The development and intellectual structure of continuous auditing research☆

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ARTICLE INFO

ABSTRACT

The advances and continuous development of technology have been identified as significant influences on the accounting profession (AICPA, 1998). In the last twenty years, both academia and the accounting profession have been giving much attention to the demand and opportunity for audits to be performed automatically, continuously and in nearly real time. This paper presents a comprehensive review of continuous auditing research by providing an overview of the emergence and growth of the continuous auditing literature and classifying the extant continuous auditing research on the basis of four research characteristics indicated by a newly developed research taxonomy.

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1. Introduction

Advances in technology, such as the advent of the Internet and electronization of business processes, are significant forces shaping many aspects of the accounting discipline (AICPA, 1998; Kogan, Sudit, & Vasarhelyi, 1999; Vasarhelyi, 2002). Within this domain, auditing has been particularly impacted by technological advancements. While external auditors assure the adequacy of financial statements in accordance with Generally Accepted Accounting Principles (GAAP), internal auditors evaluate operations relative to risk, internal controls, and governance processes to assure

operational effectiveness and efficiency.[1] The evolution in how business transactions are created, processed, and reported has necessitated a transformation relative to the structure of audit procedures and techniques for conducting both internal and external audit tasks. For example, the documentation of business events is increasingly being conducted in an exclusively electronic manner, and this suggests that many traditional manual audit activities are becoming less applicable within the contemporary business environment. Cukier and Mayer-Schoenberger (2013) indicate that, in the year 2000, only about 25 percent of all stored information was in a digital form. By contrast, today more than 98 percent of all such accumulated information is electronic. In conjunction with the expanding electronization of business, stakeholders are increasingly demanding more timely access to relevant, reliable, and decision-useful financial information, which motivates the need and provides opportunities for implementation of continuous auditing practices (CICA/AICPA, 1999).

The CICA/AICPA (1999) defines continuous auditing as "*a methodology that enables independent auditors to provide written assurance on a subject matter, for which an entity's management is responsible, using a series of auditors' reports issued virtually simultaneously with, or a short period of time after, the occurrence of events underlying the subject matter.*" A number of prior studies provide similar definitions for continuous auditing, as well as develop and illustrate its theoretical construct (e.g., Kogan et al., 1999; Rezaee, Sharbatoghlie, Elam, & McMickle, 2002). The continuous audit (CA) is differentiated from the traditional audit primarily by its frequency, focus on automated processes, and unique concept of audit by exception (Vasarhelyi & Halper, 1991). The main advantages of continuous auditing relate to enhanced relevance and timeliness of audit results.

To support the proper evolution of continuous auditing, academic research contributions in meaningful combination with experimentation by practitioners and guidance from standard setters is essential (CICA/AICPA, 1999). With the inevitable transformation of audit processes and the need of support from academic research on continuous auditing (Brown, Wong, & Baldwin, 2007; Vasarhelyi, Alles, Kogan, & O'Leary, 2004), this study contributes to the literature by examining the extensive body and multi-faceted characteristics of continuous auditing literature from the most recent three decades. The two-fold analysis encompasses a historical overview of the development and main components of the continuous auditing field, and a systematic content analysis of relevant research. It summarizes the primary research characteristics on dimensions including applied methodologies, areas of emphasis, and geography.

Although the concept of continuous auditing emerged in the late 1980s and early 1990s (e.g., Groomer & Murthy, 1989; Vasarhelyi & Halper, 1991), it was not until the 2000s that its methodology, elements, and scope began to expand into various streams (Brown et al., 2007). Since the late 1980s, auditing researchers have been proposing theoretical principles, conceptual frameworks, and development modules that illustrate the potential for continuous auditing (e.g., Groomer & Murthy, 1989; Kogan et al., 1999; Vasarhelyi & Halper, 1991). Subsequent to this, studies emphasized the need for a more frequent or continuous-based audit, and the grounds for and components of continuous auditing gradually developed. In the most recent decade, numerous studies examine its enabling technologies. Studies have evaluated the costs, benefits, and future research opportunities relative to continuous auditing (Alles, Kogan, & Vasarhelyi, 2002; Alles, Kogan, & Vasarhelyi, 2008; Alles, Kogan, & Vasarhelyi, 2008; Rezaee et al., 2002). Also, positive experiences from preliminary and partial real-world CA implementations have reinforced the importance and utility of this research area (Alles, Kogan, & Vasarhelyi, 2011). Auditing has been evolving substantially by progressively utilizing the latest technologies to improve process and procedure efficiency and effectiveness. In the near future, it is expected that continuous auditing will be more widely adopted and implemented by both internal and external audit practices (Byrnes, Ames, Vasarhelyi, Pawlicki, & McQuilken, 2012).

Given the advancements in technologies and their resulting effects on auditing, both academia and the accounting profession are giving progressively more attention to the demands and opportunities for audit tasks to be performed automatically, continuously, and even nearly in real time. However, prior research suggests that, while progress has been made in terms of theoretical development,

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[1] Definition by IIA: Internal auditing is an independent, objective assurance and consulting activity designed to add value and improve an organization's operations. It helps an organization accomplish its objectives by bringing a systematic, disciplined approach to evaluate and improve the effectiveness of risk management, internal controls, and governance processes.

continuous assurance research has been hindered by a lack of experimental and empirical studies (Vasarhelyi et al., 2004). Also, little research has extensively and systematically examined the development of continuous auditing literature and its associated characteristics. Periodically reviewing academic research contributions provides understanding about current accomplishments and reveals valuable insights concerning future research directions (Lindquist & Smith, 2009). Therefore, this study sheds light on extant continuous auditing research and reveals its longitudinal development by reviewing, summarizing, and cross comparing research characteristics of 118 relevant continuous auditing studies. This comprehensive review of over two decades of continuous auditing research will be of value to both academics and practitioners. The remainder of this paper is organized as follows: The next section presents an overview of the emergence and growth of continuous auditing research since the late 1980s. The third section examines multiple research characteristics of continuous auditing literature by applying a content analysis approach based on a unique four dimension taxonomy. Finally, future research opportunities and challenges are proposed in the last section.

2. Overview of continuous auditing research

2.1. The emergence of continuous auditing: electronic data processing and audit automation

"Technological advances are significant forces affecting the accounting profession" (AICPA, 1998). The emergence of data processing technologies such as accounting database systems, data networks, electronic data interchange (EDI), transaction-driven systems, and telecommunications triggered the transformation of audit techniques in an effort to adapt to the changing environment regarding how audit engagements are conducted in the accounting profession. Cash, Bailey, and Whinston (1977) discussed and classified several audit techniques with or without computer assistance. The authors reviewed literature on auditing within the electronic data processing system environment and suggested new approaches (e.g., The Data Base Management System and The Internal Control Model) that would involve auditors in systems design and usage of automatic internal control description methods in adaptation with the growing complexities in data management and its possible effects on financial reporting and audit tasks. Vasarhelyi (1984) examined the evolution of audit processes in light of automation. He argued that computer audit implementations did not fully leverage automation benefits because they only reflected direct computerization of manual methods rather than reengineering of associated processes.

While financial statements have long been audited months after occurrences of business activities, the timeliness, efficiency, and appropriateness aspects of traditional audit procedures have been largely questioned in the academic literature. There is an increasing demand for implementing new technologies in aiding the performance of audit tasks (Vasarhelyi, 1983). Garsombke and Tabor (1986) focused on examining the factors for applying electronic data processing (EDP) audit techniques and their usage in performing different audit tasks by surveying 105 EDP auditors. They concluded that the perceived effectiveness of techniques was the main factor explaining EDP auditors' adoption of a specific audit technique. Other factors examined included the familiarity, cost, and skills required to use the techniques. During that same period, a literature review on computer-based accounting systems, EDP auditing, and other computer information science areas relevant to accounting was examined by Amer, Bailey, and De (1987). Classification of the literature was conducted according to accounting/database systems design, EDP auditing techniques, and computing-based decision support systems. The study indicated the need for research in the theoretic conceptual and behavioral work in accounting information systems and EDP auditing. It also encouraged theories to be adapted from other scientific disciplines to enable applications of new methods and generation of new insights. The study also suggested that, as data management and communications techniques advance, changes will occur in accounting reporting and disclosures. This extrapolation from the prior literature ties the changes needed in audit process to the evolution of reporting and technology. Research in the late 1980s and early 1990s suggested that the emergence of electronic data interchange (EDI) brought auditing to a new stage by increasing its efficiency in both external and internal audit domains (Hansen & Hill, 1989; Morris & Pushkin, 1995). In external auditing, Groomer and Murthy (1989)

proposed an approach to continuously capture information of audit significance by applying Embedded Audit Modules (EAM) in the audit process. The study advocated EAM to serve as an audit tool for substantive and compliance testing. Gradually, audit tasks have been shifting toward using new approaches that feature elements such as electronic business processes, online audit capabilities, and real-time assurances. In addition to the demand for continuous auditing of financial statements, the potential and need for other continuous auditing services have arisen including: (a) continuous assurance regarding the authenticity, integrity, and non repudiation of electronic commerce transactions; (b) continuous assurance on controls over electronic commerce systems, compliance with debt covenants, and security of web sites containing reports on significant decision-making information; (c) continuous assurance on specific financial information and mutual fund unit values, including assurance on effective controls over the unit-holder system; and (d) continuous assurance regarding marketing information, media ratings, hits on websites, and banner downloads (CICA/ AICPA, 1999).

The aforementioned non-traditional audit services require updated standards, skills, and methodologies in order to be performed by auditors (Vasarhelyi, 2002). Attention has been drawn to this wide-open continuous auditing research field, and it has grown extensively over the past decade. Multiple research streams have explored continuous auditing in terms of its (1) grounding theory, framework, and elements; (2) enabling technologies, forces of assistance, value and necessity of continuous monitoring and reporting; and (3) applications and implementation experiences. The field is growing and expanding in a number of directions, which will be illustrated in more specific detail in subsequent sections of this paper. A review of pioneering work relative to the elements of continuous auditing and preliminary application since the early 1990s is illustrated next.

2.2. Demanding and promoting real-time reporting and assurance

Given the evolving and enhanced ability of information systems and techniques, academics and practitioners have conducted preliminary analyses to realize the objective of performing online and nearly real time auditing. Vasarhelyi and Halper (1991) introduced the Continuous Process Auditing System (CPAS), a system implemented at AT&T Bell Laboratories and developed to monitor, measure, and audit a large paperless real-time system for the internal audit organization. Kogan et al. (1999) presented a research agenda discussing several aspects of continuous online auditing (COA). The study characterized the online computer system, which permanently connects both auditees and auditors through computer networking, as a prerequisite for implementation of continuous auditing. In addition, the importance of fully automating the process to access relevant events and outcomes, and evaluating the technological and economic feasibility of continuous online auditing were discussed.

Obtaining real-time financial information is one of the most important goals for the development of new technology applications for business processes. As information technology advances, data transmission and online real-time financial reporting becomes less costly, faster, and more feasible. For instance, financial information and audit evidence in an electronic format can be provided under real-time accounting systems (RTA), financial disclosures can be presented on the Internet in HTML format, and the eXtensible Business Reporting Language (XBRL) taxonomy can be applied to financial statements to enhance their usability in various applications (Bovee, Ettredge, Srivastava, & Vasarhelyi, 2002; Bovee, Kogan, Nelson, Srivastava, & Vasarhelyi, 2005; Rezaee & Hoffman, 2001; Rezaee, Ford, & Elam, 2000; Rezaee et al., 2002).

The demand for timely continuous assurance becomes more urgent with the progressive transition from traditional financial statement reporting to real-time continuous reporting. Although statutory financial reporting is currently done on a quarterly basis, internal reporting with ERPs allows for close to the event reporting in many cycles (Vasarhelyi, Alles, & Williams, 2010; Vasarhelyi, Krahel, & Teeter, 2010). Furthermore, Section 409 of Sarbanes–Oxley Act (SOX) requires real time reporting, which has been defined by the SEC as rapid reporting of significant events and accelerated issuance of financial reports (SOX, 2002; SEC, 2004).

There are a number of studies that examined continuous assurance and introduced several of its applications (Halper, Snively, & Vasarhelyi, 1992; Vasarhelyi & Halper, 1991; Voarino & Vasarhelyi, 2001). Elliott (2002) pinpointed the changes needed in the assurance service environment of the

twenty first century, discussed how technology advances in financial reporting create the demand for online continuous assurance, and suggested future trends for assurance services. Alles et al. (2002) identified implementation problems of continuous assurance, such as assuror independence, payment infrastructures, and cost issues. The authors stated that inherent demand for assurance is value adding in any transaction, and the viability of continuous assurance is dependent upon assuror compensation, which reflects supply, demand, and design complexity. The concept of continuous assurance and its relevant future research issues were also examined.

Outcomes from continuous assurance processes include an expanded set of assurances, improved control processes, and enhanced data integrity (Vasarhelyi et al., 2004). A new continuous analytic monitoring-based assurance environment would allow increased understanding and monitoring in both integrated and non-integrated portions of the IT environment. The proposed levels of architecture encompass transaction evaluation, measurement rule assurance, estimate assurance and consistency of aggregate measures, and judgment assurance. A continuous analytic monitoring-based assurance is expected to further change the objectives, timing, processes, techniques and results of the assurance process. The following subsection reviews another key component of continuous auditing and assurance, the continuous controls monitoring perspective of auditing.

2.3. Continuous controls monitoring

The continuous auditing methodology enables the latency between event occurrence and related auditor assurance to be reduced. Continuous auditing focuses on a narrower aspect of continuous assurance, and may be considered as a subset of continuous assurance (Alles et al., 2002; Alles, Tostes, Vasarhelyi, & Riccio, 2006; Alles, Brennan, Kogan, & Vasarhelyi, 2006). Continuous auditing has historically entailed using software to detect auditor specified exceptions from among all transactions that are processed in a real-time environment (Helms, Mancino, Warner, & Smith, 1999). Fundamentals of continuous auditing are described in CICA/AICPA (1999). Effective continuous auditing development will enable auditors to continuously select, monitor, and analyze the client's internal control structure and accounting information systems (Rezaee et al., 2002). Rezaee et al. (2002) developed an approach for building automated auditing and a description for audit data marts and the data warehouse. Robert and Harold (2003) pointed out that only a few auditors believe they are trained well enough to effectively use audit software. Given the numerous advantages of new audit tools, the study suggested that there is a need for auditors to improve their information technology proficiency in order to deploy continuous auditing methodologies efficiently and effectively.

While continuous auditing is the automated performance of control and risk assessments in an ongoing manner, continuous monitoring helps to ensure that policies, procedures, and business processes are operating effectively, and assists management in assessing the effectiveness of internal controls (De Aquino, Da Silva, & Vasarhelyi, 2008). De Aquino et al. (2008) discuss the environment and context of continuous monitoring implementation. Under certain business processes and cycles, continuous monitoring often involves the automated testing of system activities against control rules. More recently, Vasarhelyi, Alles, et al. (2010) and Vasarhelyi, Krahel, et al. (2010), proposed a third element in the continuous audit methodology entitled continuous risk monitoring and assessment (CRMA).

In 2006, a PricewaterhouseCoopers (PWC) survey indicated that half of the responding firms have implemented some kind of continuous auditing or monitoring techniques, and most of the other firms have an implementation plan for the future. Alles, Tostes, et al. (2006) and Alles, Brennan, et al. (2006) evaluated the Continuous Monitoring of Business Process Controls (CMBPC) approach implemented in the U.S. internal IT audit department of Siemens Corporation. The study specifically examined the application of audit alarm management, alarm flood prevention, and approaches in dealing with audit issues using hierarchically structured alarms and assigning destinations via a rule-based approach.

Another PricewaterhouseCoopers study (2007) predicted that auditors will need to focus more on risk concerns, and that the rating for continuous monitoring of relevant applications will be viewed as most important for internal audit over the ensuing five years. The controls monitoring function of systems would require continuous assurance of processes and transactions. To implement continuous monitoring systems, five basic features including metrics, standards/models, analytics, alarms, and

methods of measurement are required. For instance, variances are verified by comparing the system measurement or metric with standards to conduct the control process. Analytic models are applied to establish the level of relevance of the model and the different types of alarms (Alles, Kogan, Vasarhelyi, & Warren, 2007; Vasarhelyi & Halper, 1991). In continuous auditing, transactions will be monitored and characteristics will be compared to expected results by software continuously. In this manner, when significant discrepancies occur, alarms will be triggered to alert operational managers, auditors, and top management (Vasarhelyi, 2002). Nigrini and Johnson (2008) described an audit risk score method to determine fraud or errors based on an adaptation of the IT-monitoring framework of the International Federation of Accountants – IFAC (2002). Their research is an example of the application of a continuous monitoring methodology in detecting fraud and errors using a franchise business' monthly sales reports. The following section elaborates further on the implementation phase of continuous auditing and controls monitoring.

2.4. Implementation of continuous auditing and continuous controls monitoring

In order to assist the audit process in adapting to changes in the financial reporting environment, several research studies developed and proposed frameworks (Flowerday, Blundell, & von Solms, 2006; Kogan et al., 1999; Woodroof & Searcy, 2001) that apply continuous assurance, continuous reporting, and continuous monitoring concepts.

Dull and Tegarden (2004) introduced "control charts" to monitor continuous financial information. Their results suggested that combining future refinements of this technique along with statistical and analytical skills would enable the detection of financial processes that are not in control, and thus enhance the reliability of information. Dull, Tegarden, and Schleifer (2006) proposed the automated continuous transaction verification environment (ACTVE), an innovative system that provides timely audit evidence. ACTVE assists assurance providers by presenting a framework for timely confirmation of transactions and balances. It enables transaction costs and traditional biases associated with the confirmation process to decrease, and solves confirmation response issues that arise in a traditional audit environment.

Santos, Sousa, Ferreira, and Tribolet (2008) developed a conceptual model using real time analysis and modern control theory for continuous organizational auditing. Their approach allows the implementation of continuous auditing mechanisms in real time, and, whenever a nonconformity or exception is found, the system updates or corrects the mechanisms. Gal (2008) examined issues relevant to continuous reporting systems, including information disclosed, level of detail, time lag, and methods available to query information. The study sheds light on the characteristics of continuous reporting and implications of this technology for investors, auditors, and managers.

Motivated by the occurrences of corporate fraud and scandals in the past decade, research on enterprise-risk management, internal controls, and continuous assurance issues has been expanded. For example, Vasarhelyi (2002) examined the Enron fraud case and suggested that the unreported related party partnerships could have been detected if continuous assurance processes were implemented. Vasarhelyi (2002) indicated that given the large non-repetitive data and resource flows between the corporations and its partnerships, the data flows and models under the continuous assurance process would have questioned, required justification for and signaled a level of control in need. Supervisory authorities would have been notified by a reporting system with the anomalies and could have taken preventive actions. Also, related-party transactions, conflicts of interests, overlapping management, and insider trading could have been addressed by conducting validity tests for the continuous auditing environment. Kuhn and Sutton (2006) studied the WorldCom fraud case and focused analysis on proposing a SAP-based enterprise system with an integrated continuous assurance strategy to detect fraudulent behavior. Koskivaara and Back (2007) presented an artificial neural network assistant (ANNA) application that analyzes monthly account values to assist with continuous auditing and monitoring of financial data. This application could automatically provide monthly reports for accounts that follow the predicted trend, and issue alerts about remaining accounts so that they may be subsequently investigated.

Other studies introduced or demonstrated the impact of new technologies in specific audit areas. Comunale and Sexton (2005) applied fuzzy expert systems to formalize and document the materiality

assessment process by incorporating qualitative factors. Murthy (2004) examined the effects of including continuous monitoring controls in modern e-commerce systems. Capacity planning, capacity management, and both internal and external auditors' requests for applying continuous monitoring controls in e-commerce systems were supported. Hunton, Wright, and Wright (2007) examined the potential impact of more frequent financial reporting and concurrent assurance. Their findings suggest that more frequent reporting is likely to reduce a firm's ability to "manage" earnings. Furthermore, although providing monthly reports is technically and economically feasible, concerns exist regarding the practicality of daily reporting.

The next section provides a systematic analysis of continuous auditing literature by analyzing its content, and classifying articles by their respective taxonomic attributes. The distribution and ranking of each taxonomic category illustrated in the next section will assist with our understanding of the developed characteristics of continuous auditing research, and suggest directions for future research.

3. Characteristics of continuous auditing research

3.1. Methodology: article source and collection

Using key terms (including "*continuous auditing*," "*continuous assurance*," "*continuous monitoring*," "*continuous reporting*"), a total of 118 continuous auditing related articles were identified from a search of articles in multiple online academic research databases including *EbscoHost*, *Science Direct*, *Scopus*, *Wiley Library*, *ISI Web of knowledge* and *Accounting Research Directory* (Brown & Vasarhelyi, 1994).[2] There was no limitation set on the article search time frame, since the goal was to provide analysis on an extensive set of published continuous auditing academic literature. Search results from databases were cautiously reviewed to ensure that no duplication of manuscripts occurred and only main academic studies were incorporated.

3.2. Taxonomic categories development

Content analysis is a research method that can provide descriptive results of the nature of publications (Chiu, 2013). It has been employed to study the intellectual structure of publications in certain journals (Brown, Gardner, & Vasarhelyi, 1987, Brown, Gardner, & Vasarhelyi, 1989; Chiu, 2013; Just, Meyer, Schaffer, Vasarhelyi, & Chiu, 2011; Vasarhelyi, Bao, & Berk, 1988). Brown et al. (2007) qualitatively reviewed CA research by topic, while we employ a taxonomic approach in attempting to analyze CA research from a quantitative perspective. Specifically, we develop four taxonomic categories by which to classify each CA paper: research method, topical area, specific area of emphasis, and geographical area. Definitions for these categories follow.

Research method is a traditional taxonomic category, which indicates the research methodology employed by the researcher. The three main research methods identified in the CA literature are: analytical, archival, and experimental/behavioral. Analytical studies apply either internal logic or simulations. Archival studies utilize sources from secondary records. Experimental/behavioral studies employ primary data collected from self-designed interviews, surveys, and/or experiments.

Topical area category indicates the CA related topic contribution area. We created seven items in this category based on the components of CA mentioned in Alles et al. (2007) and their related issues discussed in Brown et al. (2007). Table 1 shows the explanation of each topic. Articles in the same topical area may have different emphases, while those in different topical areas may have the same purpose. In order to comprehensively demonstrate the research stream in CA literature, another category, named the "*Specific area of emphasis*," was designed to describe the purpose or objective of each article. Following Kogan et al. (1999), this study adopts three aspects, including Architectural issues Relating to CA, Factors affecting CA, and Effects/Consequences of CA, in this category. Architectural issues relating to CA contain the description of CA related concepts, development of CA

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[2] The search incorporated articles published by late 2011. The search limited results to including full text, reference available and scholarly peer reviewed journal articles. In line with prior literature (e.g., Vasarhelyi et al., 1988), editorials, commentary, and notes less than four pages are excluded from the analysis. The list of the 118 articles is available at http://raw.rutgers.edu/docs/vc/appendix_iii.pdf.

Table 1
Explanation of topical area.

Topical area	Explanation
General CA	Involves high level CA research like grounding theory and framework of CA
Continuous assurance	Includes studies about continuous data assurance (CDA), (continuous) system assurance, continuous online assurance and external continuous assurance research
Continuous control monitoring (CCM)	Consists of research related to (continuously) monitoring of internal controls
Continuous reporting (CR)	Denotes studies of frequent reporting and disclosure
Continuous risk monitoring and assessment (CRMA)	Indicates dynamic risk measurement research
Enabling technology	Refers to the essential technologies supporting CA and CR, such as electronization and XBRL
Audit automation	Indicates studies on automating traditional manually performed auditing procedures

systems and models, and introduction of CA methods and technologies. Factors affecting CA refer to elements that may influence the implementation of CA, such as the demand for and perceived value of CA. Effects/Consequences of CA indicate the impact of applying CA in practice, such as its costs and benefits.

The last taxonomic category created captures the *geographical area* of authors. Analyzing this category facilitates discovery of the distribution of CA research around the world. The subfields in this category include United States, Canada, Europe, Asia, Australia, Africa, and Mix.

3.3. Findings: characteristics of continuous auditing literature

3.3.1. Research method

The primary research method employed in CA articles is analytical (50% of the articles), followed by experimental/behavioral studies (41% of the articles). Only 11 (9% of the articles) of the 118 CA articles are archival, three of which are literature reviews and eight are empirical studies using data from large databases, such as CRSP and COMPUSTAT. We believe the relatively short history of this research area and the lack of suitable publicly available data account for the low percentage of archival studies.

3.3.2. Topical area

Table 2 classifies the CA articles by topical area and research method. The table reveals that General CA (40 articles (33.9%)) is the most studied topical area. One possible explanation for this finding is that CA is a relatively new research area such that a large portion of CA research thought remains at a general level. The topics of CCM, enabling technology, CR, continuous assurance, and audit automation are covered in comparable proportions ranging from 9.32 to 16.95 percent. Continuous risk monitoring and assessment is a topical area that has not been extensively studied as yet. Specifically, only two articles (1.69%) address this issue, and this is not surprising because it is a relatively new topical subfield derived from Vasarhelyi, Alles, et al. (2010) and Vasarhelyi, Krahel, et al. (2010).

Table 2
Distribution of articles by topical area and research method.

Topical area	Research method			Total
	Analytical	Archival	Experimental/behavior	
General CA	31	1	8	40 (33.9%)
Continuous control monitoring (CCM)	6	2	12	20 (16.95%)
Enabling technology	9	2	7	18 (15.25%)
Continuous reporting (CR)	3	5	6	14 (11.86%)
Continuous assurance	3	1	9	13 (11.02%)
Audit automation	6	0	5	11 (9.32%)
Continuous risk monitoring and assessment (CRMA)	1	0	1	2 (1.69%)
Total	59	11	48	118 (100%)

With respect to the interplay of topical area by research method, Table 2 shows that more than half (52.54%) of the analytical studies target general CA issues, while a majority (77.50%) of general CA articles employ analytical methods. This uneven distribution may be attributable to the theoretical and conceptual nature of the general CA area. Conversely, more experimental/behavioral studies are conducted in continuous control monitoring, continuous reporting, and continuous assurance areas, which suggests that more analytical based studies and discussions could be populated in these topical areas in future research. In the topical area of enabling technology, audit automation and continuous risk monitoring and assessment, analytical and experimental/behavioral approaches are almost equally applied. Nearly half (45.45%) of the archival studies are allocated in the continuous reporting area. One possible reason for this result is that XBRL is an important topic in continuous reporting research, and XBRL documents can easily be collected from the EDGAR system. In addition, Table 2 shows that the archival approach has never been deployed in the audit automation and continuous risk monitoring and assessment area. The lack of availability of secondary data could explain this observation. Given that there are relatively few research articles classified under those two categories and the studies are mainly published in the most recent decade, opportunities exists for archival review-based studies in future research of audit automation and continuous risk monitoring and assessment.

3.3.3. Specific area of emphasis

Untabulated data reveals that architectural issues relating to CA attract most (48.31%) of the efforts from CA researchers. This finding implies that CA is an emerging research area, which is consistent with our findings in the analysis of the topical area. The results also indicate that, among all the specific area of emphasis categories, research focused on the effects/consequences of CA (28.81%) and factors affecting CA (22.88%) categories accounted for similar proportions but are the least examined subareas.

The distribution of research methods by specific area of emphasis, displayed in Table 3, demonstrates that most analytical studies are conducted to address architectural issues relating to CA and effects/consequences of CA. Conversely, more articles employed empirical methods, including archival and experimental/behavioral, when discussing factors affecting CA. Since analytical and empirical methods are equally important in these areas, more empirical studies need to be conducted to analyze architectural issues relating to CA and effects/consequences of CA. Also, more attention could be devoted to analytical studies when addressing factors affecting CA, which ties to the theoretical construct and aspects that would influence the continuous audit method and its implementation. For example, research could extend discussions about influences from relevant standards and regulations (e.g., XBRL, SOX section 201, section 404) or corporate structure/organization (e.g., audit committee) on potential CA adoption or process changes. In addition, the archival method is seldom used to discuss factors affecting CA. This is mainly because there is currently limited secondary data source available for this method to be applied in research as compared to analytical and experimental/behavior.

Table 4 depicts the distribution of the specific areas of emphasis by topical area. In general, the results show that each specific area of emphasis has been studied in every topical area, with the exception of the effects/consequences of continuous risk monitoring and assessment. Architectural issues are most extensively studied in general CA, continuous control monitoring, enabling

Table 3
Distribution of articles by research method and specific area of emphasis.

Specific area of emphasis	Research method			Total
	Analytical	Archival	Experimental/behavior	
Architectural issues relating to CA	34	5	18	57 (48.31%)
Effects/consequences of CA	18	5	11	34 (28.81%)
Factors affecting CA	7	1	19	27 (22.88%)
Total	59	11	48	118 (100%)

Table 4
Distribution of articles by specific area of emphasis and topical area.

Topical area	Specific area of emphasis			Total
	Architectural issues relating to CA	Effects/consequences of CA	Factors affecting CA	
General CA	17	17	6	40
Continuous control monitoring (CCM)	12	7	1	20
Enabling technology	11	1	6	18
Continuous reporting (CR)	3	4	7	14
Continuous assurance	7	4	2	13
Audit automation	6	1	4	11
Continuous risk monitoring and assessment (CRMA)	1	0	1	2
Total	57	34	27	118

technology, and continuous assurance and audit automation areas. Effects and consequences are analyzed in general CA and continuous control monitoring areas. The areas of factors affecting CA/CCM are mainly discussed in continuous reporting, general CA, and enabling technology areas. This analysis suggests that there are future research opportunities related to architectural issues of continuous reporting, effects/consequences of CA enabling technology and audit automation, and factors affecting continuous control monitoring and continuous assurance. Consistent with previous findings, because continuous risk monitoring and assessment is a newly emerging research area, all three specific areas of emphasis within this topical area have the potential to be further examined in future research.

3.3.4. Geographical area

The geographical distribution of CA research shows that about 68% of all CA studies have been conducted in the United States. Asia, Europe, and Mixed regions are in a distant second place, with each possessing the same percentage (8.47%). Consequently, CA has attracted a certain degree of research effort in Asia and Europe. Moreover, cross-region cooperation of CA research also speaks to the popularity of CA.

3.3.5. Longitudinal analysis of research methods by specific area of emphasis

To gain insight on the development of CA research over time, we conduct a longitudinal analysis of research methods by specific area of emphasis as shown in Table 5 and Fig. 1. In this analysis, we divide the entire time frame covered in this study into three periods: 1983–1999, 2000–2007, and 2008–2011.

Table 5
Over time trends of specific area of emphasis by research method.

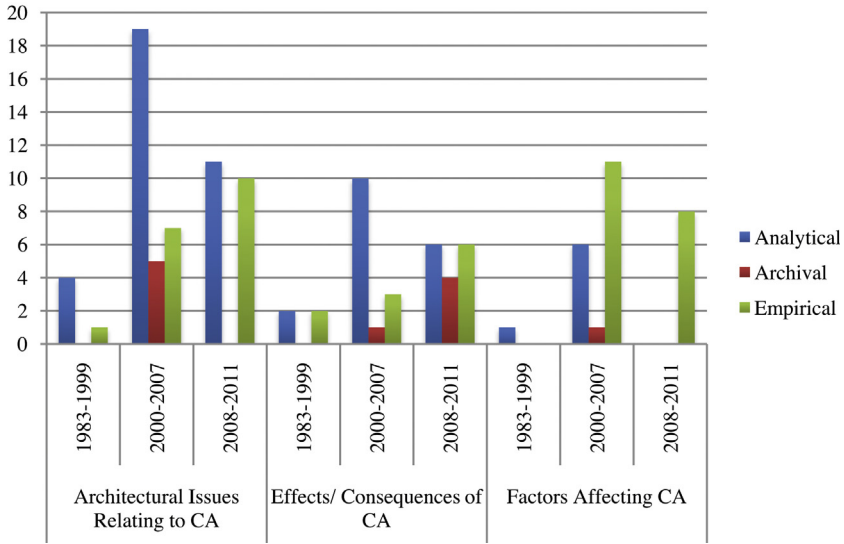| Specific area of emphasis		Research method						Total
		Analytical		Archival		Empirical		
Architectural issues relating to CA	1983–1999	4	80.00%	0	–	1	20.00%	5
	2000–2007	19	61.29%	5	16.13%	7	22.58%	31
	2008–2011	11	52.38%	0	–	10	47.62%	21
	Subtotal	*34*	*59.65%*	*5*	*8.77%*	*18*	*31.58%*	*57*
Effects/consequences of CA	1983–1999	2	50.00%	0	–	2	50.00%	4
	2000–2007	10	71.43%	1	7.14%	3	21.43%	14
	2008–2011	6	37.50%	4	25.00%	6	37.50%	16
	Subtotal	*18*	*52.94%*	*5*	*14.71%*	*11*	*32.35%*	*34*
Factors affecting CA	1983–1999	1	100.00%	0	–	0	–	1
	2000–2007	6	33.33%	1	5.56%	11	61.11%	18
	2008–2011	0	–	0	–	8	100.00%	8
	Subtotal	*7*	*25.93%*	*1*	*3.70%*	*19*	*70.37%*	*27*
Total	–	59	50.00%	11	9.32%	48	40.68%	118

Fig. 1. Over time trends of specific area of emphasis by research method.

The rationale behind this division is that the number of publications greatly increased in 2000 and 2008. Within the 15-year period after the publication of the first audit automation (the foundation of CA) paper in 1983, there are only 10 articles published in the CA area (on average 0.67 publications per year). Therefore, we consider this to be the emerging period of CA research. From 2000 to 2007, the first developing period of CA research, the average number of publications increased to 7.875 per year, which indicates a growing research interest in CA. This growth may have been triggered by the publication of the 1999 CICA and AICPA research report on Continuous Auditing. The second peak of CA publications occurred in 2008 with 17 articles published in that year. This boom of CA publications may be attributable to the requirements from governance and regulation, such as the need to comply with section 404 of the U.S. Sarbanes–Oxley Act. In the following three-year developing period of CA research, there are, on average, 10 CA articles published each year.

In the emerging period, 70% of the CA publications employ the analytical research method. The remaining 30% are empirical studies. No archival study is conducted in this period. This distribution matches with the characteristics of an emerging research area. The lack of empirical and archival studies points to an unawareness of the CA concept in the accounting profession as well as availability of limited secondary data.

In terms of specific area of emphasis, 50% of researchers in this period focus on architectural issues related to CA, such as introductory CA concepts and CA/CM models establishment. Effects/consequences of CA also attracted some research effort (40%); articles exploring this area primarily investigate the feasibility of implementing CA. The area that is paid least attention (10%) relates to factors affecting CA. The likely reason for this is that CA was not a well-known concept at that time. Therefore, factors, such as demand and perceived value that might affect CA implementation had not yet been recognized. Specifically, more than half (57%) of the analytical articles emphasize architectural issues relating to CA, followed by effects/consequences of CA (29%). Only one article (14%) investigates factors affecting CA, and that is also the only article in the entire period focusing on this area. Among the three empirical articles, two (67%) examine the effects/consequences of CA and one (33%) studies architectural issues relating to CA.

In the first developing period, the analytical approach is still the dominant research method being employed. Specifically, 55.56% articles published in this period apply the analytical method. Among these articles, 54.29% focus on architectural issues relating to CA, 28.57% discuss effects/consequences of CA, and 17.14% analyze factors affecting CA. Although the distribution of analytical articles in this

period is similar to the distribution in the emerging period, the number of articles in this area is about 4 times larger in the first developing period.

In addition, compared with the emerging period, many more (7 times) empirical studies are conducted in the developing period. This growth indicates that, with the development of CA research, investigators were becoming more concerned with the application of CA models and related technologies in audit practice. Moreover, the main research interest of empirical researchers shifted from effects/consequences of CA to factors affecting CA. In this period, there are 11 (52.38%) empirical articles emphasizing factors affecting CA, while only 3 (14.29%) focus on effects/consequences of CA. This change in research emphasis implies that the CA concept has been widely accepted such that its implementations are now being more seriously considered. The remaining 7 empirical articles (33.33%) in this period investigate architectural issues relating to CA, and mainly deal with building CA systems in practice.

The first archival study is conducted in 2002, emphasizing the architectural issues relating to CA. After that, 6 other archival studies were successively conducted with different specific areas of emphasis. But, in general, architectural issues relating to CA, such as the enabling technologies, are the major (71.43%) focus of archival studies in this period. Even though the expansion of archival studies in this period implies the development of CA, this uneven distribution reflects that CA is still a developing research area where little secondary data is available to study the effects/consequences of CA and factors affecting CA.

In the second developing period, the most significant trend is that the analytical approach is no longer the leading research method (37.78%). Instead, empirical studies are conducted more frequently (53.33%). This transition may result from an increasing acceptance and adoption of CA in practice. Archival studies (8.89%) remain the least applied research form during this period. As explained previously, this may be due to limited availability of CA-related secondary data.

Concerning specific area of emphasis, architectural issues relating to CA are still the most studied (46.67%) area in this period. One possible explanation for this phenomenon is that CA is a very technology-dependent research area. CA architecture evolves in conjunction with the associated technology. At least partially because of this, we can expect that architectural development of CA models and systems will continue to be a critical research area in the future. Furthermore, those models and systems will incorporate the most advanced information technologies. Unlike the first developing period, the second most emphasized research area is effects/consequences of CA (35.56%), and the least studied area is factors affecting CA (17.78%). Among all the studies investigating effects/ consequences of CA, half of them are empirical studies. In addition, all archival studies in this period focus on effects/consequences of CA. This distribution may be attributable to the existence of actual CA implementations providing both real cases and secondary data for researchers to use in evaluating the effects/consequences of CA. With the continuously increasing applications of CA in practice, we can anticipate that the effects/consequences of CA will remain an attractive research area in the future.

3.3.6. Longitudinal analysis of topical area by specific area of emphasis

This section analyzes the trend of the topical area of CA research by its specific area of emphasis. Longitudinally, the topical research area of continuous audit literature, as shown in the prior sections, suggests that research efforts are mostly clustered in the general CA area. By extending the analysis to cross examine each topical area by sub-areas of specific emphasis (Fig. 2 and Table 6), the overall results indicate that continuous audit research has been mainly focused in the general CA area with emphasis on architectural issues of CA (14.4%) and with emphasis on the effects/consequences issues of CA (14.4%) between 1983 and 2011. Research on the controls monitoring topical area, with analysis on architectural issues of CA (10.2%) and enabling technology relevant research with architectural issues discussions on CA (9.3%), are ranked as the third and fourth areas of focus. Overall, research on the architectural issues of CA, including systems architecture, audit parameters, information processing, and security relevant topics, were the most popular subfields in terms of research effort.

Under the general CA topical area wherein research examines the grounding theory and framework of CA, the specific area of emphasis mainly relates to the architecture of CA and effects/consequences of CA across the entire analysis time frame. In the emerging period, research emphasizing the effects/ consequences of CA was only marginally higher than that pertaining to architectural issues of CA, with
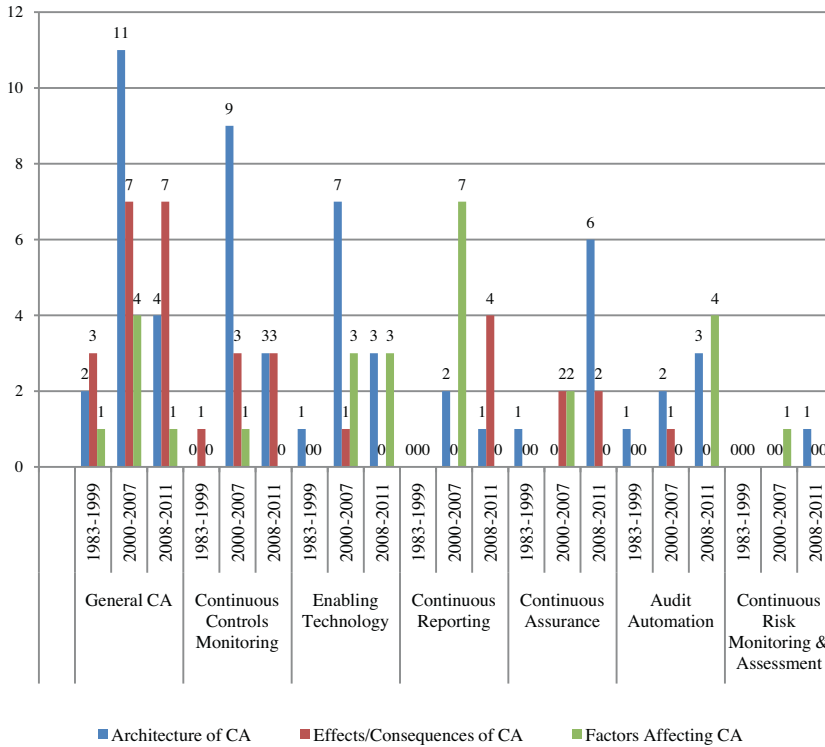
Fig. 2. Over time trends of topical area by specific area of emphasis.

one additional publication conducted in the former area. However, in the first developing period, 50% of the research focused on the architecture of CA where system architecture, audit parameters, information processing, and security aspects were investigated more in depth within a theoretical framework setting. A reversal of this observation was shown in the second developing period, where effects/consequences of CA became the dominating subarea (58.33%). In an overall sense, factors affecting CA accounts for the lowest proportion of research in all three periods, although there was a growth trend in this area from the emerging to the first developing period. This finding suggests that research concerning the grounding theoretical framework of CA was not as frequently examined jointly with the factors of CA (i.e., business functional areas amenable to CA, industry characteristics amenable to CA, and internal versus external audit differences under CA) compared to its joint analysis with architectural issues and effects/consequences of CA. This observation could suggest that the scope of business functions, industry characteristics, and impacts from internal/external audit factors of CA is considered to be rather broad when compared with systems architecture issues (under architectural) or behavioral effects (under effects/consequences of CA). These topics could be relatively more challenging to examine or envision from a theoretical framework viewpoint as a whole. However, one would expect the trend of growth from the second period to extend continuously into the third period, but this was not observed. Research opportunities still abound in these subfields.

Research in the area of continuous controls monitoring (CCM) examines the continuous monitoring of relevant internal controls issues. After the Drew (1987) publication, which examined the usage of post-audit and client-tracking audit control system tools, the apparent research development in this topical area was observed to be in the 2000–2007 period. Specifically, most CCM research in this period occurred within the architectural issues of the CA sub-area (69.23%). This is in alignment with the expectation that extensive progress would be observed initially within the design and pilot testing of controls monitoring tools/techniques, after which effects could be investigated. In

Table 6

Over time trends of topical area by specific area of emphasis.

Topical area		Specific area of emphasis						Total
		Architecture of CA		Effects/conse-quences of CA		Factors affecting CA		
General CA	1983–1999	2	33.33%	3	50.00%	1	16.67%	6
	2000–2007	11	50.00%	7	31.82%	4	18.18%	22
	2008–2011	4	33.33%	7	58.33%	1	8.33%	12
	Subtotal	*17*	*42.50%*	*17*	*42.50%*	*6*	*15.00%*	*40*
Continuous controls monitoring	1983–1999	0	0.00%	1	100.00%	0	0.00%	1
	2000–2007	9	69.23%	3	23.08%	1	7.69%	13
	2008–2011	3	50.00%	3	50.00%	0	0.00%	6
	Subtotal	*12*	*60.00%*	*7*	*35.00%*	*1*	*5.00%*	*20*
Enabling technology	1983–1999	1	100.00%	0	0.00%	0	0.00%	1
	2000–2007	7	63.64%	1	9.09%	3	27.27%	11
	2008–2011	3	50.00%	0	0.00%	3	50.00%	6
	Subtotal	*11*	*61.11%*	*1*	*5.56%*	*6*	*33.33%*	*18*
Continuous reporting	1983–1999	0		0		0		0
	2000–2007	2	22.22%	0	0.00%	7	77.78%	9
	2008–2011	1	20.00%	4	80.00%	0	0.00%	5
	Subtotal	*3*	*21.43%*	*4*	*28.57%*	*7*	*50.00%*	*14*
Continuous assurance	1983–1999	1	100.00%	0	0.00%	0	0.00%	1
	2000–2007	0	0.00%	2	50.00%	2	50.00%	4
	2008–2011	6	75.00%	2	25.00%	0	0.00%	8
	Subtotal	*7*	*53.85%*	*4*	*30.77%*	*2*	*15.38%*	*13*
Audit automation	1983–1999	1	100.00%	0	0.00%	0	0.00%	1
	2000–2007	2	66.67%	1	33.33%	0	0.00%	3
	2008–2011	3	42.86%	0	0.00%	4	57.14%	7
	Subtotal	*6*	*54.55%*	*1*	*9.09%*	*4*	*36.36%*	*11*
Continuous risk monitoring and assessment	1983–1999	0		0		0		0
	2000–2007	0	0.00%	0	0.00%	1	100.00%	1
	2008–2011	1	100.00%	0	0.00%	0	0.00%	1
	Subtotal	*1*	*50.00%*	*0*	*0.00%*	*1*	*50.00%*	*2*
Total		57	48.31%	34	28.81%	27	22.88%	118

2008–2011, an equally weighted development of research in architectural issues and effects/consequences relevant issues were examined with a proportion of 50% of publications in each respective area.

Overall, CA research in the enabling technology topical area is the third ranked topical area. The publications mainly focused on the architecture of CA issues in the first developing period (63.24%) and in the second developing period (50%). In an attempt to facilitate the application of continuous auditing in industry, a number of techniques/models/systems were developed in research such as continuous auditing web services (Murthy & Groomer, 2004), continuous auditing assistance systems (Li, Huang, & Lin, 2007), and rule-based and case-based reasoning internal audit approaches (Lee, 2008a,b). Research examining technologies and its effects on CA, such as the adoption and usage of XBRL and its relationship with continuous auditing and continuous reporting, was found to be the second most popular subfield in both the 2000–2007 and 2008–2011 periods, with the latter period accounting for the same proportion (50%) of publication as those in the research in architectural issues of CA. This suggests that the trend of research in the subfield of essential technologies that supports continuous reporting is gradually extending from the relatively technical architectural aspect toward the application and usage phase.

Of the research published in continuous reporting, an interesting observation involves the significant growth of research (77.78%) in the factors affecting CA in the first developing period 2000–2007. In particular, the seven publications examined various aspects of corporate reporting such as the

frequency and segments of reporting, real time and continuous reporting possibilities, and the role of the Internet with online reporting. In the second developing period, most of the research was found to be focused on the effects/consequences of CA (80%) of continuous reporting, in which analysis is mainly conducted with usage of financial market data.

In the continuous assurance topical area, research examines the broader aspect of continuous auditing with inclusion of continuous data assurance, systems assurance, continuous online assurance and external continuous assurance research. The apparent growth in research in this subarea is shown in the 2008–2011 period, with 75% of the research focused on the architecture issues of CA and 25% of the research on the effects/consequences of CA. In terms of average yearly publication, the trend increased from the second period from 0.5 articles per year to 2 articles per year in the third, indicating a solid increasing trend within this topical area as a whole.

Audit automation relevant research examines the issues relative to transition of auditing procedures from manual to automate. The trend of research increased over time with emphasis on the architectural issues (54.55%) and factors affecting CA (36.36%), and this began with the Vasarhelyi (1983) article on the proposed research framework for audit automation. In recent years, many studies have examined the individual and/or firm-based factors that would influence computer-based audit procedures, and the effects of those factors on technology implementation decisions in auditing (e.g., Curtis & Elizabeth, 2008; Janvrin, Bierstaker, & Lowe, 2009).

Continuous risk monitoring and assessment is a topical area with relatively fewer publications compared with other subareas. The associated studies (Fukukawa & Mock, 2011; Sutton & Hampton, 2003) examine risk assessment techniques in audit process with implications for the usefulness of risk monitoring and assessment in continuous auditing. There are certainly research opportunities that could be explored in this area, especially in the further application of these assessment tools as possible preventive techniques in continuous monitoring and internal controls.

4. Paths for future research

Unlike many other areas of research, the automation of auditing is directly and closely linked to technological developments both from the driving force of technology absorption into business and from the consequent and delayed usage in the audit process. The Internet, electronic commerce, XML, and EDI have given way to Big Data, RFID, Intelligent Agents, and Audit Analytics. Audit automation is a facilitator of close-to-the-event or continuous auditing. CA cannot be performed without a strong infrastructure of automation. Due to this closeness of structures, the terms "audit automation" and "continuous auditing" are mainly used interchangeably in this paper. Extant research described in this paper primarily entails technological understanding, normative pieces focusing on audit approaches, and analytical methods. The rapid change of technological enablement is driving the need for rapid knowledge development and leading to the obsolescence of traditional audit methods (Titera, 2013). Consequently, research in the area of audit automation will have to (1) deal with utilization of new technologies and (2) change auditing in light of these new technologies. This pattern of research focus has been observed in the three periods of research characteristics development, especially in the enabling technology, audit automation, continuous assurance and general CA sub-areas. The above macro trends show that CA research is very strongly influenced by forthcoming technology and its adaptation to usage in auditing. Consequently, we briefly discuss the future and potential paths of related research.

4.1. A view of the future

Moffitt and Vasarhelyi (2013) state, "the ubiquitous access of Big Data presents fundamental challenges and change for organizations, yet the challenges have not been fully embraced, and change has not been fully integrated by accounting and auditing functions." They proceed to examine the effects of the advent of Big Data in accounting, auditing, and standard setting.

Large data populations, computer-based processes, and a preponderance of automatic data collection are making manual auditing methods impossible. Consequently, research is needed to formalize accounting, analytic methods, and audit processes (Krahel, 2012; Vasarhelyi &

Krahel, 2011). Furthermore, this automation is not restricted to the processes but must also be reflected in published accounting and auditing standards (Titera, 2013; Zhang, Pawlicki, McQuilken, & Titera, 2012).

4.2. Potential research areas for the next cycles

The three periods of research discussed in this paper intersperse the consideration of internal control systems with the development of technology. Continuous audit and monitoring processes look at control monitoring in a progressively automated manner.

4.2.1. Internal controls

The advent of Sarbanes–Oxley Section 404 gave increasing impetus to this consideration, although lack of formalization continues to hinder the development of control benchmarks and assessment tools. The work of Bailey et al. (1985) has not been followed by formalization research that can be used for control monitoring and assessment (Vasarhelyi, Alles, et al., 2010; Vasarhelyi, Krahel, et al., 2010), which is necessary for CCM. Although traditional "data" audits had a century to evolve, the requirement of attestation of controls systems is new and guidance is very limited and qualitative. It likely is the area of audit practice research that needs more attention.

4.2.1.1. Proposed researchable questions – on internal controls.

- How can internal control structures be represented in a formal manner (Bailey et al., 1985; Cash et al., 1977)?
- How can internal control assessment be made quantitatively?
- How can the measurements of continuous risk monitoring and assessment (CRMA), Continuous Data Audit (CDA), and Continuous Control Monitoring (CCM) (Vasarhelyi, Alles, et al., 2010; Vasarhelyi, Krahel, et al., 2010) be integrated?

4.2.2. Automating and extending accounting

"Big Data can improve the core functions of accountants: recording events, reporting to regulators and stakeholders, and enforcing internal controls…... Some of the major topics that accounting researchers need to examine with respect to Big Data are measurement and representation methods, data formalization, semantic understanding of textual data, improved assurance procedures, and social welfare implications." (Moffitt & Vasarhelyi, 2013)

These factors deal with business measurement and its deficiencies. Big Data and e-commerce allow for the valuation of certain items based on real-time measurements in B2B markets, current transaction recording (e.g. real estate sales), etc. Measurements of assets based on historical values will tend to change the actual measurement of business and also the validation of the transactions being recorded maybe prior to recording. Although typically transactions are only recorded after the event, many preliminary steps must be taken for them to happen (Vasarhelyi, Romero, Mock, & Gal, 2012). The CA model can take a predictive or even preventive (Kuenkaikaew, 2013) orientation, adding characteristics to the audit such as real time verification, even maybe performing this operation prior to transaction execution.

4.2.2.1. Proposed researchable questions – on automating and extending the model.

- How can the preventive or predictive CA model be expanded with real time verification feature at the transaction level (Kuenkaikaew, 2013)?
- What are the tradeoffs between human and automated judgment when designing human machine interactions in automated audit systems?
- How do you modularize/formalize the audit process to automate some of its elements (Teeter, 2014)?

4.2.3. New evidence in auditing

Modern technologies create both tremendous efficiencies as well as threats to privacy and security. These latest advancement in technologies can also be used for audit processes. The same camera and face recognition device that monitors a warehouse and can reveal private events can also be used to confirm deliveries of materials and quantities being subsequently recorded. The same technology used for controlling access can be used to confirm access and billing hours per service.

Audit confirmations are part of the anachronistic set of methodologies in auditing that are not appropriate for assurance in the real-time age. Manual confirmations matching supplier or bank records with a sample of corporate records have little meaning within enormous transaction pools. On the other hand, automatic confirmations (Vasarhelyi, Alles, et al., 2010; Vasarhelyi, Krahel, et al., 2010) which match databases provide, in many instances, exact verification and reduce the nature of assertions necessary to be evaluated.

Other new forms of evidence brought in by CA demand not only normative research on the area of proposed tools and analytic methods but also integration of this evidence (e.g., CA alerts, discrepancy from predictive models, weakness of specific controls) into the assurance model. Furthermore, Big Data can prompt reconsideration of the audit model in light of tracking other data that complements transactions, as discussed above.

4.2.3.1. Proposed researchable questions – on continuous audit evidence.

- How can the evidence from Big Data and from devices such as GPS and RFID be integrated into the audit model (Hoodguin, Yoon, & Zhang, in press)?
- How do you integrate management monitoring needs (Ramamoorti, Cangemi, & Sinnett, 2010) with the needs of real time assurance, the bridges of Big Data, and the new forms of audit evidence?
- Can real time corrections, based on extended evidence, be part of the audit value chain or they are (in the traditional jargon) just a control?
- Have the real-time sales and order execution of E-commerce required new forms of preventive audit and support of new non-traditional evidence?

4.2.4. Analytic methods in auditing

Various analytic models, from operations research to machine learning, have been proposed for auditing (Kogan, Alles, Vasarhelyi, & Wu, 2011; Kuenkaikaew, 2013; Thiprungsri & Vasarhelyi, 2011). Large corporate ecosystems automating many of the previously manual processes require automated assurance both in terms of controls as well as data and risk monitoring (Vasarhelyi, Alles, et al., 2010; Vasarhelyi, Krahel, et al., 2010). Normative, applied, and secondary archival studies are needed in this area. Secondary archival studies (Chiu, 2013; Vasarhelyi et al., 1988) such as this paper and Brown et al. (2007) can provide a wider view of the path, conclusions, and directions for new research in CA.

4.2.4.1. Proposed researchable questions – on analytic methods in auditing.

- How can the preventive audit model be applied within the context of todays' GAAS and PCAOB oversight (Kuenkaikaew, 2013)?
- How can continuity equations (Kogan & Vasarhelyi, in press) be integrated with preventive modeling (Kuenkaikaew, 2013)?
- How do you integrate management monitoring needs (Ramamoorti et al., 2010) with the needs of real time assurance?

4.2.5. Adapting CA technology to new technology

The three periods of research on CA evaluated in this paper show the absorption of technology into business, use of technology in auditing, and utilization of technology as an assurance tool. The original illustration of CA at Bell Laboratories (Vasarhelyi & Halper, 1991) used primitive communication networks (RJE stations, print images, e-mail), limited computational power, and traditional assurance methods. Much research is needed relative to (continuous) audit of Big Data, E-Commerce, transaction level XML, intelligent agents, textual analysis, etc.

4.2.5.1. Proposed researchable questions – on adapting CA technology to new technology.

- How can Big Data be better formalized, measured and represented to enable applications of continuous auditing (Kogan & Vasarhelyi, in press)?
- How would controls and the ecosystem of audit support be different for Big Data (Kozlowski, 2014)?
- What types of textual analysis techniques can be used as "bridges" in conjunction with continuous auditing methodology (Kogan & Vasarhelyi, in press)?
- What type of new evidence will be brought into continuous auditing by Big Data (Hoodguin, Yoon, & Zhang, in press)?

4.2.6. Formalizing standards

Krahel (2012) and Vasarhelyi and Krahel (2011) have argued the need for standards that should be unambiguously embedded into computer code. The reasoning for this argument is that most accounting rules are implemented in ERPs as computer code, and any ambiguity will be resolved by systems analysts and programmers. Many accounting rules have ambiguous interpretation and rely on an extensive set of clarifications by the FASB. With the progressive automation of auditing, this need is becoming even more apparent in the audit area. Researchers will have to work to disambiguate audit rules, and, together with software vendors, negotiate clarifications from the PCAOB and other standard setters. The emergence of frequently used audit analytics will create further demands for formalization and specific guidance by the standard setters.

4.2.6.1. Proposed researchable questions – on formalization of standards.

- What type of guidance can be provided to standard setters and issuers of regulations on the nature of formalized standards?
- How should the standard setting process be changed to allow for immediately implementable into ERP standards?
- How can standards deal with the advent of Big Data (Kogan & Vasarhelyi, in press) and its usage in the initiation and the assurance of processes?

4.2.7. Other

The progressive automation of assurance and auditing is also following the trend of progressive adoption of smarter devices (McAfee & Brynjolfsson, 2012), and will eventually result in substantive adjustments to the nature of the workforce, structure of audit entities, and audit standards. The American Institute of Certified Public Accountants has issued guidance for content and formats of data to be provided to auditors (Titera, 2013; Zhang et al., 2012) as a first step to facilitate data usage. Many research issues involve the impact of audit technology on the behaviors, careers, and qualifications of auditors in a continuous audit environment.

4.2.7.1. Proposed researchable questions – on auditors' behaviors, careers & qualifications in ca environment.

- How can performance evaluations and training be conducted to assure the familiarity and credentials of auditors' work in a continuous audit environment (Vasarhelyi, Alles, et al., 2010; Vasarhelyi, Krahel, et al., 2010)?
- With the advent of many new technologies and its application in accounting and auditing tasks, how could relevant audit standards be revised accordingly to enable assurance on audit quality in the long run (Krahel, 2012)?
- Will CA decrease the number of practicing auditors due to its automation characteristics?

There are also many social welfare issues to be considered, such as the change in audit economics, benefits to the organization and society of a more detailed, frequent, and transparent audit, and discussions regarding whether the public good would be served if large research-oriented public financial related databases could be made available to the accounting research community.

5. Conclusion and implications

Advances in technology are significant forces affecting the accounting profession (AICPA, 1998). Traditional auditing has been affected by the evolution of management information systems (MIS), thus creating a new set of audit issues. The need for stakeholders to obtain more timely information as well as assurances pertaining to the integrity of that information has expanded. The opportunities and potential to apply information technology in the audit field have been continuously growing with technology advancement. Continuous auditing fundamentals, theories, and implementations have been established and explored in practice for over two decades. Acknowledging the importance of this research stream, this study reviews extant prior literature concerning continuous auditing, and reveals the development of its research characteristics using a newly developed four dimension taxonomy.

Our analysis show that continuous auditing research is longitudinally mainly normative analytical. Empirical survey and case studies categories were the second and third most frequently used methods. The specific areas of emphasis include the development of systems/models that assist with the continuous audit, demand and environment that triggers CA growth, and enabling technologies for CA applications. The work is primarily sourced in the United States.

With the application of taxonomic classification and content analysis approaches, the main characteristics of continuous auditing research since the early 1980s have been identified. It is worth noting that the studies in each of the three periods not only suggest research accomplishments but also provide educational implications in supporting accounting information systems courses in higher education programs. New scholars would find it helpful to refer to the continuous audit taxonomy for grasping the understanding of continuous audit development upon entering accounting academics. In the most recent period, research shows more collaboration between continuous audit academic research and audit practice oriented research, which is a promising and valuable sign of growth. If research ideas are generated with referencing feedback, opinions, and perceptions of practitioners, this might facilitate improved collaborations between academics and practitioners. Doing so would minimize the often-cited gap between academic accounting research and professional practice, at least in the continuous auditing field.

This study attempted to search and collect the entire set of literature relevant to continuous auditing by utilizing numerous online databases, however, there may still be a potential limitation in having an incomplete dataset. However, as both the number of articles and analysis extends beyond prior secondary review studies, the findings reported here still reveal the grand structure and characteristics of the field.

Along with the growth of applications and concepts of information technology, the need for obtaining timely financial information and assuring control data integrity have gained importance over time. These requirements can be met by applying new accounting information systems techniques within businesses. Knowledge development within the continuous auditing field as represented by research characteristics will continue to grow and mature with emerging technologies in the future.

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