The Impact of Audit Technology on Audit Task Outcomes: Evidence for Technology-Based Audit Techniques*

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ABSTRACT

As audit technology becomes more widespread, practice and academia are raising concerns about the costs and benefits of these technologies. We examine how internal auditors use technology-based audit techniques (TBATs) and how TBATs impact the efficiency and effectiveness of their audits. We use two surveys and interviews of individual auditors and chief audit executives (CAE) to examine their perceptions of TBATs. Auditors perceive TBATs as beneficial. Specifically, an increase in the use of TBATs is associated with completing more audits, finding more risk factors, providing more recommendations, and decreasing audit days. However, CAEs also perceive TBATs to be costly. An increase in the use of TBATs is associated with an increase in the size of the internal audit function. Finally, interviews with CAEs suggest that TBATs are not used more often because of difficulties in quantifying their benefits, observing their benefits in a timely manner, and hiring auditors with appropriate skills. Overall, TBATs stand to increase the efficiency and effectiveness of audit tasks, but auditors struggle to quantify their net cost-benefit tradeoff. Our findings validate the issues raised by both proponents and opponents of audit technologies and help provide empirical data to inform their decision-making process regarding the future of these tools. Additionally, our study prompts several avenues for future research that can help inform regulators, practitioners, and researchers on how these technologies are impacting the auditing profession.

Keywords: technology, internal audit, data analytics, auditing, technology-based audit techniques

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L'impact de la technologie d'audit sur les résultats des tâches d'audit : preuve de l'utilité des techniques de vérification basées sur la technologie

RÉSUMÉ

Alors que la technologie d'audit se développe, les milieux professionnel et académique soulèvent des inquiétudes quant aux couts et aux avantages de ces technologies. Les auteurs examinent comment les auditeurs internes utilisent les techniques de vérification basées sur la technologie (TVBT) et comment les TVBT ont un impact sur l'efficience et l'efficacité de leurs audits. À l'aide de deux enquêtes et d'entretiens avec des auditeurs individuels et des dirigeants de l'audit interne (DAI), ils examinent leurs perceptions des TVBT. Les auditeurs perçoivent les TVBT comme étant avantageuses. Plus précisément, une utilisation accrue des TVBT est associée à la réalisation d'un plus grand nombre d'audits, à la découverte d'un plus grand nombre de facteurs de risque, à la formulation d'un plus grand nombre de recommandations et à la diminution du nombre de jours d'audit. Cependant, les DAI considèrent également que les TVBT sont couteuses. Une augmentation de l'utilisation des TVBT est associée à une augmentation de la taille de la fonction d'audit interne. Enfin, les entretiens avec les DAI suggèrent que les TVBT ne sont pas utilisées plus souvent en raison des difficultés à quantifier leurs avantages, à les observer en temps opportun et à engager des auditeurs possédant les compétences appropriées. Dans l'ensemble, les TVBT sont susceptibles d'accroitre l'efficience et l'efficacité des tâches d'audit, mais les auditeurs ont du mal à quantifier leur rapport cout-avantage net. Ces résultats permettent de valider les questions soulevées par les partisans et les opposants des technologies d'audit et contribuent à fournir des données empiriques pour éclairer leur processus décisionnel au regard de l'avenir de ces outils. De plus, cette étude propose plusieurs pistes de recherches futures qui peuvent contribuer à informer les autorités de règlementation, les praticiens et les chercheurs sur l'impact de ces technologies sur la profession d'audit.

Mots-clés : technologie, audit interne, tanalyse de données, audit, echniques d'audit basées sur la technologie

1. Introduction

This study examines how the use of technology-based audit techniques (TBATs) influences audit efficiency, effectiveness, and costs.[1] Technology is becoming an increasingly important aspect of both internal and external audits as clients become more sophisticated users of technology; auditors face significant pressure to reduce audit fees, and technology is better able to perform audit tasks.[2] Although technology is often adopted with the goal of improving efficiency, effectiveness, and costs, studying this phenomenon in audit settings is difficult because of the relative lack of archival data sets. Prior research that attempts to address this issue finds no results or even mixed results (we review this literature in section 2). In line with these mixed findings, researchers find there is less adoption of audit technology at firms than anticipated (Lovata 1990; Janvrin et al. 2008; Vasarhelyi and Romero 2014; Eilifsen et al. 2020). This gap—technology holding significant promise but the lack of evidence of the realization of positive audit outcomes—has led to numerous calls for additional research in this area (Earley 2015; Wang and Cuthbertson 2015; Alles and Gray 2016;

1. Technology-based audit techniques are defined as "any automated audit tool, such as generalized audit software, test data generators, computerized audit programs, specialized audit utilities, and CAATs" (IIA 2017, 24). As such, it encompasses traditional technology approaches and new data analytics technologies and can be considered a holistic term for audit techniques that involve technology.
2. We expect our findings to generalize to both the external and internal audit settings and thus refer to "auditing" throughout the paper. Internal auditors and external auditors perform many similar tasks with technology including analytical and substantive procedures, tests of details, tests of balances, and tests of controls. Thus, we expect audit technology to have a similar impact on audits conducted by both groups.

Janvrin and Wood 2016; Moffitt et al. 2016; Austin et al. 2021). To our knowledge, our study is among the first to address this issue by examining a proprietary data set of auditors' use and perceptions of TBATs and how TBATs influence actual audit outcomes in the field.

Although, at first glance, it would appear relatively obvious that technology should improve audit outcomes, there are reasons why this may not be the case. First, technology may enhance the efficiency of the audit, but rather than redeploying the captured gains into more audit coverage, the organization could reduce audit budgets (for internal audit) or cut audit fees (for external auditors) so that overall audit quality does not improve. Second, to be effective, auditors must not only purchase advanced technology but also have personnel capable of using the technology successfully. The accounting profession currently faces significant challenges in hiring technological expertise, given the high demand and pay for individuals with technology skills in other disciplines (Christ et al. 2021; Maksymov et al. 2021). Third, technology may improve audit outcomes but at a cost that auditors or companies are not willing to pay. For example, Christ et al. (2021) demonstrate that automating inventory counts with drones dramatically improves efficiency and effectiveness; however, there is still relatively little adoption of this technology in the field because "drones are still expensive" (Vien 2018, para. 32).

We used three complementary approaches to gather and examine auditors' perceptions of TBATs. First, we conducted a survey of 268 internal auditors, asking their beliefs about how TBATs influence audit efficiency and effectiveness (perception data), the overall use of TBATs in the company's internal audit function (IAF) (overall data), the use of TBATs on the respondents' two most recent audit engagements (engagement data), and various measures of the efficiency and effectiveness of audit tasks. Second, we conducted another survey of 505 CAEs, asking their beliefs about the costs (in terms of personnel and budget) associated with the companies' IAFs, so we could examine whether the use of TBATs increases or decreases audit costs. Finally, we interviewed 11 CAEs to gain further insight into the decision process to adopt TBATs and how CAEs evaluate TBATs' costs and benefits.

Our findings from our first survey show that auditors perceive TBATs make auditors more efficient and effective—and this result is robust across the amount of TBAT usage in the respondents' organization, the rank of the respondent (chief audit executive (CAE) or not), and the size of the IAF of the respondent. The non-perception data we collected in the first survey supports these perception findings. We find that a one standard deviation increase in the usage of TBATs is associated with completing 18.5% more audits, finding 10.8% more risk factors, providing 12.3% more recommendations, and decreasing the days necessary to complete an audit by 13.5%. In other words, higher usage of TBATs is associated with a more efficient and effective audit. When looking at specific phases of the audit, we find that higher usage of TBATs is associated with a reduction in the number of days to prepare an audit and the number of days used in conducting fieldwork, but is not associated with the number of days to prepare audit reports.

Although these results show that TBATs can improve the efficiency and effectiveness of the audit, they do not consider the costs necessary to achieve these benefits. Therefore, we analyze the results from our second survey wherein we ask CAEs about the costs associated with TBATs. We find that a one standard deviation increase in TBAT usage is associated with a 15.5% increase in the size of the IAF (i.e., the number of auditors). In open-ended responses about factors CAEs consider to be barriers to TBAT implementation, we find that the top five barriers are high implementation costs, lack of competence of the auditors, data quality issues, high operating costs, and data access issues. When we split the respondents by TBAT usage, we find that IAFs that are low in TBAT usage are much more concerned with financial costs than IAFs that are already using TBATs at a high level.

The results of these two surveys provide both positive and negative findings on TBAT usage. Although TBATs are associated with greater audit efficiency and effectiveness (our first survey of auditors), they do come at a higher cost (our second survey from CAEs). Given the data come from different respondents, we are unable to provide an overall net benefit to the usage of TBATs. Therefore, to shed additional light on how auditors decide to invest in and assess the

costs and benefits of TBATs, we interviewed 11 CAEs. The interviewees noted that CAEs are largely responsible for deciding whether to use TBATs (i.e., management or the board does not dictate the decision) and that the decision process generally results from an informal cost-benefit analysis. However, this cost-benefit analysis is quite complicated as auditors have a difficult time quantifying all the costs and even more difficulty in assessing the benefits of TBATs.

Interviewees noted it can sometimes be difficult to value non-monetary benefits, which are not always recorded by engagement teams; and costs can sometimes be ignored when they are indirectly related to technology acquisition and implementation, such as retraining employees on new technology, operational downtime for technology installation and maintenance, and so on. Furthermore, the interviewees noted that seeing benefits from implementing TBATs can take a long time, partially because it is difficult to find auditors with the skill sets to properly implement and use TBATs. Thus, some IAFs are likely low users of TBATs because of the difficulty in measuring and observing benefits from TBATs and because of the challenge in hiring qualified auditors to realize the benefits of using TBATs. Thus, the interviews suggest that the lack of greater technology adoption is potentially more of a problem of identifying measurable benefits of technology than concerns over the costs of the technology. Our study helps address this issue by providing CAEs with measurable benefits of TBATs on audit engagements.

We make several contributions to the literature. First, we contribute to the literature on the costs and benefits of technology in auditing (Lovata 1990; Janvrin et al. 2008; Vasarhelyi and Romero 2014; Eilifsen et al. 2020). We show that auditors should expect to see improvements in efficiency and effectiveness from adopting new technologies; however, these benefits may or may not exceed the costs associated with the technology. Given that large public accounting firms are investing billions in technology (EY 2018; KPMG 2019; PwC 2019a), our results suggest that we should see improvements in audit quality, but we will not necessarily see lower audit fees, especially immediately after introducing new technology. Since many people expect technology to enhance efficiency and thus lower costs, this sets up an interesting line of future research that should investigate how key stakeholders (e.g., managers, auditors, board members, regulators) will respond to the increasing use of technology, especially if that technology does not result in cost savings that many are likely to expect. The audit fee setting process may become increasingly adversarial, and it will be important for future research to gain a better understanding of this dynamic.

Second, we identify a reason why technology is not more highly adopted in auditing—identifying costs, but more so identifying quantifiable benefits of technology, is difficult. Thus, one important contribution is that this paper identifies objective, quantifiable benefits to technology adoption in auditing for a large sample of firms. Given accounting is a science of measurement, we encourage future researchers to develop better ways to measure the benefits of technology in audit settings—especially for individual companies. Audit researchers should consider looking to the managerial accounting literature for ways to measure costs and benefits to help enable better decision-making in audit and governance contexts. This will enhance decision quality around when technology should and should not be used.

Third, we contribute to the literature by gathering propriety data about specific audit engagements and the amount of technology used on those engagements. We show that the decision to use technology in practice is more complicated than many might expect and that it is not a clear-cut choice to adopt technology. Given the significant exposure and even hype of emerging technologies for solving accounting problems (Austin et al. 2021), this study suggests future research can explore the person, task, and environmental factors that make audit technologies more likely to be used and impactful and how specific audit technologies can impact specific audit outcomes.

Finally, we inform the increasing number of researchers examining how internal auditing provides value to the organization (Prawitt et al. 2009, 2012; Ege 2015; Abbott et al. 2016; Bills et al. 2022; Ege et al. 2022; Jaggi 2022). As audit technology implementation continues to mature in organizations, our work can help launch future research into how internal auditing can provide

more value to the organizations' operating effectiveness, efficiency, risk management, accounting quality, and other issues.

2. Review of the literature and hypotheses

Increasing the amount of technology used in audit tasks receives significant attention from professionals (PwC 2018; Hood 2018). However, we know relatively little about the impact these new technologies have on the tangible outcomes of audit tasks' effectiveness and efficiency. Professionals' perceptions of technology are mixed. Some professionals express optimism about technology's impact, believing that it will improve audit task outcomes. For example, Braun et al. (2017, 41) report that auditors "that have successfully implemented sustainable analytics activities have not only been able to clearly visualize and articulate the value analytics can deliver to their functions and the broader business, but also have started to realize that value in enhanced efficiency, effectiveness, and risk awareness." In contrast, others are less optimistic about the benefits of audit technology for auditors. A Gartner survey (2018) notes that risks surrounding data and audit technological tools are the top concerns for CAEs. Furthermore, Protiviti (2019) finds relatively few organizations indicate that their audit teams understand the importance of technological innovation or that innovation is a core value for the IAF. PwC (2019b, 15) reports that many auditors "struggle to find the right fit" for emerging technologies in their work.

As a result, there are repeated calls from both practitioners and academics to research how technology will impact the audit profession (Bierstaker et al. 2001; Ramamoorti 2003; Brown-Liburd et al. 2015; Cao et al. 2015; Earley 2015; Griffin and Wright 2015; Yoon et al. 2015; Alles and Gray 2016; AICPA 2017; Richins et al. 2017; Gepp et al. 2018; Christ et al. 2021). Almost universally, the commentaries call for research to see whether the optimism or pessimism regarding audit technology impacts is warranted.[3]

Some prior archival research examines how the client's technology investments impact external auditors. The results are mixed, with research finding that more IT investment by the audit client is associated with lower audit report lags (Johnston and Zhang 2018) but higher audit fees, an increased probability of auditors' issuance of going-concern opinions, and a higher likelihood of auditors' Type II errors (Han et al. 2016). Additional evidence by Chen et al. (2014) is similarly mixed and shows that the audit client's IT capability mitigates audit fee increases but has no effect on audit delay. Lim et al. (2021) examine the clients' investment in auditing technology on external auditing outcomes and find that clients' audit data analytics technology is associated with decreased audit fees and decreases in external audit delays.

There have been relatively few studies with firm- or engagement-specific data examining the impacts of audit technology. A handful of studies examine the extent of adoption and usage of audit technology at large public accounting firms (Lovata 1990; Janvrin et al. 2008; Dowling 2009; Vasarhelyi and Romero 2014). The most recent of these is Eilifsen et al. (2020), which examines the adoption of data analytics by external auditors and at which points in the audit the technologies are used—but does not examine whether the use of data analytics enhances the efficiency and effectiveness of the audit. Although Li et al. (2018) examine audit technology adoption within the IAF, they examine auditors' perceptions of these tools on performance rather than directly measuring specific, engagement-level audit effectiveness or efficiency outcomes. Our study complements these studies by being the first to provide specific, engagement-level

3. Theoretical research also highlights the need for research in this area. DeAngelo (1981) asserts that an auditor's conditional probability of discovering an accounting error is a function of the auditor's technological capabilities, the audit procedures employed on a given audit, and the extent of sampling. Surprisingly, this model does not suggest a directional prediction for the impact of the audit technology on audit quality, noting that technology provides auditors with incentives to lower audit quality and incentives to increase audit quality. More recent models suggest investments in strategic technology should impact audit efficiency and effectiveness and call for empirical research to substantiate their model (Sirois et al. 2016).

measures of audit task effectiveness and efficiency, not only for the overall usage of audit technologies but also for audit technologies used at different stages of the audit.

Extant work suggests a few reasons why technology should improve audit task effectiveness. Technology can allow more direct testing of more transactions, which can improve audit effectiveness (Ballou et al. 2020; Barr-Pulliam et al. 2021; Cardinaels et al. 2021; Emett et al. 2021). In addition, technology allows for gathering and displaying data in unique ways to better interpret audit evidence, and thus enhance audit effectiveness, than audit procedures performed without technology (Dilla et al. 2010; Jans et al. 2014; Rose et al. 2017; Anderson et al. 2020; Pickard et al. 2020; Loraas and Holt 2021; Jans and Eulerich 2022). Finally, technology may increase efficiency (see the second hypothesis), and if any realized time savings are redeployed for additional testing, effectiveness would also be higher (KPMG 2015; CA Worldwide 2017).

Although some studies suggest technology would not improve audit effectiveness (Brazel et al. 2004; Commerford et al. 2022; Holmstrom 2021), we believe the literature, on the whole, supports TBATs improving audit effectiveness, which leads to our first hypothesis.

Hypothesis 1 (H1). *The use of TBATs is positively associated with audit task effectiveness.*

Technology may also enhance audit efficiency. Technology can increase audit planning efficiency because technology allows auditors to consider various data sources and enable new risk assessment and planning procedures (Lynch et al. 2009; Koreff 2021). Furthermore, technology allows traditional audit procedures to be performed more efficiently (Dowling and Leech 2014; Cooper et al. 2019, 2022; M. Eulerich et al. 2022; Austin et al. 2021; Christ et al. 2021). As specific examples, M. Eulerich et al. (2022) show that robotic process automation adoption in an IAF reduces the time it takes to calculate distances when evaluating compliance tests for mileage reimbursement, the time to validate documents downloaded from enterprise resource planning (ERP) systems, and the time taken to extract information from ERP systems. Practitioners also believe technology increases audit efficiency, suggesting to clients that they can increase the efficiency of their audits by using technology for digital confirmations, using natural language processing systems for legal contract analysis, and using application programming interfaces to speed up data management and extract, transform, and load processes (Davenport and Raphael 2017; AICPA 2019; IDC Research 2022).

Although some studies have suggested technology would not improve audit efficiency (Maksymov et al. 2021; Emett et al. 2021; Austin et al. 2021; Negangard et al. 2021), we believe the literature, on the whole, supports TBATs improving audit efficiency, which leads us to our second hypothesis.

Hypothesis 2 (H2). *The use of TBATs is positively associated with audit task efficiency.*

It is important to consider the effects of TBATs not only on audit effectiveness and efficiency but also on audit costs. Audit costs might be higher when auditors use TBATs because the technology can be costly, firms might need to upgrade their systems to use the latest auditing tools, training might be needed to educate auditors on how to use the tools and how to apply the tools to specific audits, and additional personnel with specialized technology training might have to be hired in greater numbers or at higher salaries than what would be required for more traditional audits. Alternatively, audit costs could be lower when auditors use TBATs because automation could reduce the number of auditors or audit hours required to perform the audit procedure; audit technology might be able to provide greater insights into risk assessments to allow for a more targeted, smaller audit program; audit technology could entirely remove the need for certain procedures to be performed; or audit technology could provide a higher level of assurance at a similar cost as traditional procedures, thus reducing the need for additional evidence to be gathered.

Thus, adopting technology could be associated with higher or lower audit costs. Given this dynamic, we explore the following non-directional hypothesis.

HYPOTHESIS 3 (H3). *The use of TBATs is associated with audit costs.*

3. Research methodology

Survey development, data collection, and description of sample

Survey 1 of internal auditors

To create our first data set, we surveyed 268 auditors.[4] We developed the survey by consulting the academic and practitioner literature, receiving feedback from two internal auditors, and working with the German chapter of the Institute of Internal Auditors (IIA). The final survey version consisted of open- and closed-response questions about the respondent's overall usage of TBATs in the IAF and specific data about the two most recent audit engagements.[5] Questions about the two most recent audit engagements cover details about the type and nature of the audit engagement, measures of effectiveness and efficiency of the audit engagement, and usage of TBATs across various stages of the audit engagement. We provided respondents with the definition of TBATs so that participants conceptualized TBATs consistently and uniformly. Survey responses were collected at two large annual conferences of a national IIA chapter. One of the authors distributed paper copies of the survey directly to the auditors at each of these events. Approximately 1,100 people were at the conferences, and we achieved approximately a 24% participation rate.

From the 268 respondents, we obtained 205 observations with complete data to run the analysis examining the number of audits performed (column (3) of Table 3). As mentioned, we asked the 268 respondents to provide information about their two most recent engagements, yielding a possible 536 observations (if provided with complete data) at the individual engagement level. As described in more detail later, we examine three audit effectiveness/efficiency outcomes at the engagement level: (i) significant risk factors found, (ii) recommendations provided, and (iii) total auditing days—we also break out total auditing days into various parts of the audit. For the model analyzing risk factors (recommendations) (total auditing days), there are 300 (340) (361) observations with complete data included in the regression model.

Survey 2 of CAEs

To examine audit costs, we use a different data set collected from a survey of CAEs.[6] This data set was also developed as a collaboration between academics and three different IIA organizations and was extensively pilot tested before collecting responses from CAEs in companies headquartered in Germany, Austria, and Switzerland. The CAEs that were contacted received an electronic invitation to participate with a hyperlink to the survey. All participants who took part in the study completed the survey anonymously. A total of 4,009 invitations were sent out to CAEs. We received responses from 505 participants, which is a response rate of 12.6%. Respondents include CAEs from a broad range of industries and different-sized companies. However, not all participants answered the survey in full.

From the sample of CAE responses, there are 349 observations that provided data about TBAT usage in their organization. As described in more detail later, we examine two audit cost outcomes: (i) the budget of the IAF and (ii) IAF size as proxied by the number of IAF employees.

4. We received human subjects' approval for all data collections in this study.
5. This is similar to Gibbins et al. (2001) and allows us to avoid problems with adverse selection of audit engagements and forgetfulness and reflects the most recent changes to audit technology and audit methodology at their firm's IAF.
6. The data set was gathered by the researchers together with the national IIA chapters from three different countries. The data from prior year administrations of this survey are also used by Carcello et al. (2018) and from the current year (data from 2020) by Bantleon et al. (2021), and Barr-Pulliam et al. (2020) within different research contexts.

For the model examining the IAF budget (IAF size), 309 (320) observations with complete data are included in the regression model.

Interviews of CAEs

We reached out to personal contacts and interviewed 11 CAEs about their usage and perceptions of the costs and benefits of TBATs. We specifically selected participants to ensure a wide representation based on their level of TBAT usage. On average, interviewees had more than 20 years of experience, and the interviews lasted, on average, 27 minutes. We used a semi-structured interview approach (see Appendix 2 for the interview script). We summarize the key things we learned from the interview process later in the paper.

Variables and models

Audit effectiveness

Although various studies suggest ways to measure audit effectiveness, there is no generally accepted measure (Arena and Azzone 2009; A. Eulerich and M. Eulerich 2020). Conceptually, audit effectiveness deals with the degree to which the audit "performs in such a way so as to accomplish the task described by the audit objective" (Dittenhofer 2001, 447). We examine audit effectiveness in several ways. First, we examine the number of audit engagements the audit department can complete. In other words, we examine the audit's coverage or scope. When auditors conduct more engagements, they can examine more issues, identify more areas for improvement, and address more matters of concern for the organization.

We run the following equation to test the association between TBAT use and the number of audits conducted:

$$Number\ of\ Audits = \alpha_0 + \alpha_1\, IA\ TBAT\ Level + \sum \alpha_j\, Controls + \varepsilon. \quad (1)$$

The dependent variable, *Number of Audits*, is measured by the natural log of the number of audits the IAF (as a whole) performed during the year. The main independent variable of interest, *IA TBAT Level*, measures the level of the internal audit (IA) department's use of TBAT (ranging from *very low* (1) to *very high* (5)). *Controls* is a vector of control variables measuring characteristics at the company level (see Appendix 1 for a full description of each variable). We control for various features of the IAF, including the number of internal audit staff (*IAF Employees*), internal audit reporting structure (*Report to Board/AC*), focus on assurance activities (*Assurance PCT*), outsourcing level (*Outsourcing PCT*), and the average number of training days for internal auditors (*Training Days*). We also control for certain firm factors—the number of employees (*Corporate Employees*) and whether the company is publicly listed on the stock exchange (*Publicly Listed*), operates in the finance industry (*Finance*), has a Big N auditor (*Big N*), and has an audit committee (*Audit Committee*). Finally, we include a control variable for the different times our surveys were collected (*Survey*). We use data from Survey 1 to run equation (1).

Dittenhofer (2001) suggests to the extent that the audit identifies problems and recommends solutions to the problems identified, the audit has been effective. Thus, holding other factors constant, a more effective audit will result in the auditor finding more significant risks and providing more recommendations. Accordingly, we test whether TBAT usage is positively associated with the number of significant risk factors found in the audit and the number of recommendations produced for the auditee. We run the following equations to test the association between TBAT use and audit effectiveness, measured by the number of significant risk factors found and the number of recommendations provided:

$$Risk\ Factors = \beta_0 + \beta_1\, Engagement\ TBAT\ Level + \sum \beta_j\, Controls + \varepsilon, \quad (2)$$

$$Recommendations = \chi_0 + \chi_1\, Engagement\ TBAT\ Level + \sum \chi_j\, Controls + \varepsilon. \quad (3)$$

For equations (2) and (3), audit effectiveness is measured using two dependent variables. The first dependent variable is *Risk Factors*, which is the natural log of the number of significant risk factors found during the audit. The second dependent variable, *Recommendations*, is the natural log of the number of recommendations produced by the audit. For both variables, we measure the outcomes at the individual audit engagement level.

For the main independent variables of interest, we measure the audit teams' overall usage of TBATs during the engagement. We asked respondents to rate their usage of TBATs across six stages of the audit process, including planning the audit schedule, planning the audit process, gathering evidence, performing analyses, reporting the audit findings, and following up on the audit findings. More specifically, we asked respondents the following question for each of the six stages of the audit engagement: "How would you rate your usage of technology-based audit techniques for the following stage of the audit?"[7] The respondents would then answer based on a seven-point Likert scale (1 = *very low* to 7 = *very high*). The responses to the six audit stages are averaged together to create *Engagement TBAT Level*, our overall TBAT usage measure for the audit engagement.[8]

For both equations (2) and (3), *Controls* is a vector of control variables (see Appendix 1 for a full description of each variable). We control for the number of days the audit team worked on the engagement (*Auditing Days*). We use indicator variables to capture information about the entity being audited (i.e., *Subsidiary*, *Plant*, *Project*, and *Process*). To control for the audit's focus, we included the following indicator variables: *Financial Focus*, *Operational Focus*, *Compliance Focus*, *Managerial Focus*, and *IT Focus*.[9] *Assurance* is an indicator variable that controls whether the audit engagement relates to assurance work and not a consulting project. We control for the number of auditors working on the engagement (*Team Size*) and the audit's size and scope (*Audit Size*). We also control for the audit object's risk and performance before the audit by including the risk level assessment (*Risk before*) and performance level (*Performance before*) of the audit object before the audit engagement. Also, we control for the size of the audit department (*IAF Employees*), whether the head of internal audit reports functionally to the supervisory board or audit committee (*Report to Board/AC*), IAF's level of assurance activities (*Assurance PCT*), IAF's outsourcing level (*Outsourcing PCT*), and the average number of training days for auditors (*Training Days*). We include the same company characteristics as control variables as used in equation (1). We use Survey 1 data about specific audit engagements to run equations (2) and (3).

Audit efficiency

Audit efficiency is measured by the time it takes the audit team to complete the audit. To investigate the effect of TBAT usage on audit efficiency, we run the following equation on data collected about individual audit engagements:

$$Auditing\ Days = \delta_0 + \delta_1\, Engagement\ TBAT\ Level + \sum \delta_j\, Controls + \varepsilon. \quad (4)$$

The dependent variable *Auditing Days* measures the number of days the audit team spent on the audit engagement, which encompasses preparing for the audit, completing fieldwork, and reporting. As additional analyses, we also examine each category of auditing days separately (*Preparation Days*, *Fieldwork Days*, and *Reporting Days*). The independent variable of interest is *Engagement TBAT Level*, which is the audit teams' overall usage of TBATs during the

7. The six stages of the audit engagement are planning the audit schedule, planning the audit processes and procedures, gathering evidence, analyzing audit findings, reporting of audit findings, and following-up on audit findings.
8. We used the average rather than a factor analysis as we did not expect a multidimensional construct to emerge. That is, our ex ante expectation was that the use of TBAT would be relatively similar throughout the stages of the audit so averaging would best capture differences between companies.
9. Auditors perform a wide variety of assurance services beyond financial audits. Our study looks at the impact of technology on audits broadly which gives our study stronger generalizability to other assurance contexts.

engagement. The variable *Engagement TBAT Level* and control variables shown in Table 5 are measured the same way as in equations (2) and (3).[10] Data from Survey 1 about specific audit engagements are used to run equation (4).

Audit costs

As we did not collect cost data in the same survey as previously described, we used data from Survey 2 to study audit costs. We run the following equation:

$$Audit\ Costs = \phi_0 + \phi_1\, IA\ TBAT\ Level + \sum \phi_j\, Controls + \varepsilon. \quad (5)$$

We investigated two dependent variables with this data: audit budget (*IAF Budget*) and audit size (*IAF Size*). We asked CAEs to categorize their budget into categories based on monetary amounts (categories were used to preserve anonymity). To get a sense of audit size, we asked CAEs the number of employees (i.e., full-time equivalent staff) working in their audit department. The main independent variable of interest, *IA TBAT Level*, measures the level of the audit department's use of TBATs (ranging from *very low* (1) to *very high* (5)). We include control variables for various firm and audit characteristics.

4. Results

Insights from respondents

Before we discuss the empirical results from the models above, we depict how the audit respondents perceive the value of TBATs. The following analyses are based on responses collected from Survey 1. Although not objective dependent variables, like those in our primary analyses, this analysis provides useful insights into how auditors view the potential benefits of TBATs.[11] We asked auditors their opinion about whether TBATs help improve the effectiveness and efficiency of audit tasks. The respondents answered each question based on a scale ranging from one (*very little*) to five (*very much*). In Table 1, panel A presents the results for effectiveness, and panel B presents the results for efficiency. The overall mean of their responses is 3.86 for effectiveness, which is statistically significantly higher than three (*neutral*). The majority (71%) of the respondents answered either four or five, suggesting auditors perceive TBATs to improve the effectiveness of audit work. For efficiency, the overall mean of their responses is 3.92, which is statistically significantly higher than three (*neutral*). The majority (75%) of the respondents answered either four or five, suggesting auditors also perceive TBATs to improve the efficiency of audit work.

In panels C and D, we split the perceived effectiveness and efficiency measures by the median size of the IAF, respectively. It is possible that larger IAFs have greater resources to invest in technology and to hire auditors more adept at using technology. Thus, any benefits from adopting technology may only be available to larger and better-funded IAFs. Although this is a possibility, the auditors do not perceive that the benefits of TBATs are only realized in larger IAFs. The results show that both groups believe technology will enhance effectiveness and efficiency more than the midpoint of the scale. Furthermore, the results do not differ between large

10. See Appendix 1 for more detailed variable definitions.

11. While the perception variables are potentially subject to individual bias, the other measures are subject to limitations, particularly concerns over endogeneity. As such, we use both perception and engagement data (as well as interview data described subsequently) to present triangulated evidence about our hypotheses. We check the correlations between the perception-based variables and the main measures for audit effectiveness and audit efficiency. We find in untabulated results that respondents' perception of TBATs' helpfulness in improving audit's work effectiveness is positively correlated with the total number of audits. It is also positively (negatively) correlated with *Risk Factors* (*Auditing Days*). In addition, respondents' perception of TBATs' helpfulness in improving audit's work efficiency is positively (negatively) correlated with *Recommendations*, and *Risk Factors* (*Auditing Days*).

TABLE 1
Auditors' perceptions of how TBATs influence effectiveness and efficiency

Panel A: TBAT perceived effectiveness

Answer	*n*	%
1 (*very little*)	9	3.47
2	16	6.18
3	49	18.92
4	114	44.02
5 (*very much*)	71	27.41

Panel B: TBAT perceived efficiency

Answer	*n*	%
1 (*very little*)	10	3.83
2	13	4.98
3	41	15.71
4	121	46.36
5 (*very much*)	76	29.12

Panel C: TBAT perceived effectiveness—Categorized by size of IAF

IAF size	*n*	Mean	One-tailed *p*-value testing if mean >3
Small IAF	120	3.85	<0.01
Large IAF	128	3.88	<0.01

Panel D: TBAT perceived efficiency—Categorized by size of IAF

IAF size	*n*	Mean	One-tailed *p*-value testing if mean >3
Small IAF	121	3.87	<0.01
Large IAF	129	3.95	<0.01

Panel E: TBAT perceived effectiveness—Categorized by the level of TBAT use

TBAT level	*n*	Mean	One-tailed *p*-value for mean >3 (*neutral*)
IA dept with low TBAT use	60	3.47	<0.01
IA dept with medium TBAT use	79	3.76	<0.01
IA dept with high TBAT use	115	4.11	<0.01

Panel F: TBAT perceived efficiency—Categorized by the level of TBAT use

TBAT level	*n*	Mean	One-tailed *p*-value for mean >3 (*neutral*)
IA dept with low TBAT use	62	3.34	0.02
IA dept with medium TBAT use	79	3.94	<0.01
IA dept with high TBAT use	115	4.21	<0.01

Panel G: Comparison of perceptions between auditors and CAEs (based on Survey 1 and Survey 2 data)

Variable	*n*	Auditors	*n*	CAEs	Difference	*p*-value
TBAT Perceived Effectiveness	259	3.86	320	3.61	0.25	<0.01
TBAT Perceived Efficiency	261	3.92	320	3.54	0.38	<0.01

(The table is continued on the next page.)

TABLE 1 (continued)

Notes: This table provides auditors' perceptions about the influence of TBATs on work effectiveness and efficiency. For TBAT perceived effectiveness, respondents provided answers to the question: "Do TBATs help auditors improve the effectiveness of audit work?" For TBAT perceived efficiency, respondents provided answers to the question: "Do TBATs help auditors improve the efficiency of audit work?" In panel A, overall mean = 3.86 (n = 259), p-value for mean >3 (*neutral*) is <0.01, one-tailed. Of the 268 auditors that participated in Survey 1, 9 had missing responses. In panel B, overall mean = 3.92 (n = 261), p-value for mean >3 (*neutral*) is <0.01, one-tailed. Of the 268 auditors that participated in Survey 1, 7 had missing responses. In panel C, small (large) IAF are those where the number of IAF employees is less than (greater than or equal to) the median value. Test for difference between small and large IAFs: p-value = 0.843, two-tailed. From Survey 1 of 268 auditors, 20 observations had missing responses for IAF size and/or TBAT perceived effectiveness. In panel D, small (large) IAF are those where the number of IAF employees is less than (greater than or equal to) the median value. Test for difference between small and large IAFs: p-value = 0.495, two-tailed. From Survey 1 of 268 auditors, 18 observations had missing responses for IAF size and/or TBAT perceived efficiency. In panel E, from Survey 1 of 268 auditors, 14 observations had missing responses for the level of TBAT usage and/or TBAT perceived effectiveness. In panel F, from Survey 1 of 268 auditors, 12 observations had missing responses for the level of TBAT usage and/or TBAT perceived efficiency. In panel G, the p-values are two-tailed. As described in panel A, there are 259 (261) auditor responses from Survey 1 about the perceived effectiveness (efficiency) of TBAT. From Survey 2, there are 320 CAE responses about the perceived effectiveness and efficiency of TBAT.

and small IAFs (comparison of perceived effectiveness p-value = 0.843, two-tailed; comparison of perceived efficiency p-value = 0.495, two-tailed).

We compare responses of auditors working in IAFs with low, medium, and high TBAT usage. In panel E (panel F) of Table 1, we show responses related to effectiveness (efficiency). As expected, auditors working at departments with high TBAT usage perceive higher effectiveness benefits (4.11) than those working at departments with either medium (3.76) or low TBAT usage (3.47). However, interestingly, auditors across the TBAT usage spectrum perceive that TBATs can provide benefits to work effectiveness. Even among auditors working at departments with relatively low TBAT usage, the response is 3.47, statistically significantly higher than three (*neutral*). Not surprisingly, auditors working at departments with high TBAT usage perceive higher efficiency benefits (4.21) than those working at departments with either medium (3.94) or low TBAT usage (3.34). As in the case with panel E, auditors across the TBAT usage continuum perceive that TBATs can benefit work efficiency. Even among auditors working at departments with low TBAT usage, the response is 3.34 for efficiency; the results are statistically significantly higher than 3 (*neutral*).

Table 1, panel G, compares responses between auditors and CAEs. This analysis uses data from Survey 2 in addition to Survey 1 data. As shown, we find that both auditors and CAEs perceive that TBATs can improve audit work effectiveness and efficiency, as responses are all significantly above 3 (*neutral*). However, we discover that auditors perceive higher effectiveness and efficiency benefits from TBATs than CAEs. One possible explanation is that auditors use TBATs more in their daily work responsibilities and hence experience the benefits from TBATs more directly than the CAEs.

Descriptive statistics

We present the descriptive statistics for the variables in our models in Table 2. Panel A presents the descriptive statistics for variables measured at the company level for the full survey observations collected (Survey 1). Panel B presents variable descriptive statistics measured at the audit engagement level for the full survey observations collected (Survey 1). As shown in panel A, the mean TBAT level is 3.27 on a five-point scale. The mean number of audits being conducted by the audit departments is 86 engagements. The mean number of audit employees is 46 full-time equivalent individuals. We note the other characteristics of IAFs in our sample: 47% of the CAEs report to the audit committee or supervisory board, assurance takes up 79% of the audit's time, 6% of audit activities are outsourced/co-sourced, and mean training days is seven days during the

TABLE 2
Descriptive statistics

Panel A: Company-level variables—Survey 1 data

Variable	*n*	Mean	Median	Std. dev.
IA TBAT Level	262	3.27	3.00	1.14
Number of Audits (Raw #)	254	86.11	57.00	104.52
IAF Employees (Raw #)	255	46.02	14.00	107.32
Report to Board/AC	266	0.47	0.00	0.50
Assurance PCT	254	0.79	0.80	0.16
Outsourcing PCT	248	0.06	0.02	0.10
Training Days	257	7.12	6.00	4.38
Corporate Employees (Raw #)	255	35,313.11	5,700.00	89,063.05
Publicly Listed	266	0.31	0.00	0.46
Finance	265	0.46	0.00	0.50
Big N	266	0.73	1.00	0.45
Audit Committee	256	0.68	1.00	0.47

Panel B: Engagement-level variables—Survey 1 data

Variable	*n*	Mean	Median	Std. dev.
Risk Factors (Raw #)	395	5.10	3.00	8.74
Recommendations (Raw #)	465	9.93	6.00	11.14
Auditing Days (Raw #)	486	39.57	28.00	47.59
Preparation Days	488	9.27	5.00	11.08
Fieldwork Days	489	22.65	15.00	34.16
Reporting Days	487	7.67	5.00	8.31
Engagement TBAT Level	478	3.25	3.17	1.42
TBAT—Planning Schedule	488	2.88	3.00	1.68
TBAT—Planning Audit Process	488	3.02	3.00	1.65
TBAT—Gathering Evidence	490	3.67	4.00	1.75
TBAT—Analyses	488	3.56	3.50	1.82
TBAT—Reporting	492	2.95	3.00	1.63
TBAT—Follow Up	488	3.39	3.00	1.87
Subsidiary	500	0.24	0.00	0.43
Plant	498	0.12	0.00	0.33
Project	498	0.14	0.00	0.35
Process	498	0.52	1.00	0.50
Financial Focus	498	0.29	0.00	0.46
Operational Focus	499	0.48	0.00	0.50
Compliance Focus	498	0.29	0.00	0.45
Managerial Focus	498	0.07	0.00	0.25
IT Focus	498	0.22	0.00	0.41
Assurance	488	0.93	1.00	0.25
Team Size	494	2.48	2.00	1.99
Audit Size	497	3.57	4.00	0.94
Risk before	496	3.27	3.00	0.93
Performance before	481	3.02	3.00	0.85

(The table is continued on the next page.)

TABLE 2 (continued)

Panel C: Variables used in Table 6 (Survey 2 data collected from CAEs)

Variable	*n*	Mean	Median	Std. dev.
IAF Budget	335	3.47	4.00	1.49
IAF Size (Raw #)	348	17.67	4.70	119.48
IA TBAT Level	349	2.51	3.00	1.29
Report to Board/AC	505	0.59	1.00	0.49
Assurance PCT	388	0.79	0.80	0.15
Outsourcing PCT	348	0.08	0.01	0.15
Training Days	343	7.89	6.00	5.49
Corporate Employees (Raw #)	437	10,478.23	2,000.00	32,746.08
Publicly Listed	505	0.33	0.00	0.47
Finance	505	0.28	0.00	0.45
Audit Committee	505	0.56	1.00	0.50

Notes: This table provides descriptive statistics for variables used in the study. For each variable, we show descriptives based on the maximum number of responses obtained from participants. Variable definitions can be found in Appendix 1. Panel A provides descriptives for variables measured at the company level (Survey 1), while panel B provides descriptives for variables measured at the audit engagement level (Survey 1). Panel C provides descriptives for variables measured at the company level from CAEs (Survey 2).

year. Regarding company characteristics, 31% of the companies are publicly traded on the stock exchange, 46% belong to the finance industry sector, 73% employ a Big N auditor, and 68% have an audit committee.

As shown in panel B of Table 2, the respondents evaluated the TBAT use in individual engagements at a mean of 3.25 on a seven-point scale. The mean number of significant risk factors found in an audit engagement is approximately five. The mean number of recommendations made by the audit is approximately 10. The mean number of days for audit engagements is about 40 days. Roughly 9 days are used for preparation, 23 days are used for fieldwork, and 8 days are used for reporting. Panel C of Table 2 shows the descriptives of the variables obtained from the supplementary CAE data collection for the full survey observations collected (Survey 2). The median value for *IAF Budget* is 4, indicating that the median total auditing budget is between 500,000 and 1,000,000 euros. The mean number of full-time equivalent staff in the audit department is approximately 18. The mean TBAT level is approximately 2.5 (maximum score is five—*very high*).

Audit effectiveness

As part of testing H1, we examine the association between TBAT usage and the number of audits conducted by an IAF in Table 3. Controlling for the number of audit employees and other factors, we find that TBAT usage is positively associated with the number of audit engagements completed. Hence, we show that IAFs with higher TBAT usage levels can conduct more audits for their organization.

In Table 4, we present the results for testing the two engagement-level measures of audit effectiveness: *Risk Factors* and *Recommendations*. We find that higher overall usage of TBATs during the engagement is associated with a higher number of significant risk factors found by the IAF and a higher number of recommendations produced by the IAF. In sum, our evidence provides support for H1 that the use of TBATs is positively associated with audit task effectiveness and is consistent with auditors' and CAEs' perceptions of TBATs.

In terms of economic magnitude, a one standard deviation increase in TBAT usage is associated with completing 18.5% more audits. In terms of engagement-specific economic magnitudes,

TABLE 3
TBAT levels and the scope of auditing

	Number of Audits		
Variable	(1) Coeff. (*p*-value)	(2) Coeff. (*p*-value)	(3) Coeff. (*p*-value)
IA TBAT Level	0.108***	0.123***	0.149***
	(0.007)	(0.003)	(0.001)
IAF Employees	0.697***	0.697***	0.574***
	(0.000)	(0.000)	(0.000)
Report to Board/AC		−0.054	−0.078
		(0.613)	(0.490)
Assurance PCT		0.654**	0.446
		(0.028)	(0.225)
Outsourcing PCT		1.172**	0.865
		(0.025)	(0.115)
Training Days		0.016	0.017
		(0.227)	(0.199)
Corporate Employees			0.051
			(0.292)
Publicly Listed			0.185
			(0.172)
Finance			0.399**
			(0.014)
Big N			0.102
			(0.407)
Audit Committee			0.041
			(0.772)
Survey	−0.073	−0.149	−0.092
	(0.418)	(0.105)	(0.340)
Constant	1.566***	0.876***	0.499
	(0.000)	(0.002)	(0.262)
Observations	240	218	205
Adjusted R^2	0.624	0.677	0.702

Notes: Using Survey 1 data, this table presents the linear regression results for examining the association between TBAT levels and the number of audits conducted, with TBAT levels shaded in gray. Based on robust standard errors with Huber/White sandwich estimator. *** and ** indicate two-tailed *p*-values less than 0.01 and 0.05, respectively. See Appendix 1 for variable definitions.

a one standard deviation increase in TBAT usage is associated with finding 10.8% more risk factors and providing 12.3% more recommendations.[12]

Audit efficiency

Our second hypothesis is that the use of TBATs is beneficial for audit efficiency. We test H2 by examining how the use of TBATs is associated with the number of days spent on the audit engagement. We report the results testing H2 in Table 5. We find that higher usage of TBATs during the engagement is associated with fewer total days of the audit (see column (1)). In

12. We base economic magnitudes on the standard deviations reported in Table 2.

TABLE 4
TBAT usage and audit engagement effectiveness

Variable	*Risk Factors* (1) Coeff. (*p*-value)	*Recommendations* (2) Coeff. (*p*-value)
Engagement TBAT Level	0.072**	0.082**
	(0.030)	(0.039)
Auditing Days	0.029	0.194***
	(0.648)	(0.004)
Subsidiary	0.067	0.187
	(0.642)	(0.211)
Plant	−0.007	0.323*
	(0.967)	(0.086)
Project	−0.030	0.093
	(0.758)	(0.534)
Process	−0.066	−0.121
	(0.533)	(0.358)
Financial Focus	0.140	0.091
	(0.153)	(0.442)
Operational Focus	0.120	0.027
	(0.126)	(0.812)
Compliance Focus	0.021	0.017
	(0.783)	(0.876)
Managerial Focus	0.069	0.010
	(0.606)	(0.950)
IT Focus	0.087	0.014
	(0.321)	(0.913)
Assurance	−0.202	−0.199
	(0.162)	(0.183)
Team Size	0.035*	0.030
	(0.071)	(0.200)
Audit Size	0.116***	0.056
	(0.007)	(0.339)
Risk before	0.087**	0.170***
	(0.029)	(0.001)
Performance before	−0.051	−0.038
	(0.193)	(0.507)
IAF Employees	0.013	−0.039
	(0.748)	(0.565)
Report to Board/AC	−0.046	0.001
	(0.559)	(0.987)
Assurance PCT	0.379	0.258
	(0.113)	(0.417)
Outsourcing PCT	0.481	0.899***
	(0.109)	(0.003)
Training Days	0.019**	−0.000
	(0.011)	(0.987)
Corporate Employees	0.051***	0.038
	(0.008)	(0.357)
Publicly Listed	−0.042	0.092
	(0.696)	(0.451)

(The table is continued on the next page.)

TABLE 4 (continued)

Variable	*Risk Factors* (1) Coeff. (*p*-value)	*Recommendations* (2) Coeff. (*p*-value)
Finance	−0.198**	−0.386***
	(0.021)	(0.003)
Big N	−0.092	−0.130
	(0.317)	(0.243)
Audit Committee	−0.067	−0.106
	(0.389)	(0.372)
Survey	0.004	−0.186**
	(0.964)	(0.049)
Constant	−0.014	0.414
	(0.965)	(0.360)
Observations	300	340
Adjusted R^2	0.249	0.249

Notes: Using Survey 1 data, this table presents the linear regression results for examining the association between TBAT levels and two measures of audit engagement effectiveness: (i) the number of risk factors found (column (1)) and (ii) the number of recommendations produced (column (2)), with both shaded in gray. Based on robust standard errors with Huber/White sandwich estimator. ***, **, and * indicate two-tailed *p*-values less than 0.01, 0.05, and 0.10, respectively. See Appendix 1 for variable definitions.

columns (2) to (4), we examine the days for the stages of the engagement: preparation, fieldwork, and reporting, respectively. We find that higher TBAT usage is associated with fewer preparation days and fieldwork days but is not associated with reporting days. Thus, our results support H2 that the use of TBATs is positively associated with audit task efficiency and that the efficiency gain is because of fewer days needed to plan the audit and conduct fieldwork.[13]

In terms of economic magnitude for efficiency at the engagement level, a one standard deviation increase in TBAT usage is associated with a 13.5% decrease in the days necessary to complete an audit. The decrease in preparation days and fieldwork days is 9.7% and 15.1%, respectively. Not only is this consistent with auditor and CAE perceptions of the impact of TBATs on the audit, but it represents significant cost savings for the firm as they reduce the time spent on engagements. Thus, increases in TBAT significantly enhance the efficiency of auditors.[14]

Audit costs

We report the results testing our hypothesis about audit costs in Table 6 (based on Survey 2 data). We find that TBAT usage is positively associated with IAF budget and IAF size. In terms of economic magnitude, a one standard deviation increase in TBAT usage is associated with a 15.5%

13. As untabulated analyses, we run the audit effectiveness and audit efficiency models by controlling for (i) how respondents perceive TBATs help auditors improve the effectiveness of audit work and (ii) how respondents perceive TBATs help auditors improve the efficiency of audit work. The inclusion of these control variables does not change our inferences of the main analyses.

14. In untabulated analyses, we rerun the risk factors, recommendations, and total auditing days models using a constant sample (based on Survey 1 data), which includes only observations with complete data on all variables in those three models ($n = 287$). Using this smaller sample, we continue to find results consistent with our hypotheses. The positive coefficient on *Engagement TBAT Level* for the risk factors (recommendations) model is significant at the 0.05 level, two-tailed (0.10 level, one-tailed). The negative coefficient on *Engagement TBAT Level* for the total auditing days model is significant at the 0.01 level, two-tailed.

TABLE 5
TBAT usage and audit engagement efficiency

Variable	*Auditing Days* (1) Coeff. (*p*-value)	*Preparation Days* (2) Coeff. (*p*-value)	*Fieldwork Days* (3) Coeff. (*p*-value)	*Reporting Days* (4) Coeff. (*p*-value)
Engagement TBAT Level	−0.089***	−0.065**	−0.099***	−0.035
	(0.001)	(0.020)	(0.003)	(0.253)
Subsidiary	0.142	0.159	0.111	0.213
	(0.248)	(0.241)	(0.387)	(0.116)
Plant	0.152	0.109	0.132	0.347**
	(0.287)	(0.495)	(0.355)	(0.023)
Project	0.319**	0.192	0.346**	0.292**
	(0.010)	(0.211)	(0.013)	(0.035)
Process	0.251**	0.141	0.336***	0.215*
	(0.018)	(0.253)	(0.003)	(0.064)
Financial Focus	0.034	0.069	0.028	−0.105
	(0.674)	(0.467)	(0.750)	(0.277)
Operational Focus	0.152**	0.185**	0.110	0.120
	(0.029)	(0.026)	(0.161)	(0.136)
Compliance Focus	0.043	−0.144	0.138	−0.018
	(0.572)	(0.106)	(0.118)	(0.835)
Managerial Focus	−0.028	−0.019	0.012	0.026
	(0.861)	(0.913)	(0.944)	(0.884)
IT Focus	0.108	0.171	−0.010	0.109
	(0.251)	(0.131)	(0.928)	(0.285)
Assurance	−0.022	−0.063	−0.037	−0.018
	(0.902)	(0.736)	(0.854)	(0.930)
Team Size	0.102***	0.082***	0.107***	0.048**
	(0.000)	(0.003)	(0.000)	(0.018)
Audit Size	0.308***	0.164***	0.346***	0.287***
	(0.000)	(0.000)	(0.000)	(0.000)
Risk before	0.008	0.032	0.011	0.017
	(0.852)	(0.474)	(0.830)	(0.710)
Performance before	−0.027	−0.002	−0.043	−0.062
	(0.530)	(0.967)	(0.374)	(0.203)
IAF Employees	0.148***	0.084*	0.193***	0.082*
	(0.000)	(0.069)	(0.000)	(0.090)
Report to Board/AC	−0.085	−0.026	−0.050	−0.190**
	(0.273)	(0.777)	(0.572)	(0.026)
Assurance PCT	0.233	−0.227	0.463*	0.575**
	(0.286)	(0.412)	(0.075)	(0.012)
Outsourcing PCT	−0.606*	0.119	−0.960**	−0.383
	(0.055)	(0.711)	(0.018)	(0.249)
Training Days	0.010	−0.003	0.018**	−0.008
	(0.127)	(0.660)	(0.028)	(0.215)
Corporate Employees	0.007	0.027	−0.013	0.049*
	(0.759)	(0.267)	(0.691)	(0.086)
Publicly Listed	−0.048	0.181*	−0.177*	−0.025
	(0.593)	(0.092)	(0.084)	(0.819)
Finance	0.031	−0.064	0.113	−0.167*
	(0.692)	(0.495)	(0.227)	(0.070)

(The table is continued on the next page.)

TABLE 5 (continued)

Variable	*Auditing Days* (1) Coeff. (*p*-value)	*Preparation Days* (2) Coeff. (*p*-value)	*Fieldwork Days* (3) Coeff. (*p*-value)	*Reporting Days* (4) Coeff. (*p*-value)
Big N	−0.017	−0.080	0.039	0.079
	(0.853)	(0.425)	(0.726)	(0.458)
Audit Committee	0.113	0.034	0.036	0.166
	(0.235)	(0.748)	(0.738)	(0.106)
Survey	−0.007	0.107	−0.069	0.012
	(0.926)	(0.189)	(0.428)	(0.888)
Constant	1.277***	0.753*	0.399	−0.556
	(0.000)	(0.054)	(0.356)	(0.120)
Observations	361	362	363	362
Adjusted R^2	0.398	0.201	0.390	0.308

Notes: Using Survey 1 data, this table presents the linear regression results for examining the association between TBAT levels and audit engagement efficiency, with TBAT levels shaded in gray. In column (1), we examine total auditing days. In columns (2), (3), and (4), we examine days for preparation, fieldwork, and reporting. Based on robust standard errors with Huber/White sandwich estimator. ***, **, and * indicate two-tailed *p*-values less than 0.01, 0.05, and 0.10, respectively. See Appendix 1 for variable definitions.

increase in the size of the audit department. We were unable to obtain data about the precise monetary amount of the budget. Instead, respondents categorized their budget into seven categories (1 = *less than 100,000 euros* to 7 = *more than 10 million euros*). We find that a one standard deviation increase in TBAT usage is associated with a 0.22 point increase in the IAF budget scale. Thus, using TBATs is not without meaningful costs. We perform additional analyses and interviews (discussed subsequently) to learn more about this topic.[15]

We also asked respondents to inform us of factors they consider to be barriers to TBAT implementation (based on Survey 2 data). Table 7 shows their responses. As shown in Table 7, panel A, the barrier that received the highest percentage selected is high implementation cost at 53%. The next three issues with the highest percentage of responses are "not sufficient competence," "lack of database quality," and "high operating costs." Interestingly, the two issues that received the lowest selections are "personal barriers" (e.g., personal unwillingness to use TBAT, lack of know-how and expertise) and "lack of support from the supervisory board."

In panel B of Table 7, we compare responses to implementation barriers between low and high TBAT users. Across most issues, low TBAT users are more likely to select an implementation barrier than high TBAT users. The largest difference is the issue of high implementation costs. Sixty-two percent of low TBAT users select high implementation costs as a barrier to TBAT implementation, while 40% of high TBAT users select this issue as a barrier. The issues with the next three largest differences between low and high TBAT users are "high operating cost," "uncertainty about software," and "not sufficient competence."

This pattern of results is interesting in that financial and non-financial costs appear to be perceived differently based on how much the IAFs use the TBATs. The companies that report high usage of TBATs believe costs are significantly less than those companies that use TBATs more

15. In untabulated analyses, we rerun the *IAF budget* and *IAF size* models using a constant sample (based on Survey 2 data), which includes only observations with complete data on all variables in those two models (n = 309). We continue to find results consistent with our hypotheses. The positive coefficient on *IA TBAT Level* for the *IAF budget* and *IAF size* models is significant at the 0.01 level, two-tailed.

TABLE 6
TBAT levels, IAF budget, and IAF size

Variable	*IAF Budget* (1) Coeff. (*p*-value)	*IAF Size* (2) Coeff. (*p*-value)
IA TBAT Level	0.173***	0.112***
	(0.000)	(0.004)
Report to Board/AC	−0.065	−0.119
	(0.676)	(0.359)
Assurance PCT	1.871***	0.837**
	(0.000)	(0.014)
Outsourcing PCT	−0.213	−1.720***
	(0.597)	(0.000)
Training Days	0.015*	0.012
	(0.061)	(0.136)
Corporate Employees	0.435***	0.339***
	(0.000)	(0.000)
Publicly Listed	0.213	0.185
	(0.138)	(0.128)
Finance	0.935***	0.901***
	(0.000)	(0.000)
Audit Committee	0.487***	0.362***
	(0.001)	(0.006)
Constant	−2.557***	−2.432***
	(0.000)	(0.000)
Observations	309	320
Adjusted R^2	0.496	0.468

Notes: Using Survey 2 data, this table presents the linear regression results for examining the association between TBAT levels and two measures of audit costs: IAF budget and IAF number of employees, with both IAF budget and IAF number of employees shaded in gray. Based on robust standard errors with Huber/White sandwich estimator. ***, **, and * indicate two-tailed *p*-values less than 0.01, 0.05, and 0.10, respectively. See Appendix 1 for variable definitions.

sparingly. Because of these findings, we explore perceptions about costs and benefits more thoroughly by interviewing CAEs.

Supplemental analyses

Effects on different-sized IAFs

In the perception data, we did not find any difference in how auditors perceived the effectiveness or efficiency of TBATs based on the size of IAF of the respondent. We perform a similar analysis with the non-perception data (based on Survey 1 data). Specifically, we split the sample into small and large IAFs based on a median split of the number of audit employees. We present the results in Table 8.

Even with relatively small sample sizes in each condition, the results show that small and large IAFs both have a positive effect on the number of audits conducted; the coefficients for *IA TBAT Level* are positive and significant at one-tailed *p*-value <0.10. In terms of risk factors, we find that small IAFs are associated with finding more risk factors as the level of TBAT usage increases, but large IAFs have no association between TBAT levels and the number of risk factors found. In contrast, we find that for the number of recommendations provided by the IAF, TBAT usage in small IAFs is not associated with more recommendations, but more TBAT usage

TABLE 7
Barriers to TBAT implementation

Panel A: Overall responses ($n = 349$)

Rank	Barrier	Percentage
1	High implementation cost	52.7
2	Not sufficient competence	46.1
3	Lack of database quality	42.7
4	High operating cost	40.1
5	Issue with data access	36.4
6	Issue with data security	26.7
7	Uncertainty about software	25.2
8	Issue with audit integration	15.5
9	Lack of support from supervisory board	11.5
10	Personal barriers	8.9

Panel B: Comparison of low and high TBAT companies

Issue	(a) Low TBAT usage ($n = 170$) (%)	(b) High TBAT usage ($n = 80$) (%)	Difference (a) − (b) (%)	*One-tailed* *p*-value (a) > (b)
High implementation cost	62.4	40.0	22.4	<0.01
High operating cost	47.6	30.0	17.6	<0.01
Uncertainty about software	32.4	20.0	12.4	0.022
Not sufficient competence	46.5	36.3	10.2	0.065
Issue with audit integration	18.8	8.8	10.1	0.020
Lack of database quality	45.9	36.3	9.6	0.076
Lack of support from supervisory board	16.5	8.8	7.7	0.051
Issue with data access	34.1	31.3	2.9	0.328
Personal barriers	8.2	11.3	−3.0	0.778
Issue with data security	22.4	26.3	−3.9	0.749

Notes: Using Survey 2 data, this table provides the factors considered by respondents to be barriers to TBAT implementation. A total of 349 responses provided information about the organization's TBAT usage. Panel A provides the percentage of respondents that answered a particular issue as a barrier to TBAT implementation. Panel B provides the percentage of respondents that answered a particular issue as a barrier to TBAT implementation split between (a) IAFs with low TBAT usage and (b) IAFs with high TBAT usage, with significant differences shaded in gray. A total of 99 observations are excluded from panel B because those relate to medium TBAT usage.

in large IAFs is associated with providing more recommendations. Finally, we find that both small and large IAFs are associated with fewer auditing days.

The results are largely consistent with the main analysis, except we see a different effect between small and large IAFs on the number of risk factors and recommendations. Although we do not have data to explain why this is the case, one possible reason is that small IAFs usually exist in smaller organizations that are likely to have more internal control issues and other challenges (Doyle et al. 2007). In these organizations, audit can see there are problems (thus the higher identification of risk factors) but might not evaluate and report all issues as this may overwhelm the auditee and not result in a meaningful change (IIA Australia 2020). In contrast, IAFs at large organizations are likely to be faced with fewer risks (i.e., the company has more resources and can better manage risks), and thus TBAT usage in large organizations is perhaps more

TABLE 8
Comparing small and large internal audit functions

	Number of Audits		*Risk Factors*		*Recommendations*		*Auditing Days*	
Variable	Small IAF Coeff. (*p*-value)	Large IAF Coeff. (*p*-value)	Small IAF Coeff. (*p*-value)	Large IAF Coeff. (*p*-value)	Small IAF Coeff. (*p*-value)	Large IAF Coeff. (*p*-value)	Small IAF Coeff. (*p*-value)	Large IAF Coeff. (*p*-value)
IAF TBAT Level	0.111 (0.105)	0.076 (0.192)						
Engagement TBAT Level			0.131*** (0.005)	−0.005 (0.890)	−0.043 (0.363)	0.164*** (0.002)	−0.082* (0.069)	−0.073** (0.023)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101	104	143	157	169	171	173	188
Adjusted R^2	0.491	0.587	0.320	0.273	0.275	0.334	0.336	0.398

Notes: Using Survey 1 data, this table presents the linear regression results for examining the association between TBAT levels and audit outcomes by splitting the sample into small and large audit departments. Small (large) audit department includes observations where the number of IA employees is below (above or equal to) the median value. For brevity, all of the control variables are included in the models but are not tabulated. Based on robust standard errors with Huber/White sandwich estimator. ***, **, and * indicate two-tailed *p*-values less than 0.01, 0.05, and 0.10, respectively. See Appendix 1 for variable definitions.

effective in providing recommendations across a wide spectrum of issues than detecting significant risk factors. Since we do not have data to validate these possible explanations, we encourage future research to study this issue.

Usage of data analytics technologies

Data analytics technology is a subset of TBATs often used in auditing. In Survey 1, we gathered data on how auditors use data analytics technology in their engagements. We provided respondents with the definition of data analytics technologies: computer programs or technologies used to identify, gather, validate, analyze, and interpret data. We constructed a measure of data analytics usage similar to how we constructed the measure of TBAT usage.[16] In untabulated analyses, we find that, both the number of significant risk factors found, and the number of recommendations provided, are positively associated with the usage of data analytics technology. We also find evidence that the total number of auditing days and fieldwork days are lower when data analytics technology usage is higher. Overall, we conclude that the usage of data analytics technology, as a subset of TBATs, can beneficially impact audit effectiveness and efficiency.

Continuous auditing

In the audit effectiveness and efficiency survey (i.e., Survey 1), we also asked auditors to evaluate the degree to which they used TBATs for continuous auditing and continuous monitoring. In line with prior research, we also asked how much the external auditor relies on the results of internal auditors (Glover et al. 2008; Prawitt et al. 2011). Consistent with prior research (Malaescu and Sutton 2015), we find in untabulated analyses that increased use of TBATs for continuous auditing (continuous monitoring) is associated with greater perceptions of external audit reliance on the work of the IAF.

16. Specifically, we asked respondents the following question for each of the six stages of the audit: "How would you rate your usage of data analytics technologies for the following stage of the audit?" The respondents would answer based on a seven-point Likert scale (1 = *very low* to 7 = *very high*). The responses to the six audit stages are averaged together to create an overall measure of data analytics technology usage in the engagement.

TABLE 9
Interview demographic variables

Interview number	Experience (years)	TBAT level	Number of employees at company	Industry
1	19	Low	~20,000	Consumer goods
2	23	High	~35,000	E-commerce
3	20	Low	~4000	Media
4	7	Medium	~50,000	Manufacturing
5	26	High	>100,000	Manufacturing
6	24	High (to low)	>90,000	Pharmaceuticals
7	29	Medium	~14,000	Pharmaceuticals
8	27	Low	~11,000	Banking
9	25	High	~40,000	Human resource management
10	32	Low	~28,000	Project management and engineering
11	17	High	~11,000	Infrastructure

Additional interview data

We interviewed 11 CAEs about their usage of TBATs and especially about their perceptions of the costs and benefits of TBATs. We specifically selected participants to ensure a wide representation based on their level of TBAT usage, firm size, and industry focus. Demographic information about the interviewees is listed in Table 9. On average, interviewees had more than 20 years of experience, and the interviews lasted, on average, 27 minutes. We used a semi-structured interview approach (see Appendix 2 for the interview script). We summarize the key things we learned from the interview process.

Most interviewees suggested that the decision to use TBATs undergoes an informal cost-benefit analysis that is primarily done within the IAF (Interviewees 1, 2, 4, 5, 6, 8, 9). When IAFs followed a more formal process, it was generally because the size of the investment required greater funding than the IAF was allocated. In these circumstances, the IAF worked with other business units (to build a joint case for funding) or with members of the C-suite and/or board to decide whether to pursue the investment. Quotes indicative of the informal nature of the cost-benefit analysis include "It's a gut feeling" (Interviewee 1); "Do we have a sort of cost-benefit analysis or something? No, we did not do this, really" (Interviewee 6); and "I never did the calculation. I don't want to do it because I'm going to see it's costing me a lot, but I see the impact coming, which is worthwhile. . . . It's not formal at all" (Interviewee 9).

Since the cost-benefit analysis is less formal, we explored what and how interviewees considered the costs and benefits of TBATs. Most interviewees mentioned that they consider operating costs and implementation costs, but several even suggested those are not significant enough to warrant much concern (Interviewees 1, 2, 4, 6, 8, 9, 10). Other costs that were mentioned that did merit attention from interviewees included training and human capital costs (Interviewees 1, 2, 5, 6, 9), data formatting (Interviewee 5), and employee time (Interviewees 5, 9, 10, 11).

Similarly, interviewees noted many benefits of TBATs, including increased efficiency (Interviewees 2, 3, 4, 5, 8, 10, 11), improved effectiveness (Interviewees 3, 4, 6, 9, 10, 11), increased audit scope (Interviewees 3, 4, 9, 10, 11), decreases in business risks (Interviewees 3, 6, 7, 9), greater insights into data (Interviewees 2, 9), more standardized audit processes (Interviewees 5, 6), and greater compliance (Interviewee 7). These reported benefits provide additional support for our hypotheses that TBAT usage improves effectiveness and efficiency.

Yet, although these benefits are observed, several interviewees indicated that the benefits are difficult to measure, which is part of the reason a formal cost-benefit analysis is not performed

(Interviewees 1, 4, 6, 9, 10, 11). For example, Interviewee 9 states, "That is an appreciation that you can give with these kind of analytics that is very difficult to quantify in euros." Interviewee 10 stated, "These are the cost factors. . . . Money is an important thing. It doesn't address everything. Unfortunately, the cost side is more measured because they look at how much do we need to spend, but . . . the benefit can be less quantifiable." Thus, one possible reason suggested by the interviewees for the lack of greater adoption of TBATs is the difficulty in analyzing costs and benefits—especially because benefits can be difficult to measure.

In terms of how the decision to use TBATs is made in this informal process, interviewees indicated that because of the difficulty in quantifying the costs and benefits of TBATs they often turn to what other IAFs are doing (Interviewees 2, 8, 9, 10) and to what other service lines in their business are doing (Interviewees 2, 5, 6, 10). For example, Interviewee 9 stated,

> So I get the implicit challenge to talk to one of the other companies of the supervisory board members, so they're like, "Hey, can you talk to this other guy, he's doing that and that and can you have an exchange?" And then we have an exchange and I report back to the same boss and they're like, "Okay, great, you learnt, you learnt, go." So it's a very implicit and very informal way of work here. I never had to showcase what it's going to cost.

Interviewee 2 stated,

> Another factor . . . is speaking with peers. I'm part of this [name redacted] group here in Europe. . . . We had a whole survey about audit tools and who's using what for what. Per that questionnaire, I got to find out what audit management tools others were using, what they were using for analytics. . . . I really trust my peers when they've told me, "Yeah, we have licenses for that, but we don't use it." And that tells me something. Or, "We've used it and we don't use it anymore." In having enough of those conversations, I can kind of triangulate in on technologies that may work for our team.

Similarly, interviewees expressed those technologies that can be used by other service lines are more likely to be used by the IAF. One interviewee asked themself about a technology, "Does this fit in the strategic landscape of a company?" (Interviewee 10). Another pointed out they try to find technology that can be used by other service lines: "I will not integrate these three lines, but where can I cooperate in a very good manner with these guys and girls in the other lines of defense? . . . We have to find something where I think we can support these three lines in a joint operation" (Interviewee 6).

Given the decentralized and informal way CAEs decide when to use TBATs is another possible reason for seeing such a discrepancy in the concerns over costs that we previously documented in the survey. If CAEs have a negative experience or know others who have had a negative experience, they are going to be slower to adopt technology moving forward. Indeed, several interviewees discussed how the benefits from technology can take a significant amount of time before they are manifest. As stated by Interviewee 1, who has a low usage of TBATs,

> I think after two years, we really did not do a structured assessment, but I was really raising the question, "What have we gained so far . . . after two years . . .? What did we really gain when using data analytics with the audits that were supported by such [technology]?" And it was not super beneficial.

In contrast, Interviewee 9, who has a high usage of TBATs, stated,

> It took us five years to start developing data analytics, use numerous tools, different tools, and the bigger the size of the population we had to check, the bigger the capacity of the tool would be, and we ended up with buying our own server as internal audit department to be able to abstract data from the operations into our server to be able to manipulate and then to do queries on it. That whole development, of course, it's a lot of time . . . [it] cost me a lot of time basically to do this.

Thus, our interviewees suggest that another reason for the lack of more TBAT adoption is that the time to see results can be long, and some CAEs are likely not to start that endeavor or to stop before the benefits start to materialize.

Finally, one additional insight into why it can take so much time to see the benefits from TBATs relates to the difficulty in finding auditors with technology skills, which was mentioned by multiple interviewees (Interviewees 1, 2, 4, 6, 10). This is illustrated by the following quotes:

> We made a decision to invest in [a specific technology]. What we quickly found is that we couldn't keep a minimum standard of analytics skills across the team. (Interviewee 2)

> You look for the internal auditor with IT background and who is the . . . [jack of all trades]. You want to have everything in one person, like, internal audit expertise, it's best you want to have the IT nerd, you want to have the guy who is really hunting for issues and so on. But . . . very soon in the process [you realize] that either such person is . . . nowhere, never, ever there are persons like that, and if we find them, we cannot pay them, because they are too expensive. (Interviewee 1)

In sum, our interviewees shed important additional light on the reason TBATs are not more heavily adopted by all IAFs. Because the choice to use TBATs is under the control of the auditors, their peers and other business units can influence their TBAT adoption. Similarly, auditors use an informal approach to assessing costs and benefits which means the auditors are not able to quantify the costs and benefits easily and so often rely on peer opinions and other business units' usage. Furthermore, observing the benefits of adopting technology can take a long time and finding the talent to execute TBATs properly is challenging. Thus, in combination, IAFs are still in various stages of adopting TBATs, even though most recognize there are benefits to their use.

5. Conclusion

This study examines whether the use of TBATs is associated with audit effectiveness, efficiency, and costs. We find that higher usage of TBATs is associated with improvements in the effectiveness and efficiency of audit work; however, we also find that TBAT usage is associated with greater audit costs. We interviewed several CAEs to study the decision process auditors use to decide their level of TBAT usage and find auditors struggle to quantify the net cost-benefit tradeoff of using TBATs.

We contribute to the discussion about the benefits of technology in increasing auditors' efficiency and effectiveness. In general, an auditor's effectiveness can be improved, while the engagement's length of time can be reduced. Thus, TBATs and data analytic technologies increase the overall assurance provided by the auditor while reducing the necessary time per audit. However, this is not a "free" benefit as TBAT usage is associated with larger budgets and IAF size.

Our study is not without limitations. Like all archival studies, endogeneity is a potential concern that cannot be completely ruled out. One particular concern is that the size of the audit is driving our results. Although we tried to rule this out with several analyses (e.g., controlling for IAF size in the models), we list this caveat for readers and future researchers. That said, we note that across multiple methods, participant groups, and data sets, we find consistent results. By leveraging different methods and data sets, we are able to triangulate between the different approaches to find greater insights and support for our research questions (Bloomfield et al. 2016).

In addition, our analysis is based on the self-reporting of our respondents. While self-reported data can be biased, we designed our main dependent measures to ask for objective data about specific engagements participants had participated in whenever possible. In addition, we only measure two of the many impacts TBATs can have on the auditing profession. Future studies could look at how the auditors' use of TBATs impact other important outcomes.

We acknowledge that we are unable to calculate the net benefit of TBATs. This is partially a limitation of our design but also a reflection of auditors not perceiving the need to perform this cost-benefit analysis themselves. Generally, we discover that auditors believe that TBATs have value but are sometimes too costly and that it can be very difficult to gauge the economic impact of

TBATs. Indeed, it is very challenging to assign a dollar value to audit findings and time spent on an audit that would appropriately capture the benefits of audit technology, something our interviews specifically noted auditors struggle to do. Future research could attempt to help practice and move forward accounting research by providing a monetary or economic metric of TBAT net benefits.

Finally, while we believe our findings generalize to the external audit setting, we did not collect data from external auditors or external audit engagements. Future research can examine how the adoption of audit technology influences external auditors. We highlight these research ideas and others previously mentioned in the paper in Appendix 3.

Appendix 1: Variable definitions

Variable	Definition
Dependent variables	
Number of Audits	Natural log of the number of audit engagements completed by internal audit + 1
Risk Factors	Natural log of the number of significant risk factors found during the audit engagement + 1
Recommendations	Natural log of the number of recommendations produced by the audit engagement + 1
Auditing Days	Natural log of the number of days spent on the audit (days in preparation + fieldwork + reporting)
Preparation Days	Natural log of the number of days spent on preparation + 1
Fieldwork Days	Natural log of the number of days spent on fieldwork
Reporting Days	Natural log of the number of days spent on reporting
IAF Size	Natural log of the number of internal auditors employed (full-time equivalents) in the company
IAF Budget	Internal audit budget (euros) equal to (i) under 100,000, (ii) 100,000 to 250,000, (iii) 250,000 to 500,000, (iv) 500,000 to 1,000,000, (v) 1,000,000 to 5,000,000, (vi) 5,000,000 to 10,000,000, and (vii) above 10,000,000
Independent variables	
IA TBAT Level	Respondent's rating of the internal audit department's use of TBAT (1 = *Very Low* to 5 = *Very High*)
Engagement TBAT Level	Use of TBAT in an audit engagement based on the use in six stages of the engagement (planning the audit schedule, planning the audit process, gathering evidence, performing analyses, reporting the audit findings, and following up on the audit findings). Specifically, the average value of (i) *TBAT—Planning Schedule*, (ii) *TBAT—Planning Audit Process*, (iii) *TBAT—Gathering Evidence*, (iv) *TBAT—Analyses*, (v) *TBAT—Reporting*, and (vi) *TBAT—Follow Up* (each ranging from 1 = *Very Low* to 7 = *Very High*)
Company level	
IAF Employees	Natural log of the number of internal audit employees + 1 (full-time equivalents)
Report to Board/AC	One if the CAE functionally reports to the supervisory board or audit committee, and zero otherwise
Assurance PCT	Percentage of time internal audit spends on assurance
Outsourcing PCT	Percentage of the internal audit activities that are outsourced/co-sourced
Training Days	Number of days (per year) internal auditors, on average, spend on training
Corporate Employees	Natural log of the number of corporate employees

(The table is continued on the next page.)

(continued)

Variable	Definition
Publicly Listed	One if the company is listed on the stock exchange, and zero otherwise
Finance	One if the company operates in the financial services industry, and zero otherwise
Big N	One if the company employs a Big N auditor, and zero otherwise
Audit Committee	One if the company has an audit committee, and zero otherwise
Survey	One if the observation belongs to the data collection of the second conference, and zero otherwise
Engagement level	
Subsidiary	One if the audit object is a subsidiary, and zero otherwise
Plant	One if the audit object is a plant, and zero otherwise
Project	One if the audit object is a project, and zero otherwise
Process	One if the audit object is a process, and zero otherwise
Financial Focus	One if the focus of the audit is financial, and zero otherwise
Operational Focus	One if the focus of the audit is operational, and zero otherwise
Compliance Focus	One if the focus of the audit is compliance, and zero otherwise
Managerial Focus	One if the focus of the audit is managerial, and zero otherwise
IT Focus	One if the focus of the audit is IT-related, and zero otherwise
Assurance	One if the type of audit work is assurance, and zero if it is consulting
Team Size	Number of individuals working on the engagement
Audit Size	Respondent's rating of the size or scope of the audit (1 = *Very Small* to 5 = *Very Large*)
Risk before	Respondent's rating of the risk level of the audit object before the audit (1 = *Very Low* to 5 = *Very High*)
Performance before	Respondent's rating of the performance level of the audit object before the audit (1 = *Very Low* to 5 = *Very High*)

Appendix 2: Interview script

After a brief introduction, collection of demographic variables, and explanation of the purpose of the interview, we used the following questions to guide our interview:

1. Currently, what is the level of your TBAT usage? Can you please describe how you currently use TBAT in your organization?
2. What factors do you consider when choosing to use TBAT?
3. What costs do you consider when choosing to use TBATs? How do you assess such costs?
4. What benefits do you consider when choosing to use TBATs? How do you assess such benefits?
5. How do you compare and contrast the benefits versus costs of TBAT usage? Is it a formal or informal process? Can you tell us more about it?

Appendix 3: Suggested questions for future research

1. For external auditors, what are the determinant factors of the decision to make TBAT investments? What factors influence their investment decision? Which stakeholders are involved in their decision?
2. How much do organizations spend on TBAT-related investments (e.g., in proportion to other IT-related spending)? How are the costs spread across the implementation, operational, and maintenance stages? How are the costs spread across infrastructure, hardware,

software, and human training? Are there differential effects on audit outcomes depending on where or what the investments were made in?

3. Regarding the potential benefits of TBATs, are there ways to measure the benefits in monetary terms? If so, do the benefits outweigh the costs for most organizations? How long does it take organizations to reap benefits that offset the costs?
4. How does the internal auditor's adoption of TBATs impact temporal changes in firm-level outcomes? Relative to the period before TBAT adoption are there improvements in operating effectiveness, operating efficiencies, risk management, financial reporting quality, disclosure quality, etc.? As TBAT usage matures and becomes more widespread within the organization, when do changes in audit engagements begin to occur?
5. How does the external auditor's use of TBATs impact audit quality? Does more technology in the audit change the planning and execution of the engagement? Do TBATs aid the external auditor in finding material weaknesses, going-concern issues, and misstatements? Does higher TBAT usage reduce the external auditor's business risks?
6. The external auditor often relies on the work of, and seeks direct assistance from, internal auditors (Auditing Standard 2605, PCAOB 2003). If more extensive TBAT is used by internal auditors, how does this affect the external auditor's reliance on the internal auditor's work? Are internal auditors able to provide the external auditors with more valuable and expansive information? Does it help offset some of the costs for audit fees?
7. A key function of internal audit is to provide consulting work to improve firm operations. How extensively do internal auditors use TBAT in their consulting function? Does more extensive TBAT use by internal audit improve the demand for consulting work?
8. How does the use of TBAT impact the ability to recruit audit professionals? What competencies must auditors have to work with TBATs? How does the use of TBATs impact turnover in audit teams? How does TBAT use affect the auditor's job satisfaction?
9. What are the impacts of specific technologies on audit engagements and audit task outcomes? Does the utilization of specific systems depend on the organization's IT competency? Are there specific tools and software that are more effective than others?

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