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Explaining the (non-) adoption of advanced data analytics in auditing: A process theory

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ABSTRACT

Audit firms are increasingly engaging with advanced data analytics to improve the efficiency and effectiveness of external audits through the automation of audit work and obtaining a better understanding of the client's business risk and thus their own audit risk. This paper examines the process by which audit firms adopt advanced data analytics, which has been left unaddressed by previous research. We derive a process theory from expert interviews which describes the activities within the process and the organizational units involved. It further describes how the adoption process is affected by technological, organizational and environmental contextual factors. Our work contributes to the extent body of research on technology adoption in auditing by using a previously unused theoretical perspective, and contextualizing known factors of technology adoption. The findings presented in this paper emphasize the importance of technological capabilities of audit firms for the adoption of advanced data analytics; technological capabilities within audit teams can be leveraged to support both the ideation of possible use cases for advanced data analytics, as well as the diffusion of solutions into practice.

1. Introduction

External audits by professional accounting firms have a long tradition. With the increasing adoption of information systems in the previous three decades, particularly enterprise resource planning (ERP) systems, technology has become increasingly important for obtaining audit evidence (Alles, 2015; Braun and Davis, 2003). The large-scale adoption of ERP systems has made IT-based auditing a necessity, as the ubiquity of these systems has forced auditors to adopt the approach of "auditing through the computer" instead of auditing around it (Alles, 2015). This accelerated the development of computer-assisted audit techniques and tools (CAATTs)—particularly generalized audit software (GAS)— which supports auditors in the extraction and analysis of data, thereby improving audit efficiency and effectiveness (Braun and Davis, 2003). Currently, a cluster of new technologies has been discussed in recent audit literature as a means to further improve both the efficiency and effectiveness of audits: Data analytics, artificial intelligence (AI), robotic process automation (RPA), and big data (Cao et al., 2015; Chan et al., 2018; Moffitt et al., 2018; Kokina and Davenport, 2017; Alles and Gray, 2016). The term big data itself relates to the nature of the data source (Chen et al., 2012). It describes the increasing rate of data generation ("velocity"), the resulting masses of data that are generated ("volume"), and the structural heterogeneity of the data ("variety") (Russom, 2011). Data analytics is used to extract information from data; visualizations, statistics, and data mining tech-

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niques can be applied to data to extract information, which in turn can be used in decision-making (Chen et al., 2012). Appelbaum et al. (2018) conducted an extensive literature review on data analytics methods that are applicable for analytical audit procedures. They found a wide spectrum of methods that could be applied through all phases of audit engagement. The authors also indicate that audit practitioners still referred to a rather narrow set of techniques compared to the spectrum of techniques employed in research. Among the techniques that they found applicable is process mining (PM). PM is a data analytics method utilized to generate process models from transactional data stored in ERP systems (Chiu and Jans, 2019; Jans et al., 2013; Jans et al., 2014; Van Der Aalst et al., 2010). This method can be employed for the assessment of control risk and replaces the walkthrough interviews that auditors conduct regularly (ibid.). Data analytics is commonly used for structured data. Deep learning, a form of machine learning, further enables the extraction of structured representations from semi- and unstructured data such as images, text, and sound (Issa et al., 2016; Sun, 2019). Issa et al. (2016) refer to deep learning in their definition of AI, along with expert systems. Expert systems employ rule-based programming for making or informing decisions but these have fallen out of use in audit practice [1] (Gray et al., 2014). Another technology that leverages the use of rules for data processing is RPA. RPA refers to software that utilizes business rules and activity choreographies on regular user interfaces to automate human tasks (Moffitt et al., 2018). Lacity and Willcocks (2016) argue that RPA is best suited for so-called "swivel-chair" processes, where a professional.

> "[...] takes in work from many electronic inputs (like emails and spreadsheets), processes it using rules, adds data as necessary by accessing more systems, and then inputs the completed work to yet other systems [...]." (Lacity and Willcocks, 2016).

For a task to be automated through RPA, it must be well defined; ambiguous tasks are problematic (Moffitt et al., 2018). In order to increase the ability of RPA to handle more complex tasks, it can be combined with machine learning (Huang and Vasarhelyi, 2019).

This cluster of technologies is referred to as advanced data analytics (ADA), as all the technologies that are part of it are related to the processing and analysis of data that goes beyond traditional audit procedures. Audit firms, usually known to lag in the adoption of new technologies (Alles, 2015), are now recognizing the impact that these emerging technologies can have on their profession, particularly as the audit industry is facing stagnating revenues from their core business (Rapoport, 2018). The efficiency of both financial and non-financial external audits can be improved from the automation of audit work, whereas the effectiveness of such audits can be increased from the analysis of data generated by the client and third parties, thereby enabling a more thorough view of the client's business and the associated risks. If adopted, the potential impact on auditing practice is significant. Issa et al. (2016) indicate the disruptive nature of ADA and envision a highly effective, fully automated audit that is similar to a production line. Several conceptual and empirical studies have explored the individual drivers and inhibitors of ADA adoption in audit firms (Alles, 2015; Alles and Gray, 2016; Dagiliene and Kloviene, 2019; Haddara et al., 2018; Salijeni et al., 2019). Thus far, extant research has not determined how the process of ADA adoption works in audit firms and how the related drivers and inhibitors affect this process. Our research aims to close this gap by addressing the following research question:

Which process do audit firms utilize to adopt ADA technologies and how is this process affected by contextual factors?

To this end, we conducted 15 semi-structured interviews with auditors and other industry experts involved in the development and implementation of ADA solutions in auditing practice. This paper contributes to the growing field of research on ADA in auditing by introducing a mid-range process theory that outlines the process underlying ADA adoption in auditing. Further, the organizational units within audit firms that are involved in the process are described and contextual factors from prior research and extent theoretical frameworks are related to the process. This paper aims to address both the AIS research community and audit practitioners. It presents a theoretical contribution to the body of research on technology adoption in auditing by using a previously unused theoretical perspective, while also providing practical insights on ADA. Further, this research makes a case for strengthening the IT-capabilities of auditors to enable audit firms, small and big, to leverage interdisciplinary skill sets for technology adoption. Therefore, it could also serve as motivation for audit standard-setters and regulators to strengthen the required IT capabilities for certified auditors.

2. Related literature

Audit firms look to information technology (IT) to improve the quality, efficiency, and effectiveness of external audits (Janvrin et al., 2008; Lowe et al., 2018). Generally, there has been an increase in IT adoption in the previous decade in the audit profession (ibid.). Moreover, this development is not limited to the Big Four audit firms, who were argued to have an advantage over smaller audit firms due to their "deep pockets" (Janvrin et al., 2008). Mid-sized audit firms have caught up in terms of their use and perceived relevance of IT and even surpassed the Big Four in certain areas, whereas small audit firms are still lagging in their adoption of IT (Lowe et al., 2018). However, the application of ADA to auditing is a rather recent phenomenon that has been perceived as potentially disruptive to the audit profession (Alles, 2015; Eilifsen et al., 2019; Hampton and Stratopoulos, 2016; Moffitt et al., 2018; Salijeni et al., 2019). Hence, ADA represents a "new breed" of technol-

[1] According to Gray et al. (2014), the reasons for the demise of expert systems in auditing are not well explored.

ogy in auditing, which also requires a new set of skills in auditing firms (Dagiliene and Kloviene, 2019; Haddara et al., 2018; Salijeni et al., 2019).

The remainder of this section is structured in the following manner: First, we introduce empirical studies on technology adoption in auditing, along with the theoretical frameworks and contextual factors used. We then review the recent research on ADA adoption in auditing, which is more explorative in nature and less guided by theory. Finally, we touch on the use of IT specialists in auditing, as they are relevant for the adoption of ADA.

2.1. Technology adoption in auditing

The adoption of IT in auditing has been extensively studied. Several empirical studies have been dedicated to determine which factors affect the adoption of audit technology in general (Janvrin et al., 2008; Lowe et al., 2018; Vasarhelyi and Romero, 2014), or the adoption of more specific IT applications such as CAATTs (Curtis and Payne, 2014; Janvrin et al., 2008; Janvrin et al., 2009; Li et al., 2018; Pedrosa et al., 2015; Pedrosa et al., 2020; Rosli et al., 2012; Siew et al., 2020) and GAS (Ahmi and Kent, 2012; Widuri et al., 2016). The studied factors are derived from popular theoretical frameworks, such as the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003), the technology organization environment (TOE) framework (DePietro et al., 1990), and the diffusion of innovations (DoI) theory (Rogers, 2003). The utilization of these frameworks depends on the unit of analysis, since technology adoption can be studied at different organizational levels (Molinillo and Japutra, 2017; Salahshour Rad et al., 2018).

The UTAUT is predominantly used to study technology adoption at an individual level (Curtis and Payne, 2014; Janvrin et al., 2008; Janvrin et al., 2009; Li et al., 2018; Payne and Curtis, 2006; Pedrosa et al., 2015). The factors typically studied in UTAUT-based adoption studies are performance expectancy, effort expectancy, social influence, and facilitating conditions, which are moderated by individual variables such as gender, age, experience, and the voluntariness of use (Venkatesh et al., 2003). However, the theory has been modified and extended to accommodate the specifics of the audit domain to include factors such as budget constraints (Curtis and Payne, 2014; Payne and Curtis, 2006), the adoption preference of superiors and the firm (Payne and Curtis, 2006; Pedrosa et al., 2015; Pedrosa et al., 2020), the effect of regulation and standards (Pedrosa et al., 2015; Pedrosa et al., 2020), or whether support was provided by IT members of the engagement team (Pedrosa et al., 2020).

DoI and TOE have been used to examine technology adoption at the audit firm-level (O'Donnell, 2010; Rosli et al., 2012; Siew et al., 2020; Widuri et al., 2016). In DoI theory, technology (or innovation) adoption is the outcome of an individual's or organization's decision process (Rogers, 2003). The organizational process encompasses five stages, which are divided into two sub-processes: The initiation phase and the implementation phase. The sub-processes are divided by the decision to adopt an innovation. During the initiation phase, the organization recognizes an organizational problem that creates a need for an innovation (*agenda setting*); this leads to the creation of an innovation that addresses this problem (*matching*). The initiation phase leads up to the *decision* to (non-) adopt an innovation. The implementation phase is initiated only if the decision to adopt is made. During this phase, the innovation is modified or reinvented to fit the organization (*redefining or restructuring*). Hereafter, the innovation is put into use throughout the organization, such that the use of the innovation becomes clearer to the members of the organization (*clarifying*). The process concludes with the *routinizing* of the innovation in which it has become so ingrained in the regular activities that the innovation loses its identity (Rogers, 2003). Most studies on technology adoption limit their reference to DoI to the 'perceived innovation characteristics' (e.g. relative advantage, compatibility, complexity), a set of variables which describe the innovation and affect the individual's innovation decision process (Molinillo and Japutra, 2017; O'Donnell, 2010; Rogers, 2003; Salahshour Rad et al., 2018; Siew et al., 2020). These innovation characteristics are often mapped to the "technology" dimension of the TOE framework; TOE and DoI are frequently used in conjunction to study technology adoption at the organizational level (Oliveira and Martins, 2010). The TOE framework is not concerned with the nature of the innovation decision-making itself, but the contextual factors that affect it. It further expands the contextual factors beyond the technology characteristics and includes factors related to the adopting organization itself (e.g. size, available resources, communication processes, technological readiness, top management support), and to its environment (e.g. competition, regulation, third party sponsorship, customer readiness) (DePietro et al., 1990; Molinillo and Japutra, 2017; Oliveira and Martins, 2010; Yoon and George, 2013).

The abovementioned factors used in DoI and TOE have been extended by audit-specific factors, such as the complexity of the audit client's IT (Rosli et al., 2012; Li et al., 2018; Siew et al., 2020), the support of regulators and professional bodies and the encouragement through standards (Li et al., 2018; Siew et al., 2020; Widuri et al., 2016), the commitment of the audit firm's management (Rosli et al., 2012; Li et al., 2018; Siew et al., 2020), the technological competence and resources within the adopting audit firm (Rosli et al., 2012; Li et al., 2018; Siew et al., 2020; Widuri et al., 2016), the existence of IT support staff (Li et al., 2018; Widuri et al., 2016), and the fit between the technology and audit task (Rosli et al., 2012; Widuri et al., 2016).

2.2. Advanced data analytics in auditing

While the usage and, hence, the research on the adoption of general IT, CAATTs, and GAS is already at a very advanced stage, the growing body of research dedicated to the application of ADA to auditing remains rather explorative in nature. Prior research has investigated potential areas of application for ADA, the drivers and inhibitors to adoption, as well as the potential impact on the profession if adopted. Apart from conceptual contributions (Alles, 2015; Alles and Gray, 2016; Appelbaum et al., 2018; Cao et al., 2015; Chiu and Jans, 2019; Huang and Vasarhelyi, 2019; IAASB, 2016; Issa et al., 2016; Jans et al., 2013; Jans et al., 2014; Moffitt et al., 2018; Sun, 2019), there have been several empirical enquiries that have explored the adoption of ADA in auditing of which most either focused on big data analytics or data analytics (Al-Htaybat and von Alberti-Alhtaybat, 2017; Barr-Pulliam et al., 2020; Dagiliene and Kloviene, 2019; Eilifsen et al., 2019; Haddara et al., 2018; Hampton and Stratopoulos, 2016; Manita et al., 2020; Michael and Dixon, 2019; Rose et al., 2017; Salijeni et al., 2019).[2] ADA is considered as a means to increase audit quality as well as efficiency (Dagiliene and Kloviene, 2019; Manita et al., 2020; Salijeni et al., 2019). Increased audit quality is commonly associated with the volumes of data that are analyzed in an audit, moving beyond sampling to the analysis of entire populations or even unstructured data (Manita et al., 2020; Salijeni et al., 2019). Hampton and Stratopoulos (2016) show that the use of ADA increases the confidence of auditors in an audit opinion. Apart from audit quality, the technical ability to access client data remotely in conjunction with standardization efforts provides the possibility of achieving efficiency gains (Salijeni et al., 2019). This enables auditors to focus on more complex and higher valued-added tasks (Manita et al., 2020; Salijeni et al., 2019), thereby ultimately leading to a more relevant audit (Manita et al., 2020). According to the results of Manita et al. (2020) and Salijeni et al. (2019), the integration of ADA is likely to enable audit firms to introduce additional, possibly non-audit, service offers.

From the evidence presented by Eilifsen et al. (2019) and Salijeni et al. (2019), it can be concluded that the current adoption of ADA remains limited, despite the potentials mentioned above. However, the adoption of ADA by audit firms is a complex matter that both affects and is affected by several factors that are related to audit firms, their clients, and the institutional environment surrounding audit firms (Dagiliene and Kloviene, 2019; Eilifsen et al., 2019; Haddara et al., 2018; Salijeni et al., 2019).

According to Dagiliene and Kloviene (2019), the characteristics of audit firms—such as size, structure, and the existence of a data-driven strategy—and the availability of professionals with ADA experience affect the adoption of ADA. With regard to the latter, Salijeni et al. (2019) and Haddara et al. (2018) identify a lack thereof in audit firms, which they consider an inhibitor to ADA adoption. ADA skills can be cultivated through training, which has been shown to increase the use of ADA by auditors (Hampton and Stratopoulos, 2016). In addition, Manita et al. (2020) argue that ADA adoption generally pushes auditors toward developing more technological skills and foster a culture of innovation in audit firms. Apart from the skill set of auditors and ADA professionals, Haddara et al. (2018) identify challenges to ADA adoption that are related to the technological preparedness for ADA in audit firms, such as a lack of hardware infrastructure and potential issues with data control and security as well as issues with data integration and storage. Additional challenges in the adoption of ADA by audit firms are the possibility of encountering high numbers of "false positives," which are data points that are falsely identified as requiring the attention of an auditor, as well as the apprehension of auditors regarding the growing influence of data scientists in the auditing practice (Salijeni et al., 2019).

Since auditing is a client-facing business, the characteristics of audit clients and the auditor–client relationship are also relevant factors for the adoption of ADA. According to Dagiliene and Kloviene (2019), the client's size, business model, industry sector, ownership structure, and level of use of technology affect the use of ADA by auditors. Eilifsen et al. (2019) found that, if used, audit firms would use ADA mostly for clients with integrated IT systems and in newly acquired engagements. Further, such clients would have expectations from auditors regarding their use of ADA, which affects its adoption (Hampton and Stratopoulos, 2016). Simultaneously, audit clients are reportedly reluctant to share their data with audit firms due to concerns regarding the auditor's motives and data security (Salijeni et al., 2019). However, the clients also benefit from ADA adoption, as it increases the transparency of the audit for the clients (Salijeni et al., 2019) and strengthens the role of an audit as a corporate governance tool (Manita et al., 2020). Further, Salijeni et al. (2019) report technology overspill effects, as audit clients observe the benefits of software used by the audit firm and intend to adopt it.

The market for audit services, regulatory policies, and professional standards form the institutional environment in which audit firms operate. This environment also affects the auditor's adoption of ADA (Dagiliene and Kloviene, 2019; Eilifsen et al., 2019; Salijeni et al., 2019). The analysis by Dagiliene and Kloviene (2019) reveals that the sharp competition within the audit market motivates the use of ADA. Salijeni et al. (2019) indicate that ADA is also referred to as a tool employed to comply with regulatory requirements. From the theory constructed by Eilifsen et al. (2019), the authors argue that the limited use of ADA is likely to persist until it is completely accepted by standard-setters (Eilifsen et al., 2019). Moreover, the effect of professional standards on the adoption of ADA has been discussed in recent literature, but their effect on ADA is not yet clear. Salijeni et al. (2019) indicate that there is a lack of guidance regarding the use of ADA in professional standards, which has been perceived both as an opportunity for ADA and an inhibitor. The Data Analytics Working Group of the International Auditing and Assurance Standards Board (IAASB) considered the International Standards for Auditing (ISA) technology-agnostic:

> "[...] ISAs do not prohibit, nor stimulate, the use of data analytics" (IAASB, 2016).

In December 2019, the IAASB issued a revised version of the ISA 315 "Identifying and Assessing the Risks of Material Misstatement," which emphasizes the importance of technology (Brown et al., 2019; IAASB, 2019b). The standard refers to "Automated Tools and Techniques," which auditors can refer to when performing audit procedures (IAASB, 2019b). The def-

[2] A tabular summary of the empirical studies cited here on ADA adoption in the audit domain can be found in B.

inition of this term is intentionally broad, as it includes emerging technologies, such as AI and RPA, in addition to data analytics (IAASB, 2019a). This development manifests the relevance of ADA technologies for the profession. Apart from this, the revision of ISA 315 does not touch on the general audit approach; the audit risk model remains the methodological basis for financial statement audits. Further, the usage of these technologies remains optional for auditors and functions as an addition to traditional audit procedures if utilized. This may slow down the adoption of such technologies in audit firms.

2.3. Use of IT specialists in financial statement audits

As mentioned above, the lack of professionals with ADA skills in audit firms is perceived as an inhibiting factor for the adoption of ADA. However, it is a common practice of audit firms to employ IT specialists (Bauer and Estep, 2014; Bauer et al., 2019; Boritz et al., 2017; Otero, 2015). The professional standards require auditors to refer to domain specialists if they do not possess the required expertise outside of accounting and auditing to obtain sufficiently appropriate audit evidence (IAASB, 2009). In the case of the client's information systems, IT specialists—or IT auditors—fill this skill gap. The required IT expertise and, therefore, the necessity for IT auditors, increases with the complexity of the client's IT environment (Curtis et al., 2009). They are mainly called upon for the testing of IT-related controls as part of the risk assessment, but they are also increasingly involved across different aspects of financial statement audits (Bauer and Estep, 2014; Bauer et al., 2019; Boritz et al., 2017; Otero, 2015). IT auditors are usually required to have a solid understanding of ERP systems, which enables them to better identify risks and select relevant controls in IT processes than financial auditors (Hoitash et al., 2008; Hunton et al., 2004; Tucker, 2001). IT auditors (and specialists in general) are more likely to question client positions (Boritz et al., 2017) and their involvement in financial statement audits is positively associated with the identification of manipulated financial information in IT systems (Otero, 2015). Despite the value they can add to audit engagements, they remain frequently underused in audit engagements (Boritz et al., 2017; Janvrin et al., 2009). The main reasons are cost restrictions, communication challenges between specialists and auditors due to differing backgrounds, and their involvement not being perceived as useful by audit teams (Boritz et al., 2017; Otero, 2015). While the involvement of IT specialists in audit engagements can also be considered as an (non-) adoption case itself, prior research has also examined the effect of the support of IT members on the adoption of audit technology by auditors (Vasarhelyi and Romero, 2014). Vasarhelyi and Romero (2014) found that IT auditors can support the adoption of audit technology by audit teams if they have a background in accounting, thereby enabling them to identify how technology could help the auditors.

In this section, different research streams are reviewed. We identify several research gaps in the literature that we aim to address in this paper. First, the literature on ADA adoption mainly discusses the potential impacts of ADA on the auditing practice along with the factors that affect ADA adoption in the auditing industry. How this adoption happens—that is, the underlying process that leads to a successful adoption—is widely ignored. Further, the research on this topic remains rather fragmented and lacks coherence, which might be attributed to its explorative nature. Therefore, a theoretical framework can help to guide future research. Second, the literature on general technology adoption in auditing is foremost concerned with variance theories, in which one dependent variable or outcome (technology adoption) is affected by several independent variables or factors, thereby implying an invariant relationship between the factors and the outcome (Markus and Robey, 1988). Variance theories are static in nature and treat the underlying adoption decision process as a black box (Langley, 1999; Markus and Robey, 1988). Uncovering this process can help contextualize the studied factors, such that the mechanism by which they affect the adoption can be further understood. Third, there is a missing link between the inclusion of IT specialists in auditing and the apparent lack of ADA professionals, which inhibits ADA adoption.

3. Methods

The goal of our study is to assess how ADA is being adopted in audit firms and which factors affect the adoption process. According to the framework of Gregor (2006), this corresponds to a theory of explanation. Common to theories of explanation are process theories, which is what we aim for in our research. As auditing firms are still at the initial stages of engaging with ADA, there is a lack of quantitative data on this subject matter that can be exploited for research purposes (Alles and Gray, 2016). This calls for explorative qualitative approaches such as interviews and case studies (ibid.). Our approach is to derive a theory using the grounded theory method given by Corbin and Strauss (1990). The grounded theory methodology usually leads to process theories that are high in accuracy (in terms of being true to the data) but rather low in terms of generalization (Langley, 1999). We collected data from interviews with industry experts, as we aim to establish a broader understanding of the entire subject and not just one specific case. The data was analyzed as we collected it, which enabled us to shift our research focus for the upcoming interviews to questions that we encountered while analyzing the data, following the idea of theoretical sampling (Corbin and Strauss, 1990). Further, we followed the recommendations for qualitative interviewing given by Myers and Newman (2007) and attempted to avoid the pitfalls and problems that the authors described.

3.1. Data

Between June 2018 and June 2019, we conducted a total of 15 interviews. Each interviewee was interviewed separately, except for IP15 and IP16, who were interviewed together, as they are from the same organization. We chose semi-structured interviews as the interview method (Myers and Newman, 2007). This enabled us to further pursue interesting cues when they came up in an interview while still providing a structure. We first developed an initial catalogue of questions that we derived from the related literature. As we progressed in our understanding of the phenomenon at hand, we generated new questions and, thus, continually developed the catalogue. Further, we partially adapted the catalogue to the experience or expertise of the interview partner if it was necessary and beneficial for the study. We acquired interview participants through our professional and personal networks as well as through internet research and cold contacting. The interviews were opened by assuring the interview partner of the confidentiality of the collected material and the non-disclosure of personal information and organizational affiliation; in addition, approval was obtained for recording the interview. If the approval was granted (in 11 cases), the interview was recorded and subsequently transcribed. If the approval was not granted or the circumstances of the interview did not allow for audio recording, notes were taken (four cases). Ten interviews were conducted via phone or Skype and the remainder were conducted in person.

Table 1 presents the interview participants along with their role(s) in their respective organization, their technical background, their professional focus within their roles, and their country of residence. We aimed at acquiring interviewees from different educational or technical backgrounds, hierarchical levels, and organizations of different sizes. This enabled us to triangulate evidence and explore the phenomenon from different perspectives, as suggested by Myers and Newman (2007).

Germany (G) is heavily represented in our sample, with fourteen of our interview partners working in Germany, one in the Unites States of America (U.S.), and one in Switzerland (CH). Germany is an interesting environment to study the adoption of ADA. Statutory external audits have a long tradition in Germany and have been encoded in commercial law since 1931 (Köhler et al., 2007). In addition to the information function for stakeholders and capital markets, external audits serve an important monitoring and control function in the German two-tier corporate governance system: The supervisory board, not the executive board, appoints the auditor and is the addressee of the long form audit report, which is issued in addition to the regular audit report (ibid.). Apart from this local characteristic, the German audit market and its institutional environment are highly internationalized. As a EU member state, the directives and regulations of the European Commission directly apply to Germany. These are aimed at harmonizing the European regulation to the post-Sarbanes–Oxley Act regulation in the U.S. through strengthening auditor independence and introducing public oversight in addition to the profession's self-administration (EU, 2006; EU, 2014; EU, 2014; Humphrey et al., 2011). They also made the adoption of the ISA mandatory for all statutory audits in the EU (Fédération des Experts Comptables Européens, 2015), including the disclosure of key audit matters (IAASB, 2016). In Germany, the ISA are adapted into local standards that take the local legislation into account (Fédération des Experts Comptables Européens, 2015; Köhler et al., 2007), which is conducted by the professional body "Institut der Wirtschaftspruefer" (IDW). The IDW and the chamber of auditors (Wirtschaftsprueferkammer, WPK), which is the other professional body, are members in the overarching professional network Accountancy Europe, just as the public auditor oversight board is a member of the International Forum of Independent Audit Regulators.

Most of the interviewees occupy leadership positions. The most frequently represented technical backgrounds are business (accounting, auditing, and tax) and information technology (IT). Although auditors are most affected by it, the adoption of ADA in auditing is a highly interdisciplinary phenomenon, which involves individuals with different professional backgrounds. Therefore, we followed the advice given by Alles and Gray (2016) and did not constrain ourselves to external auditors as interview partners but also regarded interview partners from other types of organizations, such as professional bodies, regulatory bodies, and software providers. With regard to audit firms, we interviewed individuals from the Big Four as well as mid-tier audit firms. Similar to previous research on the adoption of ADA, this study began with an explorative intention; incorporating a professionally diverse, multidisciplinary sample of interviewees enabled us to consider the phenomenon from different perspectives. This also enabled us to explore the aforementioned availability of ADA professionals in audit firms and the related required skill sets.

3.2. Analysis

In order to construct a coherent theory from the data collected through the interviews, the grounded theory methodology, as described by Corbin and Strauss (1990), was applied. The analysis was accompanied by a phased literature review (Thornberg and Dunne, 2019; Urquhart, 2012). After a first *uncommitted* review, we began with an open coding approach that gave room to consider all possible connections in the data, without a specific kind of theory in mind. During this process, 377 codes were assigned to 1164 text passages. In the fashion of a *delayed* or *integrative* literature review in grounded theory (Urquhart, 2012), which is informed by the data, we sought theoretical frameworks to which we could relate our emergent theory. Relating the emergent theory to prior research and extent formal theories can support the researcher in developing concepts and improves the analytic generalizability of the emergent theory (ibid.).

The results presented in this paper were obtained through multiple data-theory iterations. We first aimed for a causal theory that would explain the differences in technology adoption in audit firms, with the technologies being the unit of analysis. In this theory, the actual innovation process remained a black box, whose output is a binary variable describing a technology adoption or a rejection (non-adoption) of the technology. We found our theory to be relatable to the TOE framework by DePietro et al. (1990), as it addresses the adoption of technologies on an enterprise level while explicitly considering contextual factors within the adopting company as well as its environment. To this end, we categorized our concepts along the axis of the TOE framework. During this step, we concluded that the organizational concepts relate to various organizational units and would affect the technology adoption at different points in time. Therefore, the previous objective was revisited

Table 1
Interview Participants.

Participant #	Role	Background	Organization	Focus	Country
IP1	Data Scientist	STEM	Big Four	ADA	G
IP2	Data Scientist	Business, IT	Software Provider	ADA, Internal Audit	G
IP3	Partner/Director	Business	Big Four	Audit Digital Innovation	G
IP4	Partner/Director	Business	Big Four	Audit Digital Innovation	G
IP5	Partner/Director	Business	Mid-tier Audit Firm	Audit	U.S.
IP6	Head of Department	Business	Mid-tier International Company	Internal Audit	G
IP7	Partner/Director	Business, IT	Mid-tier Audit Firm	IT Audit, Audit Digital Innovation	G
IP8	Partner/Director	Business, IT	Big Four	IT Audit, Audit Digital Innovation	G
IP9	Data Scientist	IT	Mid-tier Audit Firm	IT Audit, ADA	G
IP10	Subject Matter Expert	Business	Professional Body	Audit, Audit Digital Innovation	G
IP11	Manager	IT	Big Four	Robotic Process Automation, Audit Digital Innovation	G
IP12	Subject Matter Expert	Business	Professional Body	ADA, Audit Digital Innovation	G
IP13	Audit Associate	Business	Big Four	Audit	G
IP14	Partner/Director	IT	Big Four	PM, Audit Digital Innovation	CH
IP15	Subject Matter Expert	IT	Auditor Oversight Board	(IT-) Audit	G
IP16	Subject Matter Expert	Business	Auditor Oversight Board	Audit	G

and we decided that the adoption process must be made explicit along with various organizational units. In the TOE framework, the contextual factors affect the so-called "technological innovation decision making" (DePietro et al., 1990). For the further analysis, we considered this "decision-making" to be a process and referred to the innovation decision process in organizations described by Rogers (2003). Drawing upon the DoI theory, we developed concepts that relate to the ADA adoption process—with the audit firm becoming the unit of analysis—as well as concepts relating to contextual factors affecting this process. As the concepts were developed, codes that did not fit the theory were excluded (selective coding). Out of the 377 initial codes, 157 codes were related to the phenomenon of ADA adoption and, thus, selected for further analysis. These codes were merged thematically into 61 codes, which in turn were abstracted into 22 first-order concepts and 8 second-order concepts. The first- and second-order concepts form the building blocks of the theory. Fig. 1 depicts the data model of our results. The arrows indicate the direction of abstraction, thereby indicating which first- and second-order concepts were derived from their respective subclass. Descriptions of the concepts are provided in the results section.

4. Results

From the interviews, we found that the phenomenon of audit digitization has two dimensions. One dimension is the digitization of audit tasks that relate to the management of audits, such as the organization and delegation of work packages, communication with the client, or the documentation of the audit. From the interviews, we concluded that the digitization of the management of audits is already at an advanced stage. The second dimension is the digitization of the "fieldwork"—that is, the assessment of risks—and the obtaining of audit evidence used to support the audit opinion. The digitization of the latter has a greater impact on the profession and continues to have vast potential. However, our results further indicate that the digitization of the audit fieldwork is progressing rather slowly, and despite the potential of ADA that is being discussed in the literature, its adoption is rather limited (see A.1). From the ADA technologies that are expected to have an influence on auditing practice, we found that mainly RPA and PM are being adopted on a larger scale. This is foremost driven by the Big Four audit firms and their close followers, which invest in the in–house development of solutions. The theory we present in this section explains.

1. how audit firms adopt ADA,
2. how this adoption process is affected by contextual factors relating to the audit firms themselves, their environment, and the technology to be adopted,
3. how this affects the outcome of the adoption process.

Fig. 2 depicts a model of the theory. Central to the theory is the adoption process, which comprises several activities. In the model, the process is described within the box and the rounded squares represent the activities. These activities are performed by various organizational units: audit teams, innovation teams, and management. This is represented through swim

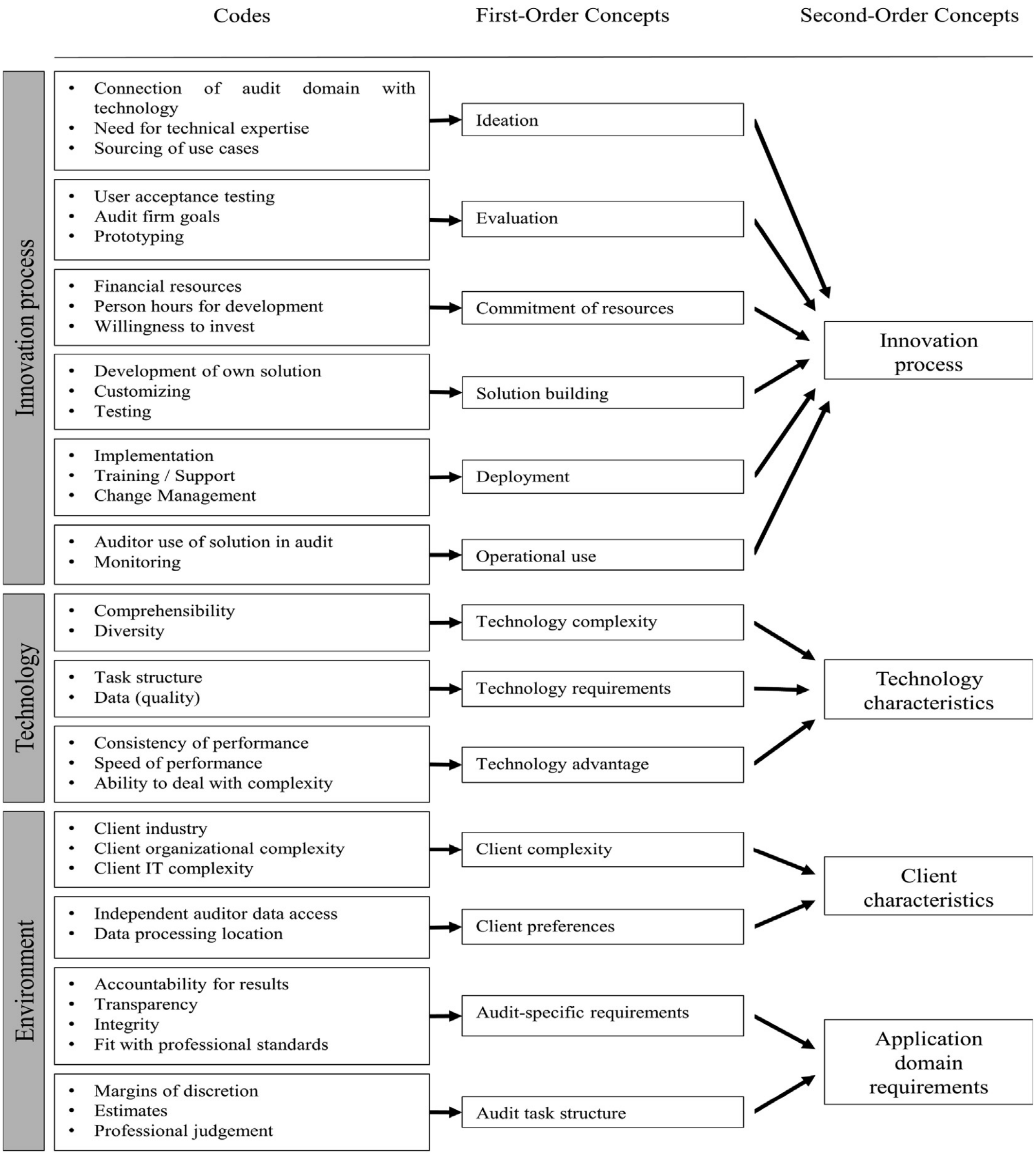

Fig. 1. Data Model.

lanes in the model. Activities breaking through swim lanes indicate that more than one organizational unit is involved in this activity. The **innovation teams** within the audit firm are tasked with the conceptualization and development of ADA-backed solutions and typically consist of data and computer scientists as well as technologically inclined auditors or consultants. The **management** comprises the audit firm's partners and directors involved in the strategic decision-making of the firm. They decide on the allocation of resources for ADA adoption. The **audit teams** are the users of the provided solutions. They employ ADA-backed solutions or resort to using traditional non-ADA audit procedures, depending on whether they see the solutions fit for implementation, given the circumstances of the audit engagements. The activities in the process are performed in a sequential order; however, there can be feedback from one activity to the previous one. In the model, the sequential order is described though arrows—the dashed arrows denote feedback (FB) loops among activities. The activities within the process are affected by contextual factors. These are represented by square boxes outside of the process and are connected via arrows to the activities and organizational units, which represent the relationship (R) through which the factors affect the process.

The findings indicate that there exists a gap between the technological and audit domains in terms of knowledge and professional mentality. In successful ADA adoptions, this gap is closed through cooperation between the audit and innovation teams. This gap is primarily relevant in the ideation activity and the diffusion phase of the process. In the ideation activity,

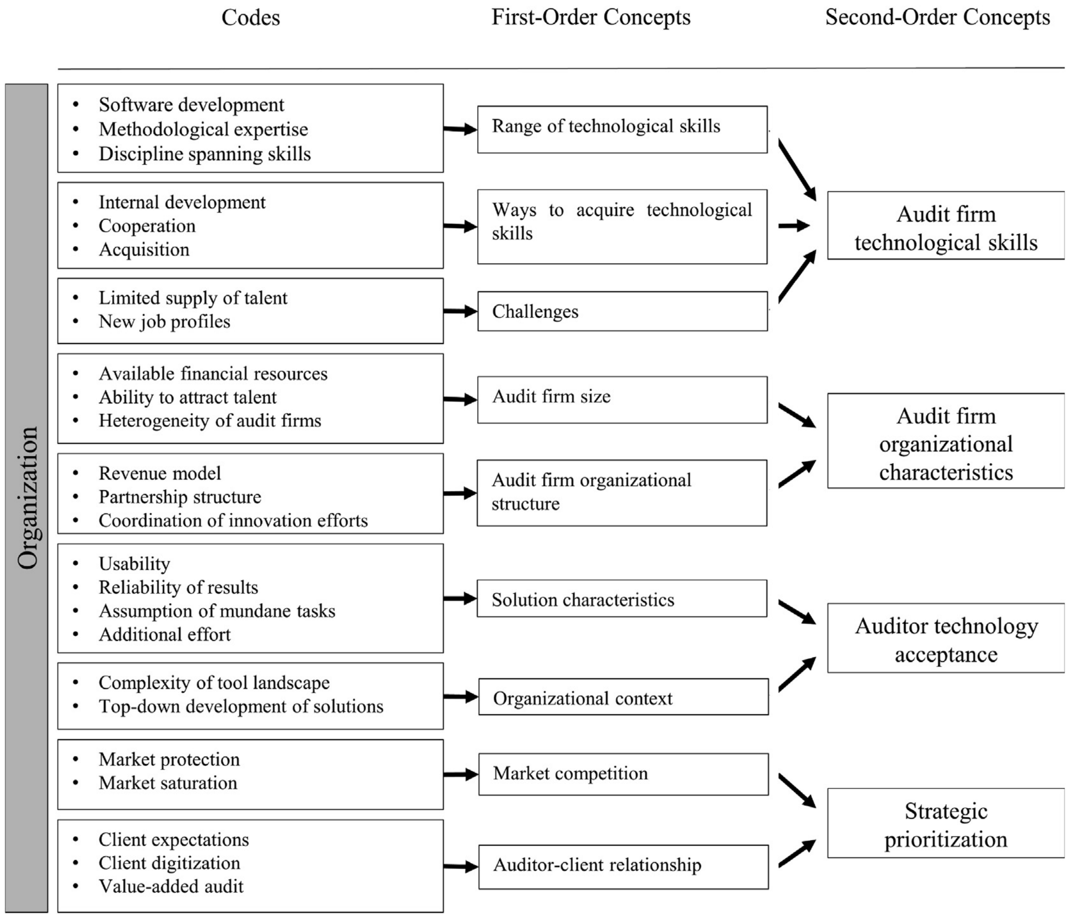

Fig. 1 (*continued*)

bridging the knowledge gap between the audit and technological domain is required to identify use-cases for ADA. The identification of use-cases requires knowledge of both the audit domain and the technologies, as well as discipline-spanning skills to connect them. In the diffusion phase, the solution is handed over to the auditors. Here, it is crucial for the solution to be accepted by the auditors so it can diffuse into operational use. The gap in the operational use activity relates to the different professional mentalities—auditors and data/computer scientists differ in terms of their way of working and approaching challenges. Innovation teams can positively affect the auditor's acceptance of a solution by adapting its design to the auditor's preferences. On the other hand, auditors take interest in ADA and its application to the audit domain. According to our interviewees, audit firms provide auditors the freedom to develop themselves to take on more technology-oriented roles. These auditors join innovation teams or help in the deployment of solutions as trainers and lead users. In the case of RPA, audit teams also actively approach innovation teams with proposals for use-cases and joint ideation workshops. In this manner, the audit teams support the ideation of solutions through audit knowledge. However, RPA exhibits a lower degree of complexity and, therefore, is more comprehensible for users of the technology. AI would be a counter-example in terms of technology complexity, which is an aspect for why audit firms are struggling to find use-cases. Therefore, from the fact that auditors can be involved in ideation activities for RPA adoption, we hypothesize that there is a relationship between an auditor's technology capability and his/her contribution to the ideation of ADA solutions. This implies that increasing the technological capability across audit teams would not only benefit audit firms through more potential lead users and trainers but also in the ideation of ADA solutions.

4.1. Process

The adoption process consists of six activities: Ideation, evaluation, commitment of resources, solution building, deployment, and operational use. Ideation, evaluation, and solution-building constitute the research and development process phase through which a solution is developed from a use-case. A broader adoption of the technology is only achieved if the solution is diffused into operational use. In order to ensure this, the solution must be made available to the users and

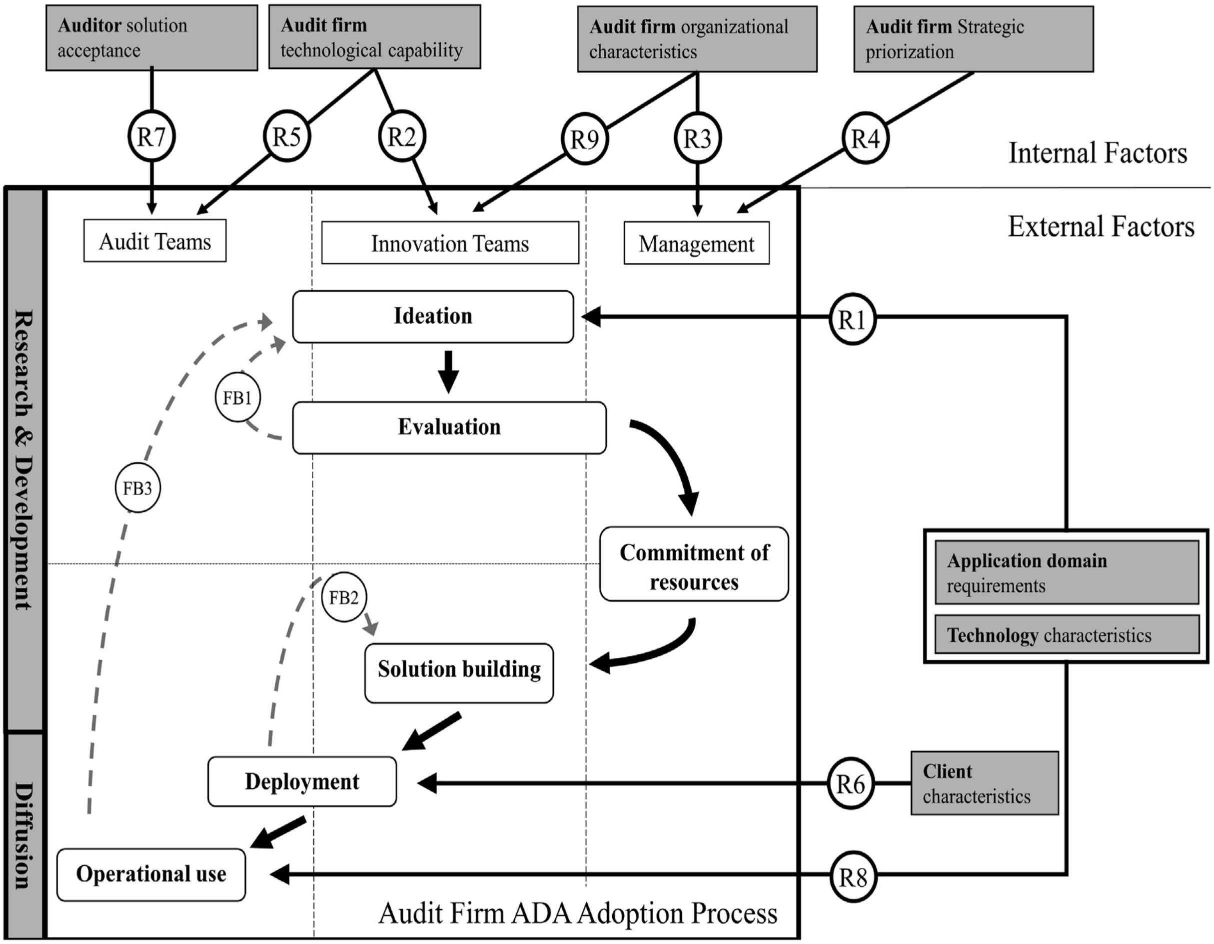

Fig. 2. Process Theory of ADA Adoption in Audit Firms.

the users must be enabled to employ it, which is achieved in the deployment activity. Within the ADA adoption process, the activity of the commitment of resources represents a phase gate. The solution-building and subsequent activities only take place if resources are allocated for them.

4.1.1. Ideation

Ideation is the first activity in the technology adoption process. In this step, a possible use-case for a technology is identified. Use-cases are application scenarios for a technology in which the technology is mapped to the application domain (how it is being used and to which end). Ideation is a non-trivial task and is still considered a challenge for audit firms (see A.2). The ideation activity is primarily performed by the innovation teams and can be assisted by the audit teams. It is affected by the technology characteristics (foremost complexity and requirements) and the application domain requirements (R1): The technology advantage motivates the use of a method or technology. A highly complex technology increases the technological capability—particularly the methodological knowledge—required by the audit firm's innovation team to identify use-cases, as they need to be able to navigate the possibilities provided by ADA. The more complex a technology or method is, the more effort must also be put into making it understandable for different stakeholder groups, such as business users and regulators.

The requirements of the application domain and the technological requirements determine the technical and technological frame for the ideation step (R1). The use-case must comply with professional standards and be relatable to business users and regulatory bodies. However, as mentioned earlier, professional standards can also motivate the use of ADA. Simultaneously, the following prerequisites of a technology or method to be used must be met: The structure of a task can be improved through internal standardization and homogenization by the audit firm, but the data quality and data volumes available are, in most cases, beyond the influence of the audit firm and depend on the use-case. Since it is primarily the innovation team that is concerned with the ideation phase, their technological capability is crucial, both in terms of methodological knowledge and discipline spanning knowledge (R2). The greater the methodological knowledge within the team, the better it is able to deal with complex technologies or methods. Further, discipline-spanning skills help to bridge the knowledge gap between auditing and technology, which—according to our interviewees—is crucial to close the aforementioned gap (see A.3).

4.1.2. Evaluation

Upon identifying the use-case, it is evaluated against the goals of the audit firm; efficiency, effectiveness and relevance. Technologies and methods from the ADA spectrum present promising possibilities to address these goals in general. Efficiency can be realized through automation as well as reducing or omitting substantive procedures based on ADA. Audit assurance can be increased through expanding the scope of analyzed data and through increased transparency, e.g. PM enabling the auditor to quantify the number of process instances being conformant to a certain standard process or the exact number of process instances that violate control tests. Further, additional information for the client can be generated as a by-product from the (better) analysis of client data. They help auditors to deliver a value-added audit, which contributes to the audit's relevance.

A prototype of the latter solution may be built, which can be used for evaluation. If the prototype is not sufficiently convincing in the evaluation, another ideation cycle can be triggered (FB1). This evaluation step is mostly performed by the innovation teams, but can also involve auditors (for user acceptance testing) and management in order to ensure alignment with goals. The stronger (in the sense of his contribution to the audit firm's goals) a use-case is, the higher is the likelihood that resources are provided for the development of a solution, which is the next step in the technology-adoption process.

4.1.3. Commitment of resources

The development of a solution from a technology or method requires both financial and human resources. Financial resources are required for hardware, software, and employee training, while human resources are required for development and further actions. If the audit firm management is not willing to invest in these resources, there will be no development or only minimal development. Therefore, this activity represents a phase gate in the adoption process. Committed resources can be existing resources as well as resources that must be acquired first, depending on the pre-existing technological capabilities. Further, the commitment of resources involves a make-or-buy decision. In an inter- or intra-organizational setting, where solutions are created by one organizational unit to be employed by another (see the solution-building activity), the employing organizational unit can decide to assign resources to the acquisition and/or customization of the solution. This commitment of resources is affected by the size of the audit firm, both in terms of financial resources and the ability to attract talent (see A.4).

Bigger firms have more financial resources available that can be allocated for ADA adoption efforts as compared to smaller firms (R3). Further, larger auditing firms have a greater ability to attract talent to improve their technological capabilities. The organizational structure of an audit firm determines the frame for the process step. Both the revenue model as well as the partnership structure affect the management's willingness to invest. The strategic prioritization of technology adoption in the audit firm affects the management's willingness to invest (R4). The strategic prioritization correlates with the size of the audit firm, as larger audit firms usually deal with larger and more digitized clients that have a different set of expectations as compared to smaller audit firms. The same applies to the competitive situation, as the Big Four and Next Ten, in particular, are currently facing a highly competitive market situation.

4.1.4. Solution-building

During the solution-building process, the use-case or prototype is turned into a solution. In this context, the term solution-building refers to both the in–house development of a solution or the customization of an existing solution, depending on the make-or-buy decision taken in the commitment of resources activity. Developing a solution requires technology capabilities that differ from the capabilities required to identify and evaluate use-cases (R2): It requires capabilities in the areas of software engineering, information systems (e.g. ERP systems), and business processes. Further, the activity is also affected by the organizational structure of the audit firm (R9): Audit firms adopt different approaches to coordinating their innovation efforts. Solution-building takes place in both centralized and decentralized settings. In a centralized setting, one organization (e.g. software company) or organizational unit (e.g. an audit firm's central innovation unit or service center) develops solutions and deploys them for other organizational units (e.g. an audit firms' national subsidiaries). In a decentralized setting, the development takes place in multiple organizational units. In a combination of both, the software can be deployed by one organizational unit and then be customized by another organizational unit to fit its needs.

4.1.5. Deployment

When a version of the solution has been developed, it can be deployed. During deployment, the solution is tested, implemented, and pushed into practice. If it becomes evident during testing that the solution still requires refinement, another development iteration can take place (FB2). Pushing the solution into operational use is challenging, as this may require change management depending on the nature of the solution. For example, in the case of PM, it was described that this new technique changed the manner in which an auditor approaches the analysis of business processes by replacing the walkthrough interview with data analysis.

The deployment activity benefits from the technological capabilities of audit teams (R5), as technology-savvy auditors can be involved in the deployment process as lead users and/or trainers and support other auditors when employing the solution. The deployment is further affected by client characteristics (R6). When implementing the solution, the complexity of the client in terms of the different information systems and data models must be considered if client data is to be accessed by the solution. Further, the greater the organizational complexity of the client company, the more scalable the solution must be in order to be applied across the client company—for example, if the client has affiliates across different branches of the industry.

4.1.6. Operational use

The operational use marks the last step in the technology adoption process. After the solution has been tested and is approved for release, auditors can go on to use it. The solution is either handed off by the innovation teams to regular IT departments for monitoring, or further developments (e.g. additional features) are initiated by the innovation team. In the latter case, the adoption process is reiterated. As an audit is seldom a production-like process, the audit teams must be able to tailor their approach to the audit around the client. For this reason, audit firms do not coerce auditors into using the provided solution or do so only to a limited extent. Therefore, the solution must be adopted by the individual auditor; hence, the auditor's solution acceptance affects the adoption and diffusion (R7). The solution acceptance correlates with the characteristics of the underlying technology (complexity and advantage) and the application domain characteristics (R8). The advantage of a technology motivates the operational use of a solution, particularly with regard to the assumption of mundane tasks. The complexity of the technology can discourage auditors from employing a solution if it is not absorbed by the usability of the solution. The application domain requirements may motivate utilization (e.g. ISA 240 and Journal Entry Testing) but can also have a negative effect, as it may require additional documentation to be prepared by the auditor. From the interviews, we learned that in the case of RPA, auditors likely directly propose the tasks for automation. Mimicking human interactions with software, RPA is rather comprehensible for the business user. Therefore, with a complex technology that is absorbable by the auditors given their technological capabilities (R5), it becomes possible to source use-cases for the technology directly from them.

4.2. Contextual factors

The process presented above is affected by several contextual factors that are related to the audit firms (internal factors) and their environment (external factors). The internal factors vary among audit firms, but also characterize how audit firms are different from companies in other industries. The strategic prioritization of technology adoption describes how much importance a firm assigns to its digitization efforts. Central to the strategic prioritization is the relationship between the audit firm and its client as well as the competition amongst audit firms. Audit firms pursue digitization to improve the effectiveness and efficiency of financial statement audits and also seek to maintain and improve their relevance. The latter is related to the audit firm's ability to conduct audits and deliver value-added audits to their clients. In the innovation process, these aspects form the basis for evaluation and influence the commitment of resources. The organizational characteristics represent the effects that the firm's size and organizational structure have on the process. Smaller audit firms usually have fewer resources at their disposal and face more challenges in attracting talent with the skills required to adopt ADA. In terms of talent, the audit firm's technological capability is indicative of the technological skills across the organizational units within the audit firm. They enable the staff to conceptualize, develop or customize, and evaluate ADA-based solutions. The end users of any ADA-based solution are the audit teams. The extent to which the individuals in the audit teams are inclined to use a solution provided to them is characterized by the level of technology acceptance among auditors. Their acceptance is influenced by the characteristics of the solutions as well as the organizational context of the solution deployment. A few of the internal factors—for example, the technological capabilities, strategic prioritization, and organizational structure—can be influenced by the audit firm. The external factors lie beyond the influence of the audit firm and relate to the ADA technology, the specifics of the audit domain, and the characteristics of audit clients. Although ADA technologies form a cluster, they still have different characteristics and requirements, which primarily affects the ideation and operational use-activities that are part of the adoption process (R1, R8). The counterpart of these activities are the requirements of the audit domain; the audit task structure determines how applicable ADA is to a specific audit task in the first place, and the audit-specific requirements define the conditions that are to be met for ADA that must be applied in the audit domain. Audit clients exhibit varying degrees of complexity and have differing preferences for data access and processing by auditors. These characteristics affect the deployment activity that is part of the adoption process (R6). Details on the contextual factors are provided in Table 2.

4.3. Effects of the contextual factors on the adoption process

In order to illustrate the effects of the contextual factors on the adoption process, the process is instantiated in this section through various configurations. The configurations comprise different sets of manifestations of contextual factors and the resulting manifestations of the process activities. They were derived from the different manifestations of the respective contextual factors along with the different process outcomes we encountered in the data. Therefore, while the configurations do not represent case studies, they are rooted in the data. We illustrate the respective effects of the technology and organizational characteristics on the process, as they represent the most significant adoption gaps encountered in the interviews. One adoption gap is between ADA technologies; RPA and PM are witnessing wider adoption, whereas ML and DL are not. The

Table 2
Contextual factors affecting the ADA adoption process.

Contextual Factor	Relation-ship(s)	Affected Process Activity	Factor Dimensions	Description
Technology Characteristics	R1, R8	Ideation, Operational Use	Advantage	The advantage of technology over human cognitive abilities and/or traditional audit procedures—such as speed and consistency of performance, ability to deal with complexity, or ability to process large amounts of data.
			Complexity	ADA technologies exhibit varying degrees of complexity in terms of comprehensibility and versatility. Versatility is the spectrum of possible uses and comprehensibility of the amount of technological knowledge required to understand and employ the technology.
			Requirements	The conditions that must be met to employ the technology: Foremost data quality, availability of (labeled) data, and task structure.
Client Characteristics	R6	Deployment	Complexity	The complexity of the audit client's organization, accounting system, information systems and their underlying data models, which differ across audit clients (see A.5 and A.6).
			Preferences	Audit clients have differing preferences regarding independent data access of auditors and the location of data processing, mostly due to concerns of data ownership and security.
Application Domain Requirements	R1, R8	Ideation, Operational Use	Audit-specific requirements	The professional standards prescribe the general audit appraoch, which was considered as possibly limiting the possibilities of ADA use (see A.7).This includes the audit risk model, which is encoded in the ISA. As auditors are legally accountable for the issued audit opinion, a high reliability of ADA solutions used to collect audit evidence must be ensured (see A.8). Further, the solutions must be transparent to regulators (see A.9).
			Audit task structure	From our interviewees, we learned that unstructured tasks that involve the auditor's professional judgment are considered more difficult to automate than more structured tasks (see A.10). RPA is usually used to automate highly structured tasks, whereas ML can deal with more complex tasks.
Audit Firm Technological Capability	R2, R5	Ideation, Evaluation, Solution building, Deployment, Operational Use	Range of Technological Skills	A range of technological skills is required to develop ADA solutions related to methods, software engineering, knowledge of business processes, and information systems. Further, a few interviewees emphasized the importance of discipline spanning skills to bridge the knowledge gap between auditing and computer or data science (see A.11).
			Ways to Acquire Technological Capabilities	Audit firms resort to different ways of acquiring technologcal capabilities—internal development, hiring, and cooperation with research facilities and specialized companies.
			Challenges	The acquisition of talent is associated with several challenges, such as the increasing dependence of audit firms on technological experts, the "war for talents" (IP15) along with a limited ability of smaller audit firms to attract such talent, as well as the new hiring practices and new career paths that are required to attract this kind of talent.
Audit Firm Organizational Characteristics	R3, R9	Ideation, Evaluation, Commitment of Resources, Deployment	Size	Audit firms are rather heterogeneous in size. The size of the audit firm affects the firm's available resources (both financial and human) as well as its ability to attract talent. Smaller audit firms usually have fewer resources available to allocate for ADA adoption and they struggle with attracting talented indivduals with a technological background.
			Organizational Structure	In most cases, audit firms follow the partnership model through which shareholders and management are unified; the firm's cashflow affects the partner's earnings, which, in turn, affects the amount of resources devoted to ADA adoption. The revenue model of most audit firms, person hours × fee, does not inlcude development costs for ADA solutions and entails opportunity costs for employees who do not generate billable hours. While these aspects are common among most audit firms, each of them differs in terms of how they coordinate their innovation efforts. Moreover, the innovation teams are embedded differently in the organization—for example, audit-specific or cross-service and national or international.
Strategic Prioritization of Technology	R4	Commitment of Resources	Market for Audit Services	Interviewees described the audit market as fiercely competitive and simultaneously protected against outsiders. The protection is established through professional titles and the knowledge

(*continued on next page*)

Table 2 (*continued*)

Contextual Factor	Relation-ship(s)	Affected Process Activity	Factor Dimensions	Description
Adoption				capital accumulated in audit firms. This made innovation less of a necessity in the past, but competition has lead audit firms to seek efficiency gains and provide better services.
			Auditor/Client Relationship	In addition to effectiveness and efficiency, auditors expect ADA to uphold their standing as experts in all financial matters, as clients increasingly digitize their financial operations. Further, clients have varying expectations from the auditor's use of innovative solutions, depending on how much they are looking to leverage the audit for themselves. They leverage the audit by obtaining additional information that is yielded as a by-product of the audit (see A.12). The ability to provide such a value-added audit can lead to advantages in the marketplace (see A.13).
Auditor Solution Acceptance	R7	Operational Use	Solution Characteristics	Characteristics of ADA solutions relevant for use by auditors are their usability, reliability of their results, the assumption of mundane tasks, and potential additional effort caused by their use from training and/or documentation. Creating usability has been associated by interviewees with bridging the gap between the mindsets of the innovation teams and the auditor (see A.14).
			Organizational Context	A few interviewees stated or implied a resistance from audit teams with regard to solutions that they felt were developed in a "top-down" manner by innovation teams, thereby indicating a disconnect between innovation teams and auditors. Another aspect here is the complexity of the tool landscape available to auditors—audit teams lose track of which tool serves which purpose and feel overwhelmed.

other adoption gap is among audit firms: From our data, we conclude that the Big Four and their close peers are leading in the adoption of ADA, whereas smaller firms are lagging behind.

4.3.1. The effect of technology characteristics on ADA adoption

Table 3 presents configurations that indicate the effect of technology characteristics on the adoption process. The different characteristics of RPA, PM, ML, and DL are examined. The technologies exhibit varying degrees of complexity and have different advantages and different requirements. RPA exhibits a low complexity compared to the other technologies presented in the table, which makes the technology easy to comprehend. This, in turn, enables the sourcing of use-cases from audit teams, even if they posses a lower -technological capability. The foremost use of RPA is to automate existing audit procedures, thereby making it independent from the clients' preferences on data access and processing. The technology is also focused on efficiency aspects, through which the evaluation and, hence, the decision to commit resources becomes rather straightforward. However, RPA depends heavily on the structure of a task or procedure to be automated. This requires a high level of standardization and homogenization of tasks and processes as well as makes it important for auditors to carefully prepare the inputs for RPA solutions. More complex tasks are out of reach for RPA if not combined with machine learning and, thus, becoming more intelligent.

Relative to RPA, PM exhibits greater complexity. This increase in complexity shifts the responsibility for ideation more towards the innovation team. A greater complexity also leads to more efforts during the deployment event, as solutions based on more complex ADA technologies require guidance in their operational use. Although RPA requires only minimal training, the use of PM and more complex technologies requires training and possibly the employment of new workflows and processes. More technologically inclined audit team members can function as lead users, trainers, and multipliers that support the deployment of the solution. On the other hand, innovation teams need to design the solutions in such a manner that maximizes acceptance by audit teams. PM relies heavily on the access of the client's transactional data. This implies that the solution must be able to deal with different IT and accounting systems as well as accommodate different database models. ML and DL are currently witnessing less broad applications in practice. Audit firms are reportedly struggling with the identification of use-cases for ML and DL in the first place (A.2), thereby hindering adoption right at the beginning of the process. There appears to be a mismatch between the audit domain and technology, which is yet to be addressed. This could be attributed to lacking technology capabilities in the audit firms, given the complexity of the technologies (also in terms of disciplinary-spanning skills) or difficulties in identifying use-cases that comply with the requirements of both the technology and audit domains.

Table 3
Effects of technology characteristics on ADA adoption.

Technology characteristics	RPA	PM	ML	DL
Advantage	Speed, Consistency	Ability to process large amounts of data, quantification of previously qualitative information	Ability to deal with complexity, automation of less structured tasks possible	Ability to deal with complexity, tasks that require human cognitive skills feasible—for example, processing of unstructured data
Complexity	Low	Mid	Mid-high	High
Requirements	Task structure	Data, Data quality	Data, Data quality	Large data volumes
Effects on adoption process				
Ideation	Use-cases can be sourced from audit teams	Use-cases have to be designed top-down and be a good fit between audit requirements and technology	Use-cases have to be designed top-down, yet can be problematic as the knowledge gap between auditing and technology must be bridged	Use-cases have to be designed top-down and are yet problematic as the knowledge gap between auditing and technology needs to be bridged
Commitment of resources	Efficiency aspect clear	Efficiency and effectiveness aspect clear	Efficiency and effectiveness to be evaluated	Efficiency and effectiveness to be evaluated
Deployment	Can be easily deployed; no dependence on client	Dependency on client data; solution must be able to deal with different ERP systems and data structures; Change management required	Dependency on client data depends on use-case, change management and training required	Dependence on client data depends on use-case, availability of large data amounts depending on use-case, change management and training required
Operational use	Minimal to no training required	Guidance for use required	Guidance for use required	Guidance for use required
Successful adoption	**Yes**	**Yes**	**Not on a broader scale**	**Not on a broader scale**

4.3.2. The effect of the organizational characteristics of the audit firm

This section explores how the organizational characteristics of the audit firm in conjunction with its technological capability affects the adoption process. The related configurations are presented in Table 4; as above, they are based on the current expression of the respective contextual factors. The table juxtaposes instances of ADA adoption of any given ADA technology in a small audit firm and a Big Four firm. In terms of organizational characteristics, the main distinction here is the size of the audit firm, which in turn affects the available resources within the firm and its ability to attract talent with technological capabilities. Due to its limited technological capabilities, the small audit firm will not be able to identify use-cases for ADA on its own and must resort to solutions provided by third-party developers. The adoption process here begins with the commitment of resources. Given that the audit firm identifies a strategic need for a third party solution, they may choose to license or buy. If the level of technological capability is sufficient, the audit firm may customize the solution to the needs of their audit teams. Further, depending on the complexity of the solution's underlying ADA technology, its use may require training. In the case of a small audit firm, training must be sourced externally, thereby adding to its dependency on third parties for ADA adoption. A Big Four firm has more resources at its disposal and better channels to attract the necessary talent. The resulting technological capability prevalent in the firm enables it to develop own-solutions as well as establish internal training. The bigger audit firm also has the possibility of coordinating their research and development efforts across country units and/or service lines, thereby enabling international deployment of solutions. Further, the in–house development of solutions in the Big Four firm enables a close feedback loop between users (audit teams) and developers of a solution (FB3) and, hence, the sourcing of use-cases from audit teams.

The configurations presented in the above sections reveal how the contextual factors that are internal and external to audit firms affect the adoption process. The course of individual process instances and even its outcome depends upon the manifestation of contextual factors. While all process activities are affected by internal contextual factors, the external factors affect only the ideation, deployment, and operational use activities. The technology characteristics and application domain requirements affect both ideation and operational use. In both activities, the audit firm is faced with the task of finding a fit between the two aspects; first in terms of identifying a use-case and subsequently in the diffusion of the solution. The latter can be supported during the deployment activity and through cooperation between audit and innovation teams throughout the process.

Table 4
Effects of organizational characteristics on ADA adoption.

Audit firm characteristics	Small firm	Big Four firm
Size	Small, mid-sized	Large
Coordination of innovation	Centralized	International, cross service line
Technological capability	Low	High
Effects on adoption process		
Ideation	None possible	Identification of use-cases from both innovation and audit teams
Make or buy decision (Commitment of resources)	Buy	Make
Solution building	Customizing	Own development
Deployment	Deployed to local teams, external training required	Deployed to international teams, internal training possible
Adopted ADA technologies	**None**	**RPA, PM**

5. Discussion

The aim of this research was to reveal the process by which audit firms adopt ADA technologies and the contextual factors relevant to the audit domain that affect the process.

Our research adopts a different perspective on ADA adoption in auditing than that adopted by previous research. Instead of discussing the adoption of ADA from a standpoint where ADA is considered a single technology, our results focus on individual solutions based on ADA. These solutions are the product of a process that can be divided into a research and development process phase and a diffusion process phase. Both phases are affected by contextual factors. The only exception are the client characteristics, which only affect the diffusion phase. In the presented theory, we acknowledge the effect of the contextual factors on the adoption process but refrain from assuming these concepts to be drivers for or inhibitors to technology adoption. The relationship between these contextual factors and the adoption process is not yet fully understood, and our research approach is oriented toward the generation of hypotheses rather than quantitative reductionism.

This paper offers a theoretical contribution to the extant body of research by employing a theoretical perspective that has not been used in prior research on technology adoption in auditing, which is primarily concerned with variance theories. The process theory introduces a sequential logic and allows for a contextualization of the related factors. The theory we present in this paper extends, in terms of certain aspects, the theoretical framework that was used for its development—the organizational innovation process as featured in Rogers (2003). Our theory depicts an organizational innovation process but focuses on the development of single ADA solutions across different organizational units. Therefore, our theory makes room for more complexity in the process and highlights the specifics of the audit domain. This results in a lower overall generalizability of the theory, which is consistent with the classification of Langley (1999) regarding the generalizability of the grounded theory. Similar to our process theory, the process in Rogers (2003) is divided into two phases: the initiation and implementation phases. The decision to (non-) adopt an innovation partitions both phases. In our theory, this adoption decision is made in the commitment of resource activity. However, it does not define the phases of the process. Rather, the research and development and diffusion phases relate to different objectives within the adoption process. The objective of the research and development phase is to develop a deployable solution from a use-case, while the objective of the diffusion phase is to ensure the operational use of the solution. The process theory in Rogers (2003) is also strictly linear, where each activity must be completed in a sequential order. Our theory allows for feedback loops between single activities. These feedback loops originate from reiterations of single-process activities in the evaluation and deployment stages, if the use-case (or prototype) or solution require revision. For example, the decision to not adopt a technology is not static, but it can be refuted if a better use case is presented. The process as a whole can be further reiterated after successful adoption for continued development (e.g. new features).

The process perspective emphasizes the active role of audit firms; the adoption of ADA requires the firm to make an effort. This contrasts the passive perspective in variance studies, which model technology adoption as a dependent variable. For example, previous studies employed the task-technology fit (Rosli et al., 2012; Widuri et al., 2016) and the related performance expectancy (Curtis and Payne, 2014; Pedrosa et al., 2015; Rosli et al., 2012) as exogenous variables to explain technology adoption in variance studies. In our theory, this fit of task to technology is achieved through the ideation activity in which the *technology characteristics* have to be matched to the *requirements of the audit domain*. The *complexity* of the underlying technology can be absorbed throughout the development of the solution, such that it maximizes the usability for auditors, which is reflected in the *solution characteristics* in the *auditor technology acceptance*. The *auditor technology acceptance* can be related to the research on technology adoption in auditing at the individual level (Curtis and Payne, 2014; Janvrin et al., 2008; Janvrin et al., 2009; Li et al., 2018; Payne and Curtis, 2006; Pedrosa et al., 2015). One interesting finding in our study, which has not been addressed in previous research, is that the *organizational context* through which ADA solutions are made available to audit teams is of relevance for the adoption.

Similar to previous research (Rosli et al., 2012; Li et al., 2018; Siew et al., 2020), our theory relates the available resources to the size of the audit firm. Our results indicate that, currently, the Big Four take the lead in the adoption of ADA. This contradicts the results of Lowe et al. (2018), which state that mid-sized audit firms have caught up to the Big Four firms in terms of their use of technology. The available resources in audit firms enable them to build own technological capabilities and engage in the development of own-solutions based on ADA. According to our results, the size of the firm also correlates with its ability to attract talent, which is crucial to the adoption process. Further, several studies have referred to the technological competence and resources within the adopting audit firm as factors for technology adoption (Haddara et al., 2018; Hampton and Stratopoulos, 2016; Rosli et al., 2012; Li et al., 2018; Salijeni et al., 2019; Siew et al., 2020; Widuri et al., 2016). These are also reflected in our theory in the *audit firm technological capability*. However, we differ between the capabilities of different groups (audit teams, innovation teams) and between the skills required for different activities that are part of the process (ideation, solution building, operational use). Here, our results also touch upon the inclusion of IT specialists and the apparent lack of ADA professionals in audit firms that inhibit ADA adoption: The innovation teams mentioned in our results represent a different kind of IT specialists—ones who are not directly involved in audit engagements themselves. Instead, they are tasked with developing solutions, which can then be employed in audits. They also possess a different set of skills, which leans more toward software development and methodological knowledge. The latter is particularly important during the ideation phase, where they are required to identify use cases. A few studies refer to the inclusion of IT support staff in the audit teams as a factor for technology adoption (Li et al., 2018; Widuri et al., 2016). In our theory, this is reflected in the existence of sufficiently high technological capability in audit teams, such that the technology-savvy staff (if available) may be leveraged to support other auditors in the deployment activity. Our results further support the findings of Vasarhelyi and Romero (2014) that interdisciplinary skills of IT specialists can have a positive impact on technology adoption. However, according to our findings, this is a two-way street—increased IT capabilities in audit teams can also help the adoption of ADA throughout the process.

Our results also have a few practical implications. The theory relates the contextual factors to the individual activities within the adoption process. The factors are separated into internal factors, which can be influenced by the audit firms, and external factors, which lie beyond its reach. Therefore, the theory provides a framework to guide both auditors and regulators when referring to the adoption of ADA. Specifically, our findings emphasize the importance of ADA capabilities in audit teams and the importance of being able to identify use-cases for ADA technologies in the first place.

The presented findings and the developed theory must be viewed in light of certain limitations, which are mostly grounded in the sampling of our interview partners and affect the generalizability of the theory. The first limitation is that many of our interview partners are in upper management positions, with most of them holding occupations related to audit digitization. This could imply that they exhibit a bias toward the potential benefits of technology and the importance this aspect holds for practice. We addressed this issue by including interviewees who are employed in audit field work. Another limitation is the country of employment of our interview partners. Most of them work in Germany; therefore, the results can be biased toward the development of the phenomenon there. However, we anticipate these effects to be weak, as a large number of our interview partners work in global companies and the German economy is the fourth-largest in the world by nominal gross domestic product and has global economic ties. As we indicate in Section 3.1., the institutional environment of the German audit market is highly internationalized. A further limitation is manifested through the role of audits in the German two-tier corporate governance setting, which is referred to in the methodology section. The motivation of audit firms to use ADA to deliver client insights beyond the normal regular audit report might be stronger in Germany than in other countries. Another limitation is associated with a design choice for the theory. For the sake of simplicity, we chose to not explicitly model existing relationships among contextual factors.

6. Conclusion and outlook

While prior research has addressed the application of ADA to auditing to a large extent, the process underlying ADA adoption in audit firms has barely received attention. This paper contributes to the research field of ADA adoption in auditing by introducing a process theory that reflects how audit firms adopt ADA. The theory further focuses on single solutions derived from ADA technologies instead of discussing the adoption of single ADA technologies into auditing practice as a whole. The process encompasses six activities through which a solution from an ADA technology is derived and diffused into practice: ideation, evaluation, solution-building, commitment of resources, deployment, and operational use. The first four activities are concerned with the development of a solution, whereas the latter two are concerned with the diffusion of solutions into operational use. The commitment of resources is a phase gate within the process, as any adoption of ADA requires financial or human resources. The derived theory further highlights how this adoption process is affected by contextual factors related to the adopting audit firm, characteristics of ADA technologies, characteristics of its clients, and requirements of the audit domain. The contextual factors related to the audit firm are its strategic prioritization of ADA, its organizational characteristics, its technological capability, and the acceptance of the solution on the part of the firm's auditors. All the activities involved in the adoption process are affected by the contextual factors related to the audit firm, whereas the external contextual factors mainly affect the ideation, deployment, and operational use activities.

Our results indicate that the technological capability of the audit firm, both amongst auditors and among innovation teams, affects successful technology adoption across different phases of the adoption process, most notably during the ideation and deployment activities. One of the greatest challenges in ADA adoption is the identification of use-cases in the ideation phase. Therefore, it is important to bridge the gap between the audit domain and technology, which can be achieved by equipping auditors with technological knowledge and by encouraging cross-disciplinary thinking in innovation teams. This effect is reinforced if a feedback loop between operational use and the ideation phase is established. Auditors with technological affinity can support the ideation phase, which in turn can improve the acceptance of solutions by other auditors, as they are involved in the development process. Involving auditors in the ideation phase can help to align the solution's design with the auditors' mindset in order to ensure usability, which affects the diffusion of the solution into operational use. Further, auditors with technological capabilities can support the deployment of a solution, where they act as trainers and lead users. However, this requires the commitment of the management of the audit firm to invest corresponding resources, even in the face of potential opportunity costs from non-billable person hours. Based on the above argument, we encourage regulators and standard-setters to consider the importance of ADA capabilities for the skill set of future auditors. Equipped with sufficient background on ADA technologies, they can identify use cases for technologies and drive the digitization of the profession from a conceptual perspective, independent from the size or pockets of their respective firms, such that, once again, the adoption gap between the Big Four and smaller firms can be closed.

This research aims to inspire further inquiries in this field. The results can be followed up by further qualitative and quantitative empirical analyses to extend the depth of the explanations of the results, further examine the nature of the relationships between the process and contextual factors, and test the hypothesized relationships between the associated factors and process outcome. Of special interest is the relationship between the audit domain requirements and the adoption process. In the presented theory, the audit risk model encoded in the professional standards affects the adoption of ADA, with some interviewees stating that they perceived the professional standards as a limiting factor for ADA adoption. However, the adoption of ADA on a broader scale could also transform the general approach of audit firms when conducting audits, thereby possibly leading to further development of the ISA. In this context, it would be interesting to examine the adoption of ADA for external audits of non-financial and diversity disclosures. Assurance services for non-financial reporting are a rather young phenomenon, where large volumes of data (e.g. environmental data) might be more prevalent than in financial reporting. Further, future research could compare the adoption of ADA across different countries to examine possible differences. Another topic that could be addressed in future research is the interaction between auditing and consulting service lines in the development of ADA solutions in Big Four firms and how this is affected by top-level management. In addition, our results indicate an interconnection among service lines, but we did not undertake a deeper examination of this aspect in this paper.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Interview quotes

All quotes have been translated from German.

> "And if you look at the newer technologies, for example, data mining, big data analytics, AI, or machine learning, yes, we're seeing that audit firms use them, that there are efforts. But currently almost only in their consulting practices and less in their audit practices. It may very well happen at some point, that they will engage more with these technologies. [...] But we have not yet been able to see this in recent audits." (IP15) (A.1)

> "Where we admittedly still have a bit of a problem [...] is to find the right use-cases for artificial intelligence." (IP12). (A.2)

> "[...] no one can guide these data science people. [...] None of their managers can tell them: We have this and that project going on now, let's have a look at it, maybe we can analyze that better. Because companies, to do data science, in my opinion, do not lack the competence, but the use-cases." (IP2). (A.3)

> "[…] because it requires investments, and the big problem is, of course, which all sectors actually have, they also need specialist [technological] knowledge. Small and medium-sized practices, in particular, have difficulties in obtaining suitable specialist staff. And that is why it is simply difficult to introduce new technologies in smaller firms." (IP10). (A.4)

> "We have found that clients are quite individual, even if they use the same ERP system, for example." (IP8). (A.5)

"And every system has a different data model. So, it contains the same information, but has a different structure." (IP9). (A.6)

"I must nevertheless take into account everything that the auditing standards prescribe, even if I may be able to audit in a completely different, perhaps more intelligent way, through the use of data analytics." (IP8). (A.7)

"What we as auditors need to make sure is that the data does resemble the reality." (IP8). (A.8)

"[...] I need to prove the reliability [of the technology]: The system has been fed this way [with data], works that way, and then comes for those reasons to this result. This also applies to the interpretation of results; everything must be made comprehensible." (IP15). (A.9)

"Everywhere where professional judgment is required, where I have to consider: Is this okay or not? Do I need to modify the audit opinion? A lot of people think that can't be replaced". (IP12). (A.10)

"You may quickly overlook that [the need for disciplinary spanning skills] and think: We just need a handful of computer scientists and a handful of auditors, and then something good will happen. But that's simply not the case." (IP2). (A.11)

"[...] from an audit point of view, we don't see any irregularities, everything seems fine, but did you actually know that if you pay your invoices three days earlier, you can raise significantly more cash discount [...]" (IP8). (A.12)

"[...] in most pitches, especially when it comes to larger mandates, where it's not just pure price competition, then of course it's all about what additional insights we can generate for the client." (IP8). (A.13)

"We achieved a certain fit there, such that the auditor does not have to change [his mindset] towards the reports, but the we change the reports in such a way, that the auditor can use them properly." (IP8). (A.14)

"Before I invest my time and run analyses which I can throw away afterwards, and possibly even make insinuations towards my client that are plain wrong, I'd rather stick with my old audit procedures." (IP10). (A.15)

Appendix B. Overview of empirical studies on ADA in auditing

Citation	Type	Country	ADA Technology	Focus	Results
Al-Htaybat and von Alberti-Alhtaybat (2017)	Interviews	Saudi Arabia	Big Data (Analytics) (BDA)	Big data (analytics) in corporate reporting, including auditing	According to the authors, the application of big data to corporate reporting is paradox: While big data is supposed to simplify reporting, the interviewees perceive the technology as very complex and identify a lack of necessary skills (statistics, programming) in their organizations.
Barr-Pulliam et al. (2020)	Experiment	U.S.	Data Analytics (DA)	Professional skepticism applied by auditors toward the outputs of analytic tool in the presence of false positives (data points falsely flagged as anomalous)	Applied skepticism is low, even when positively rewarded. The authors recommend carefully tuning data analytics tools towards reducing false positives.
Chiu and Jans (2019)	Case study	U.S.	Process Mining (PM)	Application of process mining to the evaluation of internal controls on the example of a bank	The authors show the applicability of PM to the evaluation of the effectiveness of internal controls. PM is used to analyze process variants, to check the segregation of duties, to investigate personnel data and to perform analyses on timestamp data. The authors stress the importance of data integrity for these kind of analyses and further argue that they need to become automated to increase efficiency.
Dagiliene and Kloviene (2019)	Interviews	Lithuania	Big Data (Analytics) (BDA)	Motivation for audit firms to use big data (analytics)	Three types of motivating factors are identified: • Company-related factors referring to characteristics of both audit firm and client company, for example, size, industry sector, use of technology, relationship between audit firm and client. • Technology-related factors: Digitization of business processes, accounting software used by the client company, and availability of professionals with big data analytics experience. • Institutional factors: Competition in the audit market, regulation, and education.
Jans et al. (2014)	Case study	U.S.	Process Mining (PM)	Exploration of the applicability of process mining to auditing on the example of a bank.	The case study demonstrates the applicability of process mining to auditing. Process mining focuses on paths of transactions using meta-data generated automatically by the IT system. It

					further uses the full population of transactions instead of samples. While this is an important extension of the focus of external audits, it can also create a problem of an "alarm flood" of false positives.
Eilifsen et al. (2019)	Interviews, Survey	Norway	Data Analytics (DA)	Use of data analytics in auditing practice	The actual use of DA remains limited and the use of ADA even more so. The authors find that DA is mostly used for clients with integrated IT-systems, and for newly acquired engagements. They further find that the results of DA are mostly used as supplementary audit evidence.
Haddara et al. (2018)	Interviews, Survey	Taiwan	(Big) Data Analytics (BDA)	The facilitators and inhibitors of big data analytics adoption	Several adoption barriers are identified in the paper: • Reluctance of clients to provide confidential data to auditors • Cost-Benefit uncertainty • Lack of big data-related skills in audit firms • Lack of hardware infrastructure • Data control and storage • Data integration and storage • Lack of guidelines for data usage and regulation
Hampton and			Stratopoulos (2016)	Survey	Canada
Data Analytics (DA)	The study examines the motivation for DA adoption, the effect of supporting		environment on DA usage, and the tradeoff underlying training strategies (DA expertise vs. diversity of DA tools)	The study finds that client expectations of DA use positively affect auditor use of DA. The use of DA by auditors in turn positively affects the confidence in the audit opinion, more in big audit firms than small- and medium-sized audit firms. The expectations of clients positively affect the availability of training opportunities within the audit firm, which in turn increases the use of DA. Both the DA proficiency of auditors and the diversity of DA tools are positively associated with confidence in the audit opinion. However, the results indicate that expertise in one tools is more important than basic knowledge of a diversity of tools. The authors conclude that this will pose a challenge to audit firms, professional organizations, and the education system, as auditors are required to be proficient in numerous interrelated emerging technologies.	

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Manita et al. (2020)	Interviews	France	Digitization in general; Data Analytics (DA), Artificial Intelligence (AI)	Impact of digitization on auditing through the lens of auditing as a corporate governance tool	Through digitization, audit firms will be able to deliver a more relevant, value-added audit by shifting the focus on high value-added tasks and transitioning from sample-based auditing to an audit of all data. DA and AI are likely to enable audit firms to introduce new service offers and improve audit quality. Digitization will probably shift the skill profile of auditors toward technological skills and foster a culture of innovation in audit firms.
Michael and Dixon (2019)	Survey	U.K.	Big Data (Analytics) (BDA)	The effect of BDA use by auditors on the expectation gap in audits of voluntary disclosures	The results reveal that the use of BDA decreases the expectation gap in audits of voluntary disclosures. This kind of audit requires BDA as well, as the source data is usually “big” in terms of volume and variety, as opposed to statutory financial audits, which are mainly concerned with structured financial data. The assurance of voluntary disclosures is a promising additional service enabled by ADA that audit firms can offer.
Rose et al. (2017)	Experiment	U.S.	Big Data (Analytics) (BDA)	The effect of the timing of BDA visualization in the audit process on auditor judgement	The experiment indicates that auditors do not identify crucial patterns in big data visualizations before forming initial expectations by applying traditional audit procedures. They are also more likely to express concerns regarding potential misstatements when the visualizations do not match their initially formed expectations. These findings contradict the oft-stated belief that BDA visualizations would support auditors in directing the audit toward critical areas before applying traditional procedures.
Salijeni et al. (2019)	Interviews	U.K., Belgium	Big Data (Analytics) (BDA)	The impact of BDA adoption on the audit profession	The authors identify three key aspects in this regard: The impact on the relationship between auditor and client (greater transparency for the client, technology spillover effects, provision of additional—possibly non-audit—services). The consequences of technology use for the conduct of audit engagements (improvement of audit quality and efficiency, focus on more complex issues, shift from traditional data interrogation to analysis of full populations, and even unstructured data). Common challenges associated with embedding big data analytics (lack of relevant skills in audit firms, possible high frequency of false positives, reluctance toward growing influence of data scientists)

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