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Four Decades of Chief Information Officer Research: A Literature Review and Research Agenda Based on Main Path Analysis

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Abstract

Despite the relevance and maturity of the Chief Information Officer (CIO) research field, no studies exist that exhaustively summarize the current body of knowledge, focusing on the development of the field over its entire timespan. The paper at hand addresses this research gap and presents an exhaustive literature review on the CIO research field using main path analysis. We identify the central papers in CIO research and eight main research streams by quantitatively and qualitatively analyzing 466 papers. We find that established research streams, e.g., 'Evolving role of the CIO' and 'CIO hierarchical position and relationships' as well as recently emerging research streams, e.g., 'CIO as business enabler' and 'CIOs and IT security,' draw growing attention. Based on our findings, we develop promising further avenues for research in the CIO field.

Keywords: Chief Information Officer; Literature Review; Research Agenda; Main Path Analysis; Bibliometric Analysis.

Introduction

With the increasing importance of information technology (IT) in organizations and the need to exploit new technologies to enable business growth, the role of the Chief Information Officer (CIO) as the highest-ranked IS executive enjoys unprecedented attention. The CIO is widely studied in IS research with topics including, e.g., its role (Applegate & Elam, 1992; Peppard et al., 2011), rank (Raghunathan & Raghunathan, 1989), and relationships (Feeny et al., 1992; Preston et al., 2006). Having started as a technical manager (Ives & Olson, 1981), the role of the CIO quickly evolved to that of a general manager and, lastly, even to an executive being part of the top management team (TMT) (Hütter & Riedl, 2011; Riedl et al., 2008; Stephens et al., 1992). With this change, CIOs' responsibilities and tasks increased significantly, and, hence, CIOs' role profiles became more diverse. This diversity sparked new interest in the manifestations and effects of different role profiles. Preston, Leidner, and Chen (2008) identified four CIO leadership profiles based on a CIO's strategic decision-making authority as well as strategic leadership capability. Each leadership profile, *IT Orchestrator*, *IT Laggard*, *IT Advisor*, and *IT Mechanic*, benefits an organization differently. Later on, Peppard et al. (2011) derived five distinct CIO roles using the dimensions importance of IT for differentiation in the industry and the maturity of IS leadership capabilities in the organization. From low to high along the two dimensions, the roles are *Utility IT Director*, *Evangelist CIO*, *Innovator CIO*, *Facilitator CIO*, and *Agility IT Director/CIO*. While these findings indicate that different types of CIOs are needed, most organizations still only have one CIO to incorporate multiple roles.

Over time, the CIO went from purely supply-side focused (e.g., *Utility IT Director*) to a more and more demand-side focused role (e.g., *Agility IT Director*) that not only has to run the IT but also has to enable new business opportunities (D. Q. Chen et al., 2010). Balancing supply- and demand-side leadership poses conflicting priorities for the CIO (Mehta et al., 2019). As demand-side leadership rapidly increases in importance, the CIO needs to achieve ambidexterity to drive IT-enabled business innovation and digital transformation (Bekkhuis & Hallikainen, 2017; Kalgovas et al., 2014b). Especially the evaluation and adoption of cutting-edge technologies is a top priority for organizations of all sizes; CIOs play a pivotal role in driving such adoptions (J. Li et al., 2021; Parra et al., 2021; Scuotto et al., 2022). Additionally, more recent threats, like a significant increase in IT security breaches, keep augmenting CIOs' responsibilities (Banker & Feng, 2019; Benaroch & Chernobai, 2017).

The CIO has been subject to research for about 40 years already, and the field still draws high research attention due to its relevance. Consequently, previous works reviewed and analyzed CIO research and provided insights into the research field (e.g., Drechsler, 2020; Hütter & Riedl, 2017; Karahanna & Watson, 2006). However, these reviews are limited in two ways. Some of the previous reviews limit their studies' scope by having a predefined topic, like CIO role effectiveness (Hütter & Riedl, 2017) or CIO leadership characteristics and style (Ghawe & Brohman, 2016). Other reviews limit the scope of their studies to selected publication outlets due to the vast number of publications in the research field (e.g., Drechsler, 2020; Shawosh, 2018). While both types of reviews are essential, neither focuses on identifying the flow of knowledge over time and the emergence of new streams of research in a comprehensive manner. Further, all existing reviews use qualitative-descriptive methods and limit their data to selected databases, journals, or conferences.

Conducting a descriptive literature review is demanding and, hence, restricted by its authors' knowledge structure, time, and energy (Raghuram et al., 2010). Thus, the number of papers in scope is naturally limited. This is unfavorable as the CIO research field is mature and exhibits many publications. To conduct a literature review in a mature field, the challenge of selecting relevant papers within the research field must be addressed since not all documents can be evaluated. To address the challenge of having an overwhelming number of publications in the

research area, more and more researchers advocate a combination of quantitative and qualitative methods to assess the state of the art in a research field (Larsen et al., 2019; Wagner et al., 2021). While the relevance of a paper is often derived from the prestige of the publication outlet and the number of citations, these measures alone are not sufficient to deem a paper important for a specific research field. The work of Kappelman et al. (2019), for example, is highly cited, but in our later analysis, we did not find a single citation within the CIO network. The bibliometric method we have chosen for our paper, main path analysis, quantitatively identifies research routes through citations within the CIO research network, independent of the publication outlet or number of overall citations. This way, the selection of publications to be considered in the literature review is more objective and is based on the flow of knowledge over time. Such an approach also supports the identification of emerging research streams that were previously overlooked.

Main path analysis as a method allows us to expand the scope of a literature review vastly and to apply a rigorous method for identifying relevant papers and research streams more objectively and with a focus on the development of the field over time. The focus on knowledge flow also allows the identification of emerging topics in a way that is less prone to personal bias. While the CIO research field is mature and therefore vast, it is still timely and topical, thus yielding promising future research potential. Hence, we aimed to review the field in a way that accommodated these characteristics. As not a single review used quantitative methods to analyze CIO research yet and thus could cover a comprehensive set of papers that were selected more objectively, we aim to close this void. Therefore, our aim to analyze the field as comprehensively as possible, along with a focus on knowledge dissemination and emerging fields, is reflected in the following research questions and the chosen methodology:

Research Question 1 (RQ1): What are the major and emerging research streams in CIO research, and how did they evolve?

Research Question 2 (RQ2): What are central papers in CIO research?

Research Question 3 (RQ3): What are promising further avenues for research in the CIO field?

While answering these research questions, this paper makes several contributions. We conduct the first quantitative literature review in the CIO research field and, thereby, cover a large scope of papers and apply corresponding bibliometric analysis techniques. Combined with a qualitative interpretation, we evaluate and complement the findings of previous qualitative reviews. Further, we provide a comprehensive overview of CIO research in its entirety by illustrating the structural knowledge flow, summarizing the central papers, and identifying emerging trends and promising further avenues in the CIO research field.

The paper is structured as follows: Following the introduction, we elaborate on findings from previous literature reviews of CIO research. After describing the methodology applied in the paper at hand, we summarize the data collection and analysis efforts, present our findings, and identify trends in CIO research. As the last step, we contrast our findings with existing research, illustrate a research agenda, and conclude the paper.

Previous reviews of CIO research

This section provides an overview of previous literature reviews of CIO research. CIO research was the subject of reviews in various publications (see Table 1). However, there are relatively few reviews in light of the research field's maturity and relevance. Further, all reviews use qualitative-descriptive approaches with a limited scope regarding the number of papers analyzed.

Insert Table 1 About Here

We categorize the existing literature reviews of CIO research into two groups. Reviews with a narrower research question that focus on a specific sub-stream of CIO research, e.g., CIO effectiveness or leadership capabilities, and reviews that analyze CIO research in a more general and broader review.

Four reviews (Ghawe & Brohman, 2016; Hütter & Riedl, 2017; Menz, 2012; Singh, 2015) focus on a specific sub-stream of CIO research. Menz (2012) analyzes 39 papers and describes the existing literature on functional TMT members, and contrasts and compares them. Singh (2015) classifies 28 papers into three different research streams and elaborates on existing CIO role effectiveness research gaps. Ghawe and Brohman (2016) focus on leadership characteristics and style and develop a CIO leadership framework by analyzing a total of 48 articles that fit the research question. Hütter and Riedl (2017) identify six types of CIO roles in literature and, based on that,

develop a CIO role effectiveness model by analyzing 98 articles within a time horizon of 35 years. This review is the most comprehensive and notable of the existing reviews.

The other CIO reviews belong to the group of more general reviews. The first to summarize CIO research and identify dominant themes were Karahanna and Watson (2006), who derive seven streams from 43 papers. Several years later, Shawosh (2018) synthesizes CIO research from 2007 to 2017 and derives an IS strategic leadership framework as well as theoretical and practical implications. The most recent review by Drechsler (2020) examines the contribution of IS executives to organizational performance by including publications from the IS senior scholars' basket, the MIS Quarterly Executive, as well as papers published in the proceedings of the International Conference on Information Systems (ICIS).

Method

This section provides an overview of our applied method by first introducing the principles of main path analysis, second elaborating on the two types of main paths used, and third by providing advantages of main path analysis.

Citation relationships between research publications are seen as a way to trace discoveries and follow knowledge development (Garfield et al., 1964). In any scientific field, new knowledge is developed by leveraging existing knowledge and adding new ideas. The existing knowledge is referenced through citations, leaving a citation relationship between a paper and its references. At the point of publication, the respective paper will again serve as existing knowledge and could be referenced by another paper. These citation relationships build a directed, acyclic network that grows larger over time (J. S. Liu & Lu, 2012). Using the bibliometric data in CIO research, we can build a citation network that illustrates the knowledge dissemination in this field.

There are various quantitative ways to analyze such bibliometric data (C. Chen, 2006). We use main path analysis as it not only takes the number of citations of a paper into account but instead analyzes the citation relationship between two papers itself. Hummon and Dereian (1989) are the first to suggest main path analysis to detect the main idea flow of literature within a research area. Verspagen (2007) further contribute to it by adding a methodology that searches for multiple main paths. J. S. Liu and Lu (2012) further develop this approach and ensure the inclusion of key-routes in the network. The validity of the main path analysis, in general, was shown by several studies (Hung et al., 2014; Liang et al., 2016; J. S. Liu et al., 2013). In the IS field, several research fields were already analyzed through main path analysis: IT outsourcing (Cui et al., 2012; Liang et al., 2016), business-IT alignment (Jia et al., 2018), and e-governance (Bindu et al., 2019). Also, methodological fields such as data envelopment analysis (J. S. Liu et al., 2013; J. S. Liu et al., 2016) were reviewed using main path analysis.

In a citation network, papers are represented through nodes and their citation relationships through directed links. Incoming links connect a paper to its references. Outgoing links represent citations of it by other papers. As a research field is finite, some papers only exhibit outgoing links, called sources, as well as papers that only have incoming links, called sinks. A source is where knowledge in a specific field evolves; a sink is where it ends. Most papers have incoming and outgoing links, while in rare cases, papers have neither (Liang et al., 2016; J. S. Liu & Lu, 2012).

Insert Figure 1 About Here

We make use of the search path count (SPC) method to identify the importance of each link in our citation network. Hummon and Dereian (1989) developed this method, and Batagelj (2003) later recommended it. Several other citation network analyses made use of it (e.g., Liang et al., 2016; J. S. Liu et al., 2013; J. S. Liu & Lu, 2012). Figure 1 shows an exemplary citation network with SPC values for each link. The idea of the SPC method is to follow every possible path in the network and count the times each link is traversed (i.e., passed). A path, in this case, always starts at a source and ends in a sink. One of the six possible paths, for example, is N3 to N6 to N8 (see Figure 1). By following this path, the links N3-N6 and N6-N8 are traversed, and, hence, the traversal count of each link is raised by 1. As the link from node N3 to N6 is traversed twice, its traversal count is double the traversal count of the link from, e.g., node N1 to N4. After all possible paths are followed, the result is a weighted, acyclic, and directed citation network.

The global main path refers to the path that exhibits the highest SPC, i.e., the highest overall traversal count (J. S. Liu & Lu, 2012). It combines the most traversed links and, therefore, the main knowledge dissemination path. Having the central papers of CIO research represented, it can be seen as the "backbone" of the citation network (Liang et

al., 2016). In our example, in Figure 1, the global main path is N3-N6-N5-N7, with an overall traversal count of 7.

While the global main path shows the structural knowledge flow of CIO research through a selection of central papers, it only represents a small part of the overall network. More paths can be iteratively added to the analysis to identify the knowledge flow in more detail. It is like zooming in and discovering more and more features of the network. Two potential methods are the multiple main paths and the key-route main paths analysis. We use the global key-route main paths method to complement the global main path method in this paper.

The multiple main path analysis includes the next several paths with the next highest overall SPC values. Verspagen (2007), J. S. Liu et al. (2013), and Liang et al. (2016) also use this method to observe a more detailed development of knowledge. The disadvantage of this method is that the links with the highest traversal count will not necessarily be included as the approach only considers the sum of SPC values of complete paths (J. S. Liu & Lu, 2012).

In contrast, the global key-route main paths analysis overcomes this problem by iteratively including those links with high traversal counts, i.e., key-routes, and their respective paths. First, the link with the next highest traversal count is identified. Then, the path searches backwards until a source is hit and forward until a sink is hit, maximizing the traversal count in both directions (J. S. Liu et al., 2019). Hung et al. (2014) use this method to show the technological change in lithium iron phosphate batteries, and J. S. Liu and Lu (2012) also conclude that it is the best method to visualize a knowledge development structure because it includes the relevant elements from local as well as global main paths. The more key-routes are included, the greater the level of detail in the resulting network. How many key-routes to include in the analysis is based on the level of detail one wants to analyze. The resulting network shows the most important knowledge dissemination routes in CIO research, with each paper playing an important role. To ensure procedural consistency, we closely follow the methodologies and illustration types of Liang et al. (2016).

There are several advantages of main path analysis. First, it helps to trace the main knowledge flow of a research field and to identify the emergence and evolution of research streams over time (Liang et al., 2016; J. S. Liu et al., 2013). Second, main path analysis identifies the direct and indirect importance of a paper within a specific research field by including and highlighting the ones that get traversed most often and excluding others (Hung et al., 2014). Third, the method enables the more objective identification of research streams through citation relationships and avoids subjective interpretation of literature relevance and research fields through researchers (Raghuram et al., 2010).

Data Collection and Analysis

We blend multiple bibliometric databases and identify citation links through a self-developed python script to receive a comprehensive set of publications concerning the CIO and ensure high-quality citation data. Figure 2 provides an overview of the data collection, cleaning, preparation, and analysis process, which we will outline in the following.

Insert Figure 2 About Here

While there are numerous databases for conducting bibliometric analysis in science, each has its characteristics and was developed for a different purpose (Moral-Muñoz et al., 2020). The critical aspect to consider when choosing a bibliometric database is its scientific coverage, meaning the number of indexed papers on a certain topic compared to the complete set of papers on the topic. Using a single database for bibliometric analysis has several advantages, e.g., highly reduced efforts for combining data from different databases and having a unified format of bibliometric data and, hence, avoiding the potential of human error (Donthu et al., 2021). However, it might neglect important parts of the topic since citation counts often differ between databases (Kulkarni et al., 2009). As we aim at being as comprehensive as possible, we manually blend multiple databases instead of just relying on one.

The bibliometric database *Scopus* lists a greater number of journals than *Web of Science* (Paul & Criado, 2020). Additionally, it is known for its high data quality (Baas et al., 2020) and allows for downloading all required citation data and the entire reference list of each paper in a structured format. Hence, we start with an initial set of papers from the database *Scopus* and iteratively complement it with papers from the databases *ABI/Inform*, *ACM Digital Library*, *AIS eLibrary*, *EBSCOHost Business Source Premier*, *IEEE Xplore Digital Library*, *Science Direct*, and *Web of Science*.

Since the study's goal is to provide a complete picture of CIO research, we searched for "(chief information officer[s])"

OR “cio[s]”) in article title, abstract, and keywords within an unlimited time frame up until December 2021 in Scopus (see step 1). The search resulted in a total of 3,618 papers. Since the abbreviation “cio” can have different meanings, the search results include several irrelevant subjects. For example, in medicine, “cio” is used among others as an abbreviation for “cancer information overload” or “charitable incorporated organisation.” Further, many papers in the IS literature provide recommendations for the chief information officer and therefore contain the phrase but do not directly concern the role itself.

Consequently, we performed a manual data cleaning process in three steps (see steps 2 to 4). First, we removed all non-English papers and only kept the papers published in journals or conference proceedings, eliminating 988 papers. Second, we removed 1,613 papers by excluding irrelevant subject areas (e.g., Biochemistry, Genetics and Molecular Biology, Medicine, and Physics) and source titles (e.g., Sistemi Intelligenti). Third, we manually removed 650 papers that were not primarily dealing with the CIO through reading titles and abstracts. The resulting dataset comprises a total of 367 papers.

We conducted two more steps (see steps 5 and 6) to complement the dataset with papers not indexed in Scopus and ensure we have all relevant literature in CIO research included. First, we searched the databases ABI/Inform, ACM Digital Library, AIS eLibrary, EBSCOHost Business Source Complete, IEEE Xplore Digital Library, Science Direct, and Web of Science with similar search conditions as in Scopus. In case we identified relevant papers that were not yet in our dataset, we manually added them as well as their citation data. Further, we conducted a backward search and compared our dataset with CIO research referenced in already existing CIO literature reviews (Drechsler, 2020; Ghawe & Brohman, 2016; Hütter & Riedl, 2017; Karahanna & Watson, 2006; Menz, 2012; Shawosh, 2018; Singh, 2015) and manually added papers if necessary. This step resulted in a total of 106 papers being added outside of Scopus. As the last step, we excluded the seven literature review papers as they address multiple topics and, therefore, would just create noise in the citation network. All of the above steps result in a final dataset comprising 466 papers.

The next step (see step 7) is to identify citation links within the final set of papers. This is not about how often a paper was cited in total, but how often and by whom it was cited within the final set of papers. While such data could be directly retrieved from well-known bibliometric databases, citation counts often differ across databases (Kulkarni et al., 2009). To ensure high-quality citation data, we retrieved data from different databases and used a self-developed Python script to create the primary citation network with a total of 2,648 citations. To ensure the identification of all relevant citations, we conducted a fuzzy matching of title and year of publication within the references of each paper and manually reviewed all references that the algorithm did not identify with an exact match. This approach additionally avoids certain inaccuracies of citation relationships that many of the databases suffer from due to their limited scientific coverage.

To calculate and visualize the global main path as well as the global key-route main paths (see steps 8 to 10), we use the software “Pajek” (Batagelj & Mrvar, 1998). Pajek is a tool for the analysis and visualization of larger networks. Pajek is widely applied and is used by several publications conducting main path analysis (e.g., Bindu et al., 2019; Hung et al., 2014; Liang et al., 2016; J. S. Liu et al., 2013; J. S. Liu et al., 2019). Some of the advantages of Pajek are its very modular setup, offering detailed control options for the user, as well as its high reliability since it has proven itself for decades already.

While the calculation of SPC values and the global main path are ready for interpretation with one click in Pajek, the global key-route main paths need some manual adjustments after their calculation to be able to interpret the results. In the global key-route main paths solution, there are many more citation links than papers leading to a confusing and hard to interpret network. If a node has five incoming arrows, it means that the paper references five papers that are within the global key-route main paths. To identify research streams and clusters, a tree pattern, where each paper only has one incoming citation link, i.e., one reference that it cites, is most suitable (Liang et al., 2016). Additionally, a citation link between two papers does not always have relevance for knowledge dissemination, as a paper is not always cited based on its knowledge but for many other reasons. We, therefore, follow the approach of Liang et al. (2016) (see step 11), who divide all citations into substantial and peripheral citation links. Substantial citations links are based on a paper’s content, while peripheral citation links include citations based on, e.g., a specific method or a logical argument (Liang et al., 2016). For each node, i.e., paper, in the network, we carefully analyze the incoming links, i.e., references of the paper, and only keep the one substantial link with the highest traversal count while we remove all others. In almost all cases, the link with the highest traversal count, i.e., the path that is most often crossed if all possible paths in the networks are walked through exactly once, is kept, and the other links are removed. However, in some cases, the link with highest traversal count is not a topic related link and, hence, is removed to enable a topic related link with a lower traversal count. For example, Jones et al. (1995) reference the two papers Applegate and Elam (1992) and Feeny et al. (1992). While the link between Jones

et al. (1995) and Applegate and Elam (1992) exhibits the highest traversal count, the latter is only referenced to provide an example in the introduction. However, Jones et al. (1995) clearly build on the work of Feeny et al. (1992). Hence, the link with the lower traversal count is kept in this case.

Further, we remove all links that lead back to the global main path from papers that already emerged from it as this connection does not yield any new information and would blur the illustration. After pruning, each citation link shows a knowledge-based relationship between two papers. However, a connection is a weighted citation link and does not always mean that the two papers are from the same topic. As knowledge disseminates, new research streams can emerge. As a result, we can identify research streams and sub-streams that emerge over time from the global main path and key-route main paths. To identify the research streams (see step 12), we look for commonalities of papers in certain clusters within the tree structure and label each paper with a topic label. Upon first labeling, we examine each topic cluster and check for each paper (1) whether the current cluster still fits and (2) whether there is another cluster it fits in as well. If needed, the topics are relabeled. We repeat these steps until no more new insights are generated. A paper can be associated with more than one research stream.

Results

In the following, we first present the results of our main path analysis and then analyze trends in CIO research.

Main path analysis

In this section, we elaborate on the results of our main path analysis. First, we present the global main path, which represents the backbone of CIO knowledge over time. Second, we present the global key-route main paths and discuss each research stream and sub-stream in detail.

Global main path

Figure 3 shows the global main path of CIO research, comprising 18 papers from 1982 to 2021, authored by 38 researchers. The nodes represent papers, and the arrows the citation relationship between them. The thickness of an arrow indicates the weight of the link between two papers, i.e., how often this link is traversed. This path shows the most traversed path in the CIO research citation network and, therefore, shows how knowledge evolved. However, the global main path only provides a first overview of the development trajectory and is neither complete nor exclusively contains the most relevant papers. It instead serves as an early indication of the significant knowledge flow and shows central papers in CIO research.

Further, it is essential to note that the newer the papers on the main path, the more “unstable” they are compared to the older papers. As CIO research will further evolve over the coming years, the last few years on the global main path might change while the older papers are very unlikely to change. This is due to an inherent lack of citation data for newer papers in the citation network.

Insert Figure 3 About Here

Based on the thickness of the arrows, we can identify six overarching topics. The first topic ranges from Rockart et al. (1982) to Benjamin et al. (1985) and elaborates on the role and especially the evolving role of the CIO in the organization. We label it as *Evolving role of the CIO*. Although Ives and Olson (1981) discuss the role of the CIO even earlier, they are not part of the global main path as there is no citation relationship with Rockart et al. (1982). The second theme, starting with Raghunathan and Raghunathan (1989) and ending with Earl and Feeny (1994), addresses the CIO’s hierarchical position and relationships. Preston, Chen, and Leidner (2008) later discuss the CIO’s hierarchical position and decision-making authority. We also allocate this paper to the topic *CIO hierarchical position and relationships*. Armstrong and Sambamurthy (1999) appear on the global main path with the topic *Strategic IT alignment*. We label the fourth theme *CIO influence behaviors* in line with the content of its publications from Enns et al. (2001) via Kaarst-Brown (2005) to Enns et al. (2007), who elaborate on the CIO’s ability to influence peers in order to carry through strategic IS projects. The next theme, ranging from D. Q. Chen et al. (2010) to George and Howard (2020) and Parra et al. (2021) at the very end of the global main path, evolves around IT-enabled business innovation, ambidexterity, new technology adoption, and the required CIO competencies in the digital era. We label this topic *CIO as business enabler*. In between, there are two papers on the topic *Public sector CIO*. While Estevez and Janowski (2014) develop a methodology on how to establish a government CIO, Gong et

al. (2019) discuss how public sector CIOs can foster innovation and adoption of new technology. Hence, Gong et al. (2019) is additionally associated with the topic *CIO as business enabler*.

Further, there are several researchers that, measured by the number of their publications on the global main path, significantly influenced the knowledge development in CIO research. In the very beginning, between 1982 and 1985, Rockart co-authored the two central papers on the evolving role of the CIO (Benjamin et al., 1985; Rockart et al., 1982). Later, Feeny contributed to the CEO/CIO relationship between 1992 and 1994 (Earl & Feeny, 1994; Feeny et al., 1992). Between 2001 and 2007, Enns, Huff, and Golden published several central articles on CIO influence behaviors (Enns et al., 2001; Enns et al., 2007; Enns, Huff, & Golden, 2003). Lastly, Chen and colleagues contributed to the CIO's hierarchical position (Preston, Chen, & Leidner, 2008) and paved the way for the notion of the CIO as a business enabler (D. Q. Chen et al., 2010).

Global key-route main paths

With the global main path as a basis, we created a more detailed picture of CIO research by iteratively adding the key-routes with the highest SPC values and their respective paths to it. The more key-routes we add, the more details are visible in the network. Hung et al. (2014) only include the top 60 key-routes in their main path analysis. As we aim for a representative picture of the whole literature in CIO research, we successively increased the number of key-routes. We decided to include the top 20% (~530) as more key-routes did not uncover any more relevant branches (see Figure 4).

Insert Figure 4 About Here

These global key-route main paths now represent the main knowledge dissemination routes in CIO research. However, a citation relationship originates not always from the knowledge contribution of an article, and the citation network is still far too complex to analyze, with up to 20 links for just one node. As mentioned previously, we, therefore, pruned the network by carefully examining the incoming links to a paper, i.e., its references, and only keeping the one substantial link with the highest traversal count. After applying the key-route main paths analysis and the pruning of the network, we reduced the overall CIO citation network from 466 papers and 2,648 citations to a network of 145 nodes and 144 links, and only papers with similar topics are connected (see Figure 5). Each major branch in the network represents a research stream in CIO research. Overall, we identified eight research streams: *Evolving role of the CIO*, *CIO hierarchical position and relationships*, *CIO influence behaviors*, *Strategic IT alignment*, *CIO appointment, turnover, and compensation*, *CIO as business enabler*, *Public sector CIO*, and *CIOs and IT security*. Table 2 provides an overview of the research streams. Although they have an earlier start year, some research streams occur later than others on the global key-route main paths. The reason is that the specific topic of a research stream was already addressed in one or very few papers very early but did not draw much attention at that time and, therefore, did not emerge as a research stream. The actual stream then emerged later, leaving the earlier papers on other branches. The Appendix provides a complete list of papers and their respective research streams. In the following, we will discuss each research stream in more detail.

Insert Figure 5 About Here

Insert Table 2 About Here

Evolving role of the CIO

In the 1980s, the CIO evolves from a technician, focusing on IT operations and “keeping the lights on,” to a general manager, leading initiatives of strategic importance (Benjamin et al., 1985; Rockart et al., 1982). During the 1990s, the CIO is, with increased regularity, elevated to an executive position and is often even becoming part of the TMT (Stephens et al., 1992). Further, an increasing number of CIOs start to report directly to the CEO, and they have to bring a broad business perspective with them as they spend more time on interactions outside of the IT department (Applegate & Elam, 1992; Grover et al., 1993).

With the turn of the millennium, the importance of IT in organizations is increasing rapidly. The CIO role is often expected to transition to a business visionary, focusing on the firm's strategy while still running the IT and achieving high payoffs on IT investments (Chun & Mooney, 2009; Ross & Feeny, 1999; Weill & Woerner, 2013). Increasing IT investments lead to organizations taking a closer look at the payoffs of such investments. Following, the debate about the value and effectiveness of a CIO and the role's impact on organizational performance received increased attention (Peppard, 2010; Preston, Leidner, & Chen, 2008). To increase role effectiveness, Peppard et al. (2011) suggest determining the appropriate CIO out of five distinct role types based on the criticality of IT for competitive advantage as well as the maturity of IT leadership capabilities in an organization. Additionally, how CIOs are perceived can influence their role in the organization. Gonzalez et al. (2019) find that certain stereotypes of CIOs exert influence on perceptions of a CIO's suitability to hold a strategic role. Recent advancements in analytics and big data suggest that the role of the CIO is subject to change yet another time (Morabito et al., 2016; Themistocleus et al., 2016).

As the role of the CIO evolves, the competencies that are required to achieve role effectiveness are changing as well. Hence, a research sub-stream emerges from the main research stream *Evolving role of the CIO* labeled *CIO competencies*. These publications are concerned with IT management capabilities (Y.-C. Chen & Wu, 2011) or perceptions regarding the necessary competencies (Correia & Joia, 2014; Joia & Correia, 2018). Additionally, there are several publications regarding competencies in the digital era. However, this separate research sub-stream emerges within the stream *CIO as business enabler* and, hence, will be discussed later.

CIO hierarchical position and relationships

Four sub-streams evolve within this research stream, namely, *CIO hierarchical position*, *CIO/CEO relationship*, *CIO/TMT relationship*, and *CIO reporting structure*.

The *CIO hierarchical position* stream appears first on the key-route main paths with Raghunathan and Raghunathan (1989). With the increasing importance of IS in the business world, organizations need to make the necessary changes to the IS manager's rank depending on the strategic relevance of IS in the organization (Karimi et al., 1996; Raghunathan & Raghunathan, 1989). To reflect their elevated status, some IS managers already receive the title "Chief Information Officer." With the elevation into the TMT, CIOs need to broaden their knowledge and skills in business operations, strategy, and management (Karimi et al., 1996). After about 20 years of the CIO as part of TMTs, the value of the CIO's presence is discussed. Studies find that the inclusion of the CIO in the TMT contributes to long-term firm performance as it enhances the heterogeneity in the TMT, among other things (Ranganathan & Jha, 2008; Taylor, 2015; Taylor & Vithayathil, 2018). This effect even increases for firms in dynamic environments (Hu et al., 2014). Further, having a CIO present in the TMT lets an organization recover more quickly from the losses and damages of security breaches (Zafar et al., 2016).

The second sub-stream of research is the *CIO/CEO relationship*. A strategic partnership between CIO and CEO is required that combines their complementing knowledge, skills, and networks, to successfully utilize IT for competitive advantage (Feeny et al., 1992; Gupta, 1991). The closer the CIO/CEO relationship, the stronger the positive impact of IT investments on organizational performance (M. Li & Ye, 1999). Important factors contributing to the CIO/CEO relationship and, hence, organizational performance are communication (Hütter et al., 2016; Johnson & Lederer, 2005) and mutual trust and understanding (Arnitz et al., 2017; Benlian & Haffke, 2016; Johnson & Lederer, 2010). Benlian and Haffke (2016), in particular, find that the actual opinions of both executives on business and IT topics are much more similar than they perceive them to be. This perception-bias decreases with more effective communication.

In addition to the relationship with the CEO, the CIO/TMT relationship is an essential prerequisite for organizational performance. The gap in understanding between the CIO and the TMT, often resulting from a limited understanding of business by the CIO and IS by the TMT, needs to be bridged as it exhibits a negative effect on IS strategic alignment (Feeny et al., 1992; Gupta, 1991; Preston, 2004; Preston et al., 2006). Shared understanding and social capital between CIO and TMT is a significant antecedent of IS strategic alignment and, therefore, organizational performance (Karahanna & Preston, 2013; Preston & Karahanna, 2009a).

The last research sub-stream that evolves from this branch is *CIO reporting structure*. The CIO most commonly reports either to the CEO or the CFO (Armstrong & Sambamurthy, 1999). Most studies argue in advantage of the direct reporting structure of the CIO to the CEO to increase awareness of critical issues and the CIO's understanding of strategic needs (Preston & Karahanna, 2009a; Raghunathan & Raghunathan, 1989). On the other hand, Banker et al. (2011) argue that the CIO does not always have to report to the CEO to show the CIO's strategic value, but rather that organizations should align the reporting structure with the firm's strategic positioning. While firms with a

differentiator strategy tend to have their CIO report to the CEO, cost leaders prefer the CIO to report to the CFO (Banker et al., 2011; Karanja et al., 2021). Aljazzaf et al. (2019) add another layer of complexity by showing that the optimal reporting structure depends on several factors as well as that its impact on organizational performance varies from firm to firm.

Strategic IT alignment

Strategic IT alignment enhances the business effect of IT as it enables improved IT project planning as well as risk mitigation (Kearns & Lederer, 2003; Kearns & Sabherwal, 2006). This research stream differentiates itself from other streams as its papers are not directly about the CIO. However, on the one hand, the CIO influences strategic IT alignment, and, on the other hand, we can draw a conclusion about the CIO based on the findings of those papers. With the stream's prominent placement on the main path, it is still a vital part of the CIO citation network. The CIO is the main responsible person for strategic IT alignment as the role's participation in business planning positively influences alignment (Kearns & Lederer, 2003). Specifically, a CIO's business and IT knowledge and, following that, the ability to craft and evaluate new business opportunities through IT contribute positively to IT assimilation (Armstrong & Sambamurthy, 1999; Wu et al., 2008). The main concern of CIOs is to achieve alignment with the other members of the TMT (Johnson & Lederer, 2010). The cognitive similarity of business and IT executives can help achieve this alignment (Tan & Gallupe, 2006). Contributing to alignment with business executives, Preston and Karahanna (2009b) propose different mechanisms for CIOs to achieve a shared IS vision with the TMT as a foundation for strategic alignment. Gerow et al. (2015) find that just aligning business and IT strategy is not enough to achieve excessive financial performance. IT infrastructure has to be aligned with the strategy to experience higher profits. More recent reviews elaborate on the positive influence of an organization's culture on IT alignment and discuss its connection with digital business strategy (Chtourou Ben Amar & Ben Romdhane, 2019; Wunderlich, 2018).

CIO influence behaviors

The research stream *CIO influence behaviors* differs from other streams by not branching off the global main path, but rather staying on and defining it for several years. To successfully promote strategic IS projects, CIOs require skills in exercising lateral influence on their peers (Enns et al., 2001, 2003; Enns, Huff, & Higgins, 2003). Without the necessary influence skills, regardless of technical background, one might not be chosen for the CIO role in the first place (Enns, Huff, & Golden, 2003). However, the specific influence behaviors have to be selected carefully, as they could lead to diametral outcomes. CIOs who exert rational persuasion or personal appeal tend to promote peer commitment, while exchange and pressure as influence behaviors lead to peer resistance (Enns, Huff, & Higgins, 2003).

In some cases, not even influence behaviors can cope with the negative perceptions of the IT organization (Hirschheim et al., 2003). Enns et al. (2007) recommend using specific influence behaviors based on the type of initiative, strategic vs incremental, as well as the type of CIO, true peer vs supportive subordinate. Further, Enns et al. (2011) propose a set of factors that may help to overcome competing values when support for new projects is needed.

CIO appointment, turnover, and compensation

The research stream *CIO appointment, turnover, and compensation* is a special case as it evolves from two different research streams, *Strategic IT alignment* and *CIO as business enabler*. As discussed earlier, a link between two papers does not always mean that they are about the same topic, but also new streams can emerge. In this case, the research stream *CIO appointment, turnover, and compensation* did not make it onto the global main path but emerges from two branches on the key-route main paths. Potential reasons for the emergence of a research stream from two different branches are that a popular paper in the respective stream does not cite the earlier published paper, or the time difference between the appearances of the topic is too large. Therefore, it is important to complement the quantitative analysis with a qualitative evaluation and experience in the research field.

With the growing strategic importance of IT capabilities in firms, an increasing number of firms appoint a CIO to effectively and successfully manage them (Chatterjee et al., 2001). Chatterjee et al. (2001) conclude that such first-time appointments generate a positive market perception and, consequently, increase market valuation. Khallaf and Skantz (2011) complement these results by looking at the improvement in long-term performance. While the appointment of a new CIO position increases long-term performance, firms that re-appoint CIOs perform even better (Khallaf & Skantz, 2011). Further, Khallaf and Skantz (2011) find that firms can lower their cost structure and increase returns following the appointment of a new CIO position. In addition to firm performance, the appointment

of a new CIO position also increases R&D productivity and innovation efficiency (Hsu & Liu, 2019; Khallaf & Skantz, 2015). All the mentioned effects are especially strong for IT firms and firms in high dynamic environments. Before appointing a CIO, however, firms should carefully define their goals behind the appointment, as the CIO's previous reporting line has an influence on the individual's relationships and business focus (Jones et al., 2020).

Furthermore, recent articles discuss the turnover of CIOs following security breaches, IT control weaknesses, or IT material weaknesses. Security breaches caused by system deficiency strongly increased CIO turnover (Banker & Feng, 2019). W. Li et al. (2021) find that the common practices of firms to retain their CIO in case of IT control weaknesses are ineffective. On the other hand, evidence suggests that firms rather keep their CIOs in position following disclosure of IT material weaknesses instead of replacing them (W. Li et al., 2019). However, CIO turnover is found to positively influence IT material weaknesses remediation.

Lastly, a small research sub-stream evolves around the topics CIO compensation and equity incentives, discussing what determines compensation and what factors influence equity incentives (Richardson et al., 2018; Yayla & Hu, 2014).

CIO as business enabler

With the increasing importance of IT to not only provide services but additionally grow the business through the development of products, a new research stream evolves that analyzes the *CIO as a business enabler*. Within this research stream, we identify the three research sub-streams *Ambidexterity*, *Digital transformation*, and *IT-enabled business innovation*.

The first sub-stream is labeled *Ambidexterity*. As the business and technology environment in organizations becomes more complex and dynamic, the CIO's responsibilities shift from only being in charge of running the IT, i.e., supply-side leadership, to additionally enabling new business opportunities, i.e., demand-side leadership (Al-Taie et al., 2013; D. Q. Chen et al., 2010; Chun & Mooney, 2009). The construct of supply- and demand-side leadership is first introduced by Broadbent and Kitzis (2005). A framework that examines this trade-off between explorative and exploitative activities with conflicting priorities is called ambidexterity (Kalgovas et al., 2014b). Kalgovas et al. (2014b) present specific barriers to explorative and exploitative activities, as well as balancing both activities. Kalgovas et al. (2014a) provide several recommendations to overcome these barriers. Bekkhus and Hallikainen (2017) provide a dualistic toolbox for CIOs to achieve ambidexterity. D. Q. Chen et al. (2010) conceptualize the construct of supply- and demand-side leadership and argue that it is a staged maturity model for CIOs, with the supply-side leadership as the foundation and the demand-side leadership as the more advanced stage. Al-Taie et al. (2018) support this argument and recommend that newly appointed CIOs should first focus on 'keeping the lights on' before transcending to more strategic objectives.

The second sub-stream is concerned with the topic *Digital transformation*. To successfully transform an organization, one needs to leverage supply- and demand-side leadership (Haffke et al., 2016; Kohli & Johnson, 2011). Such a transformation might impact the leadership structure of organizations (Engesmo & Panteli, 2020, 2021). As digital technology advances into nearly every corner of an organization, some start to establish a separate role for managing digital capabilities, namely, the Chief Digital Officer (CDO) (Gerth & Peppard, 2016; Haffke et al., 2016). This new role would allow the CIO again to focus on supply-side leadership. However, this setup could have overlapping responsibilities and, hence, result in conflicts if there is no proper alignment between the two roles (Haffke et al., 2016). If the CIO is responsible for digital transformation, certain competencies are required that the traditional CIO role did not have (Barnes et al., 2021; La Paz et al., 2019; Noonpakdee et al., 2020). Additionally, certain leadership attributes are needed (Pabst von Ohain, 2019). Further, we identified a whole new body of research on adopting new and disruptive technology that is rapidly evolving. The technologies include cloud computing (Malladi & Krishnan, 2012), big data (Morabito et al., 2016; Sleep & Hulland, 2019; Themistocleus et al., 2016), internet of things (IoT) (Parra et al., 2021), and artificial intelligence (AI) (J. Li et al., 2021).

The third research sub-stream is concerned with the CIO in the context of IT-enabled business innovation. While most of the research belonging to the stream *IT-enabled business innovation* is from after the year 2010, two papers discussed the topic already in 2006. Watts and Henderson (2006) analyzed how CIOs can foster innovative IT climates to drive innovation, while Y. Li et al. (2006) study the relationship between CIO characteristics and innovative usage of IT. Due to their early publication, both papers are not directly part of the research stream *IT-enabled business innovation* but appear on an earlier branch in the global key-route main paths. Saldanha and Krishnan (2011) find that for CIOs, a direct reporting structure to the CEO, involvement in product development, as well as customer interaction are all positively associated with an organization's propensity for IT-enabled business innovation. These findings suggest that a boundary spanning role with entities outside of IT is beneficial. IT

capabilities, in general, are found to trigger a positive role of the CIO in IT-enabled business innovation (Wunderlich & Beck, 2018). Hsu and Liu (2019) discuss how CIOs can enable and drive digital innovation, while D. Q. Chen et al. (2021) examine how CIOs could lead digital innovation initiatives through issue selling effectiveness and identify four enabling forces for CIOs to increase it.

Public sector CIO

Public sector CIOs are of high importance to public institutions to gain the full potential of IT (Dawson & Watson, 2011; Hussain et al., 2016). The topic *Public sector CIO* appears on the global key-route main paths as a separate research stream. Similarly to the research stream *CIO appointment, turnover, and compensation*, this stream emerges from different points on the global key-route main paths, i.e., *Evolving role of the CIO*, *CIO hierarchical position and relationships*, and *CIO as business enabler*. These are, at the same time, some of the main topics that are discussed within the research stream *Public sector CIO*. However, as public sector CIOs face different challenges than their peers in the private sector, we label it as a separate research stream (Dawson et al., 2016).

Dawson and Watson (2011) identify five archetypes of public sector CIOs and find that the business-oriented CIO is the most effective, as this type understands to align with the right stakeholders and ignore others strategically. Gong et al. (2019) analyze what CIOs need to enable innovation and adopt new technologies in the public sector. According to Dawson et al. (2016), the CIO has to be either very experienced as a CIO in the public sector or short-tenured from the private sector to create innovation effectively. However, especially institutions at the local level or in developing countries have issues properly establishing, appointing, and sustaining a CIO (Estevez & Janowski, 2014; Hussain et al., 2016). Therefore, Estevez and Janowski (2014) provide a methodology for establishing and sustaining a CIO. Additionally, several studies identify shortcomings in the education and training of these types of CIOs and provide recommendations (Estevez & Janowski, 2013; Gharawi et al., 2014).

CIOs and IT security

The newest research stream, *CIOs and IT security*, evolves from the stream *CIO hierarchical position and relationships* with its first publication in 2016. The research stream only comprises a few papers. However, all of them were published in established journals and four within the last three years. This underlines the relevance of the topic to the scientific community. For an organization, having a CIO as a part of the top management team significantly reduces the risk of security breaches (Haislip et al., 2021; Zafar et al., 2016). Cecilia Feng and Wang (2019) show that organizations with risk-averse CIOs are less likely to experience security breaches. Smith et al. (2021) find that CIO characteristics along human capital and structural capital dimensions can predict the likelihood of breaches. If a security breach has already happened, Benaroch and Chernobai (2017) discuss its impact on board-level IT governance. They find that, depending on the magnitude of negative market reaction to the operational IT failure, firms improve the IT competency of their boards to a greater or lesser extent.

Trend analysis

Our analysis reveals several trends in CIO research and confirms the future viability of long-existing research streams. Figure 6 illustrates the cumulative number of publications per research stream we identified through global key-route main paths analysis. Except for the research stream *CIO influence behaviors* that stagnated in 2011 and was mainly shaped by a few researchers, the cumulative number of publications in the identified research streams exhibit constant growth. This growth suggests a steadily rising interest in CIO research, as already long-existing research streams continue to thrive while new trends are emerging.

Insert Figure 6 About Here

The two research streams *Evolving role of the CIO* and *CIO hierarchical position and relationships* build the foundation of CIO research as they are included in all existing reviews and are confirmed by our analysis as well. As the impact of IT is vastly changing the business world, the role of the CIO itself as well as its environment are subject to change and, therefore, spark interest in those research streams. Within the last 20 years, several new research streams and sub-streams evolved in CIO research. While some of them might stagnate at some point, others have the potential to become part of the structural backbone of knowledge over time. The research stream with the steepest slope is *CIO as business enabler*. As more and more organizations are forced to transform their business models to stay competitive, this research stream will likely continue its rise.

Discussion and implications

In the following, we discuss our findings and outline implications. First, we compare our findings with existing research. Second, we derive a research agenda based on the results from main path analysis.

Comparison with existing research

In this section, we first discuss our results in light of recent major publications and, second, compare our results with previous reviews.

Recent major publications

As newer publications do not exhibit the necessary citation history, the main path analysis tends to be unstable for recent years. We, therefore, separately examine the CIO research field within the last five years starting in 2017 to identify any emerging research streams that might not have been covered by main path analysis. Taking the IS Senior Scholars' Basket, including the MIS Quarterly Executive, into account, we end up with nine publications. Seven out of the nine publications are included in research streams identified through the main path analysis. In particular, the publications are included in *CIO hierarchical position and relationships* (Taylor & Vithayathil, 2018), *Strategic IT alignment* (Cong Feng et al., 2021; Gonzalez et al., 2019), *CIO as business enabler* (D. Q. Chen et al., 2021; J. Li et al., 2021), and *CIOs and IT security* (Benaroch & Chernobai, 2017; Haislip et al., 2021). Hence, we can conclude that these publications do not form an emerging research stream we were unaware of.

The global key-route main paths did not include two publications within the IS Senior Scholars' Basket (Kappelman et al., 2019; X. K. Liu & Preston, 2021). X. K. Liu and Preston (2021) find that firms with CIOs tend to make less biased management earnings forecasts. While this paper does not fit directly into one of the identified research streams, we did not find any other publication on the key-route main paths with a similar topic. However, in case of more papers around the forecasting topic in the future, it could as well be the start of a new research stream. The remaining publication, Kappelman et al. (2019), broadly discusses IT management trends and issues. Although highly cited, the paper is not cited by publications within CIO research, illustrating again how the main path analysis works. Kappelman et al. (2019) descriptively elaborate, among other things, on the background, reporting structure, and how and with whom CIOs spend their time. They find that CIOs need to master ambidexterity and discuss the conflicts that come with it. Further, most CIOs report to C- or Board-level, emphasizing their importance in the organization. Overall, the findings of this paper do not indicate a major new trend but rather fit very well in the already identified research streams.

Previous reviews

To highlight our contribution, we compare our results with previous CIO reviews (see Table 3). An "X" in the table indicates that a previous review also identified and described the labeled topic. An X in brackets "(X)" indicates partial coverage.

Insert Table 3 About Here

Our review includes findings consistent with previous literature reviews and novel findings that add to the existing knowledge. Several findings are consistent with existing CIO reviews. The research streams *Evolving role of the CIO* and *CIO hierarchical position and relationships* are identified in more or less the same way in all existing reviews (see Table 3). Drechsler (2020), Shawosh (2018), Hütter and Riedl (2017), and Ghawe and Brohman (2016) recognized the research stream *CIO influence behaviors*. Shawosh (2018), Hütter and Riedl (2017), Ghawe and Brohman (2016), Singh (2015), and Karahanna and Watson (2006) identified *Strategic IT alignment* as a research stream in CIO research. Lastly, Shawosh (2018) and Menz (2012) analyzed the sub-streams *CIO appointment* and *CIO turnover* out of the research stream *CIO appointment, turnover, and compensation*.

In addition to confirming findings of already existing CIO reviews, our study identifies several previously overlooked research streams that all emerged within the last decade. Most existing reviews discuss the evolving role of the CIO in some way or another. However, additional insights are not gained by analyzing different CIO role profiles at one point but rather by examining their evolution over time. This way, we identified a previously overlooked stream, *Public sector CIO*, that evolves from the different role profiles of CIOs over time. Further, other reviews did not identify the stream *CIO compensation*. However, Hütter and Riedl (2017) suggested this stream for future research.

Moreover, around the year 2010, various new research streams, i.e., *Digital transformation* and *IT-enabled business innovation*, are evolving. With this increasing need for the CIO to focus on demand-side leadership while maintaining IT operations, the research stream *Ambidexterity* emerges. The newest research stream, which was also not yet covered by other literature reviews, is *CIOs and IT security*, which started around the year 2016.

Recent CIO reviews might have overlooked these emerging trends because they almost exclusively focused on journal publications. Table 2 highlights that, especially for the new emerging streams, *CIO as business enabler* and *Public sector CIO*, the relative share of journal publications is low. The exception to this pattern is the research stream *CIOs and IT security*. However, since almost 70% of the papers in this stream were published within the last three years, the existing literature reviews did not really have a chance to identify this promising new research stream.

Research agenda

Based on the main research streams and central papers we identified through main path analysis and previous reviews, we derive a research agenda by identifying research gaps and tentatively formulating potential future research questions within the most relevant and trending research streams (see Table 4).

Within the research stream *Evolving role of the CIO*, we identified gaps in how the role of the CIO has to evolve with respect to the emergence of new technologies, an organization's strategic direction, as well as in the context of small and medium-sized enterprises (SMEs). While Morabito et al. (2016) discuss the impact of big data analytics on the role of the CIO, there are only very few studies that analyze the impact of new technologies requiring increased technical expertise on the role of the CIO as well as on the required competencies for the future. Some recent studies make a start in analyzing the interdependency between a CIO and the adoption of new technology (Gong et al., 2019; J. Li et al., 2021; Scuotto et al., 2022). However, there is still a void in how top management team composition and CIO characteristics influence new technology, e.g., AI adoption (J. Li et al., 2021). Since the CIO's responsibilities increase, future research should evaluate to what extent a separate role, e.g., a CTO, is needed to evaluate and adopt new technologies. Additionally, current literature lacks a clear picture of the CIO roles needed dependent on an organization's strategic direction. There is not a single CIO role that fits every organization, but rather a mix of roles that might change over time depending on an organization's priorities and needs (Chun & Mooney, 2009; Peppard et al., 2011; Weill & Woerner, 2013). Evaluating how the CIO role profile needs to adapt depending on an organization's strategic direction, e.g., cost leader or differentiator might lead to improved guidance for CIOs and organizations. Such guidance would help with the challenge outlined by Gong et al. (2019) to better align the expectations towards the CIO with the individual's role. Further, we find that traditional IS research and CIO research, in particular, are mainly concerned with large corporations. SMEs, however, are likewise increasingly dependent on information systems and need sophisticated IT management and leadership while at the same time often having only limited resources (Cragg et al., 2013; Premkumar, 2003). To remain competitive, SMEs, in particular, need proper IT management and leadership to rapidly adapt to the ever faster-changing environment through new trends, like digital transformation and the adoption of new technology (Parra et al., 2021; Scuotto et al., 2022). However, as the IS management issues in SMEs are unique (Premkumar, 2003), an evolution of the CIO role in SMEs is needed. Considering the limited resources of most SMEs, innovative solutions need to be identified to provide SMEs access to CIOs or at least CIO experience and knowledge.

In the research stream *CIO hierarchical position and relationships*, we identified gaps addressing the rise of new IS executive roles in an organization. There are several studies concerning the CIO reporting structure (Aljazzaf et al., 2019; Banker et al., 2011; Raghunathan & Raghunathan, 1989). However, as the IS function in organizations matures, the CIO might not be the only IS executive present. Hence, the question arises of what an optimal reporting structure can look like in the case of two or more IS executives, like a CIO, CDO, or CTO, in an organization. Similar to the reporting structure, the communication frequency and effectiveness between CIO and CEO, as well as other TMT members, were subject to numerous studies (Hütter et al., 2017; Johnson & Lederer, 2005), whereas other IS executives, like the CDO or CTO, were not yet studied.

The research stream *CIO appointment, turnover, and compensation* provides several different contributions. The effects on firm performance, R&D productivity, or innovation efficiency after CIO appointments are analyzed (Hsu & Liu, 2019; Khallaf & Skantz, 2011; Khallaf & Skantz, 2015), but also the CIO's background and its impact on the CIO's business focus (Jones et al., 2020). Further, the causes and the effects of CIO turnover are discussed (Banker & Feng, 2019; W. Li et al., 2019; W. Li et al., 2021). However, all the mentioned studies rely solely on quantitative data. Enriching existing insights with qualitative analyses, e.g., through case studies or interviews with different stakeholders regarding the motivations of a CIO appointment or turnover, has the potential to greatly enhance

current results (W. Li et al., 2021). Qualitative data from different stakeholders might also help to identify the actual root causes of CIO appointment and turnover.

From our perspective, the research stream *CIO as business enabler* exhibits the highest potential for future research with the three main topics *ambidexterity*, *digital transformation*, and *IT-enabled business innovation*. Mastering ambidexterity is one of the main challenges for CIOs (Bekkhuis & Hallikainen, 2017; Kalgovas et al., 2014b). Consequently, the impact of new technologies as well as a potential split of supply- and demand-side responsibilities into separate roles, e.g., CTO and CDO, and the key success factors to master these changes are promising future research fields. Resultingly, the reasons for organizations to appoint one or more of such roles and the effects on enabling the business and driving digital transformation are promising future research streams. Further, CIOs require certain attributes (Pabst von Ohain, 2019) and mutual understanding between the top management is needed to drive digital transformation (Onay et al., 2018). However, little is known about the influence of other TMT members as well as middle management on successful digital transformation (Drechsler, 2020). Lastly, we propose studying the effects of organizational strategy, context, and leadership styles on the CIO's ability to enable business innovation and grow the business (Saldanha & Krishnan, 2011).

A previously overlooked research stream is the *Public sector CIO*. Similar to the private sector, public sector organizations are pressured to transform and innovate their processes (Gong et al., 2019). Even if a CIO is present, the individual primarily occupies an IT role, whereas a role that explores new IT-enabled business models and digitally transforms administrative processes is needed (Gong et al., 2019; Tuya et al., 2020). Hence, the question arises of how public sector organizations can change organizational structures and governance to support their expectations towards their CIOs. However, many public sector organizations would already tremendously profit from getting the basics of digital transformation and automation right. While it might have just become a habit that the CIO is primarily an IT role, the appointment of a separate role for digital transformation, e.g., a CDO, could help to shift the focus. Like in SMEs, public sector organizations have a limited budget to attract experienced individuals (Holley et al., 2004). As a result, innovative solutions to access such experience need to be developed.

The latest research stream, *CIOs and IT security*, evolves around interdependencies between security breaches and the CIO. So, on the one hand, how and why security breaches are caused and, on the other hand, what consequences they have. This stream made its first appearance on the key-route main paths in 2016, meaning it is still in its early stages of development. Like the research stream *CIO appointment, turnover, and compensation*, most analyses in this stream so far are quantitative, using larger sets of secondary data. While the existing research publications already deliver insightful results, complementing it with qualitative research might yield additional insights, like identifying the root causes for security breaches or best practices to remedy the effects. Both Zafar et al. (2016) and Cecilia Feng and Wang (2019) suggest further analyzing the dynamics before and after a security breach. Zafar et al. (2016) propose to survey CIOs after IT security breaches and combine that data with the already existing financial data. Cecilia Feng and Wang (2019) suggest focusing on qualitative factors, e.g., the CIO's risk profile, to evaluate the CIO's role in managing IT security risk. Some organizations might even have a dedicated role, e.g., a Chief Information Security Officer (CISO), for managing such risks. Hence, future research could also analyze the impact of the relationship and collaboration between CISO and CIO on IT security breaches.

In the following, we provide an aggregated view of the potential research questions sorted by research stream in Table 4.

Insert Table 4 About Here

Conclusion

The role of the CIO has been receiving attention in research for almost 40 years already, and interest continues to grow. In our study, we conducted a comprehensive review of the last four decades of CIO research. We applied main path analysis to 466 papers to examine the structural knowledge flow and identify major research streams and central papers. By complementing our quantitative analysis with a qualitative evaluation, we identified eight main research streams, compared our results to other reviews, and proposed further avenues in CIO research.

This study makes several contributions to CIO research. We conducted the first quantitative as well as the most exhaustive literature review in the CIO research field using main path analysis. Our methodology enabled us to more objectively validate and highlight the importance of topics that were already identified by qualitative reviews

and to identify new and previously overlooked research streams. Further, we illustrate the structural knowledge flow in CIO research. We identified major and emerging research streams (RQ1) that show the field's current state and analyzed their evolution over time. We further aggregated the central papers in CIO research (RQ2) by not only including papers that are relevant in general, i.e., highly cited, but papers that are relevant within the CIO research field. Lastly, we developed a research agenda (RQ3) for the CIO research field to provide further avenues to researchers.

There are several limitations to our study. First, the main path analysis favors articles with a high number of references within the research field as it increases the likelihood that the paths to and from the respective paper are traversed. As literature reviews usually exhibit an exceptionally high number of references and are often highly cited, we excluded them from our analysis. Second, very recent publications are somewhat unstable in the main path analysis as there is usually not much citation data available. To mitigate the risk of missing important trends, we separately searched the last five years of CIO literature in well-known IS journals and qualitatively compared them with our results. Third, the data source influences the results, as there is no guarantee of completeness. We, therefore, combined as many data sources as possible to mitigate that specific influence. However, despite these limitations, it is hoped that the current article instigates and guides future CIO research.

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91 - Hütter et al. (2016)			X		X		X										
92 - Luo (2016)			X	X		X											
93 - Benlian and Haffke (2016)			X		X												
94 - Morabito et al. (2016)	X									X		X					
95 - Pang et al. (2016)																X	
96 - Shao et al. (2016)			X	X				X									
97 - Themistocleus et al. (2016)	X									X		X					
98 - Haffke et al. (2016)										X		X					
99 - Gerth and Peppard (2016)									X	X		X					
100 - Arnitz et al. (2017)			X		X												
101 - Benaroch and Chernobai (2017)																	X
102 - Gerow et al. (2017)			X			X											
103 - Bekkhus and Hallikainen (2017)										X	X						
104 - Wunderlich and Beck (2018)										X				X			
105 - Joia and Correia (2018)	X	X															
106 - Carvalho et al. (2018)	X																
107 - Onay et al. (2018)										X		X					
108 - Wunderlich (2018)								X		X				X			
109 - Taylor and Vithayathil (2018)			X	X					X								
110 - F.-C. Liu et al. (2018)									X								
111 - Richardson et al. (2018)									X								
112 - Al-Taie et al. (2018)	X									X	X						
113 - Sleep and Hulland (2019)			X			X				X		X					
114 - Gong et al. (2019)										X		X			X		
115 - La Paz et al. (2019)	X	X								X		X					
116 - Cecilia Feng and Wang (2019)			X	X													X
117 - Gonzalez et al. (2019)	X							X									
118 - W. Li et al. (2019)									X								
119 - Banker and Feng (2019)									X								X
120 - Pabst von Ohain (2019)										X		X					
121 - Aljazzaf et al. (2019)			X				X										
122 - Ghawe and Gonzalez (2019)	X																
123 - Jones et al. (2020)									X								
124 - George and Howard (2020)										X		X					
125 - Tuya et al. (2020)																X	
126 - Hsu and Liu (2019)									X	X				X			
127 - Mehta et al. (2019)										X	X						
128 - Engesmo and Panteli (2020)										X		X					
129 - Noonpakdee et al. (2020)	X	X								X		X					
130 - Velinov et al. (2020)										X		X					
131 - Engesmo and Panteli (2021)										X		X					

132 - Denford and Schobel (2021)																		X	
133 - Smith et al. (2021)																			X
134 - D. Q. Chen et al. (2021)										X							X		
135 - J. Li et al. (2021)			X	X						X				X					
136 - W. Li et al. (2021)										X									
137 - Parra et al. (2021)										X				X					
138 - Haislip et al. (2021)																			X
139 - Gonzalez and Ashworth (2021)										X									
140 - Cong Feng et al. (2021)										X									
141 - Gaffley and Pelsler (2021)														X			X		
142 - Barnes et al. (2021)	X	X												X			X		
143 - Karanja et al. (2021)			X					X											
144 - Zhang et al. (2021)			X				X												
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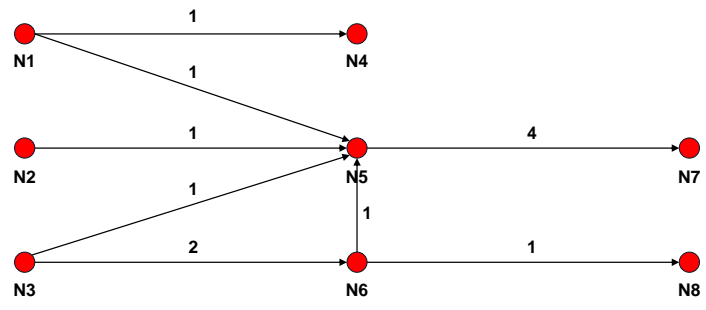


Figure 1. Exemplary citation network with SPC values

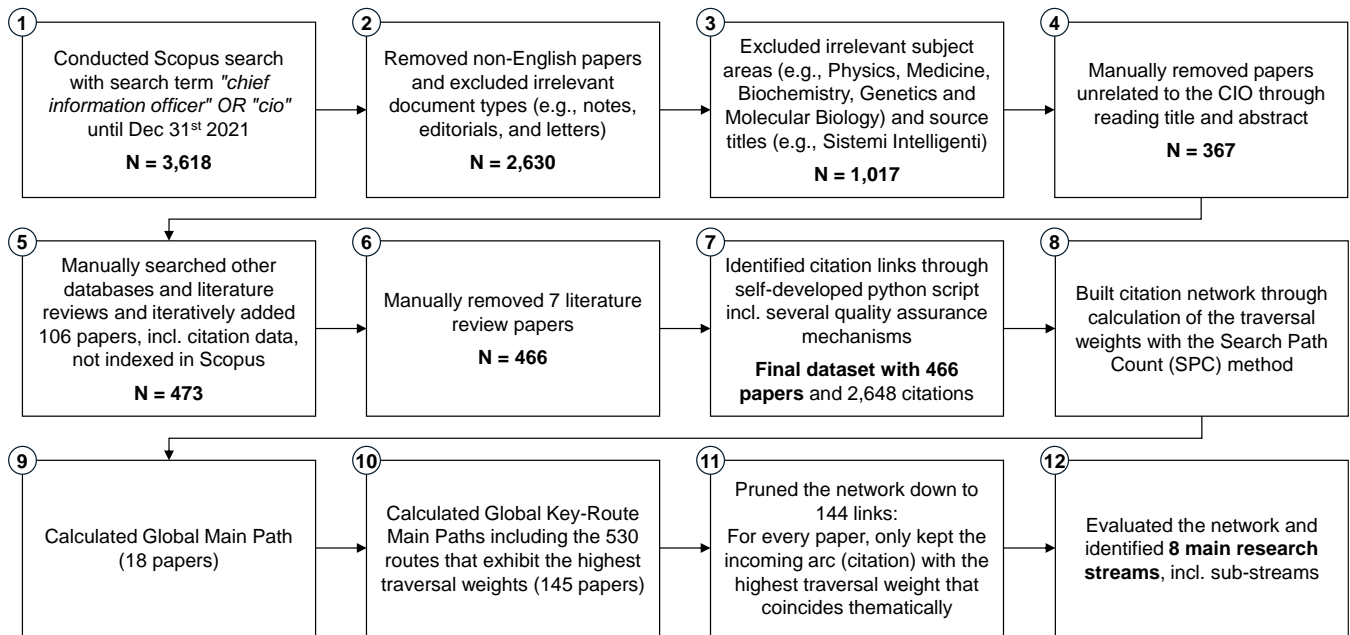


Figure 2. Data collection, cleaning, preparation, and analysis process

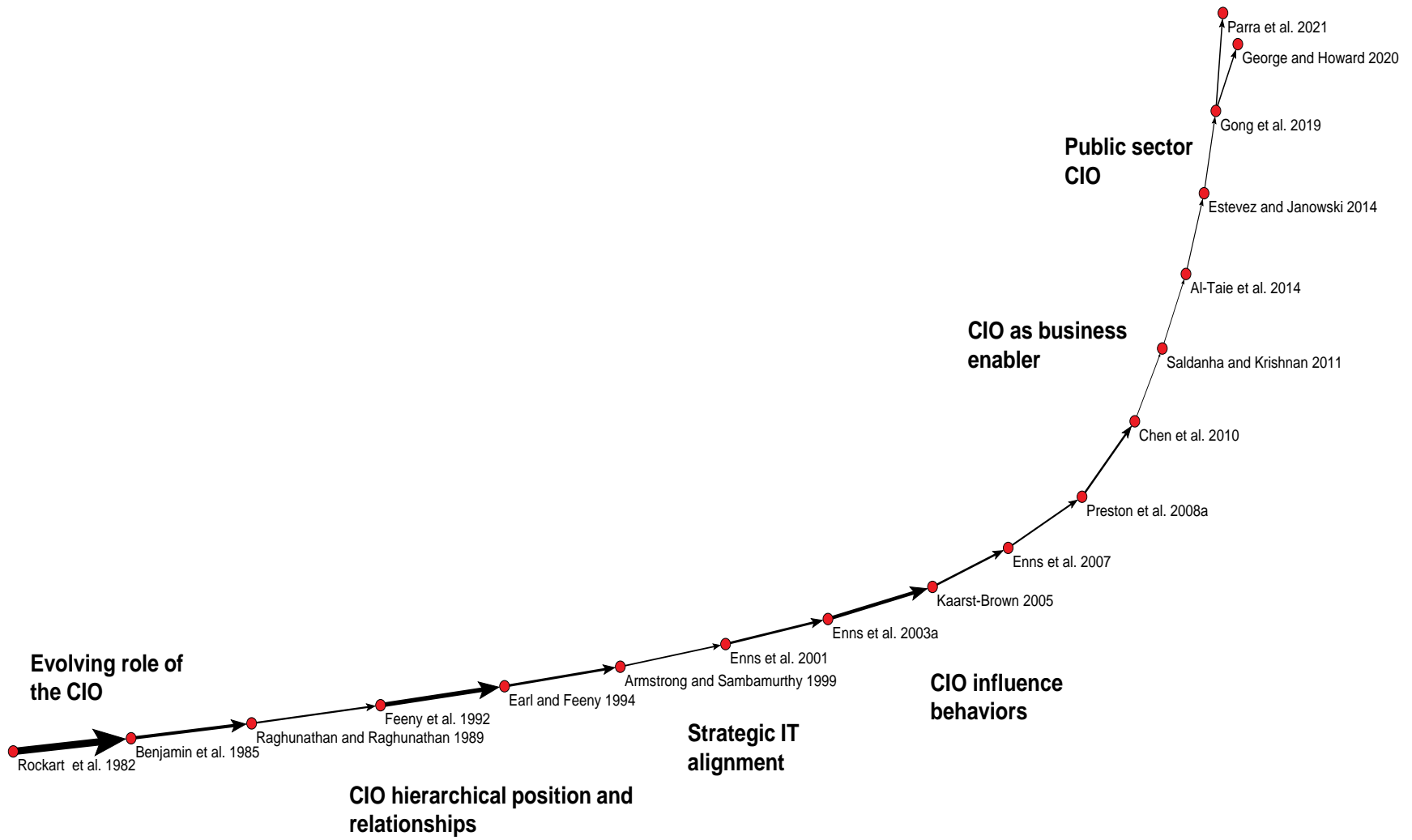


Figure 3. Global main path of the CIO citation network

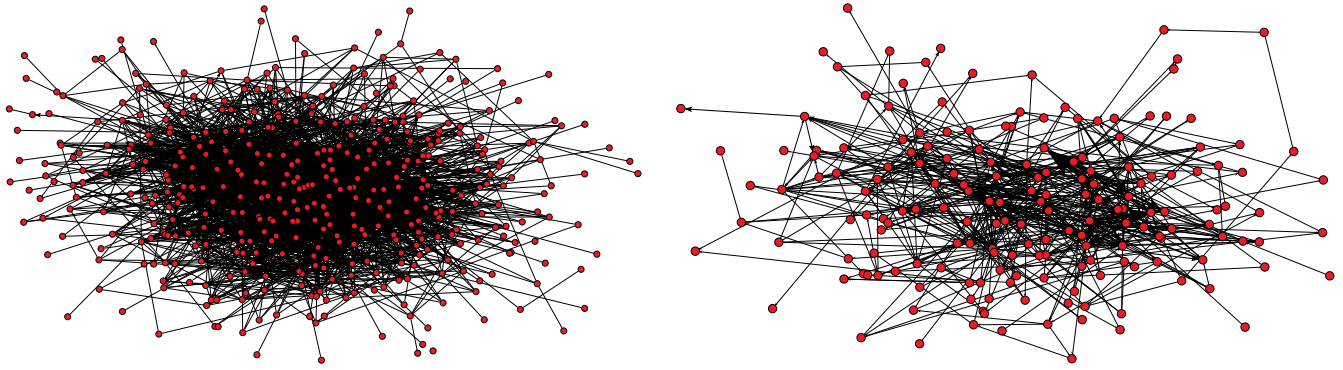
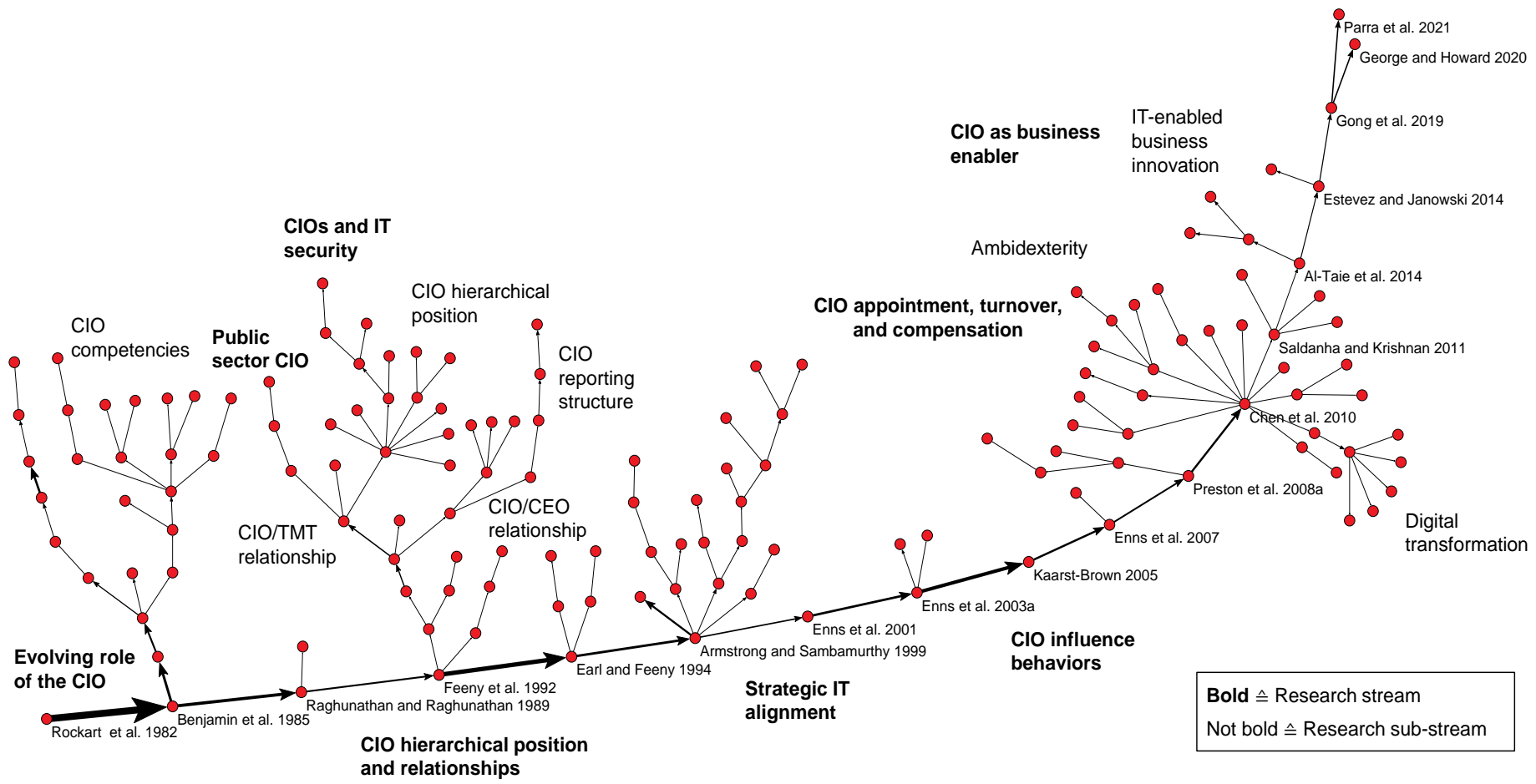


Figure 4. Complete citation network of CIO research (left) and global key-route main paths (right) until the end of 2021



Bold \triangleq Research stream
 Not bold \triangleq Research sub-stream

Figure 5. Global key-route main paths of the CIO citation network

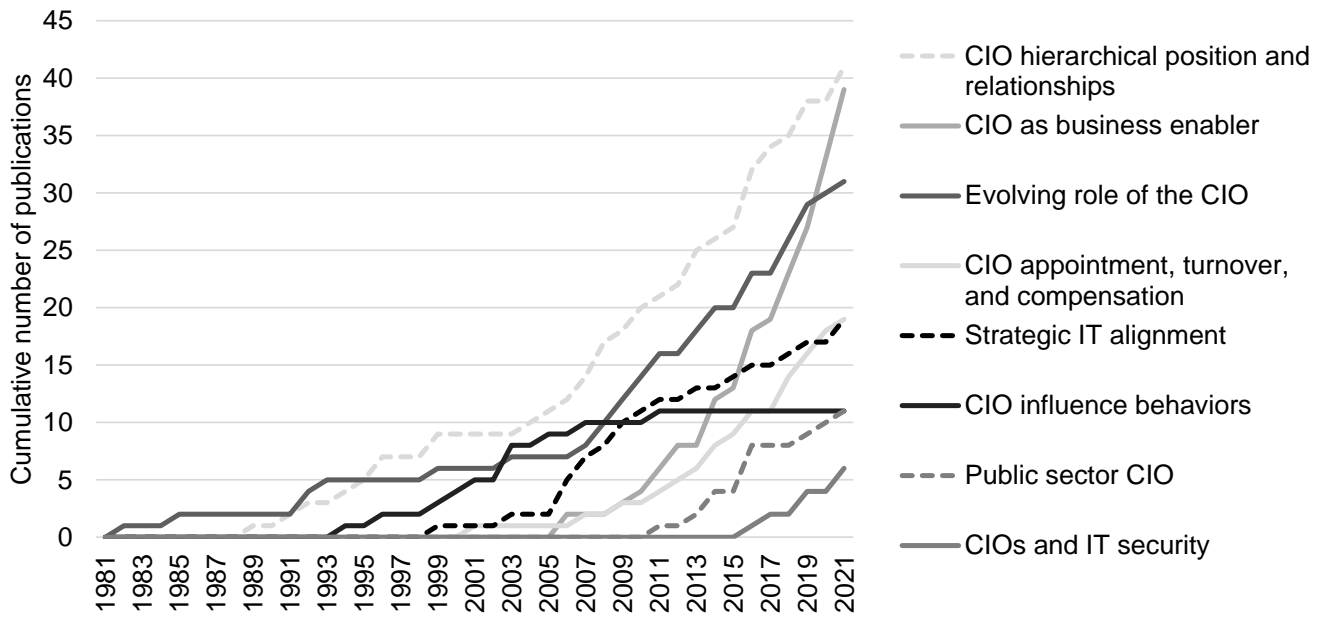


Figure 6. Cumulative number of publications in CIO research per research stream until the end of 2021

Table 1. Overview of CIO research reviews

Author(s)	Time frame	Review type	Sources in scope	Papers analyzed	Key findings
Karahanna and Watson (2006)	1982-2006	General	n/a	43	Seven themes in prior research: Role of CIO, TMT's role in IS leadership, CIO effectiveness, CIO/TMT relationship, CIO's organizational impact, IS strategic alignment, and CIO characteristics.
Menz (2012)	1976-2009	Specific sub-stream	EBSCO database and top 100 journals in business, finance, and management categories as indicated in the Social Sciences Citation Index 2008 journal ranking	39	Summary and comparison of research on different functional TMT members, e.g., Chief Financial Officer (CFO), CIO, and Chief Technology Officer (CTO). Suggestion of a framework that sets their roles into perspective to other TMT members as well as the environmental and organizational context.
Singh (2015)	1981-2011	Specific sub-stream	n/a	28	Identification of gaps in CIO role research through the lens of CIO role effectiveness
Ghawe and Brohman (2016)	1992-2015	Specific sub-stream	Google Scholar, Web of Science, ABI/INFORM Global, and ProQuest, incl. forward and backward search	48	Discussion of leadership characteristics and styles of CIOs and development of a CIO leadership framework.
Hütter and Riedl (2017)	1981-2015	Specific sub-stream	AIS Electronic Library, EBSCOhost, and Science Direct, incl. forward and backward search	98	Proposal of six types of CIO roles from existing literature: technology provider, strategic supporter, business thinker, innovation driver, integration advisor, and relationship manager. Further discussion of how each role can achieve effectiveness based on four influence factors: CIO personal competence, CIO hierarchical position, management environment, and IT infrastructure.
Shawosh (2018)	2007-2017	General	Senior Scholars' Basket, Information & Management, and MISQ Executive	33	Development of a framework for IS strategic leadership research considering the factors IS leadership, TMT members, environmental context, organizational context, organizational outcome, and IS-related outcomes.
Drechsler (2020)	1985-2019	General	Senior Scholars' Basket, MISQ Executive, and ICIS	47	Contribution of IS executives to organizational performance through the classification of CIO research using the inputs, mediators, outcomes (IMO) framework. The following research themes are identified: Educational and professional background, knowledge, skills and traits, behavior and roles, relationship with the CEO, relationship with other TMT members, level of power, structure, strategy, and information technology.

Table 2. Research streams in CIO research until the end of 2021

Research stream	Start year	Number of papers	Thereof journal publications
Evolving role of the CIO	1982	31	23 (74%)
CIO hierarchical position and relationships	1989	41	31 (76%)
CIO influence behaviors	1994	11	8 (73%)
Strategic IT alignment	1999	19	16 (84%)
CIO appointment, turnover, and compensation	2001	19	15 (79%)
CIO as business enabler	2006	40	19 (48%)
Public sector CIO	2011	11	6 (55%)
CIOs and IT security	2016	6	6 (100%)
Total		145	100 (69%)

*Double count of papers is possible as some papers are assigned to two research streams.

Table 3. Research streams identified by other reviews

	Evolving role of the CIO	CIO hierarchical position and relationships	CIO influence behaviors	Strategic IT alignment	CIO appointment, turnover, and compensation	CIO as business enabler	Public sector CIO	CIOs and IT security
Karahanna and Watson (2006)	X	X		X				
Menz (2012)	X	X			(X)			
Singh (2015)	X	X		X				
Ghawe and Brohman (2016)	X	X	X	X				
Hütter and Riedl (2017)	X	X	X	X				
Shawosh (2018)	X	X	X	X	(X)			
Drechsler (2020)	X	X	X					

Table 4. Potential future research questions in CIO research

Research stream	Indicative potential research questions
Evolving role of the CIO	<p>How do new technologies, e.g., big data, advanced analytics, or artificial intelligence, impact the roles and activities of CIOs?</p> <p>How do CIO characteristics and TMT composition influence the adoption of new technology (e.g., AI)?</p> <p>What are the competencies required by future CIOs?</p> <p>What are the different CIO roles needed dependent on the importance of IT in an organization and its strategic direction (differentiator vs cost leader)?</p> <p>How does the role of the CIO need to evolve to address the challenges of SMEs?</p> <p>What are ways for SMEs to get access to CIO knowledge and experience?</p>
CIO hierarchical position and relationships	<p>What reporting structure between CIO and other IS executives (e.g., CDO, CTO) positively influences organizational performance?</p> <p>What communication types and frequency between CIO and other IS executives (e.g., CDO, CTO) increase organizational performance?</p>
CIO appointment, turnover, and compensation	<p>What influence do the motivations of different stakeholders (e.g., CEO, CFO, CEO, board of directors) have on CIO appointment and turnover?</p> <p>What are the actual reasons for CIO appointment and turnover?</p>
CIO as business enabler	<p>What are the key success factors for CIOs to master ambidexterity?</p> <p>What is the impact of outsourcing/cloud technologies on the balance between supply- and demand-side leadership?</p> <p>What is the impact of splitting supply- and demand-side leadership into two separate roles (CIO and CDO)? How could an appropriate governance look?</p> <p>Why do organizations appoint a CDO or CTO to complement or even replace the CIO? What are the effects of such changes on organizational performance?</p> <p>How can TMT members as well as middle managers positively influence digital transformation?</p> <p>What is the impact of organizational strategy, context, and leadership styles on the CIO's ability to enable business innovation?</p>
Public sector CIO	<p>What changes in organizational structure and governance are needed in public sector organizations to support digital transformation and innovation?</p> <p>Could a dedicated role for digital transformation and innovation, e.g., a CDO, help unwind existing rigid structures and speed up the change?</p> <p>How can experienced IT executives be attracted and retained? What could be other innovative ways of getting access to such experience?</p>
CIOs and IT security	<p>What are common root causes for IT security breaches in organizations, and how could the CIO or CISO help to avoid them?</p> <p>What are lessons learnt from IT security breaches? What are best practices for executives to minimize the risk of future breaches and mitigate their effects?</p>