementation observations account for approximately 79% of the engagements in our sample (n = 1,295), with the remaining 21% of observations (n = 348) in the post-implementation period.

GNF engagements account for approximately 60% of the observations in the sample (n = 992), while NAF engagements account for the remaining 40% (n = 651). Within these subsamples, the proportions of engagements in the pre- and post-implementation periods are similar to the proportions in the overall specialists dataset. Of the 992 GNF engagements in the sample, approximately 78% (n = 777) are pre-implementation observations, while the other 22% (n = 215) are post-implementation observations. Of the 651 NAF engagements in the sample, approximately 80% (n = 518) are pre-implementation and 20% (n = 133) are post-implementation. Similarly, the proportions of GNF and NAF engagements in the pre- and post-implementation periods are roughly equal to the proportions in the overall specialists dataset. Of the 1,295 pre-implementation observations, 60% (n = 777) are GNF engagements and 40% (n = 518) are NAF engagements. Of the 348 post-implementation engagements, approximately 62% (n = 215) are GNF engagements and approximately 38% (n = 133) are NAF engagements (see **Table 2**).

Specialist Usage

On average, the proportions of inspected engagements using each type of specialist increased in the post-period — this result holds for the full sample (see **Figure 1**) and separately for GNF and NAF engagements (see **Figure 2**). **Table 4** compares the proportions of engagements using each type of specialist across the two time periods and reports the statistical significance of those pre-post differences.[11]

The proportion of inspected engagements using auditor-employed specialists increased from 68.3% in the pre-period to 77.9% in the post-period, a statistically significant difference of 9.6 percentage points. That difference was driven by an increase in the use of auditor-employed specialists among NAF engagements. Approximately 49.6% of NAF engagements used auditor-employed specialists in the post-period, compared to 30.3% in the pre-period — a statistically significant difference of 19.3 percentage

[10] In the specialists dataset, the pre-implementation period spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period spans fiscal years ending between December 15, 2020 and March 31, 2021. Tables are provided in Appendix B.

[11] **Table 4** reports the results from a standard two-sample test for the equality of proportions. In untabulated results, the same conclusions are reached using a non-parametric chi-square test.

points. The difference in the proportion of GNF engagements using auditor-employed specialists across the two periods was not statistically significant.

The proportion of inspected engagements reporting the use of auditor-engaged specialists increased from 16.6% in the pre-period to 23.0% in the post-period, a statistically significant difference of 6.4 percentage points. That difference was driven by an increase in the use of auditor-engaged specialists among GNF engagements. Approximately 20.5% of GNF engagements reported using auditor-engaged specialists in the post-period, compared to just 8.4% in the pre-period — a statistically significant increase of 12.0 percentage points. The difference in the proportion of NAF engagements using auditor-engaged specialists was not statistically significant.

The proportion of inspected engagements on which the auditor used the work of company specialists increased from 31.2% in the pre-period to 45.1% in the post period — a statistically significant increase of 13.9 percentage points. This was driven by statistically significant increases in auditors' use of the work of company specialists on both GNF and NAF engagements of 11.9 and 18.0 percentage points, respectively.

Auditor-Employed Specialist Hours

Among inspected engagements that used auditor-employed specialists, average annual hours per engagement for those specialists increased from about 342.1 hours in the pre-period to about 447.1 hours in the post-period (see Panel A of **Table 3**). Among GNF engagements, average annual auditor-employed specialist hours per engagement increased from about 400.2 hours in the pre-period to about 568.6 hours in the post-period. Among NAF engagements, although average annual auditor-employed specialist hours per engagement decreased from about 68.0 hours in the pre-period to 57.9 hours in the post-period, this change is not statistically significant.

However, as a share of total U.S. audit hours, auditor-employed specialist hours have been roughly flat (see Panel B of **Table 3**). For the full sample of inspected engagements, auditor-employed specialist hours accounted for approximately 2.4% of total audit hours in both the pre- and post-periods. Among GNF engagements, auditor-employed specialist hours accounted for approximately 2.6% of U.S. audit hours in the post-period, up slightly from approximately 2.5% in the pre-period. Among inspected NAF engagements, auditor-employed specialist hours accounted for approximately 1.7% of U.S. audit hours in the post-period, down slightly from 1.9% in the pre-period.

Comparing auditor-employed specialist hours before and after implementation of the new Specialists Requirements, we find no statistically significant differences in either (log) levels or as a share of total audit hours — these results hold for the full sample, as well as separately for GNF and NAF engagements (see **Table 5**).[12]

[12] Because auditor-employed specialist hours are highly (positively) skewed, specialist hours (in the left panel of **Table 5**) are log transformed to allow for the use of a standard two-sample t-test. The conclusions are the same if we use a non-parametric (Wilcoxon-Mann-Whitney) rank-sum test, which does not require the data to be normally distributed. This non-parametric test is also used to test differences in specialist hours as a share of total audit hours (in the right panel of **Table 5**). Here, the shares are highly skewed and bounded on the range $(0, 1)$; because a log transformation of percentages does not yield an intuitive interpretation, a non-parametric test is appropriate.

Specialist Usage by Specialization and Audit Phase

For inspected GNF engagements that use auditor-employed specialists, the PCAOB staff collects data on the type of specialists used on each engagement and the total specialist hours allocated to each phase of the audit. Using a string distance matching algorithm, we map auditor-employed specialist roles and titles contained in the raw inspections data into one of four specialist categories: actuary, valuation, advisory, and other.[13] As part of the inspections process, the PCAOB staff collects data on total U.S. audit hours and total auditor-employed specialist hours allocated to each of five phases of the audit: quarterly review, preliminary, interim, final, and after the release of the audit report.

As shown in **Figure 3**, the mix of auditor-employed specialist types used on inspected GNF engagements did not change meaningfully following implementation of the new Specialists Requirements. The proportion of engagements using each type of specialist was similar between the pre-period and post-period.

Among these inspected GNF engagements, we observe a larger share of specialist hours allocated to the quarterly review and preliminary phases of the audit in the post-period, with a corresponding decrease in the proportion of specialist hours allocated to the interim, final, and after report phases. This suggests that firms may have shifted toward using specialists earlier in the audit process. As shown in **Figure 4**, approximately 25.4% of specialist hours were allocated to the quarterly review and preliminary phases of the audit in the post-period, up from approximately 16.0% in the pre-period. Likewise, the share of specialist hours allocated to the interim and final phases of the audit decreased from a combined share of 82.7% in the pre-period to 74.0% in the post-period.

Notably, however, this shift in the allocation of specialist hours corresponds to a larger shift in total audit hours, as the two are highly correlated. On average, firms appear to be allocating a larger share of total U.S. audit hours to the quarterly review and preliminary phases of the audit, with a corresponding decrease in the proportion allocated to the other three phases.[14] As shown in **Figure 5**, approximately 34.2% of total U.S. audit hours were allocated to the quarterly review and preliminary phases of the audit in the post-period, up from approximately 28.0% in the pre-period. Meanwhile, the share of total U.S. audit hours allocated to the interim and final phases of the audit decreased from a combined share of 69.7% in the pre-period to 64.6% in the post-period.

Looking at the relative share of specialist hours to total audit hours in each phase, the shift over time is muted — this suggests that the reallocation of specialist hours illustrated in **Figure 4** may at least partly reflect a broader shift in the overall allocation of audit work. On average, auditor-employed specialist hours accounted for approximately 2.7% of total U.S. audit hours allocated to the combined quarterly review and preliminary phases in the post-period, up from approximately 2.2% in the pre-period (see **Figure 6**). Yet, the relative share of specialist hours to total audit hours allocated to the other three

[13] See Appendix E for a description of the algorithm. The "other" category contains specialist roles that were identified by the classification algorithm as specialists according to the PCAOB definition but were not able to be classified into one of the three primary categories based on the description provided by the firm. For example, vague role descriptions such as "transaction services" or "performance and reward" were classified as "other."

[14] This shift may in part be due to related changes to requirements for assessing risks of material misstatements (AS 2110, *Identifying and Assessing Risks of Material Misstatement*). Though participants in our 2022 Outreach Analysis did not specifically attribute the reallocation of work to earlier phases of the audit to these requirements, they did note that the new estimates standard focused the engagement team on identifying earlier in the audit specific risks of material misstatement within different components of estimates.

phases of the audit combined was unchanged — approximately 7.6% — between the pre- and post-period.

VI. ECONOMETRIC ANALYSIS AND DISCUSSION

In this section, we employ several commonly used econometric methods to estimate pre-post differences in specialist usage and specialist hours among inspected engagements, while controlling for engagement-level factors that could impact the outcomes of interest. First, we analyze pre-post differences in specialist usage, by type of specialist. We estimate these differences for the full sample and separately for GNF and NAF engagements — this allows us to determine whether and to what extent smaller audit firms may have been disproportionately impacted by the new Specialists Requirements. Next, for engagements that reported using auditor-employed specialists, we estimate pre-post differences in auditor-employed specialist hours in levels and as a share of total audit hours — here again, we stratify the analysis to examine differences between GNF and NAF engagements. Finally, for the subset of inspected GNF engagements that reported using auditor-employed specialists, we estimate pre-post differences in the allocation of specialist hours to various phases of the audit.

Specialist Usage

We examine post-period differences in specialist usage by estimating separate discrete choice models for each of the three specialist types: auditor-employed specialists, auditor-engaged specialists, and company specialists. This enables us to estimate the extent to which the new Specialists Requirements are associated with changes in the propensity to use each type of specialist, holding constant other engagement-level factors that could impact the specialist usage decision.[15]

We specify a model that seeks to explain pre-post differences in the response probability, $\Pr(spec = 1 \mid \mathbf{X})$, where *spec* is a binary outcome variable equal to one if the type of specialist in question is used on a particular engagement and zero otherwise. For this analysis, we rely on maximum likelihood estimates from the following logit model:

$$\Pr(spec = 1 \mid \mathbf{X}) = \Lambda(\alpha + \beta_1 post + \beta_2 NAF + \delta_1 post \times NAF + \mathbf{X}'\boldsymbol{\gamma}).$$

Here, $\Lambda(\cdot)$ is used to indicate the logistic cumulative distribution function (CDF).[16] *Post* is an indicator variable equal to one if the fiscal year-end of the issuer's financial statements is on or after December 15, 2020. *NAF* is an indicator variable equal to one if the auditor is a non-affiliated firm. The interaction of *post* and *NAF* allows post-period differences in specialist usage to vary across NAF and GNF engagements. The matrix $\mathbf{X}$ contains various issuer-level variables intended to control for other confounding factors that might impact the outcome of interest (see Section IV). The primary coefficients of interest (β_1, β_2, and δ_1) estimate differences (in log odds) in specialist usage relative to the base group — in this case, GNF engagements in the pre-implementation period. Specifically, β_1 represents

[15] Because we do not have panel data, we do not attempt to estimate potential substitution effects between auditor-employed and auditor-engaged specialists. However, our 2022 Outreach Analysis did not indicate that firms switched away from using auditor-employed specialists toward auditor-engaged or company specialists. Respondents also pointed out that the supply of qualified specialists in the market was already constrained for reasons unrelated to the new Specialists Requirements. Therefore, given market conditions, we believe that a high degree of substitution between specialist types was unlikely.

[16] In untabulated results, we also estimate specialist usage via a probit model, which fits the data using a standard normal CDF. The results are similar and the conclusions are unchanged from the analysis presented here.

the difference in the log odds of a specialist being used on a post-implementation GNF engagement relative to a pre-implementation GNF engagement. β_2 represents the difference in the log odds of a specialist being used on a pre-implementation NAF engagement relative to a pre-implementation GNF engagement. δ_1 represents the difference in the log odds of a specialist being used on a post-implementation NAF engagement relative to a pre-implementation GNF engagement.

Because of the nonlinear nature of this model and because interpreting results in terms of log odds is not intuitive, we transform these coefficients into marginal effects. The main results from the model can then be interpreted as the mean difference in the probability (in percentage points) of a specialist being used on an engagement in the post-implementation period, relative to the pre-implementation period. **Table 6** summarizes post-period marginal effects derived from this model for the full sample, as well as separately for GNF and NAF engagements; the full set of marginal effects is provided in **Table 7**.

Overall, our model suggests that the probability of an inspected engagement using an auditor-employed specialist, holding other factors constant, increased by a statistically significant 4.8 percentage points following implementation of the new Specialists Requirements. That difference was driven primarily by an 8.8 percentage point increase among NAF engagements; the difference in the use of employed specialists for GNF engagements was not statistically significant. For the full sample of inspected engagements, our model suggests that the probability of an auditor using the work of a company specialist increased by a statistically significant 10.5 percentage points, driven primarily by an increase among NAF engagements of 11.2 percentage points ($p = 0.09$); the difference among GNF engagements was not statistically significant. Finally, we find no statistically significant differences in the use of auditor-engaged specialists in the post-period.[17]

Auditor-Employed Specialist Hours

For engagements that use auditor-employed specialists, we examine post-period differences in specialist hours to determine whether and to what extent the intensity of auditor-employed specialist usage may have changed, on average, following implementation of the new Specialists Requirements. To answer this question, we start by regressing log specialist hours on a post-period indicator and the same set of issuer-level controls used previously — we estimate the following model via iteratively reweighted least squares:

$$\log(hours) = \alpha + \beta_1 post + \beta_2 NAF + \delta_1 post \times NAF + \mathbf{X}'\boldsymbol{\gamma} + \boldsymbol{u}.$$

The first column of **Table 8** summarizes the post-period marginal effects derived from this model for the full sample, as well as separately for GNF and NAF engagements; **Table 9** summarizes the full set of marginal effects. Consistent with the univariate statistics presented in Section V, we find no evidence of statistically significant differences in specialist hours after controlling for other factors. This result holds for the full sample, as well as separately for both GNF and NAF engagements.

Because there is a strong, positive correlation between total audit hours and auditor-employed specialist hours, we also estimate pre-post differences in specialist hours as a share of total audit

[17] In untabulated results, we also estimate this model using a binary dependent variable that is equal to one if *any* specialist is used on an engagement, regardless of type. Here, we find no statistically significant results either separately for GNF and NAF engagements or for the full sample.

hours.[18] The second column of **Table 8** summarizes the post-period marginal effects from this model for the full sample, as well as separately for GNF and NAF engagements; the full set of marginal effects is presented in the second column of **Table 9**. Again, consistent with the univariate statistics presented in Section V, we find no statistically significant differences in auditor-employed specialist hours as a share of total audit hours.[19]

Specialist Hours by Audit Phase

For inspected GNF engagements on which auditor-employed specialists were used, we estimate pre-post differences in auditor-employed specialist hours for each phase of the audit as a proportion of total auditor-employed specialist hours on the engagement. This allows us to test whether and to what extent audit firms may have shifted auditor-employed specialist hours to earlier phases of the audit following implementation of the new Specialists Requirements, holding other factors constant. Using the proportion of auditor-employed specialist hours allocated to each audit phase as the dependent variable, we estimate separate generalized linear models (GLMs) for each phase.[20] For brevity, we limit our analysis to the quarterly review, preliminary, interim, and final phases of the audit.

Table 10 summarizes the marginal effects from these models for each audit phase. We find a statistically significant 2.8 percentage point increase in the proportion of auditor-employed specialist hours allocated to the quarterly review phase of the audit. Additionally, we find a statistically significant 2.3 percentage point increase in the proportion allocated to the preliminary phase of the audit and a statistically significant 4.1 percentage point decrease in the proportion allocated to the final phase of the audit. We find no statistically significant difference in the proportion for specialist hours allocated to the interim phase. This result suggests that firms have shifted the use of auditor-employed specialists from the final phase of the audit to the quarterly review and preliminary planning phases of the audit — a finding that is consistent with feedback obtained from engagement partner interviews. For example, during our stakeholder outreach analysis an engagement partner with a Big Four firm indicated that, because of the new Specialists Requirements, specialists were being involved earlier in the risk assessment process and throughout the audit and that teams were making sure specialists were fully integrated in the audit. Another interview with an NAF engagement partner indicated that teams tried to engage with specialists earlier in discussions around significant assumptions as the team finalized audit planning and documentation of the risk assessment — though the substance of the team's work with the specialists did not change, it occurred earlier in the planning phase of the audit.[21]

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[18] By construction, this share is continuous and bounded on the interval $(0, 1)$, so we estimate these differences via a generalized linear model (GLM); specifically, a binomial family with logit link function.

[19] In untabulated results, we also estimated a Heckman two-step selection model and nonparametric nearest neighbor matching to test the robustness of these results to our model specification. The pre-post differences in average auditor-employed specialist hours, both in log levels and as a share of total audit hours were not statistically significant.

[20] By construction, these proportions are on the range $[0, 1]$ so we again estimate each GLM using a binomial family and logit link function.

[21] One interviewed audit engagement partner for a non-LAF audit, when asked whether communication with auditor-employed specialists changed compared to prior year audits, reported, "We tried to engage them earlier in discussions around significant assumptions as we tried to finalize our planning and enhance our documentation of risk assessment… May have had a different connection with our specialists, but substance didn't change, if anything, occurred earlier to allow us to do better phasing of our audit work, lock our planning down better." Another interviewed audit engagement partner for a non-LAF audit also reported, "Involving specialists earlier on in the risk assessment process and throughout the audit and making sure they were fully integrated in the audit… talking fully about the business and understanding where the risk in the evaluation might be."

However, as discussed in Section V, the mean proportion of total audit hours allocated to the quarterly review and preliminary phases of the audit also increased in the post-period, suggesting that the above shift in auditor-employed specialist hours may at least partly reflect a broader shift in the overall allocation of audit work. To confirm that this result holds after controlling for other factors, we estimate the same GLMs from above, this time using the proportion of total audit hours allocated to each phase as the dependent variable. Indeed, we find a statistically significant increase in the proportion of total audit hours allocated to the preliminary phase of the audit of 3.5 percentage points and a corresponding decrease in the proportion of the hours allocated to the final phase of 2.8 percentage points (see **Table 11**). We find no statistically significant differences in the proportion of total audit hours allocated to either the quarterly review or interim phases of the audit.

Finally, we estimate pre-post differences in the shares of total audit hours allocated to auditor-employed specialists in each phase. This allows us to test whether and to what extent the proportion of specialist hours to total audit hours in each phase may have changed following implementation of the new Specialists Requirements. **Table 12** shows a statistically significant 0.4 percentage point increase in the share of total audit hours allocated to auditor-employed specialists in the quarterly review phase. However, we find no statistically significant differences in the preliminary, interim, or final phases of the audit. Together these results suggest that, while the proportion of auditor-employed specialist hours allocated to the quarterly review and preliminary phases of the audit increased in the post-period, there was also a broader shift in the allocation of total U.S. audit hours to earlier phases. While there is some weak statistical evidence to suggest that there was a small increase in the proportion of auditor-employed specialist hours to total audit hours in the quarterly review phase of the audit, the relative share of specialist hours to total audit hours in each of the other three phases remained unchanged.

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APPENDIX A. DATA DEFINITIONS

The table below defines the dependent and independent variables used in the econometric analysis. Specialist usage by type, auditor-employed specialist hours, total audit hours, and auditor-employed specialist hours data by audit phase are from a PCAOB proprietary database. Issuer financial characteristics and industry classifications are from S&P Capital IQ. Audit engagement characteristics are obtained from publicly available information from Audit Analytics.

Variable	Definition
Dependent Variables	
Auditor-Employed Specialist Used	An indicator variable equal to one if an auditor-employed specialist was used on the engagement.
Auditor-Engaged Specialist Used	An indicator variable equal to one if an auditor-engaged specialist was used on the engagement.
Company Specialist Used	An indicator variable equal to one if the auditor used the work of a company specialist.
Log Auditor-Employed Specialist Hours	The natural logarithm of auditor-employed specialist hours.
Specialist Share of Total Audit Hours	Total auditor-employed specialist hours divided by total audit hours.
Share of Specialist Hours Allocated to the Preliminary Phase	Auditor-employed specialist hours allocated to the preliminary phase of the audit divided by total auditor-employed specialist hours.
Share of Specialist Hours Allocated to the Interim Phase	Auditor-employed specialist hours allocated to the interim phase of the audit divided by total auditor-employed specialist hours.
Share of Specialist Hours Allocated to the Final Phase	Auditor-employed specialist hours allocated to the final phase of the audit divided by total auditor-employed specialist hours.
Specialist Share of Preliminary Phase Audit Hours	Auditor-employed specialist hours allocated to the preliminary phase of the audit divided by total audit hours

Variable	Definition
	allocated to the preliminary phase of the audit.
Specialist Share of Interim Phase Audit Hours	Auditor-employed specialist hours allocated to the interim phase of the audit divided by total audit hours allocated to the interim phase of the audit.
Specialist Share of Final Phase Audit Hours	Auditor-employed specialist hours allocated to the final phase of the audit divided by total audit hours allocated to the final phase of the audit.
Independent Variables	
Post	An indicator variable equal to one if the fiscal year end date of an issuer audit is on or after December 15, 2020.
NAF	An indicator variable equal to one if the audit firm is not affiliated with a major global network.
Issuer Characteristics	
Log Total Assets	The natural logarithm of total assets in millions of U.S. dollars.
Return on Assets	Net income before extraordinary items divided by total assets.
Leverage Ratio	Total debt divided by the sum of total debt plus total equity.
FV Assets to Total Assets	Total fair value assets divided by total assets.
FV Liabilities to Total Assets	Total fair value liabilities divided by total assets.
Intangibles to Total Assets	The sum of goodwill plus intangible assets divided by total assets.
Merger and Restructuring Indicator	An indicator variable equal to one if the issuer reported merger or restructuring charges during the fiscal year.

Variable	Definition
Net Loss Indicator	An indicator variable equal to one if the issuer reported a net loss before extraordinary items during the fiscal year.
Issuer Industry	Categorical variable for each of the 11 industry classifications published by S&P Capital IQ.
Audit Characteristics	
December Year-End Indicator	An indicator variable equal to one if the issuer audit has a December fiscal year-end date.
New Client Indicator	An indicator variable equal to one if the current issuer audit is a new client engagement with the auditor.
Audit Firm Indicator	An indicator for each audit firm based on their PCAOB registration ID. Note that this variable is only used in models limited to GNF engagements.

APPENDIX B. TABLES AND FIGURES

TABLE 1

Sample Sizes by Inspection Year: Pre- vs. Post-Implementation and GNF vs. NAF

	2018	2019	2020	2021	Total
Inspected engagements	381	438	413	411	1,643
Pre-implementation[1]	381	438	413	63	1,295
Post-implementation	-	-	-	348	348
GNF engagements[2]	251	253	250	238	992
NAF engagements	130	185	163	173	651

[1] The new specialists standard became effective for engagements with fiscal years ending on or after December 15, 2020. In this paper, the pre-implementation period spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period spans fiscal years ending between December 15, 2020 and March 31, 2021.

[2] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

Note: Data are presented based on inspection years.

Source: PCAOB proprietary data

TABLE 2

GNF and NAF Sample Sizes, Pre- vs. Post-Implementation

	Pre[1]	Post	Total
GNF engagements[2]	777	215	992
NAF engagements	518	133	651
Total	1,295	348	1,643

[1] The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.

[2] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

Source: PCAOB proprietary data

TABLE 3

Pre-Post Summary Statistics for Auditor-Employed Specialist Hours, by Engagement Type

Panel A: Auditor-Employed Specialist Hours

	All Engagements			GNF Engagements[1]			NAF Engagements		
	Full Sample	Pre[2]	Post	Full Sample	Pre	Post	Full Sample	Pre	Post
Mean	366.7	342.1	447.1	437.2	400.2	568.6	65.0	68.0	57.9
St. Dev.	992.8	772.8	1,502.1	1,089.3	837.1	1,702.8	122.2	135.6	81.9
Median	142.0	148.0	122.0	188.5	186.0	192.0	21.0	20.5	22.3
CV[3]	2.7	2.3	3.4	2.5	2.1	3.0	1.9	2.0	1.4
n	1,150	881	269	932	727	205	218	154	64

Panel B: Auditor-Employed Specialist Hours as a Share of Total Audit Hours

	All Engagements			GNF Engagements			NAF Engagements		
	Full Sample	Pre	Post	Full Sample	Pre	Post	Full Sample	Pre	Post
Mean	0.024	0.024	0.024	0.025	0.025	0.026	0.018	0.019	0.017
St. Dev.	0.025	0.025	0.025	0.025	0.025	0.026	0.024	0.027	0.016
Median	0.016	0.016	0.016	0.017	0.018	0.017	0.009	0.009	0.012
CV	1.0	1.1	1.0	1.0	1.0	1.0	1.3	1.4	0.9
n	1,143	878	265	932	727	205	211	151	60

[1] The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.

[2] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

[3] Coefficient of variation (CV) is a measure of dispersion calculated as the ratio of the standard deviation to the mean.

Source: PCAOB proprietary data

TABLE 4

Pre-Post Comparisons of the Proportions of Engagements Using Specialists by Type

	Auditor-Employed[1]			Auditor-Engaged			Company		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
GNF engagements[2]	0.936	0.953	0.018	0.084	0.205	0.120***	0.304	0.423	0.119***
	(0.009)	(0.014)	(0.017)	(0.017)	(0.028)	(0.032)	(0.028)	(0.034)	(0.044)
n	777	215	992	273	215	488	273	215	488
NAF engagements	0.303	0.496	0.193***	0.208	0.271	0.062	0.317	0.496	0.180***
	(0.020)	(0.043)	(0.048)	(0.018)	(0.039)	(0.042)	(0.020)	(0.043)	(0.048)
n	518	133	651	518	133	651	518	133	651
Full sample	0.683	0.779	0.096***	0.166	0.230	0.064**	0.312	0.451	0.139***
	(0.013)	(0.022)	(0.026)	(0.013)	(0.023)	(0.026)	(0.016)	(0.027)	(0.031)
n	1,295	348	1,643	791	348	1,139	791	348	1,139

[1] Auditor-employed specialists refer to specialists employed by the audit firm. Auditor-engaged specialists refer to third-party specialists contracted by the audit firm. Company specialists refer to specialists employed or engaged by an issuer whose work is used by the auditor as audit evidence.

[2] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

Note: Standard errors in parentheses. Statistical significance denoted at the *p<0.10 **p<0.05 ***p<0.01 levels.

Source: PCAOB proprietary data

TABLE 5

Comparing Auditor-Employed Specialist Hours by Type of Engagement, Pre- vs. Post-Implementation

	Log Auditor-Employed Specialist Hours			Auditor-Employed Specialist Hours as a Share of U.S. Audit Hours		
	Pre[1]	Post	Δ	Pre	Post	Δ
GNF engagements[2]	5.175	5.196	0.021	0.025	0.026	0.001
	(0.049)	(0.099)	(0.110)	(0.001)	(0.002)	(0.002)
n	727	205	932	727	205	932
NAF engagements	2.918	3.226	0.309	0.019	0.017	-0.001
	(0.181)	(0.170)	(0.248)	(0.002)	(0.002)	(0.003)
n	154	64	218	151	60	211
Full sample	4.780	4.727	-0.053	0.024	0.024	0.000
	(0.059)	(0.099)	(0.115)	(0.001)	(0.002)	(0.002)
n	881	269	1,150	878	265	1,143

[1] The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.

[2] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

Note: A two-sample t-test with unequal sample variances is used to test the significance of differences in log auditor-employed specialist hours. A non-parametric Wilcoxon-Mann-Whitney rank-sum test is used to test the significance of auditor-employed specialist hours as a share of U.S. audit hours. Standard errors in parentheses. Statistical significance denoted at the *p<0.10 **p<0.05 ***p<0.01 levels.

Source: PCAOB proprietary data

TABLE 6

Post-Period Marginal Effects on Specialist Usage by Type, GNF vs. NAF

	Employed[1]	Engaged	Company
Post (full sample)	0.048**	0.063	0.105**
	(0.022)	(0.050)	(0.047)
Post (GNF only)[2]	0.028	0.090	0.078
	(0.021)	(0.077)	(0.054)
Post (NAF only)	0.088**	0.037	0.112*
	(0.044)	(0.056)	(0.066)
Industry fixed effects[3]	X	X	X
n	1,643	1,139	1,139
Pseudo R^2	0.526	0.279	0.165

[1] Auditor-employed specialists refer to specialists employed by the audit firm. Auditor-engaged specialists refer to third-party specialists contracted by the audit firm. Company specialists refer to specialists employed or engaged by an issuer whose work is used by the auditor as audit evidence.

[2] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

[3] Industry fixed effects are based on the eleven industry sectors published by S&P Capital IQ.

Note: Estimates shown are marginal effects from a logit model, so estimates are interpreted as changes in the probability of each type of specialist being used on an engagement. Standard errors, provided in parentheses, are clustered at the firm level. Statistical significance is indicated at the *p<0.10 **p<0.05 ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

TABLE 7

Pre-Post Marginal Effects on Specialist Usage, by Type

	Employed[1]	Engaged	Company
Post	0.048**	0.063	0.105**
	(0.022)	(0.050)	(0.047)
NAF audit	-0.266***	0.142***	0.218**
	(0.042)	(0.044)	(0.100)
Log total assets	0.056***	0.016	0.045***
	(0.006)	(0.011)	(0.011)
Return on assets	0.002	0.004	0.013
	(0.022)	(0.015)	(0.014)
FV assets to total assets	0.230***	0.133**	0.238***
	(0.057)	(0.053)	(0.061)
FV liabilities to total assets	-0.056	0.264***	0.072
	(0.048)	(0.065)	(0.090)
Intangibles to total assets	-0.024	0.013	0.021
	(0.028)	(0.022)	(0.021)
Merger and restructuring	0.052***	0.078***	0.121***
	(0.017)	(0.028)	(0.029)
Leverage ratio	0.004**	0.001	0.001
	(0.002)	(0.002)	(0.003)
Net loss	0.052***	0.048*	0.089*
	(0.020)	(0.026)	(0.051)
New client	-0.017	0.009	-0.050
	(0.024)	(0.028)	(0.038)
December FYE	0.017	-0.041	-0.029
	(0.024)	(0.046)	(0.036)
Industry fixed effects[2]	X	X	X
n	1,643	1,139	1,139
Pseudo R^2	0.526	0.279	0.165

[1] Auditor-employed specialists refer to specialists employed by the audit firm. Auditor-engaged specialists refer to third-party specialists contracted by the audit firm. Company specialists refer to specialists employed or engaged by an issuer whose work is used by the auditor as audit evidence.

[2] Industry fixed effects are based on the eleven industry sectors published by S&P Capital IQ.

Note: Estimates shown are marginal effects from a logit model, so estimates are interpreted as changes in the probability of each type of specialist being used on an engagement. Standard errors, provided in parentheses, are clustered at the firm level. Post-period indicator highlighted. Statistical significance is indicated at the *p<0.10 **p<0.05 ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

TABLE 8

Post-Period Marginal Effects on Specialist Hours (Logged and as a Share of Total Audit Hours), GNF vs. NAF

	Log Specialist Hours	% of Total Audit Hours
Post (full sample)	-0.040	-0.000
	(0.078)	(0.002)
Post (GNF only)[1]	-0.076	-0.001
	(0.088)	(0.002)
Post (NAF only)	0.112	0.002
	(0.161)	(0.003)
Industry Fixed Effects[2]	X	X
n	1,150	1,143
Adj. R^2, Pseudo R^2	0.526	0.216

[1] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

[2] Industry fixed effects are based on the eleven industry sectors published by S&P Capital IQ.

Note: Log specialist hours are estimated using iteratively reweighted least squares (robust regression). Specialist hours as a share of total audit hours are estimated via a generalized linear model. Standard errors, provided in parentheses, are clustered at the firm level. Statistical significance is indicated at the *p<0.10 **p<0.05 ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

TABLE 9

Pre-Post Marginal Effects on Specialist Hours
(Logged and as a Share of Total Audit Hours)

	Log Specialist Hours	% of Total Audit Hours
Post	-0.040	-0.000
	(0.078)	(0.002)
NAF audit	-1.444***	-0.013***
	(0.095)	(0.003)
Log total assets	0.375***	0.000
	(0.021)	(0.000)
Return on assets	-0.207**	-0.001
	(0.088)	(0.002)
FV assets to total assets	-0.326	0.009***
	(0.202)	(0.003)
FV liabilities to total assets	-0.175	-0.007**
	(0.136)	(0.004)
Intangibles to total assets	0.760***	0.015***
	(0.183)	(0.002)
Merger and restructuring	0.260***	0.003***
	(0.069)	(0.001)
Leverage ratio	0.199***	0.004***
	(0.068)	(0.001)
Net loss	0.293***	0.004***
	(0.076)	(0.001)
New client	0.332***	0.004
	(0.126)	(0.003)
December FYE	-0.085	-0.002
	(0.086)	(0.002)
Industry fixed effects[†]	X	X
n	1,150	1,143
Adj. R^2, Pseudo R^2	0.526	0.216

[†] Industry fixed effects are based on the eleven industry sectors published by S&P Capital IQ.

Note: Log specialist hours are estimated using iteratively reweighted least squares (robust regression). Specialist hours as a share of total audit hours are estimated via a generalized linear model. Standard errors, provided in parentheses, are clustered at the firm level. Post-period indicator highlighted. Statistical significance is indicated at the *p<0.10 **p<0.05 ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

TABLE 10

Marginal Effects from Pre-Post Regressions of Auditor-Employed Specialist Hours by Audit Phase as a Proportion of Total Auditor-Employed Specialist Hours

	Quarterly Review	Preliminary	Interim	Final
Post	0.028**	0.023*	0.001	-0.041*
	(0.014)	(0.013)	(0.023)	(0.023)
Log total assets	-0.000	0.009**	0.012**	-0.019***
	(0.003)	(0.003)	(0.005)	(0.006)
Return on assets	-0.038	0.087*	-0.058	0.087
	(0.026)	(0.047)	(0.079)	(0.073)
FV assets to total assets	-0.002	0.054	-0.019	-0.067
	(0.027)	(0.046)	(0.058)	(0.066)
FV liabilities to total assets	-0.028	-0.052*	0.068	0.031
	(0.021)	(0.027)	(0.042)	(0.043)
Intangibles to total assets	-0.043	0.009	0.123**	-0.108*
	(0.033)	(0.032)	(0.055)	(0.056)
Merger and restructuring	0.009	0.005	0.014	-0.018
	(0.011)	(0.012)	(0.019)	(0.020)
Leverage ratio	0.019***	0.008	-0.082**	-0.010
	(0.007)	(0.019)	(0.036)	(0.029)
Net loss	0.007	0.027*	-0.029	0.005
	(0.012)	(0.015)	(0.025)	(0.025)
New client	-0.008	0.048	0.052	-0.064
	(0.016)	(0.036)	(0.042)	(0.043)
December FYE	-0.016	0.004	0.029	-0.019
	(0.016)	(0.014)	(0.024)	(0.026)
Industry fixed effects[1]	X	X	X	X
Firm fixed effects[2]	X	X	X	X
n	932	932	932	932
Pseudo R^2	0.098	0.060	0.090	0.084

[1] Industry fixed effects are based on the eleven industry sectors published by S&P Capital IQ.

[2] Firm fixed effects represent each of the six global network firms: BDO, Deloitte, Ernst & Young, Grant Thornton, KPMG, and PwC.

Note: Estimates shown are marginal effects from separate generalized linear models (binomial family with logit link function) for each audit phase. Marginal effects are interpreted as the change in the proportion from the pre-period. Robust standard errors in parentheses. The post-period indicator is highlighted. Statistical significance is indicated at the *p<0.10 **p<0.05 ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

TABLE 11

Marginal Effects from Pre-Post Regressions of the Proportion of Total Audit Hours by Audit Phase

	Quarterly Review	Preliminary	Interim	Final
Post	0.007	0.035***	-0.006	-0.028***
	(0.005)	(0.006)	(0.007)	(0.005)
Log total assets	-0.011***	0.006***	0.021***	-0.017***
	(0.002)	(0.001)	(0.002)	(0.001)
Return on assets	-0.021**	0.000	0.007	0.037**
	(0.009)	(0.016)	(0.027)	(0.019)
FV assets to total assets	0.015	0.010	-0.037*	0.009
	(0.013)	(0.014)	(0.019)	(0.015)
FV liabilities to total assets	-0.018**	-0.007	0.050***	-0.018*
	(0.009)	(0.010)	(0.014)	(0.011)
Intangibles to total assets	-0.017	-0.018	0.020	0.008
	(0.012)	(0.012)	(0.017)	(0.013)
Merger and restructuring	-0.004	0.003	-0.001	0.005
	(0.004)	(0.005)	(0.006)	(0.005)
Leverage ratio	0.011***	0.006	-0.025***	-0.002
	(0.003)	(0.005)	(0.008)	(0.006)
Net loss	0.002	0.003	-0.017**	0.013**
	(0.005)	(0.006)	(0.008)	(0.006)
New client	-0.025***	0.025***	-0.012	0.019*
	(0.007)	(0.009)	(0.013)	(0.011)
December FYE	0.005	0.004	-0.000	-0.009
	(0.005)	(0.006)	(0.008)	(0.006)
Industry fixed effects[1]	X	X	X	X
Firm fixed effects[2]	X	X	X	X
n	1,086	1,086	1,086	1,086
Pseudo R^2	0.299	0.284	0.390	0.403

[1] Industry fixed effects are based on the eleven industry sectors published by S&P Capital IQ.

[2] Firm fixed effects represent each of the six global network firms: BDO, Deloitte, Ernst & Young, Grant Thornton, KPMG, and PwC.

Note: Estimates shown are marginal effects from separate generalized linear models (binomial family with logit link function) for each audit phase. Marginal effects are interpreted as the change in the proportion from the pre-period. Robust standard errors in parentheses. The post-period indicator is highlighted. Statistical significance is indicated at the *p<0.10 **p<0.05 ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

TABLE 12

Marginal Effects from Pre-Post Regressions of Auditor-Employed Specialist Hours by Audit Phase as a Proportion of Total Audit Hours in Each Phase

	Quarterly Review	Preliminary	Interim	Final
Post	0.004*	-0.001	-0.001	-0.002
	(0.002)	(0.002)	(0.003)	(0.003)
Log total assets	0.001**	0.002***	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Return on assets	-0.010**	0.002	-0.018**	-0.019**
	(0.004)	(0.007)	(0.007)	(0.008)
FV assets to total assets	0.005	0.004	0.013*	0.011*
	(0.005)	(0.005)	(0.007)	(0.006)
FV liabilities to total assets	-0.007*	-0.006*	-0.007	-0.002
	(0.004)	(0.004)	(0.007)	(0.005)
Intangibles to total assets	-0.002	0.002	0.037***	0.019***
	(0.006)	(0.004)	(0.010)	(0.006)
Merger and restructuring	0.002	0.004**	0.005*	0.003
	(0.002)	(0.002)	(0.003)	(0.002)
Leverage ratio	0.004***	0.001	-0.003	0.003
	(0.001)	(0.004)	(0.005)	(0.002)
Net loss	0.004	0.001	0.006	0.002
	(0.002)	(0.002)	(0.004)	(0.003)
New client	0.002	0.007	0.009	-0.001
	(0.003)	(0.005)	(0.008)	(0.005)
December FYE	-0.003	-0.001	-0.000	-0.000
	(0.003)	(0.002)	(0.004)	(0.003)
Industry fixed effects[1]	X	X	X	X
Firm fixed effects[2]	X	X	X	X
n	931	932	921	932
Pseudo R^2	0.103	0.113	0.108	0.221

[1] Industry fixed effects are based on the eleven industry sectors published by S&P Capital IQ.

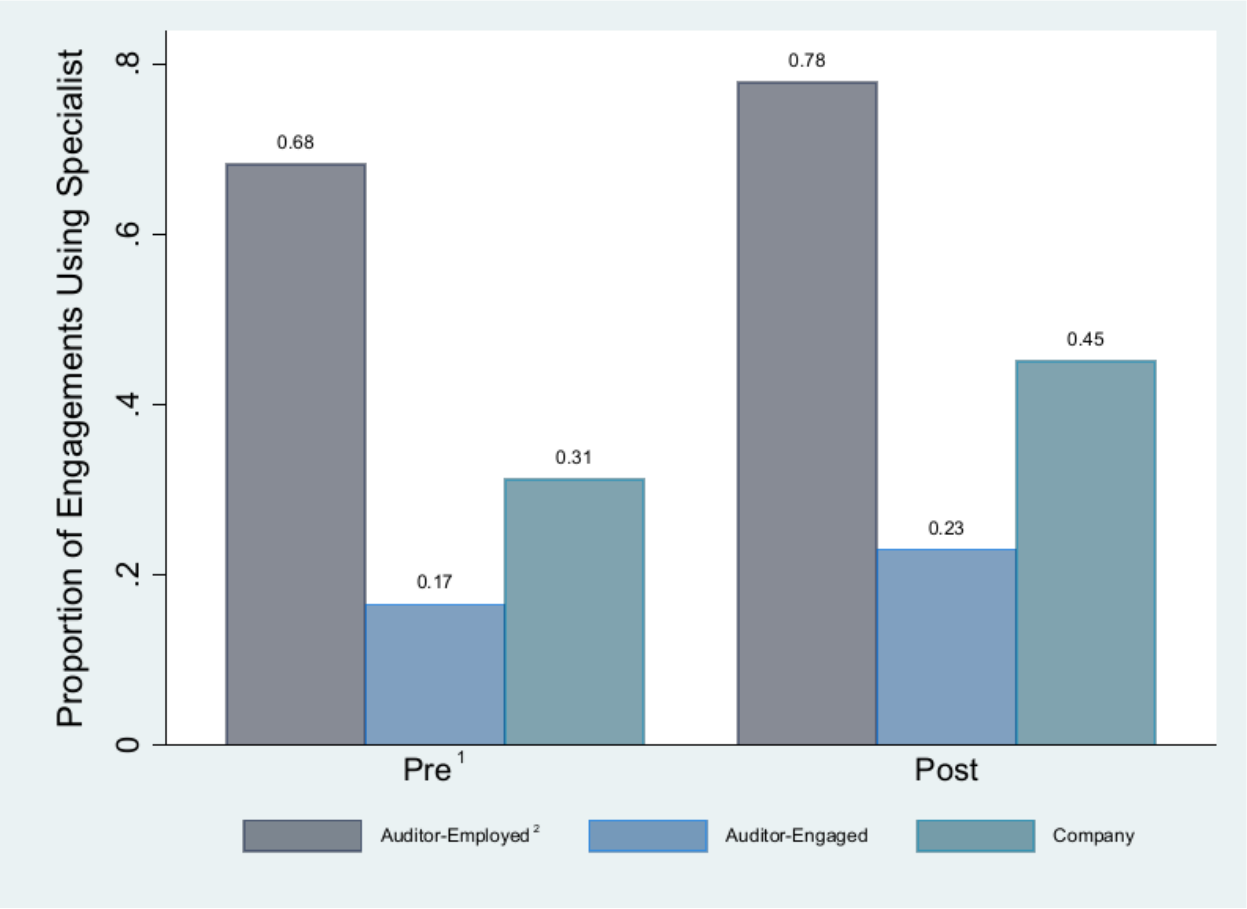
[2] Firm fixed effects represent each of the six global network firms: BDO, Deloitte, Ernst & Young, Grant Thornton, KPMG, and PwC.

Note: Estimates shown are marginal effects from separate generalized linear models (binomial family with logit link function) for each audit phase. Marginal effects are interpreted as the change in the proportion from the pre-period. Robust standard errors in parentheses. The post-period indicator is highlighted. Statistical significance is indicated at the *p<0.10 **p<0.05 ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

FIGURE 1

Mean Proportions of all Engagements Using Specialists, by Type, Before and After Implementation of the New Specialists Requirements



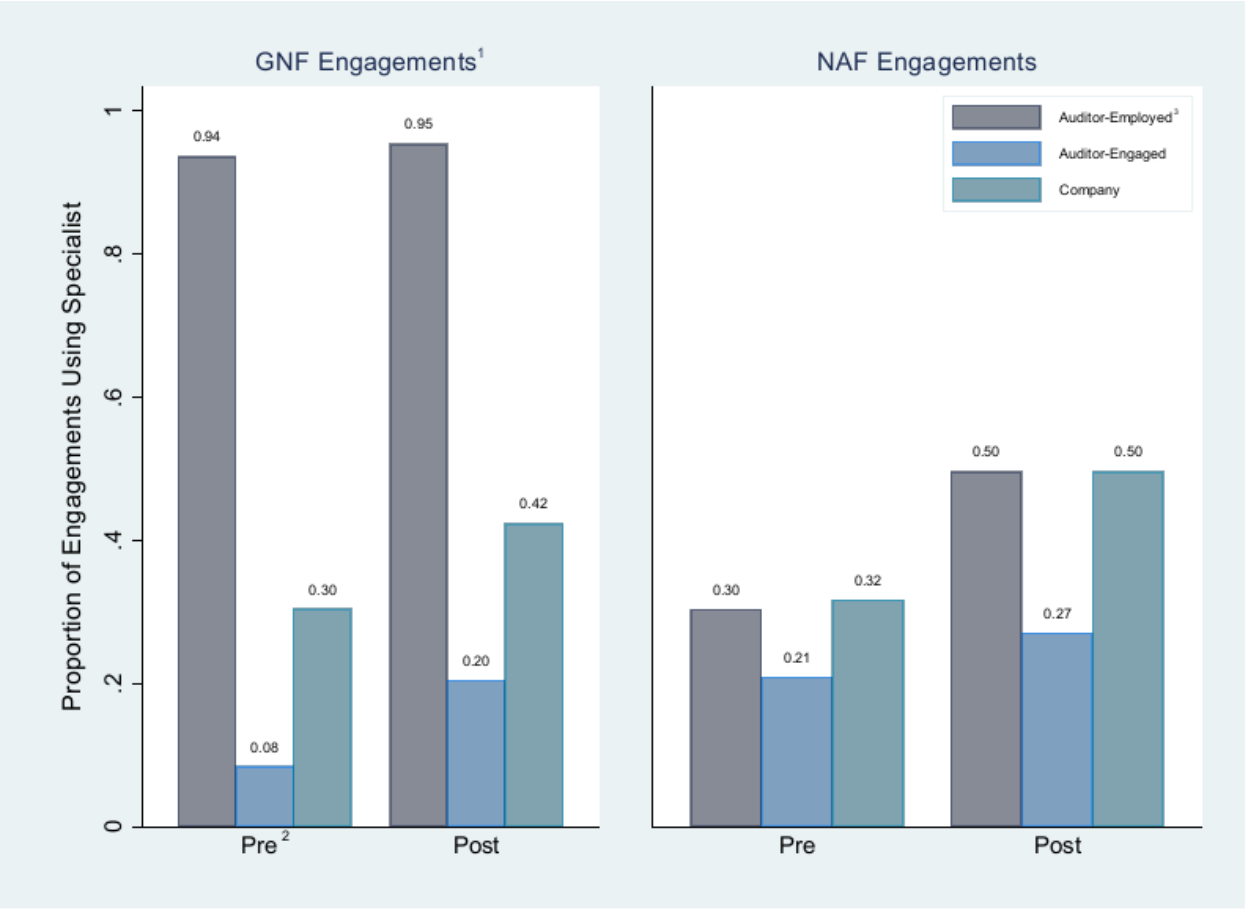
[1] The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.

[2] Auditor-employed specialists refer to specialists employed by the audit firm. Auditor-engaged specialists refer to third-party specialists contracted by the audit firm. Company specialists refer to specialists employed or engaged by an issuer whose work is used by the auditor as audit evidence.

Source: PCAOB proprietary data

FIGURE 2

Mean Proportions of GNF and NAF Engagements Using Specialists, by Type, Before and After Implementation of the new Specialists Requirements



[1] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

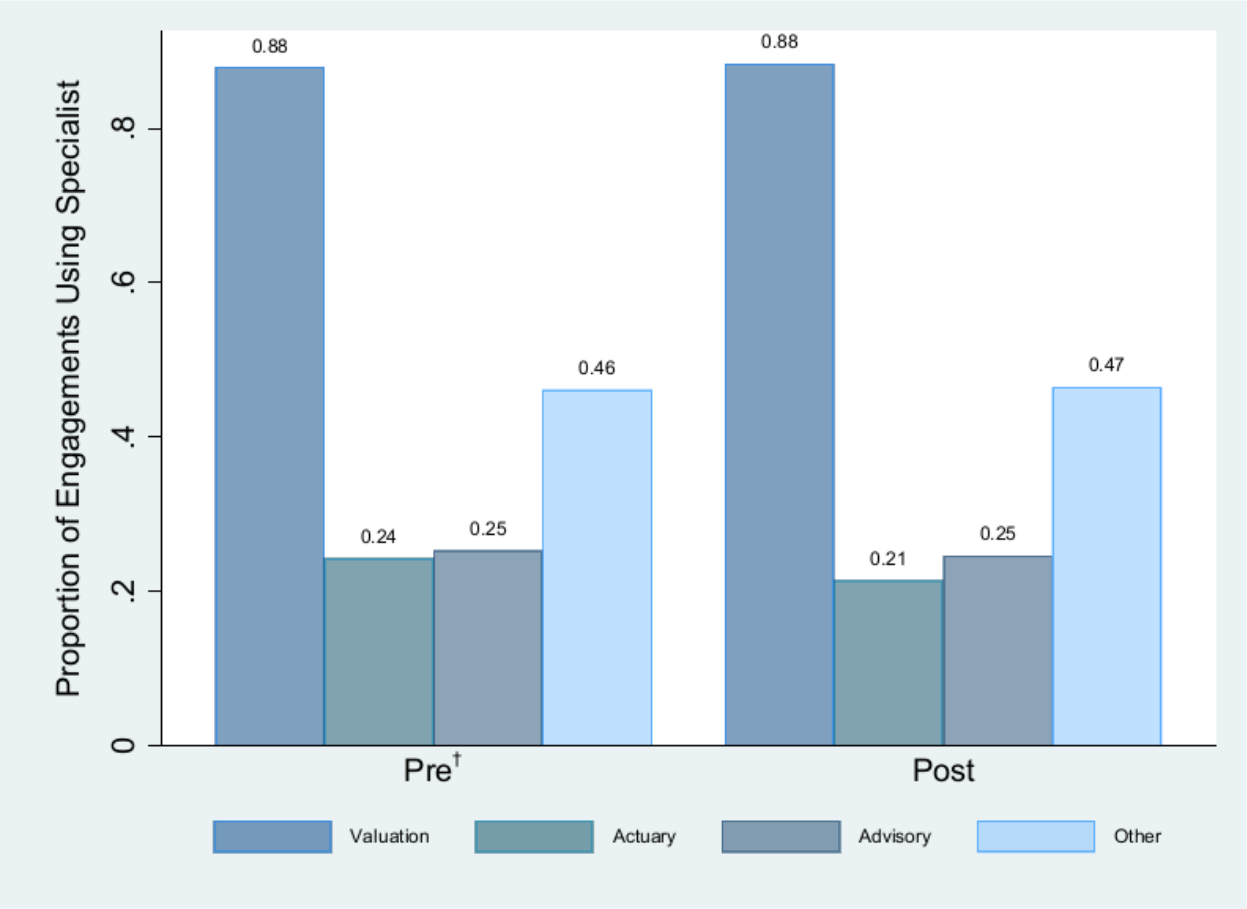
[2] The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.

[3] Auditor-employed specialists refer to specialists employed by the audit firm. Auditor-engaged specialists refer to third-party specialists contracted by the audit firm. Company specialists refer to specialists employed or engaged by an issuer whose work is used by the auditor as audit evidence.

Source: PCAOB proprietary data

FIGURE 3

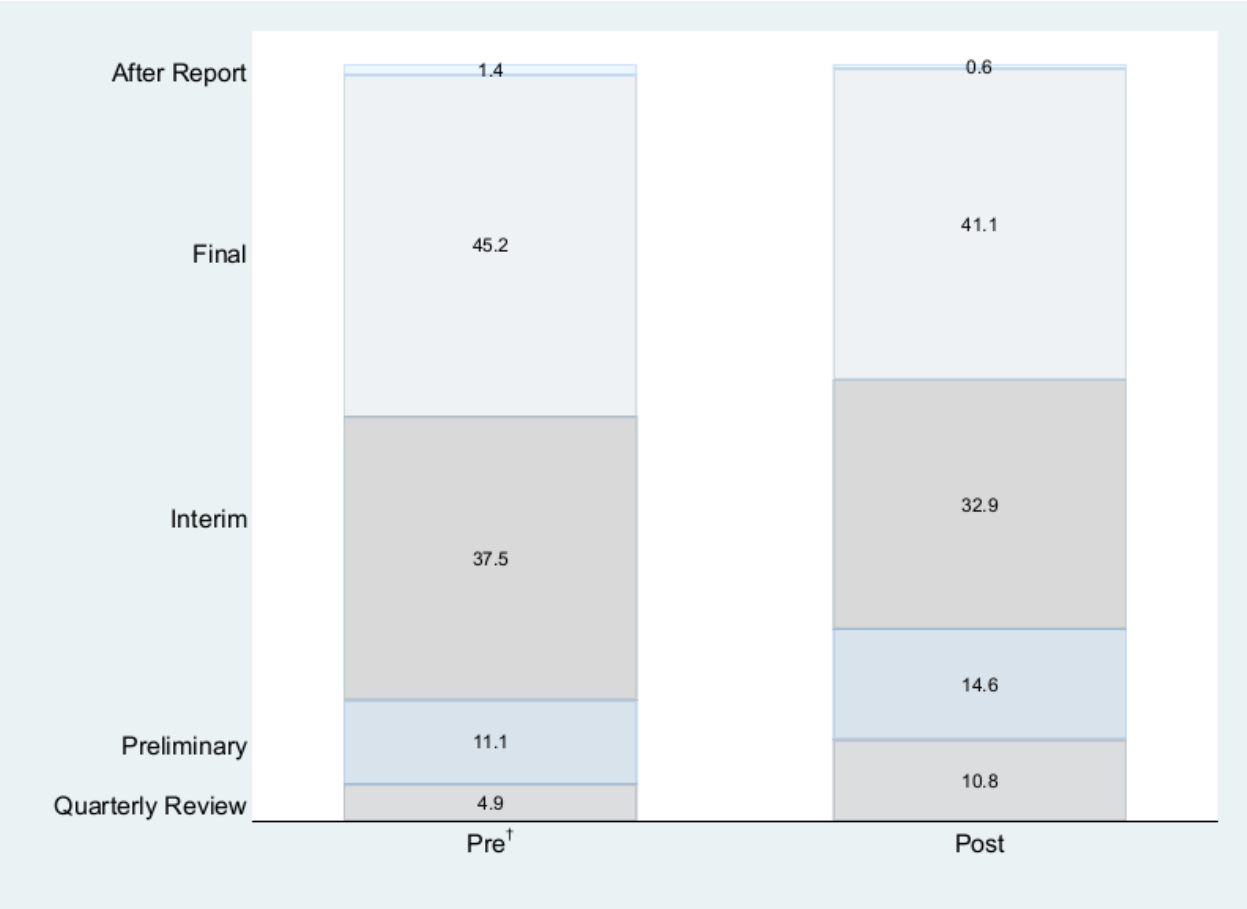
Mean Proportion of Engagements Using Auditor-Employed Specialists, by Type of Specialist, Before and After Implementation of the New Specialists Requirements



† The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.
Note: Sample includes only inspected GNF engagements.
Source: PCAOB proprietary data

FIGURE 4

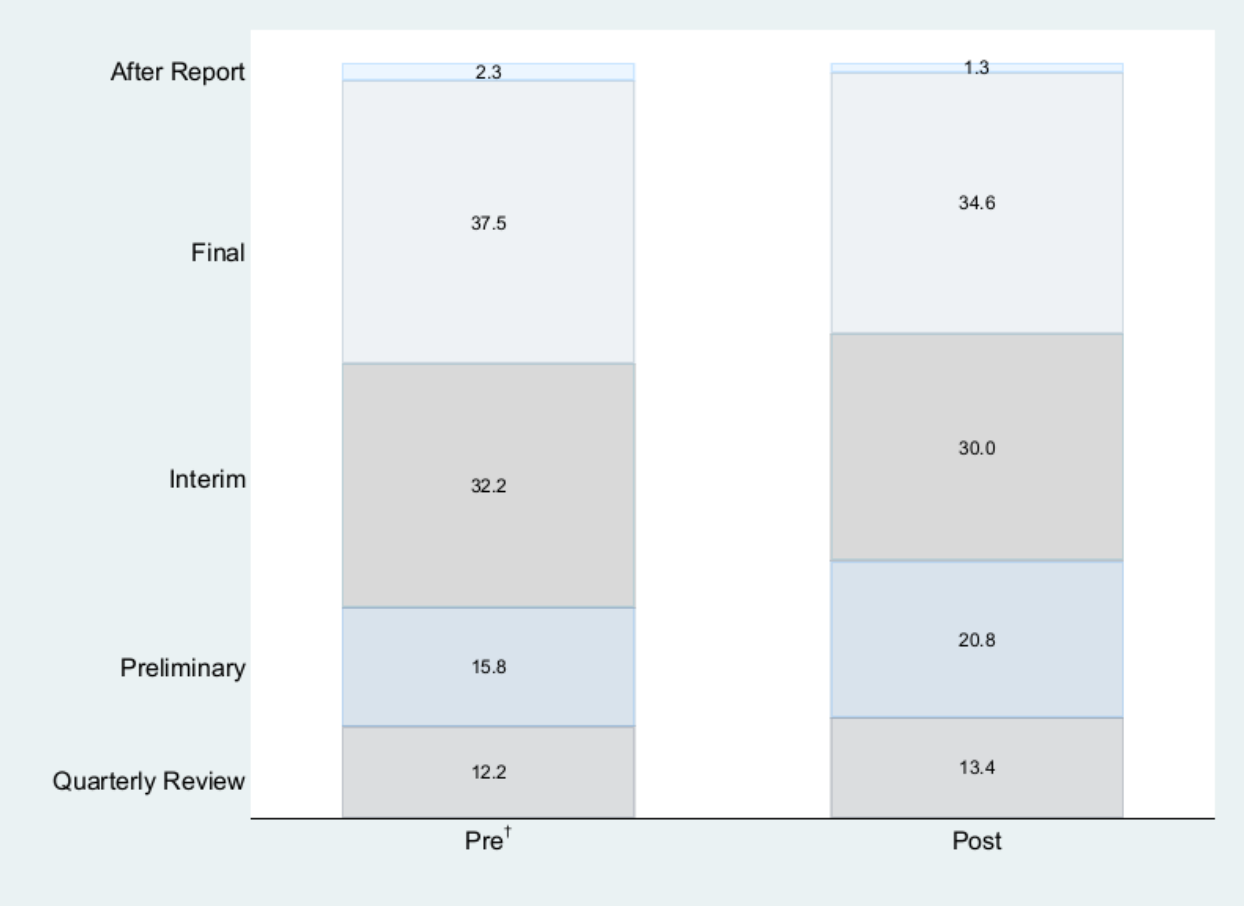
Mean Share (as a percent) of Total Auditor-Employed Specialist Hours Devoted to Each Phase of the Audit, Pre vs. Post



† The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.
Note: Sample includes only inspected GNF engagements.
Source: PCAOB proprietary data

FIGURE 5

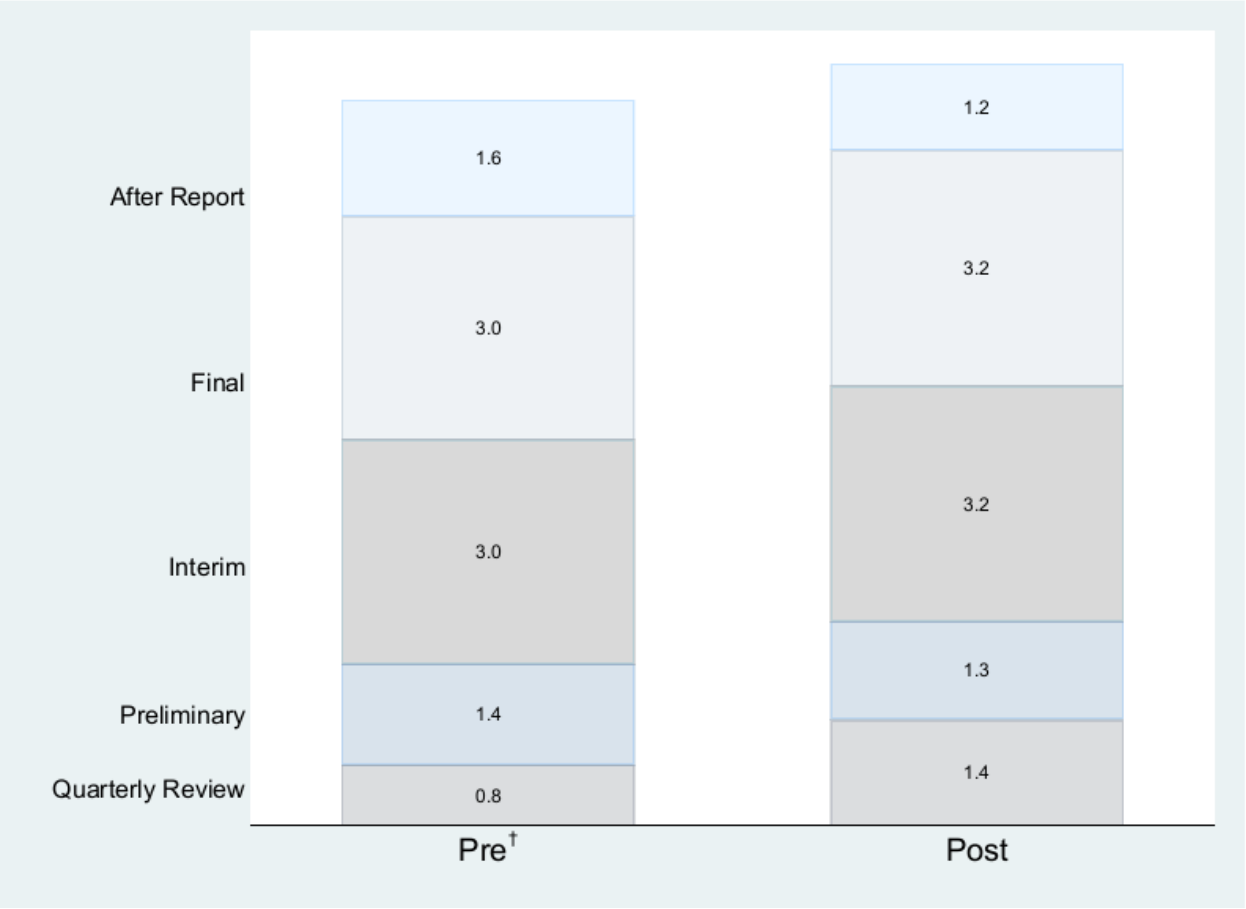
Pre-Post Percentage of Total Audit Hours Allocated to each Phase of the Audit



† The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.
Note: Sample includes only inspected GNF engagements.
Source: PCAOB proprietary data

FIGURE 6

Mean Share (as a percent) of Total U.S. Audit Hours for each Phase Attributed to Auditor-Employed Specialists, for Inspection Years 2018 through 2021



† The pre-implementation period ("Pre") spans fiscal years ending between April 30, 2017 and December 14, 2020. The post-implementation period ("Post") spans fiscal years ending between December 15, 2020 and March 31, 2021.
Note: Sample includes only inspected GNF engagements.
Source: PCAOB proprietary data

APPENDIX C. RELATED ACADEMIC RESEARCH

There are relatively few empirical studies on the use of specialists in the auditing literature. Due to the interrelated nature of auditing accounting estimates and the use of specialists, most of the studies that examine specialist usage do so in the context of complex estimates and fair value measurements (FVMs). Moreover, because of the lack of publicly available archival data on the use of specialists, the extant literature on specialist usage is disproportionately weighted toward studies that rely on interviews and surveys. There are relatively few observational studies in this space.

Using PCAOB data for GNF engagements inspected between 2006 to 2018, Zimmerman *et al*. (2021) provide descriptive statistical evidence on the association between client and audit team characteristics and the use of auditor-employed specialists. The authors find the following: (1) client size, complexity of accounting estimates, FVMs, and the audit team's experience are associated with the use of specialists, (2) involving specialists is associated with higher team hours and fees but lower engagement profitability, suggesting specialists are costly, and (3) audit quality problems are more prevalent when there is comparatively more specialist involvement, but this is mitigated by coordination with specialists and audit team experience.

Cannon and Bedard (2017) conduct a survey of 96 high-level engagement team members across Big Four firms to construct a sample of 115 audits of (mostly Level 3) FVMs at the account level. The authors provide descriptive analysis of environmental and task characteristics with audit processes and outcomes throughout different phases of the audit, including challenges related to fair value measurements and the auditor's decision to use a valuation specialist. They find: (1) neither the degree of estimation uncertainty (measured relative to materiality) or Level 3 classification of an FVM is associated with specialist usage, suggesting that an auditor's overall risk assessment drives the specialist usage decision, and (2) auditors are more likely to use a valuation specialist to help value a FVM if the issuer also uses a specialist.

Griffith (2020) conducts semi-structured interviews of 28 auditors and 14 specialists with extensive experience on audits of FVMs from each of the Big Four firms and three national firms. Using information from those interviews, she develops a theoretical framework of auditors' use of specialists in audits of FVMs. The resulting framework attempts to provide insight into how institutional factors influence trust in and competition with experts. The author finds that auditors often subordinate the work of specialists and force it to conform to auditors' views, suggesting that specialists' involvement may be largely symbolic and may not contribute to audit outcomes in the way that regulators and firms implicitly assume.

Boritz *et al*. (2020) interview 34 practitioners from 6 accounting firms — including 12 audit partners and managers and 22 specialists covering various specialties — to examine their views on the current state of specialist usage on audits. They conclude that the regulatory environment creates pressure for auditors to use specialists. However, because auditors are also concerned with budgets, time constraints, and managing client relationships, they often seek to limit specialist involvement on the engagement. They find that this leads to dissatisfaction among specialists concerned with auditors limiting the scope of their involvement on the audit and the potential impact on audit quality.

APPENDIX D. POTENTIAL CONFOUNDING FACTORS AND OTHER ROBUSTNESS CHECKS

Potential Confounding Factors

Our analysis is potentially confounded by several events that occurred concurrently with the implementation of the new Specialists Requirements. Examples of such events include macroeconomic events and implementation of other auditing and accounting standards. Because these confounding factors are likely correlated with the economic outcomes of interest discussed in this paper, the inability to control for them in our models may bias our estimates. Moreover, we cannot rule out the possibility that these confounding factors could be alternative causal explanations for the differences in specialist usage and hours discussed in our analysis.

This appendix discusses some of the confounding factors that may bias our results and, where possible, how we attempted to address them in our analysis. Nevertheless, because the new Specialists Requirements did not feature phased implementation, there is no natural control group for performing a quasi-experimental study. Without an identification strategy that allows us to reasonably control for these contemporaneous changes in the macroeconomic and regulatory environment, the results from this analysis cannot be interpreted as causal.

COVID-19 Pandemic

The new Specialists Requirements became effective for engagements with fiscal years ending on or after December 15, 2020. According to the U.S. Centers for Disease Control and Prevention, the first confirmed U.S. case of COVID-19 was recorded on January 20, 2020. The World Health Organization officially declared COVID-19 a pandemic on March 11, 2020 and the White House officially declared a national emergency on March 13, 2020. Audits that took place following the onset of the pandemic would have been impacted by the resulting disruptions to business, travel, and daily life. Similarly, it is likely that the use of specialists — including the hours and type of specialist used — would have been impacted by the pandemic. The direction and the magnitude of this impact is not immediately clear, a priori, and remains an empirical question. One could reasonably expect COVID-19 to increase the demand for the work of specialists. For example, business interruptions and asset impairments resulting from the effective shutdown of parts of the global economy during the first two quarters of 2020 could have created additional need for the expertise of valuation specialists. On the other hand, a sharp decrease in the volume of mergers, acquisitions, and corporate restructurings during the first half of 2020 likely had a negative impact on the demand for specialists.

Unfortunately, given the timing of the new Specialists Requirements and the data currently available for analysis, it is not possible to reliably control for the confounding effects of the ongoing COVID-19 pandemic in our models. In untabulated results, we estimate the models in Section VI with the addition of an indicator variable equal to one for fiscal years ending between March 11, 2020 and March 31, 2021, in order to adjust for the first year of COVID. In most of those models the coefficients on *covid* are statistically insignificant, likely because of the overlap between the pandemic and the post-implementation period. Of the 432 engagements with fiscal years ending within the first year of COVID, 344 of them were subject to the new Specialists Requirements. With the benefit of additional post-period data, future analysis may be able to better control for the confounding effects of COVID-19.

Other Auditing and Accounting Standards

Because the new Specialists Requirements and Estimates Requirements are necessarily interrelated and have the same effective date, the pre-post differences estimated in this paper could be attributed jointly to these new requirements — it is not possible to separate out the partial effects of each standard using observational data. However, to the extent that the new Estimates Requirements may be associated with changes in specialist usage or specialist hours, our analysis adjusts for some of this effect through the inclusion of controls for *FV Assets to Total Assets* and *FV Liabilities to Total Assets*. As an additional robustness check, we re-estimate the specialist usage and hours models from Section VI with interaction terms between *post* and *FV Assets to Total Assets* and between *post* and *FV Liabilities to Total Assets*. These interaction terms allow post-period differences in specialist usage and specialist hours to vary with the relative importance of FVMs on the issuer's balance sheet. The results do not change meaningfully from those presented in **Table 6** and **Table 8**.

The new Specialists Requirements also took effect at approximately the same time as provisions regarding PCAOB's CAMs requirements for audits of issuers that were not large accelerated filers and four accounting standards. Specifically, the accounting standards are: (1) Financial Instruments—Credit Losses (Topic 326), (2) Intangibles—Goodwill and Other—Internal use Software (Subtopic 350-40), (3) Compensation—Retirement Benefits—Defined Benefit Plans—General (Subtopic 715-20), and (4) Fair Value Measurement (Topic 820). Given the nature of these accounting standards, it is reasonable to assume that the combined effect of the standards would be to increase the demand for specialists. Because these standards all took effect at roughly the same time, it is not possible to separate the effects of the new Specialists Requirements from the effects of these other standards. Nevertheless, our analysis does to some extent adjust for some of these changes because we include relevant fixed effects — by audit firm and issuer industry — to accommodate trends that either do not change or change at a constant rate between the pre- and post-period. For example, FASB's credit losses standard is likely to impact issuers in the financial industry more than other issuers, but the inclusion of the financial industry fixed effect in our analysis will absorb this impact.

Other Robustness Checks

Nonparametric Matching Model for Specialist Usage

To check the robustness of the specialist usage results in Section V to the specification of our model, we also estimate the post-period differences from a nonparametric, bias-corrected, nearest neighbor matching model (Abadie *et al*., 2004; Abadie and Imbens, 2006, 2011). Matching estimators are common in non-experimental program evaluation settings, where treatments are not random and the effect of treatment on the outcome variable is confounded by other variables that are correlated with both the treatment and the potential outcomes. The basic idea is rooted in Rubin's (1974) potential outcomes framework — for each unit in our data, we observe an outcome (Y_i) under one of two treatment states (W_i):

$$Y_i = Y_i(W_i) = \begin{cases} Y_i(0) & \text{if } W_i = 0 \\ Y_i(1) & \text{if } W_i = 1 \end{cases}$$

If we could observe the potential outcomes for each unit under both treatment states, $Y_i(1)$ and $Y_i(0)$, we could estimate the average treatment effect by simply taking the mean of the differences in treated and untreated outcomes across all units. However, because we cannot observe the potential outcome

for each unit in its counterfactual state (*e.g.*, the outcome for treated units had they not been treated and vice versa), we essentially impute the unobserved potential outcome for each unit using a set of statistically similar units in the opposing treatment group.

In the context of our analysis, we define engagements inspected in the post-period to be "treated" and engagements inspected in the pre-period to be "untreated." Using the same covariates from our previous logit model, we estimate the distance between the vectors of covariates for each engagement using the Mahalanobis metric. We then impute the missing potential outcome for each observation by using the average outcomes for a set of engagements in the opposing treatment group (the m nearest neighbors) for which this distance is the smallest. For each engagement, the unit level treatment effect is the difference between the observed outcome and the average outcome for its m nearest neighbors. The average treatment effect on the treated (ATET) is estimated by averaging across the full set of unit level treatment effects.[22] The nonparametric nature of this model is attractive — it allows us to estimate pre-post differences in specialist usage without making assumptions about: (1) the functional form of the relationship between the outcome and the covariates, or (2) the process by which engagements were selected into the pre- and post-period samples.

For each type of specialist, **Table D.1** summarizes the ATET — or average post-period difference in the probability of specialist usage — after matching with replacement on the nearest $m = 1$, $m = 3$, and $m = 5$ nearest neighbors.[23] We perform this analysis for the full sample as well as separately for GNF and NAF engagements. For the full sample estimates, we perform exact matching on NAF status to ensure that GNF and NAF engagements are matched only to other GNF and NAF engagements, respectively. This provides analytical consistency with the estimates generated from the subset of GNF and NAF engagements. The results do not change meaningfully when this restriction is removed.

The results from matching generally align with the estimated marginal effects from the logit models presented in **Table 6**. In virtually every instance, the point estimates from the matching models fall within one standard error of the point estimates from the corresponding logit model. For auditor-employed specialists, the conclusions are consistent across both models. Using the $m = 5$ matching results for ease of discussion, the matching model suggests a statistically significant post-period increase in the use of auditor-employed specialists of approximately 6.5 percentage points, whereas the logit estimate suggested a slightly smaller, but still highly significant, 4.8 percentage point increase. For NAF engagements, the matching estimates suggest a statistically significant 9.8 percentage point increase in the use of auditor-employed specialists, whereas the logit estimates suggest a statistically significant 8.8 percentage point increase. Both models suggest an insignificant post-period difference among GNF engagements.

For the use of auditor-engaged specialists, the models come to different conclusions on the significance of the results, though the point estimates are again roughly consistent across the two approaches. According to the matching estimates, the use of auditor-engaged specialists increased by a statistically significant 9.5 percentage points in the post-period, driven by a 13.7 percentage point increase among GNF engagements; the difference among NAF engagements estimated from this model was not

[22] See page 294 in Abadie *et al*. (2004) for further details about the estimator.

[23] There is a tradeoff associated with additional matches: increasing the number of matches reduces bias but increases the variance of the point estimator.

statistically significant. On the other hand, the logit estimates suggested no statistically significant differences in the use of auditor-engaged specialists for either GNF or NAF engagements.

Finally, the matching model estimates a statistically significant increase in the probability of an auditor using the work of company specialists of approximately 12.1 percentage points, driven by statistically significant increases among GNF and NAF engagements of 12.5 points and 13.6 points, respectively. The logit estimates suggest a statistically significant increase across all engagements of 10.5 percentage points, driven by an increase among NAF engagements of 11.2 points but no statistically significant difference among GNF engagements.

TABLE D.1

Post-Period Average Treatment Effects on the Treated (ATET) for Specialist Usage by Type, GNF vs. NAF

	Auditor-Employed[1]			Auditor-Engaged			Company		
	m = 1	*m = 3*	*m = 5*	*m = 1*	*m = 3*	*m = 5*	*m = 1*	*m = 3*	*m = 5*
Full Sample	0.069**	0.073***	0.065***	0.092***	0.093***	0.095***	0.126***	0.111***	0.121***
	(0.027)	(0.023)	(0.022)	(0.030)	(0.027)	(0.027)	(0.041)	(0.035)	(0.034)
n	1,643	1,643	1,643	1,139	1,139	1,139	1,139	1,139	1,139
GNF Only[2]	0.000	0.006	0.004	0.138***	0.136***	0.137***	0.121**	0.136***	0.125***
	(0.024)	(0.020)	(0.019)	(0.040)	(0.036)	(0.034)	(0.053)	(0.047)	(0.047)
n	992	992	992	488	488	488	488	488	488
NAF Only	0.077	0.103*	0.098*	-0.000	0.046	0.014	0.127**	0.182***	0.136**
	(0.060)	(0.054)	(0.052)	(0.070)	(0.042)	(0.041)	(0.062)	(0.056)	(0.053)
n	651	651	651	651	651	651	651	651	651

[1] Auditor-employed specialists refer to specialists employed by the audit firm. Auditor-engaged specialists refer to third-party specialists contracted by the audit-firm. Company specialists refer to specialists employed or engaged by an issuer whose work is used by the auditor as audit evidence.

[2] GNF engagements are audit engagements performed by U.S. firms that are members of global networks. NAF engagements are audit engagements performed by firms that are not affiliated with a major global network.

Note: Estimates shown are marginal effects from bias adjusted *m*-nearest neighbor matching models and are interpreted as changes in the probability of each type of specialist being used on an engagement. Robust standard errors are in parentheses. Statistical significance is indicated at the *p<0.10, **p<0.05, and ***p<0.01 levels.

Sources: PCAOB proprietary data, Audit Analytics, and S&P Capital IQ

APPENDIX E. EXPLANATION OF ALGORITHM USED TO CATEGORIZE AUDITOR-EMPLOYED SPECIALISTS

The PCAOB's inspections data contains information about individuals who worked on inspected audit engagements. The data contains the job titles of all auditor-employed specialists who worked on the audit. The auditor-employed specialists on the engagement team are entered into the reports as "specialist" and then must be further explained by the audit firm. These explanations are typically the individual specialists' job title, or a list of that specialists' areas of expertise relevant to the audit. To address the lack of uniformity among these job titles and descriptions, the staff created a specialist categorization algorithm. The specialist categorization algorithm provides a uniform and consistent definition for each specialist role. The algorithm uses a hierarchy and a textual analysis technique that measures the similarities between words and phrases, in order to sort specialist titles into one of four categories: valuation, advisory, actuary, and other.[24]

The hierarchy is designed to create a precedence order between possible categorizations. For example: if a role is categorized as both a valuation specialist and a real estate specialist it will be considered a valuation specialist because valuation specialists take precedence in the hierarchy. The textual analysis technique used in the algorithm is called edit distance, which is used to mathematically determine how different two words or phrases are from each other. For this algorithm the measure of edit distance used is the Levenshtein String Distance. The Levenshtein String Distance, which is also known as the Levenshtein String Similarity, counts how many substitutions, insertions or deletions would be needed to turn one word or phrase into another. String Distance is a mathematical representation of a non-mathematic concept; the similarity between two words or phrases. The Levenshtein String Distance calculation was developed in 1965 by Vladimir Levenshtein. Current literature supports that a more computationally efficient calculation is likely not achievable.[25]

The input for the categorization algorithm is an extensive keyword list containing a mapping between typical specialist job titles, acronyms and common misspellings and the categories of interest. There are approximately 400 search terms contained in the keyword list. During the classification process the algorithm employs a strict hierarchy, which uses an assigned precedence order to determine which categories outrank each other in cases where the keywords associated with a particular role point to multiple possible classifications. The keyword list is based on staff's common understandings about the typical responsibilities of auditor-employed specialists. However, the irregularity in the job title descriptions in the data provided by audit firms would make some roles ambiguous. In the infrequent occasions where the roles are unclear, we excluded these observations from the analysis.

In the first step of the algorithm, which is the hierarchy step, each role contained in the data is compared to all of the keywords in the keyword list. Any matches between keywords and the role in question are flagged as potential classifications. If there is only one keyword match or if all keywords point to the same classification, then the classification is considered correct. If, after the comparison,

[24] See Ontañón (2020) for further information on computing edit distance.

[25] See Backurs and Indyk (2018) for further information on the efficiency of the Levenshtein String Distance. Computational efficiency is determined by the length of runtime and the use of disk space. Maximizing computational efficiency is an important part of algorithmic design.

the flagged keywords point to contradictory classifications, the taxonomy hierarchy is used to reconcile the classification. If the hierarchy is unable to reconcile the classifications, the role remains unclassified.

In the next step, each role that is unclassified after the prior step is edited. The editing process removes unnecessary filler words (*e.g.*, the, of, at, etc.) as well as words that do not provide helpful information (*e.g.*, other, staff, specialist, etc.). Certain punctuation like semicolons, exclamation points, and question marks are also removed along with all Arabic numerals. The resulting simplified roles are then reduced to a list of distinct roles.

Next, each distinct simplified role is compared to all of the keywords in the keyword list, just as the original roles were compared to the keywords in the taxonomy hierarchy step. This time, for each role the edit distance between that role and every keyword is calculated and the keyword with the minimum edit distance from the simplified role is selected. The smallest edit distance will belong to the keyword that needed the fewest number of substitutions, insertions, or deletions to turn it into the simplified role. If there are two or more keywords that both have the minimum edit distance neither keyword is chosen, and the role is considered unclear and remains unclassified.

Lastly, the specialist classifications are assigned to the original roles based on a mapping between the original roles and the distinct simplified roles. When the algorithm determines that a particular distance simplified role has a best match, the algorithm stores a copy of that "best match" as a key-value pair. The key is the simplified distinct role, and the value is the keyword. Any role that does not have a best match does not have any keyword recorded. This creates a master list of every key-value paired role and assigned keyword. When the simplified distinct role list was created, a mapping between the original roles and their new simplified counterpart was saved. Using that list, a match is made between the key-value pairs and their original records. This attaches a keyword to the original undefined role.

To verify the outcome of the categorization generated by the algorithm, two staff members who did not work on the categorization algorithm conducted an internal review. They manually classified a randomly selected sample (10% of the data) and compared the manual categorization to the categorization generated by the algorithm. The comparison results indicate an accuracy rate of more than 99.3%.